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High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 1: Common specifications for alternating
current switchgear and controlgear**

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 17: High-voltage switchgear and controlgear.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
17/1090/DISH	17/1095/RVDISH

Full information on the voting for the approval of this interpretation sheet can be found in the report on voting indicated in the above table.

Interpretation of 4.2.2 of IEC 62271-1:2017 regarding the altitude correction factor

Subclause 4.2.2 of IEC 62271-1:2017 contains two references for calculation of the required insulation withstand level at altitudes higher than 1 000 m, IEC 60071-2:1996 and IEC TR 62271-306. The two references are in conflict, as the altitude correction factor according to IEC 60071-2:1996 starts at sea level and that of IEC TR 62271-306 starts at an altitude of 1 000 m. This results in different altitude correction factors.

As already stated in 5.3 of IEC 62271-1:2017, the rated insulation levels refer to normal service conditions. Altitudes up to 1 000 m above sea level are covered and need no altitude correction.

For altitudes higher than 1 000 m the equation provided in 4.5.1.1 b) of IEC TR 62271-306:2012 and in H.3.4 of IEC 60071-2:2018 shall be used, i.e.

$$k_{\text{alt}} = e^{m \left(\frac{H-1\,000}{8\,150} \right)}$$

where

k_{alt} is the altitude correction factor;

H is the altitude in m above sea level;

m is an exponent.

Conservative values for the exponent m are provided in Table 4 of IEC TR 62271-306:2012. For further details about the exponent m , see H.4 of IEC 60071-2:2018.

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CONTENTS

FOREWORD	12
1 Scope	15
2 Normative references	15
3 Terms and definitions	18
3.1 General terms and definitions	18
3.2 Assemblies of switchgear and controlgear	22
3.3 Parts of assemblies	22
3.4 Switching devices	22
3.5 Parts of switching devices	24
3.6 Operation	30
3.7 Characteristic quantities	35
3.8 Index of definitions	40
4 Normal and special service conditions	43
4.1 Normal service conditions	43
4.1.1 General	43
4.1.2 Indoor switchgear and controlgear	44
4.1.3 Outdoor switchgear and controlgear	44
4.2 Special service conditions	45
4.2.1 General	45
4.2.2 Altitude	45
4.2.3 Exposure to pollution	45
4.2.4 Temperature and humidity	45
4.2.5 Exposure to abnormal vibrations, shock or tilting	46
4.2.6 Wind speed	46
4.2.7 Other parameters	46
5 Ratings	46
5.1 General	46
5.2 Rated voltage (U_r)	47
5.2.1 General	47
5.2.2 Range I for rated voltages of 245 kV and below	47
5.2.3 Range II for rated voltages above 245 kV	48
5.3 Rated insulation level (U_d , U_p , U_s)	48
5.4 Rated frequency (f_r)	52
5.5 Rated continuous current (I_r)	52
5.6 Rated short-time withstand current (I_k)	52
5.7 Rated peak withstand current (I_p)	53
5.8 Rated duration of short-circuit (t_k)	53
5.9 Rated supply voltage of auxiliary and control circuits (U_a)	54
5.9.1 General	54
5.9.2 Rated supply voltage (U_a)	54
5.10 Rated supply frequency of auxiliary circuits and control circuits	55
5.11 Rated pressure of compressed gas supply for controlled pressure systems	55
5.11.101 Rated pressure of compressed gas supply for insulation and/or switching	55
5.11.102 Rated pressure of compressed gas supply for operation	55

5.101	Rated short-circuit making current (I_{ma}).....	55
5.102	Classification of earthing switches for short-circuit making	55
5.103	Rated contact zone	55
5.104	Rated static mechanical terminal load	56
5.105	Classification of disconnectors for mechanical endurance	57
5.106	Classification of earthing switches for mechanical endurance.....	58
5.107	Rated ice-coating	58
5.108	Rated values of disconnectors for bus-transfer current switching.....	58
5.108.1	Rated bus-transfer current.....	58
5.108.2	Rated bus-transfer voltage.....	58
5.109	Classification and rated values of earthing switches for induced current switching	59
5.110	Classification and rated values of disconnectors for bus-charging current switching	60
6	Design and construction	61
6.1	Requirements for liquids in disconnectors and earthing switches.....	61
6.2	Requirements for gases in disconnectors and earthing switches.....	61
6.3	Earthing of disconnectors and earthing switches.....	62
6.4	Auxiliary and control equipment and circuits	62
6.4.1	General.....	62
6.4.2	Protection against electric shock.....	63
6.4.3	Components installed in enclosures	63
6.5	Dependent power operation	66
6.6	Stored energy operation.....	67
6.6.1	General.....	67
6.6.2	Energy storage in gas receivers or hydraulic accumulators	67
6.6.3	Energy storage in springs (or weights)	67
6.6.4	Manual charging.....	67
6.6.5	Motor charging	67
6.6.6	Energy storage in capacitors.....	68
6.7	Independent unlatched operation (independent manual or power operation)	68
6.8	Manually operated actuators	68
6.9	Operation of releases	68
6.9.1	General.....	68
6.9.2	Shunt closing release	68
6.9.3	Shunt opening release	68
6.9.4	Capacitor operation of shunt releases	69
6.9.5	Under-voltage release	69
6.10	Pressure/level indication	69
6.10.1	Gas pressure.....	69
6.10.2	Liquid level.....	69
6.11	Nameplates	69
6.11.1	General.....	69
6.11.2	Application	70
6.12	Locking devices.....	74
6.13	Position indication	74

6.14	Degree of protection provided by enclosures	74
6.14.1	General.....	74
6.14.2	Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects (IP coding)	74
6.14.3	Protection against ingress of water (IP coding)	75
6.14.4	Protection against mechanical impact under normal service conditions (IK coding)	75
6.15	Creepage distances for outdoor insulators.....	75
6.16	Gas and vacuum tightness	75
6.16.1	General.....	75
6.16.2	Controlled pressure systems for gas	76
6.16.3	Closed pressure systems for gas	76
6.16.4	Sealed pressure systems.....	76
6.17	Tightness for liquid systems.....	76
6.17.1	General.....	76
6.17.2	Leakage rates	76
6.18	Fire hazard (flammability)	77
6.19	Electromagnetic compatibility (EMC)	77
6.20	X-ray emission	77
6.21	Corrosion	77
6.22	Filling levels for insulation, switching and/or operation	77
6.101	Particular requirements for earthing switches.....	78
6.102	Requirements in respect of the isolating distance of disconnectors.....	78
6.103	Mechanical strength.....	78
6.104	Operation of disconnectors and earthing switches – Position of the movable contact system and its indicating and signalling devices	78
6.104.1	Securing of position.....	78
6.104.2	Additional requirements for power-operated mechanisms.....	79
6.104.3	Indication and signalling of position.....	79
6.105	Maximum force required for manual (dependent or independent) operation	80
6.105.1	General.....	80
6.105.2	Operation requiring more than one revolution	80
6.105.3	Operation requiring up to one revolution.....	80
6.106	Dimensional tolerances.....	81
6.107	Earthing switches with short-circuit making current capability.....	81
7	Type tests.....	81
7.1	General.....	81
7.1.1	Basics	81
7.1.2	Information for identification of test objects	83
7.1.3	Information to be included in type test reports	83
7.2	Dielectric tests.....	84
7.2.1	General.....	84
7.2.2	Ambient air conditions during tests.....	84
7.2.3	Wet test procedure	85
7.2.4	Arrangement of the equipment	85
7.2.5	Criteria to pass the test.....	85
7.2.6	Application of the test voltage and test conditions.....	86
7.2.7	Tests of disconnectors and earthing switches of $U_r \leq 245$ kV	90

7.2.8	Test of disconnectors and earthing switches of $U_r > 245$ kV	91
7.2.9	Artificial pollution tests for outdoor insulators.....	92
7.2.10	Partial discharge tests	92
7.2.11	Dielectric tests on auxiliary and control circuits.....	92
7.2.12	Voltage test as condition check.....	92
7.3	Radio interference voltage (RIV) test.....	93
7.4	Resistance measurement.....	93
7.4.1	Measurement of the resistance of auxiliary contacts class 1 and class 2	93
7.4.2	Measurement of the resistance of auxiliary contacts class 3.....	93
7.4.3	Electrical continuity of earthed metallic parts test	93
7.4.4	Resistance measurement of contacts and connections in the main circuit as a condition check.....	93
7.5	Continuous current tests	94
7.5.1	Condition of the test object	94
7.5.2	Arrangement of the equipment	94
7.5.3	Test current and duration.....	95
7.5.4	Temperature measurement during test	96
7.5.5	Resistance of the main circuit	97
7.5.6	Criteria to pass test	97
7.6	Short-time withstand current and peak withstand current tests	101
7.6.1	General.....	101
7.6.2	Arrangement of the disconnectors and earthing switches and of the test circuit.....	101
7.6.3	Test current and duration.....	108
7.6.4	Conditions of disconnectors and earthing switches after test.....	109
7.7	Verification of the protection	110
7.7.1	Verification of the IP coding	110
7.7.2	Verification of the IK coding	111
7.8	Tightness tests	111
7.8.1	General.....	111
7.8.2	Controlled pressure systems for gas	112
7.8.3	Closed pressure systems for gas	112
7.8.4	Sealed pressure systems.....	113
7.8.5	Liquid tightness tests.....	113
7.9	Electromagnetic compatibility tests (EMC).....	114
7.9.1	Emission tests.....	114
7.9.2	Immunity tests on auxiliary and control circuits	116
7.9.3	Additional EMC tests on auxiliary and control circuits	119
7.10	Additional tests on auxiliary and control circuits.....	119
7.10.1	General.....	119
7.10.2	Functional tests	119
7.10.3	Verification of the operational characteristics of auxiliary contacts.....	119
7.10.4	Environmental tests	120
7.10.5	Dielectric test	121
7.11	X-ray radiation test for vacuum interrupters	122
7.11.1	General requirements	122
7.11.2	Test voltage and measurement procedure	123
7.11.3	Acceptance criteria.....	123

7.101	Test to prove the short-circuit making performance of earthing switches.....	124
7.101.1	General test conditions	124
7.101.2	Arrangement of the earthing switch for tests	124
7.101.3	Test frequency	124
7.101.4	Test voltage	125
7.101.5	Test short-circuit making current	125
7.101.6	Test circuits	125
7.101.7	Test procedures	126
7.101.8	Behaviour of earthing switches when making short-circuit currents.....	126
7.101.9	Condition of earthing switch after short-circuit making tests	126
7.101.10	Invalid tests.....	127
7.101.11	Type test reports	128
7.102	Operating and mechanical endurance tests	128
7.102.1	General test conditions	128
7.102.2	Contact zone test	128
7.102.3	Mechanical endurance test	131
7.102.4	Operation during the application of rated static mechanical terminal loads.....	133
7.102.5	Extended mechanical endurance tests	134
7.102.6	Testing of mechanical interlocking devices.....	135
7.103	Operation under severe ice conditions.....	135
7.103.1	General.....	135
7.103.2	Test arrangement.....	135
7.103.3	Test procedure	136
7.104	Low- and high-temperature tests	137
7.104.1	General.....	137
7.104.2	Measurement of ambient air temperature	138
7.104.3	Low-temperature test.....	138
7.104.4	High-temperature test.....	140
7.105	Tests to verify the proper functioning of the position-indicating device	140
7.105.1	General.....	140
7.105.2	Tests on the power kinematic chain and the position-indicating kinematic chain	141
7.106	Bus-transfer current switching tests on disconnectors	141
7.106.1	General.....	141
7.106.2	Making and breaking tests	141
7.107	Induced current switching tests on earthing switches	145
7.107.1	General.....	145
7.107.2	Arrangement of the earthing switch for tests	145
7.107.3	Earthing of test circuit and earthing switch	146
7.107.4	Test frequency	146
7.107.5	Test voltage	146
7.107.6	Test currents.....	146
7.107.7	Test circuits	146
7.108	Bus-charging current switching tests on disconnectors.....	151
7.108.1	General.....	151
7.108.2	Test duties	152
7.108.3	Arrangement of the disconnector for tests	152
7.108.4	Test frequency	152

7.108.5	Test voltages for making and breaking tests	153
7.108.6	Test circuits for making and breaking tests	154
7.108.7	Performance of making and breaking tests	156
7.108.8	Behaviour of the disconnector during making and breaking tests	156
7.108.9	Condition after test	157
7.108.10	Type test reports	157
7.108.11	Requirements for U_{TVE} measurements	158
8	Routine tests	158
8.1	General	158
8.2	Dielectric test on the main circuit	159
8.3	Tests on auxiliary and control circuits	160
8.3.1	Inspection of auxiliary and control circuits, and verification of conformity to the circuit diagrams and wiring diagrams	160
8.3.2	Functional tests	160
8.3.3	Verification of protection against electrical shock	160
8.3.4	Dielectric tests	160
8.4	Measurement of the resistance of the main circuit	160
8.5	Tightness test	161
8.5.1	General	161
8.5.2	Controlled pressure systems for gas	161
8.5.3	Closed pressure systems for gas	161
8.5.4	Sealed pressure systems	161
8.5.5	Liquid tightness tests	161
8.6	Design and visual checks	162
8.101	Mechanical operating tests	162
8.102	Verification of earthing function	162
9	Guide to the selection of disconnectors and earthing switches (informative)	163
9.1	General	163
9.2	Selection of rated values	163
9.2.101	General	163
9.2.102	Selection of rated voltage and rated insulation level	164
9.2.103	Selection of rated continuous current	164
9.2.104	Selection of rated contact zone	164
9.2.105	Selection of rated static mechanical terminal load	164
9.2.106	Selection of a bus-transfer current switching capability for disconnectors of $U_r > 52$ kV	164
9.2.107	Selection of an induced-current switching capability for earthing switches of $U_r > 52$ kV	165
9.2.108	Selection of rated short-time withstand current and of rated duration of short-circuit	165
9.2.109	Selection of rated peak withstand current and of rated short-circuit making current for earthing switches	165
9.2.110	Selection of short-circuit making capability for earthing switches	165
9.3	Cable-interface considerations	166
9.4	Continuous or temporary overload due to changed service conditions	166
9.5	Environmental aspects	166
9.5.1	Service conditions	166
9.5.2	Clearances affected by service conditions	166

9.5.3	High humidity	166
9.5.4	Solar radiation	166
9.5.101	Local environmental conditions	166
10	Information to be given with enquiries, tenders and orders (informative)	167
10.1	General	167
10.2	Information with enquiries and orders	167
10.3	Information with tenders	169
11	Transport, storage, installation, operating instructions, and maintenance	170
11.1	General	170
11.2	Conditions during transport, storage and installation	170
11.3	Installation	170
11.3.1	General	170
11.3.2	Unpacking and lifting	170
11.3.3	Assembly	171
11.3.4	Mounting	171
11.3.5	Connections	171
11.3.6	Information about gas and gas mixtures for controlled and closed pressure systems	171
11.3.7	Final installation inspection	172
11.3.8	Basic input data by the user	172
11.3.9	Basic input data by the manufacturer	172
11.4	Operation	173
11.5	Maintenance	173
11.5.1	General	173
11.5.2	Information about fluids and gas to be included in maintenance manual	173
11.5.3	Recommendations for the manufacturer	173
11.5.4	Recommendations for the user	175
11.5.5	Failure report	175
12	Safety	176
12.1	General	176
12.2	Precautions by manufacturers	177
12.3	Precautions by users	177
13	Influence of the product on the environment	178
Annex A	(normative) Identification of test objects	179
A.1	General	179
A.2	Data	179
A.3	Drawings	179
Annex B	(informative) Determination of the equivalent RMS value of a short-time current during a short-circuit of a given duration	181
Annex C	(normative) Method for the weatherproofing test for outdoor switchgear and controlgear	182
Annex D	(informative) References for auxiliary and control circuit components	185
Annex E	(normative) Tolerances on test quantities during tests	187
Annex F	(informative) Information and technical requirements to be given with enquiries, tenders and orders	190
F.1	General	190

F.2	Normal and special service conditions (refer to Clause 4)	190
F.3	Ratings (refer to Clause 5)	191
F.4	Design and construction (refer to Clause 6)	191
F.5	System information	192
F.6	Documentation for enquiries and tenders	192
Annex G (informative)	List of symbols	193
Annex H (informative)	Electromagnetic compatibility on site	194
Annex I (informative)	List of notes concerning certain countries	195
Annex J (informative)	Extension of validity of type tests	196
J.1	General	196
J.2	Dielectric tests	196
J.3	Short-time withstand current tests	196
J.4	Continuous current test	196
J.5	Electromagnetic immunity test on auxiliary and control circuits	197
J.6	Environmental tests on auxiliary and control circuits	197
Annex K (informative)	Exposure to pollution	198
K.1	General	198
K.2	Pollution levels	198
K.3	Minimum requirements for switchgear	198
Annex A (informative)	Test voltage for the most disadvantageous dielectric position of an earthing switch during operation (minimum temporary clearance)	200
Annex B (informative)	Current-switching capability required of disconnectors and earthing switches	201
B.1	Bus-transfer current switching capability of disconnectors	201
B.2	Bus-charging current switching capability of disconnectors	201
B.3	Induced current-switching capability of earthing switches	202
Annex C (normative)	Tolerances on test quantities for type tests	203
Annex D (normative)	Alternative test methods for short-circuit current making tests	205
D.1	General	205
D.2	Alternative methods	205
D.2.1	Synthetic test method with both rated voltage and rated short-circuit current	205
D.2.2	Test methods with reduced voltage	205
Annex E (informative)	Extension of validity of type tests	207
E.1	General	207
E.2	Dielectric tests	207
E.3	Short-time withstand current tests	207
E.4	Short-circuit making performance of earthing switches	207
E.5	Operating and mechanical endurance tests	207
E.6	Bus-transfer current switching tests on disconnectors	207
E.7	Induced current switching tests on earthing switches	208
Bibliography		209

Figure 1 – Examples of classes of contacts	66
Figure 1 – Position indicating/signalling device(s)	79
Figure 2 – Diagram of connections of a three-pole switching device	87
Figure 2 – Three-phase test arrangement for disconnectors and earthing switches	103
Figure 3 – Single-phase test arrangement for disconnectors with a horizontal isolating distance and for earthing switches of $U_T > 52$ kV, to be used with flexible or with rigid conductors	105
Figure 4 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_T > 52$ kV with a vertical isolating distance, to be used with flexible conductors	106
Figure 5 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_T > 52$ kV with a vertical isolating distance, to be used with rigid conductors	107
Figure 3 – Diagram of a test circuit for the radio interference voltage test	115
Figure 4 – Test location of radiation survey instrument	123
Figure 6 – Fixed contact parallel to support	129
Figure 7 – Fixed contact perpendicular to support	130
Figure 8 – Example of the application of rated static mechanical terminal loads to a (divided support) pantograph disconnector (or earthing switch)	131
Figure 9 – Example of the application of rated static mechanical terminal loads to a two-column disconnector	132
Figure 10 – Test sequences for low and high temperature tests	138
Figure 11 – Example of test circuit for bus-transfer current switching tests	143
Figure 12 – Test circuit for electromagnetically induced current switching tests	147
Figure 13 – Test circuits for electrostatically induced current-switching tests	149
Figure 14 – Test circuit for test duty 1	153
Figure 15 – Typical voltage waveform (Including VFT and FT components)	155
Figure 16 – Test circuit for test duty 2	155
Figure 17 – Test circuit for test duty 3	156
Figure B.1 – Determination of short-time current	181
Figure C.1 – Arrangement for weatherproofing test	183
Figure C.2 – Nozzle for weatherproofing test	184
Figure B.1 – Examples of resistor-fitted disconnectors	202
Table 1 – Rated insulation levels for rated voltages of range <i>I</i> , series <i>I</i>	49
Table 2 – Rated insulation levels for rated voltages of range <i>I</i> , series <i>II</i> (based on current practice in some countries, including US)	50
Table 3 – Rated insulation levels for rated voltages of range <i>II</i>	51
Table 4 – Additional rated insulation levels for range <i>II</i> , based on current practice in some countries, including US	52
Table 5 – Peak factors for rated peak withstand current	53
Table 6 – Direct current voltage	54
Table 7 – Alternating current voltage	54
Table 1 – Classification of earthing switches for short-circuit making	55
Table 2 – Preferred contact zones for "fixed" contacts supported by flexible conductors	56
Table 3 – Preferred contact zones for "fixed" contacts supported by rigid conductors	56

Table 4 – Preferred static mechanical terminal loads.....	57
Table 5 – Classification of disconnectors for mechanical endurance	57
Table 6 – Classification of earthing switches for mechanical endurance	58
Table 7 – Rated bus-transfer voltages of disconnectors.....	59
Table 8 – Classification of earthing switches for induced-current switching	59
Table 9 – Rated induced currents and voltages	60
Table 10 – Classification of disconnectors for bus-charging switching.....	61
Table 11 – Standard rated bus-charging currents	61
Table 8 – Auxiliary contact classes	65
Table 9 – Nameplate information	71
Table 12 – Product information (1 of 2)	72
Table 13 – List of type tests.....	82
Table 10 – Test conditions in general case	87
Table 11 – Power-frequency test conditions	88
Table 12 – Impulse test conditions.....	89
Table 13 – Test conditions for the alternative method	89
Table 14 – Power frequency withstand voltages	90
Table 14 – Limits of temperature and temperature rise for various parts, materials and dielectrics of high-voltage switchgear and controlgear.....	98
Table 15 – Permissible leakage rates for gas systems.....	112
Table 16 – Application of voltages at the fast transient/burst test.....	117
Table 17 – Application of voltage at the damped oscillatory wave test.....	118
Table 18 – Assessment criteria for transient disturbance immunity.....	118
Table 15 – Requirements on the instant of making	126
Table 16 – Invalid tests	127
Table 17 – Standard values of recovery voltages for electromagnetically induced current breaking tests.....	148
Table 18 – Test circuit capacitances (C_1 values) for electrostatically induced current switching tests	150
Table 19 – Test voltages for making and breaking tests.....	153
Table 20 – Number of tests	156
Table 21 – Power frequency voltage tests.....	159
Table D.1 – List of reference documents for auxiliary and control circuit components	185
Table E.1 – Tolerances on test quantities for type test.....	188
Table K.1 – Environmental examples by site pollution severity (SPS) class	199
Table K.2 – Minimum nominal specific creepage distance by pollution level	199
Table B.1 – Average impedances	201
Table C.1 – Tolerances on test quantities for type tests.....	203

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 102: Alternating current disconnectors and earthing switches

FOREWORD

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This extended version (EXV) of the official IEC Standard provides the user with a comprehensive content of the Standard.

IEC 62271-102:2018+AMD1:2022 EXV includes the content of the references made to IEC 62271-1:2017+AMD1:2021 CSV.

Particular subclauses of IEC 62271-1:2017+AMD1:2021 CSV are displayed in the content on a blue background.

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 62271-102 edition 2.1 contains the second edition (2018-05) [documents 17A/1173/FDIS and 17A/1180/RVD] and its amendment 1 (2022-04) [documents 17A/1322/CDV and 17A/1337/RVC].

International Standard IEC 62271-102 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

This second edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) new numbering according to IEC 17/1025/RQ to harmonize with ISO/IEC Directives, Part 2, and IEEE Std. C37.100.1;
- b) clause numbering has been aligned with IEC 62271-1:2017;
- c) the Scope has been extended to cover all indoor and outdoor installations. Consideration of switching devices having disconnecting and/or earthing switch functionalities, apart from other functions, are also covered by this document;
- d) ratings have been moved from Annexes B, C and E to Clause 5; the order of the subclauses now corresponds to the order of subclauses in Clause 7;
- e) new rating values for bus-transfer current and bus-transfer voltage have been assigned;
- f) new class of mechanical endurance for earthing switches has been added (M1);
- g) subclause "Rated values of electrical endurance for earthing switches" is now called "Classification of earthing switches for short-circuit making capability";
- h) new subclause with ratings for ice-coating has been added;
- i) new subclause with classification of bus-charging switching capability has been added;
- j) new withstand requirements for interlocking devices have been added;
- k) the way to comply with the requirements of the isolating distance of disconnectors has been modified;
- l) design and construction requirements for position-indicating devices have been modified, aligning the requirements for position indication and signalling;
- m) the value of the operating force has been changed;
- n) the test procedures and validation criteria have been revised and modified where necessary;
- o) requirements for applied voltage during single-phase test on non-simultaneous closing earthing switches have been changed;
- p) non-verifiable requirements have been deleted;
- q) a new subclause has been added for testing mechanical interlocking devices;
- r) the high- and low-temperature test is mandatory if the temperature limits for the service conditions of the apparatus (defined by the manufacturer) are above +40 °C or below –5 °C, and a more detailed testing procedure is given;
- s) the testing procedure to verify the proper functioning of the position-indicating device allows a more practicable testing for every technology used;
- t) a new Annex B has been added with title: "Current-switching capability required of disconnectors and earthing switches";
- u) a new Annex C has been added with title: "Tolerances on test quantities for type tests";
- v) a new Annex E has been added with title: "Extension of validity of type tests".

This standard is to be read in conjunction with IEC 62271-1:2017, to which it refers and which is applicable, unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses, except annexes, is used as in IEC 62271-1:2017. Additional subclauses are numbered from 101.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62271 series, published under the general title *High-voltage switchgear and controlgear*, can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 102: Alternating current disconnectors and earthing switches

1 Scope

This part of IEC 62271 applies to alternating current disconnectors and earthing switches, designed for indoor and outdoor installations for nominal voltages above 1 000 V and for service frequencies up to and including 60 Hz.

It also applies to the operating devices of these disconnectors and earthing switches and their auxiliary equipment.

Additional requirements for disconnectors and earthing switches in enclosed switchgear and controlgear are given in IEC 62271-200, IEC 62271-201 and IEC 62271-203.

NOTE Disconnectors in which the fuse forms an integral part are not covered by this standard.

This document is also applicable to switching devices having disconnecting and/or earthing functionalities apart from other functions, such as high-speed earthing switch, circuit-breaker and switch-disconnector.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60038:2009, *IEC standard voltages*

IEC 60050-131:2002, *International Electrotechnical Vocabulary (IEV) – Part 131: Circuit theory*

IEC 60050-151, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-192:2015, *International Electrotechnical Vocabulary (IEV) – Part 192: Dependability*

IEC 60050-351, *International Electrotechnical Vocabulary (IEV) – Part 351: Control technology*

IEC 60050-441, *International Electrotechnical Vocabulary – Chapter 441: Switchgear controlgear and fuses*

IEC 60050-471, *International Electrotechnical Vocabulary – Part 471: Insulators*

IEC 60050-551, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics*

IEC 60050-581:2008, *International Electrotechnical Vocabulary (IEV) – Part 581: Electromechanical components for electronic equipment*

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60050-605, *International Electrotechnical Vocabulary (IEV) – Chapter 605: Generation, transmission and distribution of electricity – Substations*

IEC 60050-614, *International Electrotechnical Vocabulary – Part 614: Generation, transmission and distribution of electricity – Operation*

IEC 60050-811, *International Electrotechnical Vocabulary (IEV) – Part 811: Electric traction*

IEC 60050-826:2004, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations*

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60137, *Insulating bushings for alternating voltages above 1 000 V*

IEC 60255-21-1:1988, *Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section One: Vibration tests (sinusoidal)*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF₆) for use in electrical equipment*

IEC 60480, *Guidelines for the checking and treatment of sulphur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use*

IEC 60507, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on a.c. systems*

IEC 60512-2-2, *Connectors for electronic equipment – Tests and measurements – Part 2-2: Electrical continuity and contact resistance tests – Test 2b: Contact resistance – Specified test current method*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC TS 60815-1:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC TS 60815-2:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems*

IEC TS 60815-3:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems*

IEC 60865-1, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-17:2009, *Electromagnetic compatibility (EMC) – Part 4-17: Testing and measurement techniques – Ripple on d.c. input power port immunity test*

IEC 61000-4-18, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

IEC 61000-4-29, *Electromagnetic compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

IEC 61180, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

IEC 61810-7:2006, *Electromechanical elementary relays – Part 7: Test and measurement procedures*

IEC 62262:2002, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

IEC 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-4, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF₆) and its mixtures*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-101:2012, *High-voltage switchgear and controlgear – Part 101: Synthetic testing*
IEC 62271-101:2012/AMD1:2017

IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-201:2014, *High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC/TR 62271-305, *High-voltage switchgear and controlgear – Part 305: Capacitive current switching capability of air-insulated disconnectors for rated voltages above 52 kV*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR TR 18-2, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

ISO 2768-1, *General tolerances – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-131, IEC 60050-151, IEC 60050-192, IEC 60050-351, IEC 60050-441, IEC 60050-471, IEC 60050-551, IEC 60050-581, IEC 60050-601, IEC 60050-605, IEC 60050-614, IEC 60050-811 and IEC 60050-826, some of which are recalled hereunder, and the following

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

NOTE Terms and definitions are classified in accordance with IEC 60050-441. References from other parts than IEC 60050-441 are classified so as to be aligned with the classification used in IEC 60050-441.

3.1 General terms and definitions

3.1.1

switchgear and controlgear

general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures

[SOURCE: IEC 60050-441:2000, 441-11-01]

3.1.2

external insulation

distances in atmospheric air and along the surfaces in contact with atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin, etc.

[SOURCE: IEC 60050-614:2016, 614-03-02]

3.1.3

degree of protection

extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and against mechanical impact

[SOURCE: IEC 60529:1989, 3.3, modified – leave out “verified by standardized test methods” and add “against mechanical impact” after “water and”.]

3.1.4

IP code

coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection

[SOURCE: IEC 60529:1989, 3.4]

3.1.5

protection provided by an enclosure against access to hazardous parts

protection of persons against

- contact with hazardous low-voltage live parts;
- contact with hazardous mechanical parts;
- approach to hazardous high-voltage live parts below adequate clearance inside an enclosure

Note 1 to entry: This protection may be provided:

- by means of the enclosure itself;
- by means of barriers as part of the enclosure or distances inside the enclosure.

[SOURCE: IEC 60529:1989, 3.6]

3.1.6

IK code

coding system to indicate the degree of protection provided by an enclosure against harmful external mechanical impacts

[SOURCE: IEC 62262:2002, 3.3]

3.1.7

maintenance

combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required

Note 1 to entry: Management is assumed to include supervision activities.

[SOURCE: IEC 60050-192:2015, 192-06-01]

3.1.8

visual inspection

visual investigation of the principal features of the switchgear and controlgear

Note 1 to entry: This inspection is generally directed toward pressures and/or levels of fluids, tightness, position of relays, pollution of insulating parts, but actions such as lubricating, cleaning, washing, etc. which can be carried out with the switchgear and controlgear in service are also included.

Note 2 to entry: Observations resulting from inspection can lead to the decision to carry out overhaul.

Note 3 to entry: This inspection can be used for determining the state of tested objects on e.g. cracks in solid insulators.

3.1.9**diagnostic test**

comparative test of the characteristic parameters of switchgear and controlgear to verify that it performs its functions, by measuring one or more of these parameters

Note 1 to entry: The result from a diagnostic test can lead to the decision to carry out overhaul.

3.1.10**overhaul**

work performed with the objective of repairing or replacing parts which are found to be out of tolerance by inspection, diagnostic test, examination or as required by manufacturer's maintenance manual, in order to restore the component and/or the switchgear and controlgear to an acceptable condition (within tolerance)

3.1.11**failure**

loss of ability to perform as required

Note 1 to entry: A failure of an item is an event that results in a fault of that item: see fault (IEC 60050-192:2015, 192-04-01).

Note 2 to entry: Qualifiers, such as catastrophic, critical, major, minor, marginal and insignificant, can be used to categorize failures according to the severity of consequences, the choice and definitions of severity criteria depending upon the field of application.

Note 3 to entry: Qualifiers, such as misuse, mishandling and weakness, may be used to categorize failures according to the cause of failure.

[SOURCE: IEC 60050-192:2015, 192-03-01]

3.1.12**major failure** (of switchgear and controlgear)

failure of switchgear and controlgear which causes the cessation of one or more of its fundamental functions

Note 1 to entry: A major failure may result in an immediate change in the system operating conditions, for example, the backup protective equipment will be required to remove the fault or will result in mandatory removal from service within 30 min for unscheduled maintenance.

3.1.13**minor failure** (of switchgear and controlgear)

any failure of a constructional element or a subassembly which does not cause a major failure of the switchgear and controlgear

3.1.14**defect**

imperfection in the state of an item (or inherent weakness) which can result in one or more failures of the item itself, or of another item under the specific service or environmental or maintenance conditions, for a stated period of time

3.1.15**ambient air temperature**

temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

Note 1 to entry: For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[SOURCE: IEC 60050-441:2000, 441-11-13]

3.1.16

monitoring

observation of the operation of a system or part of a system to verify correct functioning by detecting incorrect functioning, this being done by measuring one or more variables of the system and comparing the measured values with the specified values

Note 1 to entry: Some definitions are given for this term in IEC 60050 (all parts). They are related to different cases of application.

3.1.17

supervision

activity, performed either manually or automatically, intended to observe the state of an item

Note 1 to entry Automatic supervision may be performed internally or externally to the item.

3.1.18

site pollution severity class

SPS

classification of pollution severity at a site, from very light to very heavy, as a function of the SPS (site pollution severity)

Note 1 to entry: Adapted from: IEC TS 60815-1:2008, 3.1.15, modified – the term (site pollution severity) is added.

3.1.19

internal insulation

internal distances of the solid, liquid or gaseous parts of the insulation of equipment which are protected from the effects of atmospheric and other external conditions

[SOURCE: IEC 60050-614:2016, 614-03-03, modified – addition of "parts of".]

3.1.20

non-sustained disruptive discharge

NSDD

disruptive discharge associated with current interruption that does not result in the resumption of power frequency current or, in the case of capacitive current interruption, does not result in current in the main load circuit

3.1.101

indoor switchgear and controlgear

switchgear and controlgear designed solely for installation within a building or other housing, where the switchgear and controlgear is protected against wind, rain, snow, abnormal dirt deposits, abnormal condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-04]

3.1.102

outdoor switchgear and controlgear

switchgear and controlgear suitable for installation in the open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-05]

3.1.103

user

person or legal entity using the disconnectors or earthing switches

Note 1 to entry: This can include the purchaser (for example an electricity supplier), but it can also include the contracting company, the staff responsible for erection of installation, the maintenance or operating staff or

anybody else temporarily or permanently responsible for the disconnector, earthing switch or electrical installation, or even the operation of the switchgear.

3.2 Assemblies of switchgear and controlgear

3.2.1

test object

equipment needed to represent the specimen for a particular type test

[SOURCE: IEC 62271-1:2017, 3.2.1, modified – "switchgear and controlgear" replaced by "specimen"]

3.3 Parts of assemblies

3.3.1

transport unit

part of switchgear and controlgear intended for transportation without being dismantled

3.3.2

busbar

low-impedance conductor to which several electric circuits can be connected at separate points

Note 1 to entry: In many cases, the busbar consists of a bar.

[SOURCE: IEC 60050-151:2001, 151-12-30]

3.4 Switching devices

3.4.1

(mechanical) switch

mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions which may include specified operating overload conditions and also carrying for a specified time currents under specified abnormal circuit conditions such as those of short-circuit

Note 1 to entry: A switch may be capable of making but not breaking short-circuit currents.

[SOURCE: IEC 60050-441:2000, 441-14-10]

3.4.2

disconnector

mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

Note 1 to entry: A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying currents for a specified time under abnormal conditions such as those of short-circuit.

[SOURCE: IEC 60050-441:2000, 441-14-05]

3.4.101

disconnector

mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

Note 1 to entry: A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time currents under abnormal conditions such as those of short-circuit.

Note 2 to entry: "Negligible current" implies currents such as the capacitive currents of bushings, busbars, connections, very short lengths of cable, currents of permanently connected grading impedances of circuit-breakers and currents of voltage transformers and dividers (see also IEC/TR 62271-305). For $U_r \leq 420$ kV, a current not exceeding 0,5 A is a negligible current for the purpose of this definition; for $U_r > 420$ kV and currents exceeding 0,5 A, the manufacturer should be consulted. "No significant change in voltage" refers to such applications as the by-passing of induction voltage regulators or circuit-breakers and bus transfer.

[SOURCE: IEC 60050-441:2000, 441-14-05, modified – Note 2 to entry has been added]

3.4.102

divided support disconnecter

divided support earthing switch

disconnecter (or earthing switch) in which the fixed and moving contacts of each pole are not supported by a common base or frame

Note 1 to entry: A typical example is the pantograph or semi-pantograph disconnecter (or earthing switch).

[SOURCE: IEC 60050-441:2000, 441-14-06 and -07, modified – The term "earthing switch" is completed with "divided support" and the term "disconnecter" substituted by "earthing switch" in Note 1 to entry when appropriate; Note 2 to entry deleted.]

3.4.103

centre-break disconnecter

disconnecter in which both contacts of each pole are movable and engage at a point substantially midway between their supports

Note 1 to entry: This term applies to high-voltage disconnectors only.

[SOURCE: IEC 60050-441:2000, 441-14-08]

3.4.104

double-break disconnecter

disconnecter that opens a circuit at two points

[SOURCE: IEC 60050-441:2000, 441-14-09]

3.4.105

resistor-fitted disconnecter

disconnecter fitted with resistor in series or in parallel to the switching contacts in order to mitigate the very fast transient overvoltage (VFTO) during both the opening and closing operation in metal-enclosed gas-insulated switchgear

3.4.106

earthing switch

mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time currents under abnormal conditions such as those of short-circuit, but not required to carry current under normal conditions of the circuit

Note 1 to entry: An earthing switch may have a short-circuit making capacity.

Note 2 to entry: An earthing switch of $U_r > 52$ kV may have a rating for switching and carrying induced currents.

Note 3 to entry: These devices may sometimes be operated against short-circuit. The different classes of earthing switches are related to the number of short-circuit making operations.

Note 4 to entry: In some cases, earthing switches are used as fault-initiating devices.

[SOURCE: IEC 60050-441:2000, 441-14-11, modified – the Notes 2, 3 and 4 to entry have been added]

3.4.107**combined function earthing switch**

earthing switch having a common contact system for earthing and at least one of the following functions:

- disconnecting;
- making and/or breaking of currents up to the short-circuit current.

3.4.108**switch-disconnector**

switch which, in the open position, satisfies the isolating requirements specified for a disconnector

[SOURCE: IEC 60050-441:2000, 441-14-12]

3.5 Parts of switching devices**3.5.1****enclosure**

housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: Enclosures provide protection of persons or livestock against access to hazardous parts. Barriers, shapes of openings or any other means (whether attached to the enclosure or formed by the enclosed equipment) suitable to prevent or limit the penetration of the specified test probes, are considered as a part of the enclosure, when they are secured in position either by means of interlocks, keys, or by hardware requiring a tool to be removed.

[SOURCE: IEC 60050-826:2004, 826-12-20, modified – the Note 1 to entry has been added]

3.5.2**hazardous part**

part that is hazardous to approach or touch

[SOURCE: IEC 60529:1989, 3.5]

3.5.3**contact** (of a mechanical switching device)

conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.4**auxiliary circuit** (of a switching device)

all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit, the earthing circuit and the control circuits of the device

Note 1 to entry: Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[SOURCE: IEC 60050-441:2000, 441-15-04, modified – "earthing circuit" has been added]

3.5.5**control circuit** (of a switching device)

all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[SOURCE: IEC 60050-441:2000, 441-15-03]

3.5.6

auxiliary switch (of a mechanical switching device)

switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:2000, 441-15-11]

3.5.7

control switch (for control and auxiliary circuits)

mechanical switching device which serves the purpose of controlling the operation of switchgear or controlgear, including signalling, electrical interlocking, etc.

Note 1 to entry: A control switch consists of one or more contact elements with a common actuating system.

[SOURCE: IEC 60050-441:2000, 441-14-46]

3.5.8

auxiliary contact

contact included in an auxiliary circuit and operated by the switching device

[SOURCE: IEC 60050-441:2000, 441-15-10, modified – delete "mechanically"]

3.5.9

control contact

contact included in a control circuit of a switching device and operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09, modified – delete "mechanical" and "mechanically"]

3.5.10

connection (bolted or the equivalent)

two or more conductors designed to ensure permanent circuit continuity when forced together by means of screws, bolts or the equivalent

3.5.11

position indicating device

part of a mechanical switching device which indicates whether it is in the open, closed, or where appropriate, earthed position

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.12

monitoring device

device intended to observe automatically the status of an item

3.5.13

pilot switch

non-manual control switch actuated in response to specified condition of an actuating quantity

Note 1 to entry: The actuating quantity may be pressure, temperature, velocity, liquid level, elapsed time, etc.

[SOURCE: IEC 60050-441:2000, 441-14-48]

3.5.14

partition (of an assembly)

part of an assembly separating one compartment from other compartments

[SOURCE: IEC 60050-441:2000, 441-13-06]

3.5.15

actuator

part of the actuating system to which an external actuating force is applied

Note 1 to entry: The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

[SOURCE: IEC 60050-441:2000, 441-15-22]

3.5.16

splice

connecting device with barrel(s) accommodating electrical conductor(s) with or without additional provision to accommodate and secure the insulation

[SOURCE: IEC 60050-581:2008, 581-24-19, modified – addition of "electrical".]

3.5.17

terminal

point of interconnection of an electric circuit element, an electric circuit or a network with other electric circuit elements, electric circuits or networks

Note 1 to entry: For an electric circuit element, the terminals are the points at which or between which the related integral quantities are defined. At each terminal, there is only one electric current from outside into the element.

Note 2 to entry: The term "terminal" has a related meaning in IEC 60050-151.

[SOURCE: IEC 60050-131:2002, 131-11-11]

3.5.18

terminal block

assembly of terminals in a housing or body of insulating material to facilitate interconnection between multiple conductors

[SOURCE: IEC 60050-581:2008, 581-26-26]

3.5.19

contactor

mechanical contactor

mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

Note 1 to entry: Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[SOURCE: IEC 60050-441:2000, 441-14-33]

3.5.20

starter

combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

Note 1 to entry: Starters may be designated according to the method by which the force for closing the main contacts is provided.

[SOURCE: IEC 60050-441:2000, 441-14-38]

3.5.21

vacuum interrupter

component being part of a switching device in which electrical contacts operate in a highly evacuated, hermetically sealed environment

3.5.22

operation counter

device indicating the number of operating cycles a mechanical switching device has accomplished

3.5.23

coil

set of series-connected turns, usually coaxial

[SOURCE: IEC 60050-151:2001, 151-13-15]

3.5.24

auxiliary and control circuits

entity of

- control and auxiliary circuits, mounted on or adjacent to the switchgear or controlgear, including circuits in central control cubicles;
- equipment for monitoring, diagnostics, etc. that is part of the auxiliary circuits of the switchgear or controlgear;
- circuits connected to the secondary terminals of instrument transformers, that are part of the switchgear or controlgear

3.5.25

subassembly (of auxiliary and control circuits)

part of auxiliary and control circuits, with regard to function or position, having its own interface and normally placed in a separate enclosure

3.5.26

interchangeable subassembly (of an auxiliary and control circuits)

subassembly which is intended to be placed in various positions within an auxiliary and control circuits, or intended to be replaced by other similar subassemblies

Note 1 to entry: An interchangeable subassembly has an accessible interface.

3.5.27

interlocking device

device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.5.101

pole of a switching device

portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.102**main circuit**

<of a switching device> all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.103**contact**

<of a mechanical switching device> conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.104**main contact**

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.105**control contact**

contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.106**"a" contact****make contact**

control or auxiliary contact that is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.107**"b" contact****break contact**

control or auxiliary contact that is open when the main contacts of a mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.108**position-indicating device**

part of a mechanical switching device that indicates whether it is in the open, closed, or where appropriate, earthed position

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.109**position-signalling device**

part of a disconnector or earthing switch which uses auxiliary energy to indicate whether the contacts of the main circuit are in the open or closed position

3.5.110

terminal

conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

[SOURCE: IEC 60050-151:2014, 151-12-12, modified – the note has been deleted.]

3.5.111

contact zone

<for divided support disconnectors and earthing switches> spatial region of positions the fixed contact may take up for correct engagement with the moving contact

3.5.112

power kinematic chain

mechanical connecting system between the operating mechanism and the moving contacts, both included

Note 1 to entry: Refer to Figure 1.

3.5.113

position-indicating kinematic chain

mechanical connecting system between the moving contacts and the position-indicating device(s), both included

3.5.114

position-signalling kinematic chain

mechanical connecting system between the moving contacts and the position of the signalling device(s)

3.5.115

connecting point

most upstream point (i.e. the closest to the source of energy) of the common part of the power and position-indicating/signalling kinematic chains

3.5.116

strain limiting device

device that limits to a defined value the torque or force transmitted to the downstream side of the device irrespective of the torque or force applied to the upstream side

3.5.117

torque (force) controlling system

system that monitors and controls the torque (force) transmitted to the downstream side of the device in comparison with defined value

3.5.118

bushing

device that enables one or several conductors to pass through a partition such as a wall or a tank, and insulate the conductors from it

[SOURCE: IEC 60050-471:2007, 471-02-01, modified – Notes 1 and 2 to entry deleted]

3.5.119

source of energy

origin of the energy released or of the force/torque applied to the power kinematic chain of a switching device during an operation or at any stable position of it

Note 1 to entry: The origin of the energy or force/torque can be human, electrical, hydraulics, pneumatics and mechanics i.e. springs, weights, etc. alone or in combination.

3.6 Operation

3.6.1

dependent power operation (of a mechanical switching device)

operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.2

stored energy operation (of a mechanical switching device)

operation by means of energy stored in the drive mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

Note 1 to entry: This kind of operation may be subdivided according to:

- the manner of storing the energy (spring, weight, etc.);
- the origin of the energy (manual, electric, etc.);
- the manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:2000, 441-16-15, modified – addition of "drive".]

3.6.3

independent unlatched operation

stored energy operation where energy is stored and released in one continuous operation such that the speed and force of the operation are independent of the rate of applied energy

Note 1 to entry: The energy stored for the operation may originate from the operator (manual) or a power source.

3.6.4

positively driven operation

operation which, in accordance with specified requirements, is designed to ensure that auxiliary contacts of a mechanical switching device are in the respective positions corresponding to the open or closed position of the main contacts

Note 1 to entry: A positively driven operating device is made by the association of a moving part, linked mechanically to the main contact of the primary circuit, without the use of springs, and a sensing element. In the case of mechanical auxiliary contacts, this sensing element can be simply the fixed contact, directly connected to the secondary terminal. In the case where the function is achieved electronically, the sensing element can be a static transducer (optical, magnetic, etc.) associated with a static switch, or associated with an electronic or electro-optic transmitting element.

[SOURCE: IEC 60050-441:2000, 441-16-12, modified – the Note 1 to entry has been added]

3.6.5 Terms and definitions relative to pressure (or density)

3.6.5.1

filling pressure p_{ra} for insulation and/or switching

filling density ρ_{ra} for insulation and/or switching

pressure (in Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

3.6.5.2

filling pressure p_{rm} for operation

filling density ρ_{rm} for operation

pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the energy storage device is filled before being put into service or automatically replenished

3.6.5.3

alarm pressure p_{ae} for insulation and/or switching

alarm density ρ_{ae} for insulation and/or switching

pressure (in Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal may be provided

3.6.5.4

alarm pressure p_{am} for operation

alarm density ρ_{am} for operation

pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal from the energy storage device may be provided

3.6.5.5

minimum functional pressure p_{me} for insulation and/or switching

minimum functional density ρ_{me} for insulation and/or switching

pressure (in Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained

3.6.5.6

minimum functional pressure p_{mm} for operation

minimum functional density ρ_{mm} for operation

pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment of the energy storage device becomes necessary

Note 1 to entry: This pressure is often designated as interlocking or lockout pressure.

3.6.6 Terms and definitions relating to gas and vacuum tightness

3.6.6.1

controlled pressure system for gas

volume which is automatically replenished from an external compressed gas supply or internal gas source

Note 1 to entry: Examples of controlled pressure systems are air-blast circuit-breakers or pneumatic drive mechanisms.

Note 2 to entry: A volume may consist of several permanently connected gas-filled compartments.

3.6.6.2

closed pressure system for gas

volume which is replenished when needed by manual connection to an external gas source

Note 1 to entry: Example of closed pressure systems are SF₆ single-pressure circuit-breakers.

3.6.6.3

sealed pressure system

volume for which no further liquid, gas or vacuum processing is required during its expected operating duration

Note 1 to entry: Examples of sealed pressure systems are vacuum interrupters or some SF₆ circuit-breakers.

Note 2 to entry: Sealed pressure systems are completely assembled and tested in the factory.

Note 3 to entry: Expected operating duration starts when the device is sealed.

3.6.6.4**absolute leakage rate** F

amount of gas escaped by time unit

Note 1 to entry: The absolute leakage rate is usually expressed in $\text{Pa} \times \text{m}^3 \times \text{s}^{-1}$.

3.6.6.5**permissible leakage rate** F_n

maximum permissible absolute leakage rate of gas specified for a part, a component or a sub-assembly, or by using the tightness coordination chart, for an arrangement of parts, components or subassemblies connected together in one pressure system

3.6.6.6**relative leakage rate** F_{rel}

absolute leakage rate related to the total amount of gas in the system at filling pressure (or density)

Note 1 to entry: The relative leakage rate is expressed in percentage per year or per day.

3.6.6.7**time between replenishments** t_r

time elapsed between two replenishments performed manually when the pressure (density) reaches the alarm level, to compensate the leakage rate F

Note 1 to entry: This value is applicable to closed pressure systems.

3.6.6.8**number of replenishments per day** N

number of replenishments to compensate the leakage rate F

Note 1 to entry: This value is applicable to controlled pressure systems.

3.6.6.9**pressure drop** Δp

drop of pressure in a given time caused by the leakage rate F , without replenishment

3.6.6.10**tightness coordination chart**

survey document supplied by the manufacturer, used when testing parts, components or sub-assemblies, to demonstrate the relationship between the tightness of a complete system and that of the parts, components and/or sub-assemblies

3.6.6.11**sniffing**

action of slowly moving a leak meter sensing probe around an assembly to locate a gas leak

3.6.6.12**cumulative leakage measurement**

measurement which takes into account all the leaks from a given assembly to determine the leakage rate

3.6.7 Terms and definitions relating to liquid tightness

3.6.7.1

absolute leakage rate

F_{lia}

amount of liquid escaped by time unit

Note 1 to entry: The absolute leakage rate is usually expressed in $\text{cm}^3 \times \text{s}^{-1}$.

3.6.7.2

permissible leakage rate

$F_{\text{n(lia)}}$

maximum permissible leakage rate specified by the manufacturer for a liquid pressure system

3.6.7.3

number of replenishments per day

N_{lia}

number of replenishments to compensate the leakage rate F_{liq}

3.6.7.4

pressure drop

Δp_{lia}

drop in pressure in a given time caused by the leakage rate F_{liq} without replenishment

3.6.101

operation

<of a mechanical switching device> transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this may be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:2000, 441-16-01]

3.6.102

operating cycle

<of a mechanical switching device> succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:2000, 441-16-02]

3.6.103

closing operation

<of a mechanical switching device> operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:2000, 441-16-08]

3.6.104

opening operation

<of a mechanical switching device> operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:2000, 441-16-09]

3.6.105

dependent manual operation

<of a mechanical switching device> operation solely by means of directly applied manual energy, such that the speed and force of the operation are dependent upon the action of the operator

Note 1 to entry: Dependent manual operation may be performed by a crank or by a swing lever (horizontal or vertical).

Note 2 to entry: Switching devices with dependent manual operation have not any inherent switching capability.

[SOURCE: IEC 60050-441:2000, 441-16-13, modified – Notes 1 and 2 to entry have been added]

3.6.106

dependent power operation

<of a mechanical switching device> operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.107

stored energy operation

<of a mechanical switching device> operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

Note 1 to entry: This kind of operation may be subdivided according to:

- 1) the manner of storing the energy (spring, weight, etc.);
- 2) the origin of the energy (manual, electric, etc.);
- 3) the manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:2000, 441-16-15]

3.6.108

independent manual operation

<of a mechanical switching device> stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

[SOURCE: IEC 60050-441:2000, 441-16-16]

3.6.109

closed position

<of a mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

Note 1 to entry: Predetermined continuity means that the contacts are fully closed to carry the rated continuous and the rated short-circuit currents, as applicable.

[SOURCE: IEC 60050-441:2000, 441-16-22, modified – Note to entry has been added]

3.6.110

open position

<of a mechanical switching device> position in which the predetermined clearance between open contacts in the main circuit of the device is secured

[SOURCE: IEC 60050-441:2000, 441-16-23]

3.6.111

toggle point

point beyond which any further movement of the charging mechanism causes the stored energy to be released

3.6.112

mechanical endurance

<of a disconnecter or earthing switch> capability of a disconnecter or earthing switch to perform a defined number of operations without voltage on or current through the circuit under specified operation conditions

3.7 Characteristic quantities

3.7.1

isolating distance (of a pole of a mechanical switching device)

clearance between open contacts meeting the withstand voltage requirements specified for disconnectors

[SOURCE: IEC 60050-441:2000, 441-17-35, modified – "safety" replaced by "withstand voltage".]

3.7.2

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.7.3

highest voltage for equipment

U_m

greatest value of phase-to-phase voltage (RMS value) for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards

Note 1 to entry: Under normal service conditions specified by the relevant apparatus committee this voltage can be applied continuously to the equipment.

[SOURCE: IEC 60050-614: 2016, 614-03-01, modified – The note to entry was added]

3.7.4

supply voltage (of auxiliary and control circuits)

RMS value or, if applicable, the DC value, of the voltage existing at a given instant at a point of supply, measured over a given time interval

Note 1 to entry: If a supply voltage is specified for instance in the supply contract, then it is called "declared supply voltage".

Note 2 to entry: The supply voltage of auxiliary and control circuits is measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

[SOURCE: IEC 60050-614: 2016, 614-01-03, modified – add Note 2 to entry.]

3.7.101

peak making current

<of an earthing switch> peak value of the first major loop of the current in a pole of the earthing switch during the transient period following the initiation of current during a making operation

Note 1 to entry: Where, for a three-phase circuit, a single value of (peak) making current is referred to, this is, unless otherwise stated, the highest value in any phase.

3.7.102

peak current

peak value of the first major loop of current during the transient period following initiation

3.7.103

short-time withstand current

current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-17]

3.7.104

peak withstand current

value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-18]

3.7.105

insulation level

set of withstand voltages specified which characterize the dielectric strength of the insulation

[SOURCE: IEC 60050-614:2016, 614-03-23]

3.7.106

power frequency withstand voltage

RMS value of sinusoidal power frequency voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

[SOURCE: IEC 60050-614:2016, 614-03-22]

3.7.107

lightning impulse withstand voltage

peak value of the lightning impulse voltage which the insulation of the disconnector or earthing switch withstands under specified test conditions

3.7.108

switching impulse withstand voltage

peak value of the switching impulse voltage which the insulation of the disconnector or earthing switch withstands under specified test conditions

3.7.109

external insulation

distances in atmospheric air, and along the surfaces in contact with atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin, etc.

Note 2 to entry: External insulation is either weather-protected or non-weather-protected, designed to operate inside or outside closed shelters, respectively.

[SOURCE: IEC 60050-614:2016, 614-03-02, modified – Note 2 to entry has been added]

3.7.110

internal insulation

internal distances of the solid, liquid or gaseous insulation of equipment which are protected from the effects of atmospheric and other external conditions

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.7.111

self-restoring insulation

insulation which completely recovers its insulating properties within a short time after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-04]

3.7.112

non-self-restoring insulation

insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge

Note 1 to entry: Definitions 3.7.111 and 3.7.112 apply only when the discharge is caused by the application of a test voltage during a dielectric test. However, discharges occurring in service can cause a self-restoring insulation to lose partially or completely its original insulating properties.

[SOURCE: IEC 60050-614:2016, 614-03-05, modified – Note to entry has been added]

3.7.113

parallel insulation

insulator arrangement with two insulators in parallel where the distance between the two insulators might influence the dielectric strength

Note 1 to entry: With open terminal disconnectors and earthing switches, parallel insulation is used when a drive insulator is situated next to a support insulator.

3.7.114

disruptive discharge

failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between electrodes to practically zero

Note 1 to entry: Non-sustained disruptive discharge in which the test object is momentarily bridged by a spark or arc may occur. During these events the voltage across the test object is momentarily reduced to zero or to a very small value. Depending on the characteristics of the test circuit and the test object, a recovery of dielectric strength may occur and may even allow the test voltage to reach a higher value. Such an event should be interpreted as a disruptive discharge unless otherwise specified by the relevant technical committee.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric the loss may be only temporary.

[SOURCE: IEC 60060-1:2010, 3.1.1]

3.7.115

clearance

distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:2000, 441-17-31]

3.7.116

clearance between poles

clearance between any conductive parts of adjacent poles

[SOURCE: IEC 60050-441:2000, 441-17-32]

3.7.117

clearance to earth

clearance between any conductive parts and any parts which are earthed or intended to be earthed

[SOURCE: IEC 60050-441:2000, 441-17-33]

3.7.118

clearance between open contacts

total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position

Note 1 to entry: The total clearance is the sum of the clearances existing between the contacts

[SOURCE: IEC 60050-441:2000, 441-17-34, modified – Note to entry has been added]

3.7.119

mechanical terminal load

external load acting on each terminal

Note 1 to entry: The external load is the result of the combined mechanical forces which may be applied to the terminals of the switching device. Wind forces acting on the equipment itself are not included as they do not contribute to the external load acting on terminals.

Note 2 to entry: A disconnector or earthing switch can be subjected to several mechanical forces different in value, direction and point of action.

Note 3 to entry: The terminal loads as defined here do not usually apply to enclosed switchgear.

3.7.119.1

static mechanical terminal load

static mechanical terminal load at each terminal equivalent to the mechanical force to which this terminal of the disconnector or earthing switch is subjected by the flexible or rigid conductor connected to this terminal

Note 1 to entry: The static mechanical terminal load includes forces resulting from ice, wind and connected conductors.

3.7.119.2

dynamic mechanical terminal load

combination of the static mechanical load and the electromagnetic forces under short-circuit conditions

3.7.120

bus-transfer current switching

opening and closing of disconnectors under load when this load is not interrupted, but transferred from one bus to a parallel bus

3.7.121

bus-transfer current

current that flows when a load is transferred from one bus system to another

3.7.122

bus-transfer voltage

power frequency voltage across the open disconnector after breaking or before making the bus-transfer current

3.7.123

induced current switching

making or breaking of inductive or capacitive currents by an earthing switch, whereupon the currents are induced in an earthed or unearthed system by adjacent energized lines or cables

Note 1 to entry: When two or more transmission lines are mounted together, energy will be induced electrostatically and/or electromagnetically from a live system into a de-energized system resulting in capacitive or inductive currents flowing in this system, depending whether it is earthed at one or at both ends.

3.7.124

electromagnetically induced current

<on an earthing switch> inductive current that flows through an earthing switch when it connects to and disconnects from earth one termination of a de-energized transmission line, with the other termination earthed, and with an energized line carrying current in parallel with, and in proximity to, the earthed line

Note 1 to entry: The inductive current in a de-energized line earthed at both terminations is dependent upon the current in the energized line and the coupling factor to the energized line, as determined by the circuit configuration.

3.7.125

electrostatically induced current

<on an earthing switch> capacitive current that flows through an earthing switch when it connects to and disconnects from earth one termination of a de-energized transmission line, with the other termination open, and with an energized line in parallel with, and in proximity to, the earthed line

Note 1 to entry: The capacitive current in a de-energized line earthed at one termination is dependent upon the voltage of the energized line, the coupling factor to the energized line as determined by the circuit configuration, and the length of the earthed line between the earthed termination and the open termination.

3.7.126

bus-charging current switching

making or breaking of bus-charging currents by disconnectors

3.7.127

bus-charging current

capacitive current that flows when an isolated part of a busbar system is energised or de-energised

3.7.128

transient voltage to earth

U_{TVE}

voltage to earth which appears at the first prestrike during a closing operation of a disconnector

3.7.129

filling pressure for insulation and/or switching

filling density for insulation and/or switching

pressure in Pascal (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

[SOURCE: IEC 62271-1:2017, 3.6.5.1]

3.7.130

minimum functional pressure for insulation and/or switching

minimum functional density for insulation and/or switching

pressure (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or

absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment becomes necessary

[SOURCE: IEC 62271-1:2017, 3.6.5.5]

3.8 Index of definitions

A – B

"a" contact	3.5.106
Absolute leakage rate.....	3.6.6.4 and 3.6.7.1
Actuator.....	3.5.15
Alarm pressure (or density) for insulation and/or switching	3.6.5.3
Alarm pressure (or density) for operation	3.6.5.4
Ambient air temperature	3.1.15
Auxiliary and control circuits	3.5.24
Auxiliary circuit	3.5.4
Auxiliary contact.....	3.5.5
Auxiliary switch	3.5.7
"b" contact	3.5.107
Busbar.....	3.3.2
Bus-charging current.....	3.7.127
Bus-charging current switching	3.7.126
Bushing	3.5.118
Bus-transfer current	3.7.121
Bus-transfer current switching	3.7.120
Bus-transfer voltage	3.7.122

C

Centre-break disconnecter	3.4.103
Clearance	3.7.115
Clearance between open contacts	3.7.118
Clearance between poles	3.7.116
Clearance to earth	3.7.117
Closed position (of a mechanical switching device)	3.6.109
Closed pressure system for gas.....	3.6.6.2
Closing operation (of a mechanical switching device)	3.6.103
Coil.....	3.5.23
Combined function earthing switch.....	3.4.107
Connecting point.....	3.5.115
Connection (bolted or the equivalent).....	3.5.10
Contact.....	3.5.3
Contact (of a mechanical switching device).....	3.5.103
Contact zone (for divided support disconnectors and earthing switches)	3.5.111
Control circuit	3.5.5
Control contact.....	3.5.9
Control contact.....	3.5.105
Control switch	3.5.7
Controlled pressure system for gas.....	3.6.6.1
Cumulative leakage measurement	3.6.6.12

D

Defect.....	3.1.14
Degree of protection.....	3.1.3
Dependent manual operation (of a mechanical switching device).....	3.6.105
Dependent power operation (of a mechanical switching device).....	3.6.1
Dependent power operation (of a mechanical switching device).....	3.6.106
Diagnostic test.....	3.1.9
Disconnecter.....	3.4.2
Disconnecter.....	3.4.101
Disruptive discharge.....	3.7.114
Divided support disconnecter.....	3.4.102
Divided support earthing switch.....	3.4.102
Double-break disconnecter.....	3.4.104
Dynamic mechanical terminal load.....	3.7.119.2

E – F

Earthing switch.....	3.4.106
Electromagnetically induced current (on an earthing switch).....	3.7.124
Electrostatically induced current (on an earthing switch).....	3.7.125
Enclosure.....	3.5.1
External insulation.....	3.1.2
External insulation.....	3.7.109
Failure.....	3.1.11
Filling pressure (or density) for insulation and/or switching.....	3.6.5.1
Filling pressure (or density) for operation.....	3.6.5.2

H – I

Hazardous part.....	3.5.2
Highest voltage for equipment.....	3.7.3
IK code.....	3.1.6
Independent manual operation (of a mechanical switching device).....	3.6.108
Independent unlatched operation.....	3.6.3
Indoor switchgear and controlgear.....	3.1.101
Induced current switching.....	3.7.123
Insulation level.....	3.7.105
Interchangeable subassembly (of auxiliary and control circuits).....	3.5.26
Interlocking device.....	3.5.27
Internal insulation.....	3.1.19
Internal insulation.....	3.7.110
IP Code.....	3.1.4
Isolating distance of a pole.....	3.7.1

L – N

Lightning impulse withstand voltage.....	3.7.107
Main circuit (of a switching device).....	3.5.102
Main contact.....	3.5.104
Maintenance.....	3.1.7

Major failure (of switchgear and controlgear).....	3.1.12
(Mechanical) contactor.....	3.5.19
Mechanical endurance of a disconnecter or earthing switch.....	3.6.112
(Mechanical) switch.....	3.4.1
Mechanical terminal load.....	3.7.119
Minimum functional density for insulation.....	3.7.130
Minimum functional pressure for insulation.....	3.7.130
Minimum functional pressure (or density) for insulation and/or switching.....	3.6.5.5
Minimum functional pressure (or density) for operation.....	3.6.5.6
Minor failure (of switchgear and controlgear).....	3.1.13
Monitoring.....	3.1.16
Monitoring device.....	3.5.12
Non-self-restoring insulation.....	3.7.112
Non-sustained disruptive discharge	3.1.20
Number of replenishments per day	3.6.6.8 and 3.6.7.3

O

Open position (of a mechanical switching device).....	3.6.110
Opening operation (of a mechanical switching device).....	3.6.104
Operation counter	3.5.22
Operation (of a mechanical switching device).....	3.6.101
Operating cycle (of a mechanical switching device).....	3.6.102
Outdoor switchgear and controlgear	3.1.102
Overhaul.....	3.1.10

P

Parallel insulation.....	3.7.113
Partition (of an assembly).....	3.5.14
Peak current	3.7.102
Peak making current (of an earthing switch).....	3.7.101
Peak withstand current.....	3.7.104
Permissible leakage rate	3.6.6.5 and 3.6.7.2
Pilot switch	3.5.13
Pole of a switching device	3.5.101
Position indicating device	3.5.11
Position-indicating device.....	3.5.108
Position-indicating kinematic chain	3.5.113
Position-signalling device	3.5.109
Position-signalling kinematic chain	3.5.114
Positively driven operation.....	3.6.4
Power frequency withstand voltage.....	3.7.106
Power kinematic chain.....	3.5.112
Pressure drop	3.6.6.9 and 3.6.7.4
Protection provided by an enclosure against access to hazardous parts.....	3.1.5

R – S

Rated filling density for insulation	3.7.129

Rated filling pressure for insulation	3.7.129
Rated value	3.7.2
Relative leakage rate	3.6.6.6
Resistor-fitted disconnecter	3.4.105
Sealed pressure system	3.6.6.3
Self-restoring insulation	3.7.111
Short-time withstand current	3.7.103
Site pollution severity class	3.1.18
Sniffing	3.6.6.11
Source of energy	3.5.119
Splice	3.5.16
Starter	3.5.20
Static mechanical terminal load	3.7.119.1
Stored energy operation (of a mechanical switching device)	3.6.2
Stored energy operation (of a mechanical switching device)	3.6.107
Strain limiting device	3.5.116
Subassembly (of auxiliary and control circuits)	3.5.25
Supervision	3.1.17
Supply voltage (of auxiliary and control circuits)	3.7.4
Switch-disconnector	3.4.108
Switchgear and controlgear	3.1.1
Switching impulse withstand voltage	3.7.108

T – V

Terminal	3.5.17
Terminal	3.5.110
Terminal block	3.5.18
Test object	3.2.1
Test object	3.2.1
Tightness coordination chart	3.6.6.10
Time between replenishments	3.6.6.7
Toggle point	3.6.111
Torque (force) controlling system	3.5.117
Transient voltage to earth	3.7.128
Transport unit	3.3.1
User	3.1.103
Vacuum interrupter	3.5.21
Visual inspection	3.1.8

4 Normal and special service conditions

4.1 Normal service conditions

4.1.1 General

Unless otherwise specified, high-voltage switchgear and controlgear, including the operating devices and the auxiliary equipment which form an integral part of them, are intended to be used in accordance with their rated characteristics and the normal service conditions listed in 4.1.

Operation under normal service conditions is considered to be covered by the type tests according to this document and relevant product standard.

4.1.2 Indoor switchgear and controlgear

The normal service conditions for indoor switchgear and controlgear are:

- a) the ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h does not exceed 35 °C. The ambient air temperature does not drop below –5 °C;
- b) there is no influence from solar radiation;
- c) the altitude does not exceed 1 000 m;
- d) the ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapours or salt and would be considered as having site pollution severity class (SPS) “very light” according to IEC TS 60815-1:2008;
- e) the conditions of humidity are as follows:

- the average value of the relative humidity, measured over a period of 24 h, does not exceed 95 %;
- the average value of the water vapour pressure, over a period of 24 h, does not exceed 2,2 kPa;
- the average value of the relative humidity, over a period of one month, does not exceed 90 %;
- the average value of the water vapour pressure, over a period of one month, does not exceed 1,8 kPa.

NOTE 1 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2 High humidity can also be due to ground level rainwater or for underground applications, from incoming cable raceways connected to switchgear.

- f) vibrations due to causes external to the switchgear and controlgear or earth tremors do not exceed the impact of vibrations caused by operation of the switchgear itself.

4.1.3 Outdoor switchgear and controlgear

The normal service conditions for outdoor switchgear and controlgear are:

- a) the ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h does not exceed 35 °C;

the ambient air temperature does not drop below –25 °C;

NOTE 1 Rapid temperature changes can occur, for example a hot sunny day followed by a sudden rain.

- b) solar radiation does not exceed a level of 1 000 W/m²;

NOTE 2 Details of global solar radiation are given in IEC 60721-2-4 [6].

- c) the altitude does not exceed 1 000 m;

- d) the ambient air may be polluted by dust, smoke, corrosive gas, vapours or salt, the pollution does not exceed site pollution severity class (SPS) “medium” as defined by IEC TS 60815-1:2008;

- e) ice coating does not exceed 20 mm;

- f) the wind speed does not exceed 34 m/s;

NOTE 3 Characteristics of wind are defined in IEC 60721-2-2 [8].

- g) the average humidity values given in 4.1.2 e) may be exceeded. Condensation or precipitation may occur;

NOTE 4 Characteristics of precipitation are defined in IEC 60721-2-2 [8].

NOTE 5 The conditions of humidity are always the effect of a combination of relative humidity with other environmental parameters, primarily temperature and rapid change of temperature.

h) vibrations due to causes external to the switchgear and controlgear or earth tremors do not exceed the impact of vibrations caused by operation of the switchgear itself.

4.2 Special service conditions

4.2.1 General

When high-voltage switchgear and controlgear is expected to be used under conditions different from the normal service conditions given in 4.1, the user's requirements should refer to standardized steps in 4.2.2 up to 4.2.7 if not provided by product standards.

NOTE 1 Appropriate actions are also taken to ensure proper operation under such conditions of other components, such as relays.

NOTE 2 Detailed information concerning classification of environmental conditions is given in IEC 60721-3-3 [9] (indoor) and IEC 60721-3-4 [10] (outdoor).

4.2.2 Altitude

For installations at an altitude higher than 1 000 m, the required insulation withstand level of external insulation at the service location shall be determined according to Clause 4 of IEC 60071-2:1996. The rated insulation level of the switchgear and controlgear should be equal to or higher than this value, reference is made to IEC TR 62271-306 [4].

NOTE 1 For internal insulation, the dielectric characteristics are identical at any altitude and no special precautions need to be taken. For external and internal insulation, refer to IEC 60071-2:1996.

NOTE 2 For low-voltage auxiliary and control equipment, no special precautions need to be taken if the altitude is lower than 2 000 m. For higher altitudes, refer to IEC 60664-1 [11].

4.2.3 Exposure to pollution

For outdoor application ambient air that may be polluted by dust, smoke, corrosive gas, vapours or salt at a level that exceeds severity class (SPS) "medium" as defined by IEC TS 60815-1:2008 should be classified as "heavy" or "very heavy" as defined by IEC TS 60815-1:2008.

For indoor application, ambient air that may be polluted by dust, smoke, corrosive gas, vapours or salt at a level that exceeds severity class (SPS) "very light" as defined by IEC TS 60815-1:2008 should be classified as "light", "medium", "heavy" or "very heavy" as defined by IEC TS 60815-1:2008.

NOTE More information about exposure to pollution can be found in Annex K (informative).

For indoor application up to and including 52 kV, IEC TS 62271-304 [12] can be specified, in particular if there are concerns regarding pollution of the switchgear insulation.

4.2.4 Temperature and humidity

For installation at a location where the ambient temperature can be different from the normal service condition ranges stated in 4.1, the ranges of minimum and maximum temperature to be specified should be:

- a) -50 °C to 40 °C for extremely cold climates;
- b) -40 °C to 40 °C for very cold climates;
- c) -30 °C to 40 °C for cold climates;
- d) -25 °C to 40 °C for cold climates (indoor conditions);
- e) -15 °C to 40 °C for moderate climates (indoor conditions);
- f) -5 °C to 55 °C for very hot climates.

In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be up to 98 %.

NOTE In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature and/or atmospheric pressure can occur.

4.2.5 Exposure to abnormal vibrations, shock or tilting

Standard switchgear and controlgear is designed for mounting on substantially level structures, free from excessive vibration, shock, or tilting. Where any of these standard conditions may not exist, the requirements for the particular application should be specified by the user.

For installations where earthquakes are likely to occur, the severity level according to a relevant publication or specification (e.g. IEC TR 62271-300 [13], IEC 62271-207 [14] and IEC TS 62271-210 [15]) should be specified by the user. In case of earthquake risk, the user should specify the operational requirements and admissible damage level.

Installations with other unusual forms of vibration shall be identified, such as installations in close proximity to mine blasting or mobile applications.

NOTE Other relevant publications for seismic evaluations are IEEE Standard 693 [16] and IEEE Standard C37.81 [17].

4.2.6 Wind speed

If the wind speed is expected to be in excess of the normal service wind speed of 34 m/s, the user should specify the requirements for a particular application.

4.2.7 Other parameters

When special environmental conditions prevail at the location where switchgear and controlgear is to be placed in service, they should be specified by the user by reference to IEC 60721-1 [18], IEC 60721-2 (all parts) [19] and IEC 60721-3 (all parts) [20].

5 Ratings

5.1 General

Clause 5 of IEC 62271-1:2017 is applicable for a disconnector or earthing switch, including their operating devices and auxiliary equipment.

The common ratings of switchgear and controlgear assigned by the manufacturer, including their operating devices and auxiliary equipment, shall be selected from the following (as applicable):

- a) rated voltage (U_r);
- b) rated insulation level (U_p , U_d and U_s where applicable);
- c) rated frequency (f_r);
- d) rated continuous current (I_r);
- e) rated short-time withstand current (I_k);
- f) rated peak withstand current (I_p);
- g) rated duration of short-circuit (t_k);
- h) rated supply voltage of auxiliary and control circuits (U_a);
- i) rated supply frequency of auxiliary and control circuits;
- j) rated pressure of compressed gas supply for controlled pressure systems.

- k) rated short-circuit making current (for earthing switches only);
- l) rated contact zone;
- m) rated static mechanical terminal load;
- n) rated ice-coating;
- o) rated values of the bus-transfer current switching capability (for disconnectors only);
- p) rated values of the induced current switching capability (for earthing switches only);
- q) rated values of the bus-charging current switching capability (for disconnectors only).

In addition to the rated values given above, the following classifications may be assigned:

- r) short-circuit making class (for earthing switches only);
- s) mechanical endurance class;
- t) induced current switching class (for earthing switches only);
- u) bus-charging current switching class (for disconnectors only).

NOTE Other ratings can be necessary and will be specified in the relevant IEC product standards.

Ratings define the common specifications of the switchgear and controlgear that are necessary for adequate selection and use in a particular network. Other important characteristics of the switchgear and controlgear are defined in Clause 3, e.g., minimum functional pressure for insulation, some of which are included on the nameplate but are not ratings. Still other characteristics refer to installation, operation and maintenance; they are not considered as ratings since they are related to the technology used for switchgear and controlgear. Examples include normal filling level or filling / alarm pressure (density) of fluids and tightness for liquids, gas and vacuum systems.

Disconnectors or earthing switches being classified for more than one switching capability may indicate their classification by combined class designations. For example, an earthing switch having short-circuit making capability class E1 and an induced current switching capability class B may be classified as class B+E1.

Ratings for making and breaking capabilities cannot be assigned to disconnectors and earthing switches with only manual dependent operation.

In the case of disconnectors and earthing switches with both dependent power and dependent manual operation, any making and breaking capability is not valid for dependent manual operation.

5.2 Rated voltage (U_r)

5.2.1 General

The rated voltage (U_r), as used in this document, is the phase-to-phase RMS voltage equal to the maximum system voltage for which the equipment is designed. It indicates the maximum value of the "highest system voltage" of networks for which the equipment may be used (see 3.7.3, highest voltage for equipment U_m). The rated voltages are given in 5.2.2 and 5.2.3 below.

NOTE The term "rated maximum voltage" used in most IEEE switchgear standards has the same meaning as the term "rated voltage" as used in this document.

5.2.2 Range I for rated voltages of 245 kV and below

Series I: 3,6 kV – 7,2 kV – 12 kV – 17,5 kV – 24 kV – 36 kV – 40,5 kV – 52 kV – 72,5 kV – 100 kV – 123 kV – 145 kV – 170 kV – 245 kV.

Series II (Voltages based on the current practice in some countries, e.g. US):

4,76 kV – 8,25 kV – 15 kV (see Note 1) – 15,5 kV – 25,8 kV (see Note 2) – 27 kV – 38 kV – 48,3 kV – 72,5 kV – 123 kV – 145 kV – 170 kV – 245 kV.

NOTE 1 The 15 kV rating is used in US and some other countries. It has historically been associated with metal-clad and metal-enclosed switchgear used for applications that are primarily indoors and/or outdoors where the insulation level is less than that required for outdoor overhead applications. For applications other than metal-clad or metal-enclosed switchgear, the 15,5 kV rating is preferred.

NOTE 2 The 25,8 kV, still used in IEEE C37.04 [21] as a circuit breaker rating and in some other countries, has been replaced by the 27 kV rating in most relevant equipment standards. For new applications and designs, the 27 kV rating is preferred.

5.2.3 Range II for rated voltages above 245 kV

300 kV – 362 kV – 420 kV – 550 kV – 800 kV – 1 100 kV – 1 200 kV.

5.3 Rated insulation level (U_d , U_p , U_s)

The rated insulation level of switchgear and controlgear shall be selected from the values given in Table 1, Table 2, Table 3 and Table 4.

Withstand values given in Table 1, Table 2, Table 3 and Table 4 cover the application of switchgear and controlgear under normal service conditions defined in 4.1 including altitudes from sea level up to 1 000 m. However for testing purposes to verify a rating or capability, they shall be considered as insulation values at the standardized reference atmosphere temperature (20 °C), pressure (101,3 kPa) and humidity (11 g/m³) specified in IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010. For special service conditions, refer to IEC TR 62271-306 [4].

NOTE According to IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010 the insulation levels in Table 1 to Table 4 cover the temperature range of -40 °C up to 40 °C.

The rated withstand voltage values for lightning impulse voltage (U_p), switching impulse voltage (U_s) (when applicable), and rated short-duration power-frequency voltage (U_d) shall be selected without crossing the horizontal marked lines in Table 1, Table 2, Table 3, and Table 4.

The "common values" used in Table 1 and Table 2 apply to phase-to-earth, between phases and across the open switching device, if not otherwise specified in this document. The withstand voltage values "across the isolating distance" apply to the switching devices where the clearance between open contacts is designed to meet the dielectric requirements specified for disconnectors.

For disconnectors rated above 52 kV and disconnectors having an isolating distance in parallel to the base of the disconnector and having integrated earthing switches, the insulation level between moving parts of the earthing switch and the opposite live parts, during operation of the earthing switch, shall be at least the short-duration power frequency withstand voltage for the smallest gap between them specified in 7.2.6.

If national safety regulations specify higher withstand values for earthing switches that have manual operating mechanisms only, this has to be agreed upon between the user and the manufacturer.

Table 1 – Rated insulation levels for rated voltages of range I, series I

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value	Across the isolating distance	Common value	Across the isolating distance
(1)	(2)	(3)	(4)	(5)
3,6	10	12	20	23
			40	46
7,2	20	23	40	46
			60	70
12	28	32	60	70
			75	85
17,5	38	45	75	85
			95	110
24	50	60	95	110
			125	145
36	70	80	145	165
			170	195
40,5 (NOTE)	80	90	185	215
52	95	110	250	290
72,5	140	160	325	375
100	150	175	380	440
	185	210	450	520
123	185	210	450	520
	230	265	550	630
145	230	265	550	630
	275	315	650	750
170	275	315	650	750
	325	375	750	860
245	360	415	850	950
	395	460	950	1 050
	460	530	1 050	1 200

NOTE The rated voltage of 40,5 kV is recognized in IEC 60038:2009 with a note that unification with the rated voltage of 36 kV is under consideration. Present values are adopted from IEC 60071-1:2006, Annex B.

**Table 2 – Rated insulation levels for rated voltages of range I, series II
(based on current practice in some countries, including US)**

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value	Across the isolating distance	Common value	Across the isolating distance
(1)	(2)	(3)	(4)	(5)
4,76	19	21	60	66
8,25	36	40	95	105
15 (NOTE)	36	40	95	105
15,5	36	40	95	105
	50	55	110	121
25,8 (NOTE)	60	66	125	138
			150	165
27	60	66	125	138
	70	77	150	165
38	70	77	150	165
	80	88	170	187
	95	105	200	220
48,3	105	115	250	275
	120	132	250	275
72,5	160	--	350	385
	175	193	350	385
123	260	286	550	--
	280	308	550	605
145	310	--	650	--
	335	369	650	715
170	365	--	750	--
	385	424	750	825
245	425	--	900	--
	465	512	900	990

NOTE For 15 kV and 25,8 kV ratings, see NOTE 1 and NOTE 2 in 5.2.2.

Table 3 – Rated insulation levels for rated voltages of range II

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated switching impulse withstand voltage U_s kV (peak value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth and between phases (NOTE 2)	Across open switching device and/or isolating distance (NOTE 2)	Phase-to-earth and across open switching device (NOTE 2)	Between phases (NOTES 2 and 3)	Across isolating distance (NOTES 1 and 2)	Phase-to-earth and between phases (NOTE 2)	Across open switching device and/or isolating distance (NOTES 1 and 2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
300	395	435	750	1 125	700(+245)	950	950(+170)
			850	1 275		1 050	1 050(+170)
362	450	520	850	1 275	800(+295)	1 050	1 050(+205)
			950	1 425		1 175	1 175(+205)
420	520	610	950	1 425	900(+345)	1 300	1 300(+240)
			1 050	1 575		1 425	1 425(+240)
550	620	800	1 050	1 680	900(+450)	1 425	1 425(+315)
			1 175	1 760		1 550	1 550(+315)
800	830	1 150	1 425	2 420	1 175(+650)	2 100	2 100(+455)
			1 550	2 480			
1 100	1 100	1 100	1 550	2 635	1 550 + (900)	2 250	2 250 + (630)
		1 100 + (635)	1 800	2 880	1 675 + (900)	2 400	2 400 + (630)
1 200	1 200	1 200	1 800	2 970	1 675 + (980)	2 400	2 400 + (685)
		1 200 + (695)	1 950	3 120		2 550	2 550 + (685)

NOTE 1 In column (6), values in brackets are the peak values $U_r \times \sqrt{2}/\sqrt{3}$ of the power-frequency voltage applied to the opposite terminal (combined voltage).

In column (8), values in brackets are the peak values $0,7 U_r \times \sqrt{2}/\sqrt{3}$ of the power-frequency voltage applied to the opposite terminal (combined voltage).

NOTE 2 Values of column (2) are applicable:

- a) for type tests, phase-to-earth and phase-to-phase;
- b) for routine tests, phase-to-earth, phase-to-phase, and across the open switching device.

The values of columns (3), (4), (5), (6), (7) and (8) are applicable for type tests only.

NOTE 3 These values are derived using the multiplying factors given in Table 3 of IEC 60071-1:2006/AMD1:2010.

Table 4 – Additional rated insulation levels for range II, based on current practice in some countries, including US

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated switching impulse withstand voltage U_s kV (peak value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth and between phases	Across open switching device and/or isolating distance	Phase-to-earth switching device closed	Terminal to terminal, switching device open	Phase-to-earth and between phases	Across open switching device and/or isolating distance
	(NOTE)	(NOTE)	(NOTE)	(NOTE)	(NOTE)	(NOTE)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
362	555	555	825	900	1 300	1 300
362	610	671	885	825+(295)	1 300	1 430
550	860	890	1 180	1 300	1 800	1 800
550	810	891	1 150	1 000+(450)	1 800	1 980
800	960	960	1 430	1 500	2 050	2 050
800	940	1 034	1 300	1 000+(650)	2 050	2 255
NOTE Values of column (2) are applicable: a) for type tests, phase-to-earth and phase-to-phase; b) for routine tests, phase-to-earth, phase-to-phase, and across the open switching device. Values of columns (3), (4), (5), (6) and (7) are applicable for type tests only. In Column (5), values in brackets are the peak values $U_r \sqrt{2}/\sqrt{3}$ of the power-frequency voltage applied to the opposite terminal (combined voltage).						

5.4 Rated frequency (f_r)

The preferred values of the rated frequency are 16,7 Hz, 25 Hz, 50 Hz and 60 Hz.

5.5 Rated continuous current (I_r)

This subclause applies only to disconnectors.

This rating defines the RMS value of the current the switchgear and controlgear can carry continuously for its service conditions (see Clause 4).

The values of rated continuous current should be selected from the R 10 series, specified in IEC 60059.

NOTE 1 The R 10 series comprises the numbers 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10^n .

NOTE 2 The term rated continuous current associated with the continuous current test in 7.5 as used in this edition is equivalent to the term rated normal current used in the previous edition of this document.

5.6 Rated short-time withstand current (I_k)

This rating defines the RMS value of the short-circuit current that the switchgear and controlgear can carry in the closed position during its rated duration (see 5.8) under its service conditions (see Clause 4).

The value of rated short-time withstand current should be selected from the R 10 series specified in IEC 60059.

NOTE The R 10 series comprises the numbers 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10^n .

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.7 Rated peak withstand current (I_p)

This rating defines the peak current associated with the first major loop of the rated short-time withstand current that the switchgear and controlgear can carry in the closed position under its service conditions (see Clause 4).

The rated peak withstand current is obtained by multiplying the RMS value of the rated short-time withstand current with a peak factor. This peak factor is a function of the DC time constant of the network and the rated frequency.

A DC time constant of 45 ms covers the majority of cases and corresponds to a rated peak withstand current equal to 2,5 times the rated short-time withstand current for a rated frequency of 50 Hz. For a rated frequency of 60 Hz, it is equal to 2,6 times the rated short-time withstand current.

Table 5 gives peak factors for different time constants and rated frequencies.

NOTE 1 IEC TR 62271-306 [4] gives the information for calculating peak factors according to rated frequency and time constant of the network.

NOTE 2 For non-simultaneous drive mechanisms of each pole the peak factor can be different, for details, see IEC TR 62271-306 [4].

Table 5 – Peak factors for rated peak withstand current

Rated frequency (f_r) Hz	DC time constant ms			
	45	60	75	120
16,7	2,1	2,3	2,4	2,5
25	2,3	2,4	2,5	2,6
50	2,5	2,6	2,7	2,7
60	2,6	2,7	2,7	2,7

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.8 Rated duration of short-circuit (t_k)

This rating defines the interval of time for which the switchgear and controlgear can carry, in the closed position, a current equal to its rated short-time withstand current.

The preferred value of rated duration of short-circuit is 1 s.

An alternative value lower or higher than 1 s may be chosen, e.g. 0,5 s, 2 s, 3 s.

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.9 Rated supply voltage of auxiliary and control circuits (U_a)

5.9.1 General

Several auxiliary voltages can be used on a single piece of switchgear and controlgear.

5.9.2 Rated supply voltage (U_a)

The rated supply voltage should be selected from the standard values given in Table 6 and Table 7.

Table 6 – Direct current voltage

U_a V
24
48
60
110
125
220
250

Table 7 – Alternating current voltage

Line number	Three-phase, three-wire or four-wire systems V	Single-phase, three-wire systems V	Single-phase, two-wire systems V
(1)	(2)	(3)	(4)
1	–	120/240	120
2	120/208	–	120
3	(220/380)	–	(220)
4	230/400	–	230
5	(240/415)	–	(240)
6	277/480	–	277
7	347/600	–	347

The value 230/400 V indicated in line 4 of this table should be, in the future, the IEC standard voltage replacing the values 220/380 V and 240/415 V in lines 3 and 5 and its adoption is recommended in new systems. The voltage variations of existing systems at 220/380 V and 240/415 V should be brought within the range 230/400 V $\pm$ 23/40 V. The reduction of this range will be considered at a later stage of standardization.

NOTE The lower values in the column (2) of this table are voltages to neutral and the higher values are voltages between phases. The lower value in the column (3) is the voltage to neutral and the higher value is the voltage between lines.

5.10 Rated supply frequency of auxiliary circuits and control circuits

When alternating current supply voltage is used, the preferred values of rated supply frequency are 50 Hz and 60 Hz.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

The preferred values of rated pressure (relative pressure) are:

0,5 MPa – 1 MPa – 1,6 MPa – 2 MPa – 3 MPa – 4 MPa.

NOTE Examples of controlled pressure systems are air-blast circuit-breakers or pneumatic drive mechanisms.

5.11.101 Rated pressure of compressed gas supply for insulation and/or switching

The limits of pressure shall be given by the manufacturer.

5.11.102 Rated pressure of compressed gas supply for operation

External pneumatic or hydraulic supply:

Unless otherwise specified by the manufacturer, the limits of the operating pressure are 85 % and 110 % of the rated pressure.

5.101 Rated short-circuit making current (I_{ma})

The rated short-circuit making current is applicable only to the earthing switches class E1 and E2. This shall be equal to the rated peak withstand current.

Subclause 5.102 provides a classification of earthing switches for short-circuit making capability.

5.102 Classification of earthing switches for short-circuit making

The short-circuit making capability of earthing switches to perform a defined number of short-circuit making operations, without major maintenance, shall correspond to one of the classes given in Table 1.

NOTE The increased number of making operations of Class E2 is typically related to voltages up to and including 52 kV depending on the operating conditions and the protection systems of such networks.

Table 8 – Classification of earthing switches for short-circuit making

Class	Type of earthing switch
E0	Earthing switch with no short-circuit making capability
E1	Earthing switch with capability to perform two short-circuit making operations
E2	Earthing switch with capability to perform five short-circuit making operations

5.103 Rated contact zone

In case of divided support disconnectors and divided support earthing switches the manufacturer shall state the rated values of the contact zone (indicated by x_r , y_r and z_r). Preferred values are given in Table 2 and Table 3. The rated values shall be specified by the manufacturer. This refers also to a tolerable angular displacement of the fixed contact.

Table 9 – Preferred contact zones for "fixed" contacts supported by flexible conductors

Rated voltage U_r kV	x mm	y mm	z_1 mm	z_2 mm	
72,5 – 100	100	300	200	300	
123 – 145		350			
170	200	400	250	450	
245		500			300
300					
362			400	500	
420					
550					
800	250	650	450	550	
1 100 – 1 200	300	700	500	600	
x = total amplitude of longitudinal movement of the supporting conductor (temperature). y = total horizontal deflection (perpendicular to supporting conductor) (wind). z = vertical deflection (temperature and ice).					
NOTE z_1 are values for short-span, z_2 are values for long-span of the flexible conductors to which the fixed contacts are mounted.					

Table 10 – Preferred contact zones for "fixed" contacts supported by rigid conductors

Rated voltage U_r kV	x mm	y mm	z mm
72,5 – 100 – 123 – 145	100	100	100
170 – 245 – 300 – 362 – 420	150	150	150
550	175	175	175
800	200	200	200
1 100 – 1 200	250	250	250
x = total amplitude of longitudinal movement of the supporting conductor (temperature). y = total horizontal deflection (perpendicular to supporting conductor) (wind). z = vertical deflection (ice).			

5.104 Rated static mechanical terminal load

When disconnectors or earthing switches are intended to be directly connected to lines, i.e. flexible or rigid conductors, the rated static mechanical terminal load of each terminal shall be assigned, indicating the directions of application.

The maximum static mechanical terminal load to which a terminal of a disconnector or earthing switch is allowed to be subjected under the most disadvantageous conditions is the rated static mechanical terminal load.

Preferred values of static mechanical terminal loads are given in Table 4 and are intended to be used as a guide.

Table 11 – Preferred static mechanical terminal loads

Rated voltage U_r kV	Rated continuous current I_r A	Two- and three-column disconnectors or earthing switches		Divided support disconnectors or earthing switches		Vertical Force F_c^a N
		Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	
		In Figure 9		In Figure 8		
		N	N	N	N	
72,5	$\leq 1\,600$	400	130	800	200	500
	$> 1\,600$	500	170	800	200	
100 – 123 – 145	$\leq 1\,600$	500	170	800	200	1 000
	$> 1\,600$	600	200	1 000	300	
170	$\leq 1\,600$	600	200	1 000	300	
	$> 1\,600$	800	250	1 250	400	
245	$\leq 2\,500$	800	270	1 250	400	1 250
	$> 2\,500$	1 000	330	1 600	500	
300 – 362	$\leq 2\,500$	1 000	400	1 600	500	1 500
	$> 2\,500$	1 500	500	1 800	600	
420	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
550	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
800	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
1 100 – 1 200	$\leq 4\,000$	2 000	660	4 000	1 600	2 000
	$> 4\,000$	2 500	1 000	5 000	2 000	

^a F_c simulates the downward forces caused by the weight of the connecting conductors. F_c does not apply to flexible conductors.

NOTE The static mechanical terminal load includes forces resulting from ice, wind and connected conductors.

5.105 Classification of disconnectors for mechanical endurance

The mechanical endurance of disconnectors shall correspond to one of the classes given in Table 5. The performance is associated to a programme of maintenance defined by the manufacturer.

Table 12 – Classification of disconnectors for mechanical endurance

Class	Number of operating cycles	Mechanical endurance
M0	1 000	Normal
M1	2 000	Extended
M2	10 000	Extended

5.106 Classification of earthing switches for mechanical endurance

The mechanical endurance of earthing switches shall correspond to one of the classes given in Table 6. The performance is associated to a programme of maintenance defined by the manufacturer.

Table 13 – Classification of earthing switches for mechanical endurance

Class	Number of operating cycles	Mechanical endurance
M0	1 000	Normal
M1	2 000	Extended

5.107 Rated ice-coating

For disconnectors and earthing switches able to operate under ice-conditions a rated ice-coating shall be assigned by the manufacturer.

Preferred ratings of ice-coating are: 1 mm, 10 mm and 20 mm.

5.108 Rated values of disconnectors for bus-transfer current switching

5.108.1 Rated bus-transfer current

The rated bus-transfer current of disconnectors used in both air-insulated and gas-insulated installations is:

- for $52 \text{ kV} < U_r < 245 \text{ kV}$ 80 % of the rated continuous current of the disconnector, but limited to 1 600 A;
- for $245 \text{ kV} \leq U_r \leq 550 \text{ kV}$ 60 % of the rated continuous current of the disconnector, but limited to 4 000 A;
- for $U_r > 550 \text{ kV}$ 80 % of the rated continuous current of the disconnector, but limited to 4 000 A.

Rated bus-transfer currents greater than the values given above may be assigned by the manufacturer.

NOTE 1 It is recognised that disconnectors of $U_r \leq 52 \text{ kV}$ can also have bus-transfer switching capability. In this case, checking of the performance is subjected to an agreement between the user and the manufacturer.

NOTE 2 For more information refer to the following: for information about 60 % and 80 %, refer to CIGRE TB 570 – 2014 [1]¹ and CIGRE SC A3 third report, presented in Paris (FR), 2016, and about 4 000 A refer to CIGRE SC A3 and B3 colloquium in Nagoya (JP), paper no. 212, 2015.

5.108.2 Rated bus-transfer voltage

Rated bus-transfer voltages are given in Table 7. Different bus-transfer voltages than the values given in Table 7 below may be assigned by the manufacturer.

¹ Numbers in square brackets refer to the Bibliography.

Table 14 – Rated bus-transfer voltages of disconnectors

Rated continuous current I_r A	Rated voltage U_r			Rated voltage U_r		
	$52 \text{ kV} < U_r < 245 \text{ kV}$	$245 \text{ kV} \leq U_r \leq 550 \text{ kV}$	$U_r > 550 \text{ kV}$	$52 \text{ kV} < U_r < 245 \text{ kV}$	$245 \text{ kV} \leq U_r \leq 550 \text{ kV}$	$U_r > 550 \text{ kV}$
	Gas-insulated installations V (RMS value)			Air-insulated installations V (RMS value)		
2 000	10	15	20	100	175	250
2 500					220	310
3 150		20	30		275	390
4 000		25	42		350	500
5 000					435	625
6 300		35			550	
8 000					580	

NOTE The values in the table are based on calculations of a bus-transfer current corresponding to the rated continuous current of the disconnector taking into account typical loop lengths and impedances given in Annex B.

5.109 Classification and rated values of earthing switches for induced current switching

Rated induced current and voltage shall be assigned to earthing switches of $U_r > 52 \text{ kV}$ and designed for making or breaking of inductive or capacitive induced currents (see 3.7.124 and 3.7.125), hence requiring an induced current switching capability.

For this application, a classification for induced current switching (class A or B) shall be assigned to the earthing switch. This class depends upon the severity of the induced current switching duty. The classification of earthing switches for induced current switching is given in Table 8.

Table 15 – Classification of earthing switches for induced-current switching

Class	Type of earthing switch
A	Earthing switch designed to be used in circuits having relatively short sections of line or low coupling to adjacent energized circuits
B	Earthing switch designed to be used in circuits having relatively long sections of lines or high coupling to adjacent energized circuits

The values of rated induced current and voltage for the two classes of earthing switches are given in Table 9. These values represent the maximum switching capabilities for each rated voltage.

Table 16 – Rated induced currents and voltages

Rated voltage U_r kV	Electromagnetic coupling				Electrostatic coupling			
	Rated induced current A (RMS value)		Rated induced voltage kV (RMS value)		Rated induced current A (RMS value)		Rated induced voltage kV (RMS value)	
	Class		Class		Class		Class	
	A	B	A	B	A	B	A	B
72,5	50	80	0,5	2	0,4	2	3	6
100								
123			1			3		9
145								
170			80			160		1,4
245								
300								
362	2	20		2	25		8	25
420								
550								
800	110	440	5	65	7,5	50	20	40
1 100								
1 200								

NOTE 1 In some situations (very long sections of the earthed line in proximity to an energized line; very high loading on the energized line; energized line having a service voltage higher than the earthed line, etc.), the induced current and voltage can be higher than the given values. For these situations, the rated values are subject to agreement between manufacturer and user.

NOTE 2 The rated induced voltages correspond to line-to-earth values for both single-phase and three-phase tests (see 7.107.5).

5.110 Classification and rated values of disconnectors for bus-charging current switching

Disconnectors forming part of the gas-insulated switchgear and controlgear of $U_r \geq 300$ kV shall be classified for bus-charging current switching performance. Tests for disconnectors of $U_r < 300$ kV are generally not necessary and are subject to agreement between the manufacturer and the user. In any case, for $52 \text{ kV} < U_r < 300 \text{ kV}$, the test for classification of BCS is not mandatory.

NOTE Bus-charging switching capability for air-insulated disconnectors is subject to agreement between the manufacturer and the user, refer to IEC/TR 62271-305.

Four classes are distinguished depending upon application. See Table 10, where the associated test duties are also indicated.

Table 17 – Classification of disconnectors for bus-charging switching

Class	Application	Associated test duties (see 7.108.2)
BCS	Switching of very short sections of busbar ducts of open circuits	TD ₁
BCB	BCS class + switching of parallel capacitors associated to circuit-breakers, under 180° out-of-phase condition of open circuits	TD ₁ & TD ₂
BCL	BCS class + switching of long sections of busbar ducts of open circuits	TD ₁ & TD ₃
BCT	BCS class + BCB class + BCL class	TD ₁ , TD ₂ & TD ₃

The rated bus-charging current is associated only to disconnectors classified as BCL or BCT. No rated bus-charging current can be assigned to TD₁ and TD₂, as they depend on the design, the physical construction of the installation, and rated voltage. The standard values for this rating are given in Table 11. These values are only associated to the de-energizing of long sections of busbar ducts in accordance with test duty 3 in 7.108.2. For more information, refer to Annex B.

Table 18 – Standard rated bus-charging currents

Rated voltage U_r kV (RMS value)	72,5	100	123	145	170	245	300	362	420	550	800	1 100	1 200
Rated bus-charging current A (RMS value)	0,1	0,1	0,1	0,1	0,1	0,25	0,25	0,5	0,5	0,5	0,8	1,0	1,0
NOTE The values are normally not exceeded in practice. They apply to 50 Hz as well as to 60 Hz. In the case of higher values in practice, other test values are considered by agreement between the manufacturer and the user.													

6 Design and construction

6.1 Requirements for liquids in disconnectors and earthing switches

The manufacturer shall specify the type and the required quantity and quality of the liquid used in switchgear and controlgear.

The manufacturer shall provide the user with necessary instructions for renewing the liquid and maintaining its required quantity and quality (refer to 11.5.2) except for sealed pressure systems.

For oil-filled switchgear and controlgear, insulating oil complying with IEC 60296 shall be used.

6.2 Requirements for gases in disconnectors and earthing switches

The manufacturer shall specify the type and the required quantity, and quality of the gas used in switchgear and controlgear.

The manufacturer shall provide the user with necessary instructions for renewing the gas and maintaining its required quantity and quality (refer to 11.5.2 and item a) of 11.5.3). This requirement does not apply to sealed pressure systems.

For sulphur hexafluoride (SF_6) filled switchgear and controlgear, SF_6 in accordance with IEC 60376 for new SF_6 and IEC 60480 for reused SF_6 shall be used. For switchgear and controlgear with SF_6 mixtures, reference is made to IEC 62271-4.

In order to prevent condensation, the maximum allowable humidity content within gas-filled switchgear and controlgear filled with gas at the filling density for insulation ρ_{re} shall be such that the dew point at filling pressure (density) for insulation is not higher than -5 °C for a measurement at 20 °C during service life, refer to 11.3.6.

NOTE In general, the term "gas" for insulation and/or switching in this document refers to SF_6 . However, the principles expressed could be also used for other gases.

6.3 Earthing of disconnectors and earthing switches

Switchgear and controlgear shall be provided with a reliable earthing point for connection of an earthing conductor suitable for specified fault conditions. The connecting point shall be marked with the "protective earth" symbol, as indicated by symbol IEC 60417-5019:2006-08. Conductive parts of the switchgear and controlgear intended to be connected to the earthing system, may be designed to be part of the earthing circuit.

All conductive components and enclosures that may be touched during normal operating conditions and are intended to be earthed shall be designed to carry 30 A (DC) with a voltage drop of maximum 3 V to the earthing point provided at the switchgear and controlgear.

NOTE For guidance on the connection of the earthing point of the switchgear and controlgear to the main station earth, Clause 10 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 [22] applies.

For disconnectors and earthing switches used in enclosed switchgear and controlgear assemblies, 5.3 of IEC 62271-200:2011, IEC 62271-201:2014 or IEC 62271-203:2011 is applicable (as it corresponds).

Metallic enclosures and operating mechanisms not mounted together with and not electrically connected to the metallic frame of the disconnector or earthing switch, shall be provided with an earthing terminal marked with the protective earth symbol.

If, for testing purposes after installation (e.g. cable testing, contact resistance measurement), a removable connection for earthing the main circuit through the earthing switch exists, it shall be able to withstand the rated peak and short-time withstand current. The relevant insulation level (DC and AC) of this external connection – when removed – shall be stated by the manufacturer.

6.4 Auxiliary and control equipment and circuits

Refer also to 6.104 of this document.

6.4.1 General

Switchgear and controlgear include all auxiliary and control equipment and circuits, including but not limited to, electronic controls, supervision, monitoring and communication.

Auxiliary and control equipment and circuits shall operate normally when the voltage measured during operation at the supply terminals of the auxiliary and control equipment and circuits:

- is within 85 % to 110 % of rated supply voltage (U_a);
- in the case of DC, a ripple voltage is not greater than 5 % of U_a ;
- is free of the voltage dips and interruptions which exceed the limits declared by the manufacturer according to IEC 61000-4-29 (DC supply voltage) and IEC 61000-4-11 (AC supply voltage).

In case of supply interruptions (also during operations) that exceed the duration limits declared by the manufacturer for normal operation:

- there shall be no false operation, false alarms or false remote signalling resulting from the interruption or re-instatement of the supply;
- the manufacturer shall state the behaviour of the device when the supply voltage gets interrupted (for example impact on internal energy storage);
- the manufacturer shall state the behaviour of the device when the supply voltage returns;
- subsequent actions shall only be completed in response to a new valid operational command (where applicable).

The fulfilment of the above conditions can be demonstrated at any convenient dip duration that exceeds the declared limit.

NOTE 1 Possible actions can be:

- a) completing the pending action without manual intervention such that the equipment achieves a defined, safe operating state for example open, closed, charged, discharged;
- b) manual intervention such that the equipment achieves a defined, safe operating state for example open, closed, charged, discharged;
- c) completing the action after giving another command for the same switching operation that was interrupted.

This choice can also be dependent on the duration of the interruption.

Specific conditions are given in 6.9 for shunt closing releases, shunt opening releases and under-voltage releases.

For supply voltages lower than the minimum stated above, precautions shall be taken to prevent any damage to electronic equipment and/or unsafe operation.

Requirements for the interface with digital communication that ensure compliance with IEC 61850 (all parts) [23] are detailed in IEC 62271-3 [24].

NOTE 2 The logical nodes in IEC 62271-3:2015 (XCBB, XSWI) and their additional data objects described in Annex B of IEC 62271-3:2015 cover only some properties required by the electronic nameplates of some switchgear and controlgear of the IEC 62271 series of standards. The other properties required for the physical nameplate, tendering, quotation and ordering phases are not covered.

6.4.2 Protection against electric shock

6.4.2.1 Protection of auxiliary and control circuits from the main circuit

Auxiliary and control circuits that are installed on the frame of switchgear and controlgear shall be suitably protected against disruptive discharge from the main circuit. This is verified by dielectric type tests specified in 7.2, see 7.2.5 c).

6.4.2.2 Safety clearance during service

Auxiliary and control circuits to which access is required during service shall be accessible without the need to compromise clearances to hazardous parts.

6.4.3 Components installed in enclosures

6.4.3.1 Selection of components

All components used in the auxiliary and control circuits shall be designed or selected to be operational with their rated characteristics over the full range of service conditions inside auxiliary and control circuits enclosures. Suitable precautions (for example, heaters, ventilators, insulation, etc.) should be taken to ensure that those service conditions essential for proper operation of relays, contactors, low-voltage switches, meters, operation counters, push-buttons, etc. are maintained.

NOTE These internal conditions in control cabinet for auxiliary and control circuits can differ from the external service conditions specified in Clause 4.

The loss of “suitable precautions” shall not cause failure of the auxiliary and control circuits within the enclosure or untimely operation of the switchgear within the specified time. Selection of components should take into account the temperature obtained in the cabinet of the control and auxiliary circuit during a 2-hour period following the loss of the “suitable precautions” in order to ensure the proper operation of switchgear and controlgear until the end of this 2-hour period.

After this 2-hour period non-operation is acceptable. If the loss of the “suitable precautions” is longer than 2 h but does not exceed 24 h in total, the functionality of the switchgear and controlgear shall come back to its original characteristics when the service conditions are recovered.

Where heating is essential for correct functioning of the equipment, monitoring of the heating circuit shall be provided.

In the case of switchgear and controlgear designed for outdoor installation, suitable arrangements (ventilation and/or internal heating, etc.) may be required to prevent harmful condensation in auxiliary and control circuit enclosures.

6.4.3.2 Accessibility

Closing and opening actuators and emergency shut-down system actuators shall be located between 0,4 m and 2 m above the floor, ground or operating platform normally used by operating personnel.

Other actuators should be located at such a height that they can be easily operated, and indicating devices should be located at such a height as to be readily legible.

Where a component may need adjustment during its service life, access shall be provided with protection level of at least IP XXB, refer to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

6.4.3.3 Identification

Identification of components installed in enclosures shall be in agreement with the indication on the wiring diagrams and drawings. If a component is of the plug-in type, an identifying mark should be placed on the component and on the fixed part where the component plugs in.

6.4.3.4 Requirements for auxiliary and control circuit components

6.4.3.4.1 General

The auxiliary and control circuit components shall comply with applicable IEC standards if one exists. Annex D (informative) is provided as a quick reference to many of the component standards.

6.4.3.4.2 Cables and wiring

Where a facility for external wiring is provided, it shall be through an appropriate connecting device, e.g. terminal blocks or plug-in terminations.

Polarity reversal at the interfacing point shall not damage auxiliary and control circuits.

Terminal blocks should be fixed. Cables between two terminal blocks shall have no intermediate splices or soldered joints.

Cables and wiring shall be adequately supported and shall not rest against sharp edges.

The available wiring space for external connection shall permit spreading of the cores of multi-core cables and the proper termination of the conductors without undue stresses.

Conductors connected to components mounted on doors shall be so installed that no mechanical damage can occur to the conductors as a result of movement of these doors.

6.4.3.4.3 Terminals

If facilities are provided for connecting incoming and outgoing neutral, protective and PEN (protective earthed neutral) conductors, they shall be situated in the vicinity of the associated phase conductor terminal.

6.4.3.4.4 Auxiliary switches

Auxiliary switches shall be suitable for the number of operating cycles specified for the high-voltage switching device to which they are linked.

Auxiliary switches which are operated in conjunction with the main contacts shall be positively driven in both directions. An auxiliary switch may consist of a set of two one-way positively driven auxiliary contacts (one for each direction).

6.4.3.4.5 Auxiliary and control contacts

Auxiliary and control contacts shall be suitable for the number of operating cycles specified for the switching device. This requirement is verified by the mechanical endurance test of the high-voltage switching devices to which they are linked.

The operational characteristics of the auxiliary contacts that are made available to the user shall comply with one of the classes shown in Table 8.

Table 19 – Auxiliary contact classes

DC current				
Class	Rated continuous current	Rated short-time withstand current	Breaking capacity	
			$U_a \leq 48 \text{ V}$	$110 \text{ V} \leq U_a \leq 250 \text{ V}$
1	10 A	100 A/30 ms		440 W
2	2 A	100 A/30 ms		22 W
3	200 mA	1 A/30 ms	50 mA	

NOTE 1 Control contacts which are included in a control circuit of a mechanical switching device can be covered by this table.

NOTE 2 If insufficient current is flowing through the contact, oxidation can increase the resistance. Therefore, a minimum value of current is specified for class 1 contact.

NOTE 3 In the case of the application of solid state contacts, the rated short-time withstand current can be reduced if current-limiting equipment, other than fuses, is employed.

NOTE 4 For all classes, breaking capacity are based on a circuit time constant of 20 ms with a tolerance of $^{+20}_0$ %.

NOTE 5 An auxiliary contact which complies with class 1 2 or 3 for DC is normally able to handle corresponding AC current and voltage.

NOTE 6 Breaking current at a defined voltage value between 110 V and 250 V can be deduced from the indicated power value for class 1 and class 2 contacts (for example, 2 A at 220 V DC for a class 1 contact).

Examples of the use of the three contact classes are shown in Figure 1.

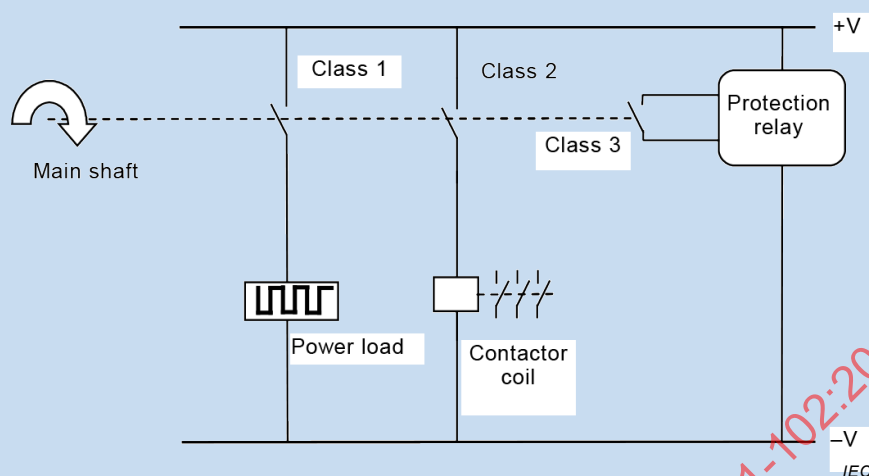


Figure 1 – Examples of classes of contacts

6.4.3.4.6 Heating elements

All heating elements shall be designed to prevent touching an electrically live part.

Where contact with a heater or shield can occur accidentally, the surface temperature shall not exceed the temperature limits for accessible parts not to be touched in normal operation, as specified in 7.5.6.

6.4.3.5 Operation counter

Operation counters shall be suitable for their intended duty in terms of environmental conditions and for the number of operating cycles specified for the switching devices.

6.5 Dependent power operation

A switching device arranged for dependent power operation with external energy supply shall be able to switch its rated making and/or breaking currents (if any) when the voltage or the pressure of the power supply of the operating device is at the lower of the limits specified under 6.4.1 and 6.6.2 (the term "operating device" here embraces intermediate control relays and contactors where provided).

Except for slow operation during maintenance, the main contacts shall only move under the action of the drive mechanism and in the designed manner. The closed or open position of the main contacts shall not change as a result of loss of the energy supply or the re-application of the energy supply after a loss of energy, to the closing and/or opening device.

In case of disconnectors and earthing switches with both dependent power and dependent manual operation, the noncapability of making and breaking, when manually operated, shall be clearly stated in the instruction manual and close to the point of manual operation.

Disconnectors and earthing switches having a pneumatic or hydraulic operating device shall be capable of closing and opening when the supply pressure is between the minimum and the maximum supply pressure specified (refer to 5.11.102).

See also 6.105 for maximum manual operating forces.

6.6 Stored energy operation

See also subclause 6.105 for maximum manual operating (storing energy) forces.

6.6.1 General

A switching device arranged for stored energy operation shall be capable of making and breaking all currents up to its rated values when the energy storage device is suitably charged. Except for slow operation during maintenance, the main contacts shall only move under the action of the drive mechanism and in the designed manner, and not due to re-application of the energy supply after a loss of energy (electric power or pressure supply).

A device indicating when the energy storage device is charged shall be mounted on the switching device except in the case of an independent unlatched operation.

It shall not be possible for the moving contacts to move from one position to the other, unless the stored energy is sufficient for satisfactory completion of the opening or closing operation. Stored energy devices shall be able to be discharged to a safe level prior to access.

6.6.2 Energy storage in gas receivers or hydraulic accumulators

When the energy storage device is a gas receiver or hydraulic accumulator, the requirements of 6.6.1 apply at operating pressures between the limits specified in items a) and b).

a) External pneumatic or hydraulic supply

Unless otherwise specified by the manufacturer, the limits of the operating pressure are 85 % and 110 % of their specified rated pressure.

These limits do not apply when the gas receivers also store compressed gas for interruption.

b) Compressor or pump integral with the switching device or the operating device

The limits of operating pressure shall be stated by the manufacturer.

6.6.3 Energy storage in springs (or weights)

When the energy storage device is a spring (or weight), the requirements of 6.6.1 apply when the spring is charged (or the weight lifted).

6.6.4 Manual charging

If a spring (or weight) is charged by hand, the direction of motion of the handle shall be marked.

The manual charging facility shall be designed such that the handle is not driven by the operation of the switching device.

The maximum actuating force required for manually charging a spring (or weight) shall not exceed 250 N.

6.6.5 Motor charging

Motors, and their electrically operated auxiliary equipment for charging a spring (or weight) or for driving a compressor or pump, shall operate satisfactorily between 85 % and 110 % of the rated supply voltage (refer to 5.9), the frequency, in the case of AC, being the rated supply frequency (refer to 5.10).

NOTE For electric motors, the limits do not imply the use of non-standard motors but only the selection of a motor which at these values provides the necessary power, and the rated voltage of the motor need not coincide with the rated supply voltage of the auxiliary and control circuits.

6.6.6 Energy storage in capacitors

When the energy storage is a charged capacitor, the requirements of 6.6.1 apply when the capacitor is charged.

6.7 Independent unlatched operation (independent manual or power operation)

The mechanism shall not reach the energy release point of a close operation if the switching device is in the closed state or of an open operation if it is open.

NOTE 1 This requirement is to prevent the inadvertent, and potentially damaging, discharge of stored energy against an already closed or already open switching device.

It shall not be possible to progressively store energy by incomplete operations against an interlock, if supplied. During the operation, any movement of the contacts prior to release of the energy shall not reduce any electrically stressed gap to below that which will withstand rated insulation levels.

For a switching device with short-circuit making capacity but no short-circuit current breaking capacity, a time delay shall be introduced between the closing and opening operation. This time delay shall be not less than the rated duration of the short-circuit (refer to 5.8).

NOTE 2 The intention of the provision is to let the switching device “ride out” the short-circuit in the closed position until a back-up device safely clears the fault.

See also subclause 6.105 for maximum manual operating (storing energy) forces.

6.8 Manually operated actuators

The direction of operation of manually operated actuators shall be self-evident or explicit.

Preferred operation principles are to

- turn clockwise to close and anti-clockwise to open, or
- push in to close and pull out to open, or
- move right to close and move left to open, or
- move upwards to close and move downwards to open.

Other design may be implemented.

NOTE Reference is made to IEC 60447.

6.9 Operation of releases

6.9.1 General

See 6.4.1 for the basis of operation limits with respect to supply voltage.

6.9.2 Shunt closing release

A shunt closing release shall be able to operate within a voltage range of the power supply, measured at the input terminals, between 85 % and 110 % of the rated supply voltage of the closing device (refer to 5.9), the frequency, in the case of AC, being the rated supply frequency of the closing device (refer to 5.10).

6.9.3 Shunt opening release

A shunt opening release shall be able to operate under all operating conditions of the switching device up to its rated short-circuit breaking current (if any), and between 70 % in the case of DC – or 85 % in the case of AC – and 110 % of the rated supply voltage of the

opening device measured at the input terminals (refer to 5.9), the frequency, in the case of AC, being the rated supply frequency of the opening device (refer to 5.10).

6.9.4 Capacitor operation of shunt releases

When a rectifier-capacitor combination is provided as an integral part of the switching device for stored energy of a shunt release, the charge of the capacitors derived from the voltage of the main circuit or auxiliary supply, shall be sufficient for satisfactory operation of the release 5 s after the voltage supply has been disconnected from the terminals of the combination and replaced by a short-circuiting link.

The voltages of the main circuit before disconnection shall be taken as the lowest voltage of the system associated with the rated voltage of the switching device. IEC 60038:2009 shall be referred to for the relation between “highest voltage for equipment” and system voltages.

6.9.5 Under-voltage release

When an under-voltage release is provided, it shall operate to open and prevent closing of the switching device for all values of the voltage at its terminals below 35 % of its rated supply voltage.

Between 70 % and 35 % of its rated supply voltage, the under-voltage release may operate, opening the switching device and preventing its closing.

On the other hand, the under-voltage release shall not operate to open the switching device when the voltage at its terminals exceeds 70 % (AC or DC) of its rated supply voltage.

The closing of the switching device shall be possible when the value of the voltage at the terminals of the release is equal to or greater than 85 % of its rated voltage.

6.10 Pressure/level indication

6.10.1 Gas pressure

Closed pressure systems filled with compressed gas for insulation and/or operation and having a minimum functional pressure for insulation and/or operation above 0,2 MPa (absolute pressure), shall be provided with a device capable of monitoring the pressure (or density).

The uncertainty of the gas monitoring device should be established and take into account pressure coordination (filling, minimum functional and alarm pressure) and leakage rate.

6.10.2 Liquid level

A device for checking the liquid level, with indication of minimum and maximum limits permissible for correct operation, shall be provided. This requirement is not applicable to dashpots or shock-absorbers.

6.11 Nameplates

6.11.1 General

Switchgear and controlgear (and their operating devices where applicable) shall be provided with nameplates that contain the information required to identify the equipment, its ratings and appropriate operating parameters as specified in the relevant IEC standards.

6.11.2 Application

Table 9 shall be used where applicable if the product standard does not provide more specific information.

In particular, the terminology, abbreviations and units given in the table shall be used as appropriate. Annex G (informative) provides an extended list including non-rated values. The following recommendations should be considered as appropriate:

- a) the type and mass of insulating fluid should be noted either on a nameplate or on a label placed in a visible location;
- b) it should be stated whether pressures are absolute or relative values;
- c) switchgear and controlgear installed outdoors or in high humidity should have nameplates and have methods of attachment that are weather-proof and corrosion-proof;
- d) switchgear and controlgear that consist of several poles with individual drive mechanisms should be provided with a nameplate for each pole;
- e) for an operating device combined with a switchgear device, it may be sufficient to use only one combined nameplate;
- f) nameplates should be visible in the position of normal service and installation;
- g) technical characteristics on nameplates and/or in documents which are common to several kinds of high-voltage switchgear and controlgear should be represented by the same symbols;
- h) since other characteristics (such as type of gas or temperature limits) are specialized, they shall be represented by the symbols which are used in the relevant standards.
- i) Disconnectors, earthing switches and their operating devices that are designed to be:
 - used as stand alone or may be integrated as components for switchgear, shall be provided with nameplates that contain information in accordance with Table 12;
 - integrated in a particular family of switchgear and controlgear shall integrate the information on the nameplate(s) and/or in the manufacturer instruction manual of the switchgear and controlgear, as indicated in Table 12.

Table 20 – Nameplate information

Item		Abbreviation	Unit	(**)	Condition: Marking only required if
(1)	(2)	(3)	(4)	(5)	(6)
1	Name of manufacturer			X	
2	Type designation and serial number			X	
3	Rated voltage	U_r	kV	X	
4	Rated short-duration power-frequency withstand voltage	U_d	kV	X	
5	Rated lightning impulse withstand voltage	U_p	kV	X	
6	Rated switching impulse withstand voltage	U_s	kV	Y	rated voltage 300 kV and above
7	Rated frequency	f_r	Hz	X	
8	Rated continuous current	I_r	A	X	
9	Rated short-time withstand current	I_k	kA	X	
10	Rated peak withstand current	I_p	kA	X	
11	Rated duration of short-circuit	t_k	s	Y	different from 1 s
12	Filling pressure for operation(*)	p_{rm}	MPa	X	
13	Filling pressure for insulation(*)	p_{re}	MPa	X	
14	Alarm pressure for insulation(*)	p_{ae}	MPa	X	
15	Alarm pressure for operation(*)	p_{am}	MPa	X	
16	Minimum functional pressure for insulation and/or switching(*)	p_{me}	MPa	X	
17	Minimum functional pressure for operation(*)	p_{mm}	MPa	X	
18	Rated supply voltage(s) of auxiliary and control circuits. Specify DC / AC (with rated frequency)	U_a	V	X	
19	Type and mass of fluid (liquid or gas) for insulation	M_f	kg	X	
20	Mass of switchgear and controlgear (including any fluid)	M	kg	Y	more than 300 kg
21	Year of manufacture			X	
22	Minimum and maximum ambient air temperature		°C	Y	If different from –5 °C and/or 40 °C
(*) Absolute pressure (abs.) or relative pressure (rel.) to be stated on the nameplate					
(**) X = the marking of these values is mandatory, where applicable. Y = conditions for marking of these values are given in column (6).					
NOTE 1 The abbreviation in column (3) can be used instead of the terms in column (2) to be stated on the nameplate.					
NOTE 2 When terms in column (2) are used, the word “rated” does not need to appear.					

Table 21 – Product information (1 of 2)

Information to be put on the nameplate	Abbreviation	Unit	Disconnecter	Earthing switch ^a	Operating device
Manufacturer			x	x	x
Manufacturer's type designation			x	x	x
Mechanical endurance class			x ^b	x ^b	x
Short-circuit making capability class				x ^b	
Instruction book reference			x	x	x
Year of manufacture			x	x	x
Reference of this standard			x	x	x
Serial number			x	x	x
Rated voltage	U_r	kV	x	x	
Rated frequency	f_r	Hz	x	x	
Rated lightning impulse withstand voltage	U_p	kV	x	x	
Rated switching impulse withstand voltage for $U_r \geq 300$ kV	U_s	kV	x	x	
Rated power-frequency withstand voltage	U_d	kV	x	x	
Rated continuous current	I_r	A	x		
Rated short-time withstand current	I_k	kA	x	x	
Rated duration of short-circuit	t_k	s	x ^c	x ^c	
Rated peak withstand current	I_p	kA	x	x	
Rated short-circuit making current	I_{ma}	kA		x ^d	
Insulating fluid and mass	M_f	kg	x ^e	x ^e	
Minimum and maximum ambient air temperature		°C	x ^f	x ^f	x ^f

Table 12 (2 of 2)

Information to be put either on the nameplate or in the instruction manual	Abbreviation	Unit	Disconnecter	Earthing switch ^a	Operating device
Rated bus-charging current	I_{bc}	A	x ^g		
Class of bus-charging current switching			x ^g		
Rated bus-transfer current	I_{bt}	A	x ^h		
Rated bus-transfer voltage	U_{bt}	V	x ^h		
Class of earthing switch (class A or B) ⁱ				x ⁱ	
Rated induced current (electromagnetic)	I_{im}	A		x ⁱ	
Rated induced voltage (electromagnetic)	U_{im}	V		x ⁱ	
Rated induced current (electrostatic)	I_{is}	A		x ⁱ	
Rated induced voltage (electrostatic)	U_{is}	V		x ⁱ	
Value of the resistor	R	Ω	x ^j		
Rated filling pressure for operation	P_{rm}	Pa			x
Minimum functional pressure for operation	p_{mm}	Pa			x
Alarm pressure for operation	P_{am}	Pa			x
Rated filling pressure for insulation	P_{re}	Pa	x	x	
Minimum functional pressure for insulation	p_{me}	Pa	x	x	
Alarm pressure for insulation	P_{ae}	Pa	x	x	
Minimum functional pressure for switching	p_{sw}	Pa	x	x	
Rated supply voltage of auxiliary and control circuits	U_a	V			x ^k
Rated static mechanical terminal load	F	N	x	x	
Mass (including liquid)	M	kg	x	x	x
Rated ice-coating		mm	x	x	x
Rated contact zone	x_r, y_r and z_r	mm	x ^l	x ^l	

NOTE 1 The marking of values indicated by x is mandatory (if applicable).

NOTE 2 The word "rated" does not need to appear on the nameplate.

- ^a One nameplate may be used for an earthing switch and disconnector assembled as a single unit.
- ^b The class marking is mandatory if different from M0 or E0. It may be included into the type designation to avoid additional space requirement.
- ^c Mandatory if t different from 1 s.
- ^d For earthing switches having short-circuit making capability.
- ^e Chemical formula for gas or commercial name for liquid (if any of both) shall be indicated.
- ^f Mandatory if different from –5 °C and/or +40 °C.
- ^g For disconnectors forming a part of gas-insulated switchgear and controlgear of $U_r \geq 300$ kV.
- ^h For disconnectors of $U_r > 52$ kV having bus-transfer current switching capability.
- ⁱ For earthing switches of $U_r > 52$ kV having induced current switching capability.
- ^j For resistor-fitted disconnectors.
- ^k Rated supply voltages of auxiliary and control circuits may have separate values which have to be indicated. Manufacturer shall also indicate if the supply is dc or ac source.
- ^l For divided support disconnectors and/or divided support earthing switches of $U_r > 52$ kV.

6.12 Locking devices

Switching devices, the incorrect operation of which can cause damage or which are used for assuring isolating distances, shall be provided with locking facilities (for example, provision for padlocks).

Disconnectors and earthing switches to be mechanically interlocked by blocking the operating shaft or power kinematic chain of the disconnector or earthing switch, and not integrated in switchgear and controlgear assemblies covered by the standards IEC 62271-200, IEC 62271-201 or IEC 62271-203, shall be designed to withstand:

- during motor-operation, the strain produced by the motor starting torque at the maximum motor supply voltage, or, if a strain limiting device is present, to its limiting value, and
- during manual-operation, 3 times the value of the corresponding maximum force given for manual operation in 6.105 (without considering peak value) or, if a strain limiting device is present, to 1,5 times its limiting value.

6.13 Position indication

Indication of the actual position of the main contacts of the switching devices shall be provided unless the contacts themselves are visible in all positions.

Requirements for position indicating devices are as follows:

- it shall be possible to read the position-indicating device when operating locally;
- all stable positions such as open, closed and test positions shall be clearly indicated.

Identification of the open, closed and where appropriate earthed positions should use symbols and/or colours defined by the relevant IEC publications: IEC 60073 [25] for colours, IEC 60417 [26] for symbols and IEC 60617 [27] for diagrams.

Refer also to 6.104 of this document.

6.14 Degree of protection provided by enclosures

For enclosures containing auxiliary and control circuits:

The degree of protection provided by enclosures for outdoor installation shall be a minimum of IP3XDW of IEC 60529:1989 + AMD1:1999 + AMD2:2013.

For indoor installations the degree of protection shall be not less than IP2X of IEC 60529:2013.

6.14.1 General

The enclosures shall provide degrees of protection in accordance with 6.14.2 through 6.14.4.

6.14.2 Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects (IP coding)

The degree of protection of persons and of equipment provided by an enclosure against access to hazardous parts of the main circuit, control and/or auxiliary circuits and to any hazardous moving parts and against ingress of solid foreign objects shall be at least IP1XB according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

6.14.3 Protection against ingress of water (IP coding)

For equipment of indoor installation, no minimum degree of protection against harmful ingress of water is specified, i.e. the second characteristic numeral of the IP code is X according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

Equipment for outdoor installation shall be at least IPX3 according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013. If it is provided with additional protection features against rain and other weather conditions (supplementary letter W), the performance refers to the situation with these features in place and shall be demonstrated according to Annex C (normative) (see 7.7.1).

6.14.4 Protection against mechanical impact under normal service conditions (IK coding)

For indoor installation, the preferred impact level is IK07 according to IEC 62262:2002 (2 J).

For outdoor installation without additional mechanical protection, the minimum impact level shall be IK10 according to IEC 62262:2002 (20 J).

Insulators and bushings of high-voltage switchgear and controlgear are not subjected to this requirement.

6.15 Creepage distances for outdoor insulators

Annex K gives general rules that assist in choosing insulators which should give satisfactory performance under polluted conditions.

The general rules given in Annex K (informative) are applicable for glass, ceramic and polymer insulators.

6.16 Gas and vacuum tightness

6.16.1 General

The following specifications apply to all switchgear and controlgear that use vacuum or gas, other than ambient air, as an insulating, switching, combined insulating and switching, or operating medium.

For vacuum tightness no leakage rate F needs to be specified, instead the level of vacuum and the expected operating duration shall be given.

NOTE 1 IEC TR 62271-306 [4] and Cigre Brochure 430 [28] give some information, examples and guidance for tightness.

The absolute leakage rate F shall not exceed the specified value of the permissible leakage rate F_p at standardized ambient temperature of 20 °C.

An increased leakage rate at extreme temperatures is permissible, provided that this rate resets to a value not higher than the permissible value F_p at standardized ambient temperature of 20 °C. The increased temporary leakage rate shall not exceed the values given in 7.8.1.

NOTE 2 The average leakage rate observed during service life can be higher than the specified leakage rate due to the temporary increased leakage rate at temperatures above or below the standardized ambient temperature.

6.16.2 Controlled pressure systems for gas

The tightness of controlled pressure systems for gas is specified by the number of replenishments per day (N) or by the pressure drop per day (Δp). SF_6 gas and SF_6 mixtures are not applicable for controlled pressure systems.

NOTE Most controlled pressure systems use air as the gas; however, other gases can be used.

6.16.3 Closed pressure systems for gas

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of each compartment. The maximum values under the standardized ambient temperature of 20 °C are:

- for SF_6 and SF_6 mixtures, 0,5 % per year;
- for other gases, 1 % per year.

NOTE 1 Some local or governmental regulations can require a lower SF_6 leakage rate, e.g. 0,1 % per year.

The tightness characteristic of a closed pressure system and the time between replenishments under normal service conditions shall be stated by the manufacturer. This time shall be at least 10 years for maintenance planning purposes. Means shall be provided to enable gas systems to be replenished while the equipment is in service.

NOTE 2 The term “in service” implies “under live conditions”.

NOTE 3 Manufacturer’s instructions and the user’s operating practices provide guidance for replenishing gas.

6.16.4 Sealed pressure systems

The tightness of sealed pressure systems is specified by their expected operating duration. The expected operating duration shall be specified by the manufacturer and shall be at least 20 years. Other preferred values are 30 years and 40 years.

The tightness of gas insulated switchgear and controlgear shall be designed in a way to ensure that the minimum functional pressure (density) shall not be attained before the expected end of life. The manufacturer shall specify a permissible leakage rate.

NOTE 1 For some designs verification of an expected operating duration greater than 20 years can be impractical for a type or routine test.

NOTE 2 Sealed SF_6 switchgear and controlgear is considered to have insignificant SF_6 losses (less than 0,1 % per year) during their expected operating duration.

6.17 Tightness for liquid systems

6.17.1 General

The following specifications apply to all switchgear and controlgear that use liquids as insulating, or combined insulating and switching, or operating medium with or without permanent pressure.

6.17.2 Leakage rates

The permissible leakage rate $F_{\text{n(lin)}}$ for liquid shall be indicated by the manufacturer. A clear distinction shall be made between internal and external tightness where internal tightness refers to leakage between two compartments within a single closed system and external tightness refers to leakage outside of the closed system.

- a) total tightness (sealed pressure system): no liquid loss can be detected;
- b) relative tightness: slight loss is acceptable under the following conditions:

- the leakage rate, F_{liq} shall be less than the permissible leakage rate, $F_{\text{p(liq)}}$;

- the leakage rate, F_{liq} shall not increase with time or in the case of switching devices, with number of operations;
- the liquid leakage shall not cause malfunction of the switchgear or controlgear, nor cause any injury to operators in the normal course of their duty.

6.18 Fire hazard (flammability)

No technical requirement is defined for high-voltage switchgear and controlgear due to the large variety of designs and lack of acceptance criteria. The information below is provided for guidance.

IEC 60695-1 (all parts) [29] provides guidance for assessing the fire hazard of electrotechnical products.

IEC 60695-7 (all parts) [30] provides guidance on the minimization of toxic hazards due to fires involving electrotechnical products.

6.19 Electromagnetic compatibility (EMC)

Switchgear and controlgear shall be capable of satisfying the EMC tests specified in 7.9.

6.20 X-ray emission

This subclause is applicable to vacuum interrupters used in switchgear and controlgear. Vacuum interrupters shall be designed in such a way that the acceptance criteria about X-ray emission levels specified in 7.11.3 are satisfied when subjected to the test specified in 7.11.

6.21 Corrosion

Due to the large number of parameters to be considered no standard requirements can be given. General recommendations are given in IEC TR 62271-306 [4].

6.22 Filling levels for insulation, switching and/or operation

The pressure (or density) or liquid mass shall be assigned by the manufacturer. The pressure (or density) of gas is referred to atmospheric conditions of 20 °C at which gas filled switchgear is filled before being put into service.

In addition to the filling levels the following values have to be assigned by the manufacturer (when applicable):

- alarm pressure p_{ae} (or density ρ_{ae}) for insulation and/or switching;
- alarm pressure p_{am} (or density ρ_{am}) for operation;
- minimum functional pressure p_{me} (or density ρ_{me}) for insulation and/or switching;
- minimum functional pressure p_{mm} (or density ρ_{mm}) for operation.

The pressure in Pa (or density) or liquid mass shall be assigned by the manufacturer referred to atmospheric air conditions of 20 °C at which the gas- or liquid-filled switchgear is filled before being put into service.

For operating devices having their own compressor or pump integral to them and with their own supplying pressure tank, the limits of filling (operating) pressure shall be stated by the manufacturer.

6.101 Particular requirements for earthing switches

Any material and any cross-section is allowed for connections between movable parts of an earthing switch and its frame, provided that the connections are able to withstand the electrical, mechanical and environmental stresses that occur in service.

6.102 Requirements in respect of the isolating distance of disconnectors

When the insulation across the isolating distance may be subjected to pollution in service, care shall be taken to ensure the suitability of insulator design (e.g. creepage distance, hydrophobicity, orientation of insulator). IEC/TS 60815 (all parts) [3] can be used for guidance selecting the appropriate insulator design. The satisfactory performance of the insulation across the isolating distance under polluted conditions should be verified with the appropriate voltage withstand level corresponding to the isolating distance for which the disconnector is intended.

The design has also to take into account the effects of contamination caused by wear and arcing by-products. The effectiveness of the design to withstand these effects is verified by the condition checks specified in Clause 7 after the relevant type tests.

NOTE 1 It is usual that the isolating gap of a disconnector is longer than the phase-to-ground insulating distance, since IEC 62271-1:2017 specifies higher voltage withstand levels across the isolating distance than for the phase-to-ground insulation. However, where a long creepage distance is required, the phase-to-ground insulation distance can become longer than the isolating gap of the disconnector. For such cases the use of protective devices such as surge arresters or rod gaps can be necessary.

NOTE 2 Test method for insulators can be found in IEC 60507 [2] and IEC/TS 60815 (all parts) [3]

6.103 Mechanical strength

The disconnector and earthing switch, including the insulators used, installed according to the manufacturer's instructions shall be able to:

- open and close correctly the main contacts under its rated static mechanical terminal loads;
- carry the rated continuous current (when applicable) under its rated static mechanical terminal loads;
- withstand the dynamic forces on its terminals under short-circuit conditions.

The required cantilever strength of an insulator shall be calculated taking into consideration the height of the terminal above the top of the insulator as well as additional forces acting on the insulator (see 3.7.119 and 9.102.4).

6.104 Operation of disconnectors and earthing switches – Position of the movable contact system and its indicating and signalling devices

6.104.1 Securing of position

Disconnectors and earthing switches, including their operating mechanisms, shall be designed in such a way that they cannot come out of their open or closed position by gravity, wind pressure, vibrations, reasonable shocks or accidental touching of the connecting rods of their operating system according to their service conditions as defined in Clause 4.

Disconnectors and earthing switches shall permit temporary mechanical locking in at least the open position (for disconnectors) and closed position (for earthing switches) except for disconnectors or earthing switches whose contacts are directly moved by a hook-stick.

6.104.2 Additional requirements for power-operated mechanisms

Power operated mechanisms shall also provide a manual operating facility. Connecting a hand-operating device (for instance a hand crank) to the power-operated mechanism shall ensure safe interruption of the control energy to the power-operated mechanism.

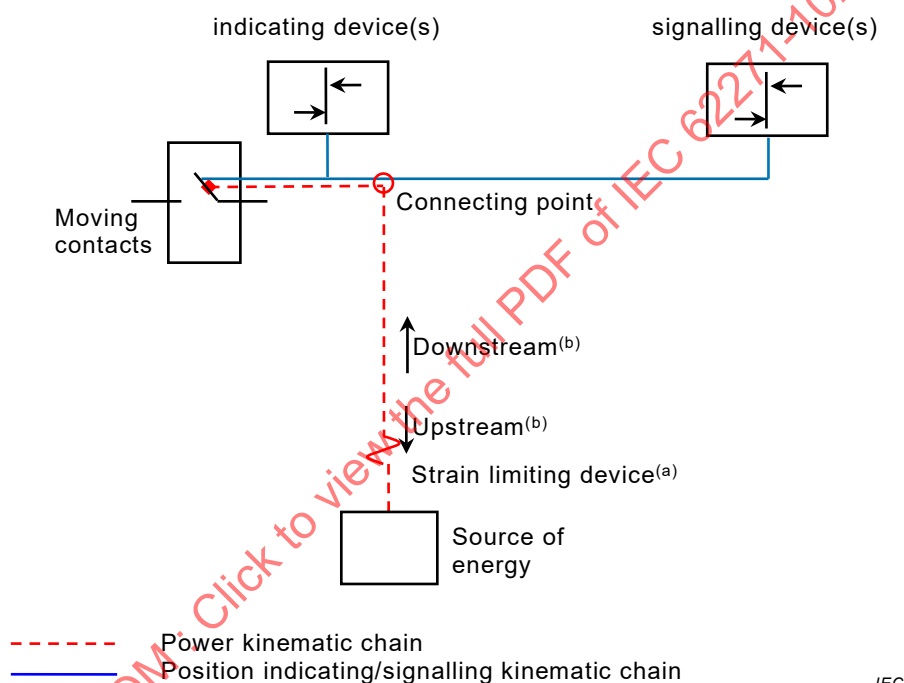
6.104.3 Indication and signalling of position

6.104.3.1 General requirements

Indication and signalling of the closed and open position shall not take place unless the moving contacts have reached their closed or open position, respectively.

NOTE For the definition of "closed" and "open" see 3.6.109 and 3.6.110.

Figure 1 represents the different elements involved in indication and signalling of positions, and some design conditions.



a) The strain limiting device (if any) can be an external device or an internal as part of the source of energy, e.g. torque (force) controlling system.

b) Upstream is the direction towards the source of energy, downstream is the direction towards the contacts.

Figure 1 – Position indicating/signalling device(s)

The strain limiting device (if any) may be placed at any point along the power kinematic chain between the source of energy and the connecting point, but it shall not be along the position indicating/signalling kinematic chain. See 6.104.3.2 and 6.104.3.3.

The position-indicating device(s) shall be fixed directly on a mechanical part of the power kinematic chain or mechanically connected to it through a separate position indicating/signalling kinematic chain. If the position indicator is not directly fixed on the mechanical part of the power kinematic chain, then the position-indicating kinematic chain from the connecting point shall be placed inside an enclosure providing a minimum degree of protection equivalent to IP2XC of IEC 60529:1989 + AMD1:1999 + AMD2:2013, and with an impact level IK 07 of IEC 62262:2002.

The position-signalling kinematic chain shall be placed inside an enclosure with the same levels of protection as defined for the position-indicating kinematic chain.

6.104.3.2 Indication of position

It shall be possible to know the position of the disconnecter or earthing switch. The indication of the position of the disconnecter or earthing switch is given if one of the following conditions is fulfilled:

- at least the position of the moving contacts of each pole is visible for disconnectors in open position and for earthing switches in closed position;
- both the open and closed positions of the moving contacts of each pole are indicated by a reliable position-indicating device. A common position-indicating device may be used only if all the poles of the disconnecter or earthing switch are operated by a common operating mechanism.

NOTE In some countries the design of the disconnecter is such that the isolating distance is visible (Canada).

The kinematic chain between the moving contacts and the position-indicating device shall be designed with sufficient mechanical strength to meet the requirements of the specified tests (7.105). The operation of the position-indicating kinematic chain shall be positively driven. The position-indicating device may be marked directly on a mechanical part of the power kinematic chain by suitable means. The strain-limiting device, if any, shall not form part of the position-indicating kinematic chain.

6.104.3.3 Signalling of position by auxiliary contacts

A common signal for all poles of a disconnecter or earthing switch shall be given only if all poles of the disconnecter or earthing switch are in a position in accordance with 6.104.3.1.

A common position-signalling device is permitted to be used only if the disconnecter or earthing switch is three-pole operated by a common operating mechanism.

The kinematic chain between the moving contacts and the position-signalling device(s) shall be designed with sufficient mechanical strength to meet the requirements of the mechanical endurance tests. The position-signalling kinematic chain operation shall be positively driven. The strain-limiting device, if any, shall not form part of the position-signalling kinematic chain.

6.105 Maximum force required for manual (dependent or independent) operation

6.105.1 General

The values given in 6.105.2 and 6.105.3 also apply to maintenance manual operation of normally motor-operated disconnectors and earthing switches.

NOTE These values include ice-breaking, if applicable.

6.105.2 Operation requiring more than one revolution

The maximum force needed to operate or store energy in a disconnecter or earthing switch with more than one revolution (hand crank for example) shall not exceed 80 N during 90 % of the total required revolutions and never exceed 120 N.

6.105.3 Operation requiring up to one revolution

The force needed to operate or store energy in a disconnecter or earthing switch requiring up to one revolution (swing lever for example) should not exceed 250 N (refer to 6.6.4 of IEC 62271-1:2017). A maximum value of 450 N is accepted during a rotation of 15° maximum.

6.106 Dimensional tolerances

For disconnectors and earthing switches installed and/or connected by the user, the relevant mounting dimensions and the dimensions of high-voltage connections as well as the earthing connections of disconnectors and earthing switches, the tolerances given in ISO 2768-1 shall apply for linear and angular dimensions.

6.107 Earthing switches with short-circuit making current capability

Earthing switches assigned for short-circuit making current shall be capable of making at rated and lower voltage, any current up to and including the rated short-circuit making current. This requirement is considered to be satisfied if the earthing switch successfully demonstrates its electrical endurance class.

7 Type tests

7.1 General

7.1.1 Basics

The type tests are for the purpose of proving the ratings and characteristics of switchgear and controlgear, their operating devices and their auxiliary equipment. Each individual type test or type test sequence shall be made on test objects as defined in 3.2.1, in the condition as required for service (filled with the specified types and quantities of liquid or gas), with their operating devices and auxiliary equipment, all of which in principle shall be in, or restored to, a new and clean condition at the beginning of each type test or type test sequence.

Reconditioning during individual type tests or test sequence may be allowed, according to the relevant IEC product standard. The manufacturer shall provide a statement to the testing laboratory of those parts that may be renewed during the tests.

Tolerances on test quantities are listed in Table E.1.

Information regarding the extension of validity of type tests is given in Annex J (informative).

Disconnectors and earthing switches shall be tested to verify their rated characteristics, under the proper conditions of installation and use (e. g. they shall be tested as normally installed in the gas-insulated or metal-enclosed switchgear and controlgear) with all associated components, the arrangement of which may influence the performance, such as connections, supports, provisions for venting, resistors etc.

Disconnector and earthing switches that are different in construction or mounting arrangements as compared to the given examples in Clause 7 shall be tested in conditions that are representative of the actual installation.

NOTE Associated components are likely to influence the performance. Mechanical forces due to the short-circuit current, venting of arc-products, the possibility of disruptive discharges, etc., could characterise this influence. It is recognized that, in some cases, such influences may be quite negligible.

The same setting of the position-signalling device for closed and open positions shall be used for the dielectric test and the short-time withstand current and peak withstand current tests.

The type tests for disconnector and earthing switch are listed in Table 13. For the type tests, the tolerances on test quantities are given in Annex C.

Information regarding the extension of validity of type tests is given in Annex E (informative).

Table 22 – List of type tests

Type test, dependent upon application, rating or design	Condition	Related device		Subclauses
		Disconnector	Earthing switch	
Dielectric tests	a	x	x	7.2
Measurement of the resistance of the main circuit	a	x		7.4.4
Continuous current tests	a	x		7.5
Short-time withstand current and peak withstand current tests	a	x	x	7.6
Mechanical endurance tests	a	x	x	7.102.3
Verification of the degree of protection	Assigned IP- and/or IK-code	x	x	7.7
Radio interference voltage (RIV) test	$U_r \geq 245$ kV	x	x	7.3
Tightness tests	Controlled, sealed or closed pressure systems	x	x	7.8
EMC tests	Presence of electronic components	x	x	7.9
Additional tests on auxiliary and control circuits	Presence of auxiliary and control circuits	x	x	7.10
X- ray radiation test	Presence of vacuum interrupters	x	x	7.11
Test to prove the short-circuit making performance of earthing switches	Class E1 or E2		x	7.101
Contact zone test	Divided support	x	x	7.102.2
Operation during application of rated static mechanical terminal load	Assigned mechanical terminal load	x	x	7.102.4
Extended mechanical endurance tests	Class M1 or M2	x	x	7.102.5
Testing on mechanical interlocking devices	Presence of interlock blocking the operating shaft or power kinematic chain	x	x	7.102.6
Operation under severe ice conditions	10 mm and above	x	x	7.103
Low and high temperature tests	If maximum ambient temperature $> +40^\circ\text{C}$ or minimum ambient temperature $< -5^\circ\text{C}$	x	x	7.104
Tests to verify the proper functioning of the position-indicating device	Presence of position-indicating device	x	x	7.105
Bus-transfer current switching tests	Bus-transfer current switching capability ^b	x		7.106
Induced current switching tests	Class A or B ^c		x	7.107
Bus-charging current switching tests	Bus-charging current switching capability ^{d, e}	x		7.108
^a Mandatory without condition for the related device. ^b Applicable to disconnectors of $U_r > 52$ kV. ^c Applicable to earthing switches of $U_r > 52$ kV. ^d Applicable to disconnectors of $U_r > 52$ kV forming part of gas-insulated switchgear. For $U_r < 300$ kV, tests are generally considered not necessary and are subject to agreement between user and manufacturer. ^e Bus-charging switching capability for air-insulated disconnectors is subject to agreement between the manufacturer and the user, refer to IEC/TR 62271-305.				

7.1.2 Information for identification of test objects

The manufacturer shall submit to the testing laboratory, drawings and other data containing sufficient information to unambiguously identify by type the essential details and parts of the switchgear and controlgear presented for test. A summary list of the drawings and data schedules shall be supplied by the manufacturer and shall be uniquely referenced and shall contain a statement that the manufacturer guarantees that the drawings or data sheets listed are the correct version and represent the switchgear and controlgear to be tested.

The testing laboratory shall check that drawings and data sheets adequately represent the essential details and parts of the test object but is not responsible for the accuracy of the detailed information.

Particular drawings or data required to be submitted by the manufacturer to the test laboratory for identification of essential parts of test object are specified in Annex A (normative).

At the beginning of the type tests, the mechanical operating characteristics and their tolerances for the disconnector or earthing switch during opening and/or closing shall be given by the manufacturer, e.g. time between events during operation and no-load travel curves.

7.1.3 Information to be included in type test reports

The results of all type-tests shall be recorded in type-test reports containing sufficient data to prove compliance with the ratings and the test clauses of the relevant standards and sufficient information shall be included so that the essential parts of the test object can be identified. In particular, the following information shall be included:

- the manufacturer;
- the type designation and the serial number of the test object;
- the rated characteristics of the test object as specified in the relevant IEC standard;
- the general description of the test object, including number of poles;
- the manufacturer, type, serial numbers and ratings of essential parts, where applicable (for example, drive mechanisms, interrupters, shunt impedances);
- the general details of the supporting structure of the switching device or enclosed switchgear of which the switching device forms an integral part;
- the details of the operating-mechanism and devices employed during tests, where applicable;
- photographs to illustrate the condition of the test object before and after test;
- sufficient outline drawings and data schedules to represent the test object;
- the reference numbers of all drawings including revision number submitted to identify the essential parts of the test object;
- a statement that the test object complies with the drawings submitted;
- details of the testing arrangements (including diagram of test circuit);
- statements of the behaviour of the test object during tests, its condition after tests and any parts renewed or reconditioned during the tests;
- in case of breaking operations with some specific technologies, NSDDs may occur during the recovery voltage period. Their number is of no significance to interpreting the performance of the device under test. They shall be reported in the test report only in order to differentiate them from restrikes;
- records of the test quantities during each test or test duty, as specified in the relevant IEC standard;
- the location, laboratory name where the tests were conducted and date of test.

Where applicable:

When for testing purposes, the insulators are not provided by the manufacturer of the disconnector or earthing switch, the most important features of insulators used during type tests shall be included in the relevant test reports for comparison with those described in the manufacturer's documentation:

- rated cantilever strength;
- rated torsional strength of support insulators (and operating insulators, where applicable);
- height and number of elements;
- creepage length and shed-profile;
- deflection under load.

In the case of dielectric tests, information shall be included regarding the smallest gap at which the indicating or signalling device can signal the position OPEN. For air-insulated devices, the minimum size of the gap and the height above ground used for the test shall be stated (see 7.2.4). Also the distance of the lowest part of insulation to ground shall be given.

7.2 Dielectric tests

7.2.1 General

Dielectric tests shall be performed in compliance with IEC 60060-1:2010, unless otherwise specified in this document.

7.2.2 Ambient air conditions during tests

Reference shall be made to IEC 60060-1:2010 regarding standard reference atmospheric conditions and atmospheric correction factors.

For test objects where external insulation in ambient air is of principal concern, the atmospheric correction factor K_t shall be applied.

The humidity correction factor k_2 shall be applied only for the dry tests where insulation in ambient air is of principal concern.

For switchgear and controlgear of rated voltage of 52 kV and below, it can be assumed that

- $m = 1$ and $w = 0$ when the absolute humidity is higher than that of the reference atmosphere, i.e. when $h > 11 \text{ g/m}^3$;
- $m = 1$ and $w = 1$ when the absolute humidity is lower than that of the reference atmosphere, i.e. when $h < 11 \text{ g/m}^3$.

For test objects having external and internal insulation, the correction factor K_t shall be applied if its value is between 0,95 and 1,05. However, in order to avoid over-stressing of internal insulation, the application of the correction factor K_t may be omitted where the satisfactory performance of external insulation has been established.

If K_t is above 1,0 then to fully test the external insulation system the internal insulation will be overstressed and steps may be necessary to prevent overstressing the internal insulation systems. If K_t is below 1,0 then to test the internal insulation system fully, the external insulation will be overstressed and steps may be necessary to prevent overstressing the external insulation systems. Some methods are discussed in IEC 60060-1:2010.

For test objects having only internal insulation, the ambient air conditions are of no influence and the correction factor K_t shall not be applied.

For combined tests, parameter g shall be calculated considering the total test voltage value.

7.2.3 Wet test procedure

When a wet test is required, the standard wet test procedure given in IEC 60060-1:2010 shall be followed.

7.2.4 Arrangement of the equipment

Dielectric tests shall be made on switchgear and controlgear completely assembled, as in service with any supplementary insulation such as tape or barriers if stated in the installation instructions; the outside surfaces of insulating parts shall be in clean condition.

The test object shall be mounted for test with minimum clearances and height as specified by the manufacturer if such surrounding influences the performance.

Tests shall be performed with the test object installed at a height above ground equal to or less than the height used in service.

When the distance between the poles of the test object is not inherently fixed by the design, the distance between the poles for the test shall be the minimum value stated by the manufacturer. However, to obviate the necessity of erecting large three-pole test objects, the artificial pollution and the radio interference voltage tests may be made on a single pole and, if the minimum clearance between poles is equal to or larger than those given in Tables A.1 and A.2 of IEC 60071-2:1996, all other dielectric tests may be made on a single pole.

If arcing horns or rings are part of the design for gradient distribution, they shall remain in position for the test. If they are proposed as overvoltage protection devices for the system, they are not part of the design of the test object and shall be not installed for tests.

For test objects using compressed gas for insulation, dielectric tests shall be performed at minimum functional pressure (density) for insulation. The temperature and pressure of the gas during the tests shall be noted and recorded in the test report.

NOTE In the dielectric testing of switchgear and controlgear incorporating vacuum switching devices, precautions are taken to ensure that the level of possible emitted X-radiation during high-voltage testing is within safe limits (see 7.11). National regulations can influence the safety measures established.

Dielectric tests on disconnectors or earthing switches when in the OPEN position shall be carried out with the minimum isolating distance for the disconnector or gap for the earthing switch at which the indicating or signalling device can signal the position OPEN or the minimum isolating distance compatible with the locking arrangements specified in 6.104.1, whichever is the smallest. This requirement does not apply to independent operated indoor disconnectors and earthing switches.

Where the design requires an adjustment of the position indicator or the position-signalling device, this shall be performed according to the instruction manual. No deviation of these devices is acceptable for dielectric tests.

7.2.5 Criteria to pass the test

a) Short-duration power-frequency withstand voltage tests

The test object shall be considered to have passed the test if no disruptive discharge occurs.

If during a wet test a disruptive discharge (as defined in IEC 60060-1:2010) on external self-restoring insulation occurs, this test shall be repeated in the same test condition without intermediate cleaning and the test object shall be considered to have passed this test successfully if no further disruptive discharge occurs.

b) Impulse tests

The test procedure B of IEC 60060-1:2010, adapted for test objects that have self-restoring and non-self-restoring insulation, is the preferred test procedure. The test object has passed the impulse tests if the following conditions are fulfilled:

- each series has at least 15 tests;
- the number of disruptive discharges does not exceed two for each complete series;
- no disruptive discharge on non-self-restoring insulation occurs. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge.

This procedure leads to a maximum possible number of 25 impulses per series.

Procedure C of IEC 60060-1:2010 may be used when all three poles are tested, refer to 7.2.6.2.

c) General comment

- When testing switchgear and controlgear, the part of equipment through which the test voltage is applied may be subjected to numerous test sequences to check the insulating properties of other downstream parts of equipment (circuit-breakers, disconnectors, other bays). It is recommended that parts be tested in sequence, starting with the first connected part. When this part has passed the test according to the above-mentioned criteria, its qualification is not impaired by possible disruptive discharges which could occur in it during further tests on other parts.

These discharges can have been generated by accumulation of discharge probability with the increased number of voltage applications or by reflected voltage after a disruptive discharge at a remote location within the equipment. To reduce the probability of occurrence of these discharges in gas-filled equipment, the pressure of compartments which are not subject of the test can be increased. Compartments at increased pressure should be clearly identified in the test report(s).

- A disruptive discharge to the auxiliary and control circuits shall be considered as a failure.

7.2.6 Application of the test voltage and test conditions

7.2.6.1 General

Distinction shall be made between the general case, where the three test voltages (phase-to-earth, between phases and across open switching device) are the same and the special cases where the test voltages across the isolating distance and/or between phases are higher than the test-voltage phase to earth.

Some insulating materials retain a charge after an impulse test, and for these cases care should be taken when reversing the polarity. To allow the discharge of insulating materials, the use of appropriate methods, such as the application of two impulses between 60 % and 80 % of the rated withstand voltage in the reverse polarity before the test, is recommended.

When testing switchgear incorporating an open vacuum interrupter, for each polarity a maximum of 25 preliminary impulses may be performed at up to and including the rated withstand voltage. The number and level of preliminary impulses is to be stated by the manufacturer. Breakdowns that are observed during these preliminary tests shall be disregarded for the purpose of withstand statistics used to determine pass or fail performance of the equipment.

7.2.6.2 General case

With reference to Figure 2, which shows a diagram of connection of a three-pole switching device, the test voltage shall be applied according to Table 10, as applicable.

Table 23 – Test conditions in general case

Test condition	Switching device	Voltage applied to	Earth connected to
1	Closed	Aa	BCbcF
2	Closed	Bb	ACacF
3	Closed	Cc	ABabF
4	Open	A	BCabcF
5	Open	B	ACabcF
6	Open	C	ABabcF
7	Open	a	ABCbcF
8	Open	b	ABCacF
9	Open	c	ABCabF

NOTE 1 Test conditions 3, 6 and 9 can be omitted if the arrangement of the outer poles is symmetrical with respect to the centre pole and the frame.

NOTE 2 Test conditions 2, 3, 5, 6, 8, 9 can be omitted if the arrangement of the poles is fully symmetrical with respect to each other and to the frame.

NOTE 3 Test conditions 7, 8 and 9 can be omitted if the arrangement of the terminals of each pole is symmetrical with respect to the frame.

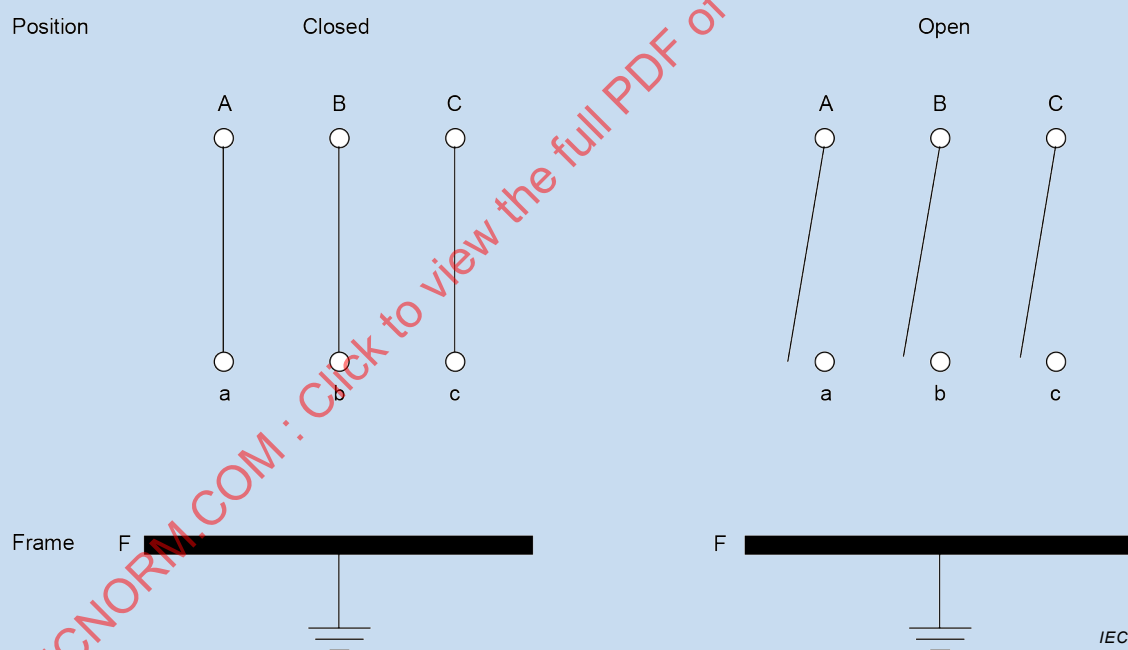


Figure 2 – Diagram of connections of a three-pole switching device

7.2.6.3 Special cases

When the test voltage across the isolating distance is higher than the phase-to-earth withstand voltage, test methods a) or b) may be used.

When the test voltage between phases is higher than the phase-to-earth withstand voltage, test method a) shall be used.

a) Preferred method

Unless otherwise specified in this document, the preferred method is the use of combined voltage tests (refer to Clause 9 of IEC 60060-1:2010).

– Power-frequency voltage tests

The tests shall be performed using two different voltage sources in out-of-phase conditions in order to obtain the specified test value. The voltage share is specified in 7.2.7.2 and in 7.2.8.2.

In this case, the test voltage across the open switching device (or isolating distance) shall be applied according to Table 11.

Table 24 – Power-frequency test conditions

Test condition	Voltages applied to	Earth connected to
1	A and a	BCbcF
2	B and b	ACacF
3	C and c	ABabF
NOTE 1 Test condition 3 can be omitted if the arrangement of the outer poles is symmetrical with respect to the centre pole and the frame.		
NOTE 2 Test conditions 2 and 3 can be omitted if the arrangement of the poles is fully symmetrical with respect to each other and to the frame.		

– Impulse voltage tests

The rated impulse withstand voltage phase-to-earth constitutes the main part of the test voltage and is applied to one terminal; the complementary voltage is supplied by another voltage source of the opposite polarity and applied to the opposite terminal. This complementary voltage may be either another impulse voltage, the peak of a power-frequency voltage or a DC voltage. The other poles and the frame are earthed.

To take into account the influence of the impulse on the power-frequency voltage wave, caused by capacitive coupling between the two voltage circuits, the following test requirement shall be fulfilled: the sum of the impulse voltage peak and the complementary voltage at the instant of the peak of the impulse shall be equal to the total test voltage required with a tolerance of $\pm 3\%$. To achieve such a condition, the instantaneous power-frequency voltage or the impulse voltage might be increased. The instantaneous power-frequency voltage may be increased up to, but no more than $U_r \times \sqrt{2} / \sqrt{3}$ for the lightning impulse tests, and not more than $1,2 \times U_r \times \sqrt{2} / \sqrt{3}$ for the switching impulse tests.

The voltage drop on the power frequency wave can be greatly reduced by using a capacitor of a convenient value connected in parallel to the terminal of the power-frequency side.

The test voltage shall be applied according to Table 12.

Table 25 – Impulse test conditions

Test condition	Main part	Complementary part	Earth connected to
	Voltage applied to		
1	A	a	BbCcF
2	B	b	AaCcF
3	C	c	AaBbF
4	a	A	BbCcF
5	b	B	AaCcF
6	c	C	AaBbF

NOTE 1 Test conditions 3 and 6 can be omitted if the arrangement of the outer poles is symmetrical with respect to the centre pole and the frame.

NOTE 2 Test conditions 2, 3, 5 and 6 can be omitted if the arrangement of the poles is fully symmetrical with respect to each other and to the frame.

NOTE 3 Test conditions 4, 5 and 6 can be omitted if the arrangement of the terminals of each pole is symmetrical with respect to the frame.

b) Alternative method

When only one voltage source is used, the insulation across the open switching device (or isolating distance) may be tested as follows, for both power-frequency voltage tests and impulse voltage tests:

- the total test voltage U_t is applied between one terminal and earth; the opposite terminal is earthed;
- when the resulting voltage across the supporting insulation of the phase conductors of the switching device would exceed the rated phase-to-earth withstand voltage, the frame and the two phases of the main circuit not under test are fixed at a partial voltage with respect to earth U_f , so that $U_t - U_f$ has a minimum level of 70 % of the rated withstand voltage phase-to-earth; an upper limit has to be defined by the switchgear manufacturer (depending on the acceptable overstress of the phase-to-earth insulation);
- If reference is made in 7.2.7 to this alternative method, all terminals not under test and the frame may be insulated from earth.

Table 13 shows how to apply the different voltages.

Table 26 – Test conditions for the alternative method

Test condition	Main part		Fixed at partial voltage U_f^a
	Voltage U_t applied to	Earth connected to	
1	A	a	B, b, C, c, F
2	B	b	A, a, C, c, F
3	C	c	A, a, B, b, F
4	a	A	B, b, C, c, F
5	b	B	A, a, C, c, F
6	c	C	A, a, B, b, F

^a If permitted, all terminals (not under test) and the frame may even be insulated from earth, considering reference is made in 7.2.7 to the alternative method of 7.2.6.3.

Disconnectors of $U_r > 52$ kV having an isolating distance in parallel to the base of the disconnector and having integrated earthing switches, shall also be tested in open position, in dry conditions only, with the power frequency test voltage given in Table 14 in the most disadvantageous dielectric position of the earthing switch. If the minimum temporary clearance is larger than the clearances given in IEC 60071-1, no test is required.

Table 27 – Power frequency withstand voltages

Rated voltage U_r kV	Test voltage kV
72,5	94
100	130
123	160
145	188
170	221
245	283
300	346
362	418
420	484
550	635
800	924
1 100	1 270
1 200	1 386

NOTE See Annex A for rationale of the values given in Table 14.

For testing of earthing switches, the test voltage shall be applied with the earthing switch in the open position (see Table 21):

- between adjacent insulated terminals with the bases earthed (e.g. A to B with F earthed);
- between all the insulated terminals connected together and the bases earthed (e.g. ABC to F earthed).

7.2.7 Tests of disconnectors and earthing switches of $U_r \leq 245$ kV

7.2.7.1 General

The tests shall be performed with the test values equal to the rated withstand voltages selected from Table 1 or Table 2.

7.2.7.2 Power-frequency voltage tests

The test object shall be subjected to short-duration power-frequency voltage withstand tests in accordance with IEC 60060-1:2010. The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

The tests shall be performed in dry conditions and also in wet conditions for outdoor switchgear and controlgear with external insulation.

For the special cases considered in 7.2.6.3 the isolating distance may be tested as follows.

- Preferred method: In this case, neither of the two voltage values applied to the two terminals shall be higher than the rated withstand voltage phase-to-earth.

- Alternative method: for metal-enclosed gas-insulated switchgear and controlgear with a rated voltage up to and including 52 kV and for any other technology of switchgear and controlgear of any rated voltage the voltage to earth of the frame U_f needs not be fixed so accurately and the frame may even be insulated.
- Due to the large scatter of the results of the power-frequency voltage wet tests for switchgear and controlgear of rated voltage equal to 170 kV and 245 kV, an alternative is to replace these tests by a wet 250/2 500 μ s switching impulse voltage test, with a peak value equal to 1,55 times the RMS value of the specified power-frequency test voltage.

7.2.7.3 Lightning impulse voltage tests

The test object shall be subjected to lightning impulse voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1,2/50 μ s according to IEC 60060-1:2010.

When the alternative method is used to test the isolating distance of metal-enclosed gas-insulated switching device with a rated voltage up to and including 52 kV and for any other technology of switching device of any rated voltage, the voltage to earth of the frame U_f needs not be fixed so accurately and the frame may even be insulated.

7.2.8 Test of disconnectors and earthing switches of $U_r > 245$ kV

7.2.8.1 General

In the closed position, the tests shall be performed in conditions 1, 2 and 3 of Table 10. In the open position, the tests shall be performed as stated below (but refer to 7.2.4). In addition, phase-to-phase switching impulse voltage tests shall be performed as stated below. The tests shall be performed with the test values equal to the rated withstand voltages.

7.2.8.2 Power-frequency voltage tests

The test object shall be subjected to short-duration power-frequency voltage withstand tests in accordance with IEC 60060-1:2010. The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

The tests shall be performed in dry conditions only.

The insulation across the open switching device or isolating distance shall be tested. The preferred method is a) of 7.2.6.3 above. Subject to agreement with the manufacturer, the alternative method b) of 7.2.6.3 may also be used. Whichever method is chosen, neither of the voltages applied between one terminal and the frame shall be higher than the rated voltage U_r .

7.2.8.3 Switching impulse voltage tests

The test object shall be subjected to switching impulse voltage tests. The tests shall be performed with voltages of both polarities using the standardized switching impulse 250/2 500 μ s according to IEC 60060-1:2010. Wet tests shall be performed for outdoor switchgear and controlgear with external insulation only.

The isolating distance shall be tested with the preferred method a) of 7.2.6.3.

The insulation between poles shall be tested in dry conditions only according to Table 13 with a test voltage as per column 5 of Table 3 and/or Table 4, by the preferred method a) of 7.2.6.3 in which the main part shall be equal to or higher than 90 % of the value given in column 4 of Table 3 and Table 4. This value shall not exceed 100 % of the value indicated in column 4 of Table 3 and Table 4 without the consent of the manufacturer. The complementary part shall be applied to the adjacent phase in phase opposition in order that the sum of both

voltages (main part and complementary part) is equal to the value indicated in column 5 of Table 3 and Table 4.

The actual voltage share shall be as balanced as possible. Any unbalanced share of the total test voltage is more severe. When voltage components are different in shape and/or amplitude, the test shall be repeated reversing the connections.

7.2.8.4 Lightning impulse voltage tests

The test object shall be subjected to lightning impulse voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1,2/50 μ s according to IEC 60060-1:2010.

7.2.9 Artificial pollution tests for outdoor insulators

Artificial pollution tests are not required for insulators having creepage distances that are following the recommendations of 6.15 and Annex K (informative).

If the creepage distances differ from the recommended values given in Annex K (informative) artificial pollution tests shall be performed according to IEC 60507, using the rated voltage and the application factors given in IEC TS 60815-1:2008.

NOTE The performance of parallel insulation can be affected under pollution and rain (additional pollution tests could be necessary).

7.2.10 Partial discharge tests

Unless otherwise specified by the relevant product standard, partial discharge tests are not required. When tests are required, the measurements shall be made according to IEC 60270.

Partial discharge tests are not required to be performed on the complete disconnect or earthing switch except when required by the assembly standards i.e. IEC 62271-200, IEC 62271-201 and IEC 62271-203. However, in the case of disconnectors and earthing switches using components for which a relevant IEC standard exists, including partial discharge measurements (for example, bushings, see IEC 60137), evidence shall be provided by the manufacturer showing that those components have passed the partial discharge tests as laid down in the relevant IEC standard. For partial discharge measurement, see IEC 60270.

NOTE 1 The measurement of partial discharge test is a suitable means of detecting certain defects in the equipment under test and is a useful complement to the dielectric tests. Experience shows that partial discharges can lead in particular arrangements to a degradation in the dielectric strength of the equipment, especially of solid insulation.

NOTE 2 Other methods, for example UHF or acoustic methods, for measuring or detecting the partial discharge other than the one considered in IEC 60270, can be employed by agreement.

7.2.11 Dielectric tests on auxiliary and control circuits

The dielectric test on auxiliary and control circuits are covered under 7.10.5.

7.2.12 Voltage test as condition check

When a dielectric test is required as condition check, a power-frequency withstand voltage test in dry condition according to 7.2.7.2 or 7.2.8.2 at the following value of power-frequency voltage shall be applied.

For equipment with rated voltages up to and including 245 kV:

- 80 % of the relevant rated short-duration power-frequency withstand voltages.

For equipment with rated voltages from 300 kV and above:

- 100 % for isolating distances or 80 % for other test situations, of the respective rated short-duration power-frequency withstand voltages.

NOTE The reduction of the test voltage is motivated by the insulation coordination margin in the rated withstand voltages, which takes ageing, wear and other normal deterioration into account, and by the statistical nature of the flashover voltage.

7.3 Radio interference voltage (RIV) test

This test applies only to switchgear and controlgear having rated voltages of 245 kV and above when specified in the relevant product standard. Radio interference voltage test is regarded as EMC emission test and covered under 7.9.1.

NOTE Experience from service conditions shows that radio interference effects are negligible below 245 kV.

7.4 Resistance measurement

7.4.1 Measurement of the resistance of auxiliary contacts class 1 and class 2

One sample of each type of class 1 and class 2 auxiliary contacts shall be inserted into a resistive load circuit through which flows a current of (10 ± 2) mA when energized by a source having an open circuit voltage of 6 V DC with a relative tolerance of $^{+0}_{-15}$ % and the resistance measured according to IEC 60512-2-2.

The resistance of the closed class 1 and class 2 auxiliary contacts shall not exceed 50 Ω under these measuring conditions.

NOTE On contact materials, oxidation which decreases the effective current-carrying capabilities can occur. This results in an increased contact resistance or even no conduction at very low voltage while no problems are observed at higher voltage. This test is intended to verify the contact performance under these low-voltage conditions. The assessment criterion takes into account the non-linearity of the resistance. The 50 Ω value results from statistical considerations and has already been taken into account by users.

7.4.2 Measurement of the resistance of auxiliary contacts class 3

One sample of class 3 auxiliary contacts shall be inserted into a resistive load circuit through which flows a current ≤ 10 mA when energized by a source having an open circuit voltage ≤ 30 mV DC and the resistance measured according to 4.12 of IEC 61810-7:2006.

The resistance of the closed class 3 auxiliary contacts shall not exceed 1 Ω .

7.4.3 Electrical continuity of earthed metallic parts test

Generally visual inspection is sufficient to assess compliance with requirements in 6.3.

However, as an alternative, the metallic components and enclosures that may be touched during normal operating conditions and are intended to be earthed may be tested at 30 A (DC) to the earthing point provided. The voltage drop shall be lower than 3 V.

NOTE It may be necessary to locally remove coating at measuring points.

7.4.4 Resistance measurement of contacts and connections in the main circuit as a condition check

7.4.4.1 Resistance measurement test procedure

When resistance measurements are called for as a condition check after a specific test, the following procedure shall be applied.

The resistance across the contacts or connections being checked shall be measured before the test. The measuring test points shall be the nearest accessible points to and on either side of the contacts or connections in question. An average value of the resistance shall be calculated based on three measurements. If the test object comprises switching devices, one no-load open and close operation cycle shall be made on each device between each of the measurements. If the test object comprises removable elements, one remove / replace cycle shall be made between each of the measurements.

The measurements shall be made with DC at full rated continuous current (-20 % to 0 %) if less than or equal to 50 A or any convenient value of current between (and including) 50 A and the rated continuous current if it is higher than 50 A.

NOTE In some designs it may be only practical that several connections and/or contacts are measured in series in the main circuit or even the complete poles of a device are measured during type testing.

After the completion of the test, the resistance shall be measured again using the identical procedure to that used for the resistance measurements made prior to the tests. Before this resistance measurement, some conditioning of the contacts is acceptable based on the manufacturer's recommendations such as no-load operation cycles or the application of rated continuous current for some time.

The resistance measurements before and after shall be performed at ambient temperature with a maximum difference of 10 K between the measurements. The resistance increase is calculated by the difference between the average value of the measurements before and after the test.

7.4.4.2 Making and breaking tests

For making and breaking tests of any switching device, the resistance condition check of the test sample after completion of the test is considered to be satisfactory if the resistance increase for each phase determined in 7.4.4.1 is not greater than 100 %.

NOTE The acceptance criterion of 100 % increase in resistance as a condition check after making and breaking test is a default value for this document. The criterion may not be appropriate for all switchgear designs, e.g. designs with parallel arcing and main contacts. In such cases, the relevant product standards provide their own methods or criteria for a condition check.

7.4.4.3 Other tests

For tests other than making and breaking tests, the resistance condition check of the test object after completion of the test is considered to be satisfactory if the resistance increase for each phase determined in 7.4.4.1 is not greater than 20 %. If the resistance increase exceeds 20 % then a continuous current test (7.5) is applicable to determine if the test object can carry its rated continuous current.

NOTE The acceptance criterion of 20 % increase in resistance as a condition check after test is a default value for this document. The criterion may not be appropriate for all switchgear designs, in which case, the relevant product standards provide their own methods or criteria for a condition check.

7.5 Continuous current tests

7.5.1 Condition of the test object

The continuous current test of the main circuits shall be made on a test object, if applicable, with clean contacts and filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test.

7.5.2 Arrangement of the equipment

The test shall be made indoors in an environment substantially free from air currents, except those generated by heat from the test object. In practice, this condition is reached when the air velocity does not exceed 0,5 m/s.

For continuous current tests of parts other than auxiliary equipment, the test object and their accessories shall be mounted in all significant respects as in service, including all normal covers of any part of the test object (including any extra cover for testing purpose, for example cover surrounding a busbar extension), and shall be protected against undue external heating or cooling.

When the test object, according to the manufacturer's instructions, may be installed in different positions, the continuous current tests shall be made in the most unfavourable position.

These tests shall be made in principle on three-pole switchgear and controlgear but may be made on a single pole or on a single unit provided the influence of the other poles or units is negligible. This is the general case for non-enclosed switchgear above 52 kV. For three-pole switchgear and controlgear with a rated continuous current not exceeding 1 250 A, the tests may be made with all poles connected in series.

For particularly large test objects for which the insulation to earth has no significant influence on temperature rises, this insulation may be appreciably reduced.

For three-pole test objects, the test shall be made in a three-phase circuit with the exceptions mentioned above.

Where temporary connections to the main circuit are used, they shall be such that there is no significant difference in heat conducted away from, or conveyed to, the test object compared to the connections intended to be used for service (see 7.5.4.2).

NOTE To make the continuous current test more reproducible, the type and/or sizes of the temporary connections can be specified in relevant standards.

7.5.3 Test current and duration

7.5.3.1 Test on main circuit

The test shall be made at the rated continuous current (I_r) of the switchgear and controlgear. The supply current shall be practically sinusoidal.

This requirement is fulfilled when the RMS value of the harmonics does not exceed 5 % of the value of the fundamental current. By agreement of the manufacturer harmonic content higher than 5 % may be accepted.

Test object shall be tested at rated frequency with a tolerance of $^{+2}_{-5}$ %. The test frequency shall be recorded in the test report.

For switchgear and controlgear rated for both frequencies at 50 Hz and 60 Hz and having no ferromagnetic components adjacent to the current-carrying parts, the test can be performed at 50 Hz and covers both frequencies provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values. Tests performed at 60 Hz cover both frequencies.

The test shall be made over a period of time sufficient for the temperature rise to reach a stable value. This condition is deemed to be obtained when the variation of temperature rise does not exceed 1 K in 1 h. This criterion will normally be met after test duration of five times the thermal time constant of the test object.

The time for the whole test may be shortened by preheating the circuit with a higher value of current, provided that sufficient test data is recorded to enable calculation of thermal time constant.

7.5.3.2 Test of the auxiliary and control equipment

The test is made with the specified supply voltage (AC or DC), and for AC at its rated frequency (tolerance $\begin{smallmatrix} +2 \\ -5 \end{smallmatrix}$ %).

The auxiliary equipment shall be tested at its rated supply voltage (U_n) or at its rated continuous current. The AC supply voltage shall be practically sinusoidal.

Coils rated for continuous duty shall be tested over a period of time sufficient for the temperature rise to reach a constant value. This condition is usually obtained when the variation does not exceed 1 K in 1 h.

For circuits energized only during operations, the tests shall be made under the following conditions.

- a) When the operating device has an automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the circuit shall be energized 10 times, for either 1 s or until the automatic breaking device operates, the interval between the instant of each energizing being 10 s or, if the construction of the operating device does not permit this, the lowest interval possible.
- b) When the operating device has no automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the test shall be made by energizing the circuit once for duration of 15 s.

7.5.4 Temperature measurement during test

7.5.4.1 Ambient air temperature

The ambient air temperature is the average temperature of the air surrounding the test object (for enclosed switchgear and controlgear, it is the air outside the enclosure). It shall be recorded during the tests by means of at least three thermometers, thermocouples or other temperature-measuring devices equally distributed around the test object at about the average height of its current-carrying parts and at a distance of about 1 m from the test object. The thermometers or thermocouples shall be protected against air currents and undue influence of heat.

In order to avoid indication errors because of rapid temperature changes, the thermometers or thermocouples may be put into small bottles containing about 0,5 l of oil.

During the last quarter of the test period, the change of ambient air temperature shall not exceed 1 K in 1 h. If this is not possible because of unfavourable temperature conditions of the test room, the temperature of an identical switchgear and controlgear under the same conditions, but without current, may be taken as a substitute for the ambient air temperature. This additional switchgear and controlgear shall not be subjected to an undue amount of heat.

The ambient air temperature during tests shall be more than 10 °C but shall not exceed 40 °C without the consent of the manufacturer. No correction of the temperature-rise values shall be made for ambient air temperatures within this range and above.

7.5.4.2 Temperature of test object

Precautions shall be taken to reduce the variations and the errors due to the time lag between the temperature of the test object and the variations in the ambient air temperature.

For coils, the method of measuring the temperature rise by variation of resistance shall normally be used. Other methods are permitted only if it is impracticable to use the resistance method.

The temperature of the various parts other than coils for which limits are specified shall be measured with thermometers or thermocouples, or other sensitive devices of any suitable type, placed at the hottest accessible point.

The surface temperature of a component immersed in a dielectric liquid shall be measured only by thermocouples attached to the surface of this component. The temperature of the liquid dielectric itself shall be measured in the upper layer of the dielectric.

For measurement with thermometers or thermocouples, the following precautions shall be taken:

- a) the bulbs of the thermometers or thermocouples shall be protected against cooling from outside (dry clean wool, etc.). The protected area shall, however, be negligible compared with the cooling area of the apparatus under test;
- b) good heat conductivity between the thermometer or thermocouple and the surface of the part under test shall be ensured;
- c) when bulb thermometers are employed in places where there is any varying magnetic field, it is recommended to use alcohol thermometers in preference to mercury thermometers, as the latter are more liable to be influenced under these conditions.

Sufficient temperature measurements shall be made during the test, at time intervals not exceeding 30 min, in order to calculate the thermal time constant, and shall be recorded in the test document.

The temperatures at the terminals of the main circuit and at the temporary connections at a distance of 1 m from the terminals shall be measured. The difference in temperature rise shall not exceed 5 K.

However, if the temperature rise of the temporary connections at the distance of 1 m from the terminal of the main circuit exceeds by more than 5 K the temperature rise of the terminal, the test can be considered as valid if all criteria to pass the test defined in 7.5.6 are fulfilled.

7.5.5 Resistance of the main circuit

A measurement of the resistance of the main circuit shall be made before the continuous current test, with the test object at the ambient air temperature according to the measurement procedure as defined in 7.4.4.

The resistance value measured before the continuous current tests is made for comparison between the switchgear and controlgear type tested for continuous current and all other switchgear and controlgear of the same type subjected to routine tests (see Clause 8).

7.5.6 Criteria to pass test

7.5.6.1 General

The test object has passed the test if the temperature rise of the parts of the test object for which limits are specified, has not exceeded the values specified in Table 14.

If the insulation of a coil is made of several different insulating materials, the permissible temperature rise of the coil shall be taken as that for the insulating material with the lowest limit of temperature rise.

If the test object is fitted with various equipment complying with particular standards (for example, rectifiers, motors, low-voltage switches, etc.), the temperature rise of such equipment shall not exceed the limits specified in the relevant standards.

Table 28 – Limits of temperature and temperature rise for various parts, materials and dielectrics of high-voltage switchgear and controlgear

Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3 in 7.5.6.2) (Refer to NOTE 1)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C (NOTE 2) K
1 Contacts (refer to point 4) Bare-copper or bare-copper alloy – in OG (refer to point 5) – in NOG (refer to point 5) – in oil Silver-coated or nickel-coated (refer to point 6) – in OG (refer to point 5) – in NOG (refer to point 5) – in oil Tin-coated (refer to point 6) – in OG (refer to point 5) – in NOG (refer to point 5) – in oil	75 115 80 115 115 90 90 90 90	35 75 40 75 75 50 50 50 50
2 Connection, bolted or the equivalent (refer to point 4) Bare-copper, bare-copper alloy or bare-aluminium alloy – in OG (refer to point 5) – in NOG (refer to point 5) – in oil Silver-coated or nickel-coated (refer to point 6) – in OG (refer to point 5) – in NOG (refer to point 5) – in oil Tin-coated – in OG (refer to point 5) – in NOG (refer to point 5) – in oil	100 115 100 115 115 100 105 105 100	60 75 60 75 75 60 65 65 60
3 All other contacts or connections made of bare metals or coated with other materials	(Refer to point 7)	(Refer to point 7)
4 Terminals for the connection to external conductors by screws or bolts (refer to points 8 and 14) – bare – silver or nickel coated – tin-coated – other coatings	100 115 105 (Refer to point 7)	60 75 65 (Refer to point 7)
5 Oil for oil switching devices (refer to points 9 and 10)	90	50
6 Metal parts acting as springs	(Refer to point 11)	(Refer to point 11)

Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3 in 7.5.6.2) (Refer to NOTE 1)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C (NOTE 2) K
7 Materials used as insulation and metal parts in contact with insulation of the following classes (refer to point 12) – Y – A – E – B – F – Enamel: oil base synthetic – H – C other insulating material	90 105 120 130 155 100 120 180 (Refer to point 13)	50 65 80 90 115 60 80 140 (Refer to point 13)
8 Any part of metal or of insulating material in contact with oil, except contacts	100	60
9 Accessible surfaces Surfaces of manual control components to be touched in normal operation: – Uncoated metal – Coated metal – Non metal Other surfaces to be touched in normal operation but not to be held continuously in the hand: – Uncoated metal – Coated metal – Non metal Surfaces not to be touched in normal operation: – Uncoated metal – Coated metal – Non metal	(Refer to point 15) 55 55 65 65 70 80 80 80 90	(Refer to point 15) 15 15 25 25 30 40 40 40 50
NOTE 1 The points referred to in this table are those in 7.5.6.2.		
NOTE 2 For switchgear and controlgear with special service conditions including a maximum temperature different from 40 °C, the maximum values of temperature applies and the maximum values of temperature rise are calculated accordingly.		

7.5.6.2 Particular points of Table 14

The following points are referred to in Table 14 and complete it.

Point 1 According to its function, the same part may belong to several categories as listed
in Table 14.

In this case the permissible maximum values of temperature and temperature rise
to be considered are the lowest among the relevant categories.

- Point 2** For vacuum switching devices, the values of temperature and temperature-rise limits do not apply to parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in Table 14.
- Point 3** Care shall be taken to ensure that no damage is caused to the surrounding insulating materials.
- Point 4** When engaging parts have different coatings or one part is of bare material, the permissible temperatures and temperature rises shall be:

- a) for contacts, those of the surface material having the lowest value permitted in item 1 of Table 14;
- b) for connections, those of the surface material having the highest value permitted in item 2 of Table 14.

- Point 5** NOG (Not Oxidizing Gases), for the purposes of this document, are non-reactive gases that are considered as not accelerating ageing of contacts by corrosion or oxidation, due to their chemical characteristics and demonstrated operational records.

Recognized NOG are SF₆, N₂, CO₂, CF₄. They can be used pure or as a mixture of various NOG.

OG (Oxidizing Gases), for the purposes of this document, are reactive gases that can accelerate ageing of contacts either by corrosion phenomena (presence of humidity) or by oxidation phenomena (mostly due to ambient air medium like oxygen). Gases classified as OG are ambient air, "dry" air, any gas not classified as NOG and any mixture including part of OG.

NOTE Some gases considered as OG in the classification above could be re-classified as NOG, in future revision of this document.

For description of these corrosion and oxidation phenomena, refer to IEC TR 60943 [2].

Due to the absence of corrosion and oxidation in NOG, a harmonization of the limits of temperature for different contact and connection parts in the case of gas insulated switchgear appears appropriate.

The permissible temperature limits for bare copper and bare copper alloy parts are equal to the values for silver-coated or nickel-coated parts in the case of NOG atmospheres.

In the particular case of tin-coated parts, due to fretting corrosion effects, an increase of the permissible temperatures is not applicable, even under the corrosion and oxidation free conditions of NOG. Therefore, the values for tin-coated parts are lower.

- Point 6** The quality of the coated contacts shall be such that a continuous layer of coating material remains in the contact area:

- a) after the making and breaking test (if any);
- b) after the short-time withstand current test;
- c) after the mechanical endurance test.

according to the relevant standard for each equipment. Otherwise, the contacts shall be regarded as "bare".

- Point 7** When materials other than those given in Table 14 are used, their properties shall be considered, notably in order to determine the maximum permissible temperature rises.
- Point 8** The values of temperature and temperature rise are valid even if the conductor connected to the terminals is bare.
- Point 9** The temperature is to be measured at the upper part of the oil.
- Point 10** Special consideration should be given when low flash-point oil is used in regard to vaporization and oxidation.
- Point 11** The temperature shall not reach a value where the elasticity of the material is impaired.
- Point 12** Classes of insulating materials are those given in IEC 60085.
- Point 13** The temperature is limited only by the requirement not to cause any damage to surrounding parts.
- Point 14** These values do not take into account any influence on insulation of cable or cable termination.
- Point 15** For further details regarding temperature limits for hot surfaces to be touched, refer to IEC Guide 117 [3].

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

The tests apply to the main circuits and where applicable, to the earthing circuits of the test object to demonstrate their ability to carry their rated peak withstand current and their rated short-time withstand current for their rated duration of short-circuit.

The test shall be made with a power supply of any suitable voltage and at the rated frequency with a tolerance of $\pm 10\%$ except as provided in 7.6.3.

For rated frequencies of 50 Hz and 60 Hz, tests may be performed at either frequency provided that the rated peak withstand current is demonstrated.

The test may be performed at any convenient ambient temperature.

7.6.2 Arrangement of the disconnectors and earthing switches and of the test circuit

The test object shall be mounted on its own support(s) or on an equivalent support(s) and installed with its own operating device(s) as far as necessary to make the test representative for checking mechanical and thermal effects of the test currents. It shall be in the closed position, where relevant.

Each test shall be preceded by a no-load opening operation of the mechanical switching device(s) (if any) and, with the exception of earthing switches, by measurement of the resistance of the main circuit according to 7.4.4. The no-load opening operation shall be carried out at the rated value of the supply voltage in the case of power operated devices and the force/torque shall be measured in the case of dependent manually operated devices.

The test may be made three-phase or single-phase. In the case of a single-phase test, the following shall apply.

- On a three-pole test object, the test shall be made on two adjacent poles in series.
- In the case of test object with separated poles, the test may be made either on two adjacent poles or on one pole with the return conductor at phase distance equal to the distance of an adjacent pole in service. If the distance between poles is not fixed by the design, the test shall be made at the minimum distance indicated by the manufacturer.
- Above the rated voltage of 52 kV, unless otherwise specified in the relevant standards, the return conductor need not be taken into account, but in no case shall it be located closer to the tested pole than the minimum distance indicated for phase centres by the manufacturer.

The distance between the terminals and the nearest supports of the conductors or the nearest clamping points of cable on both sides of the test object shall be in accordance with the instructions of the manufacturer.

The test arrangement shall be noted in the test report.

7.6.2.101 General test conditions

The disconnectors or earthing switches under test shall be installed with their own operating mechanism as far as necessary to make the test representative.

Disconnectors having accessories to accommodate a bus-transfer current switching capability, and earthing switches having accessories to accommodate induced current switching capability, shall be tested with these devices mounted.

Tests shall be carried out employing the least favourable position of the operating mechanism and the main contacts. Consideration should be given to 6.104.3 and, where applicable, to 7.105.

Where the design requires an adjustment of the position indicator or the position-signalling device, this shall be performed according to the instruction manual. No deviation of these devices is acceptable for short-circuit tests.

If the design allows tolerances, these shall be declared by the manufacturer prior to the test. The short-time withstand current and peak withstand current tests shall be performed with the signalling device set at the maximum or minimum specified tolerance giving the least favourable status of the main contacts indicated by the signalling device. This requirement does not apply to independently operated indoor disconnectors and earthing switches.

NOTE The least favourable status of the main contacts is the first position at which during closing operation the "CLOSED" signal appears.

Open type disconnectors and earthing switches shall be tested with one of the appropriate test arrangements as specified in Figures 2, 3, 4 or 5. Where flexible conductors are used in the test setup, the terminals of the disconnectors or earthing switches under test shall be loaded with their longitudinal rated static mechanical terminal loads applied in the directions indicated by the manufacturer.

The test arrangement shall also be representative of the least favourable conditions of electromagnetic forces tending to open the disconnector or earthing switch. The tests on an earthing switch integral to a disconnector shall be made with the same test connections as for the disconnector test.

Single phase tests on disconnector or earthing switches having one common operating mechanism for three poles shall be performed on a single pole farthest from the operating mechanism.

Earthing switches not forming an integral part of a disconnector shall be tested in an arrangement that fulfils the same requirements as for disconnectors.

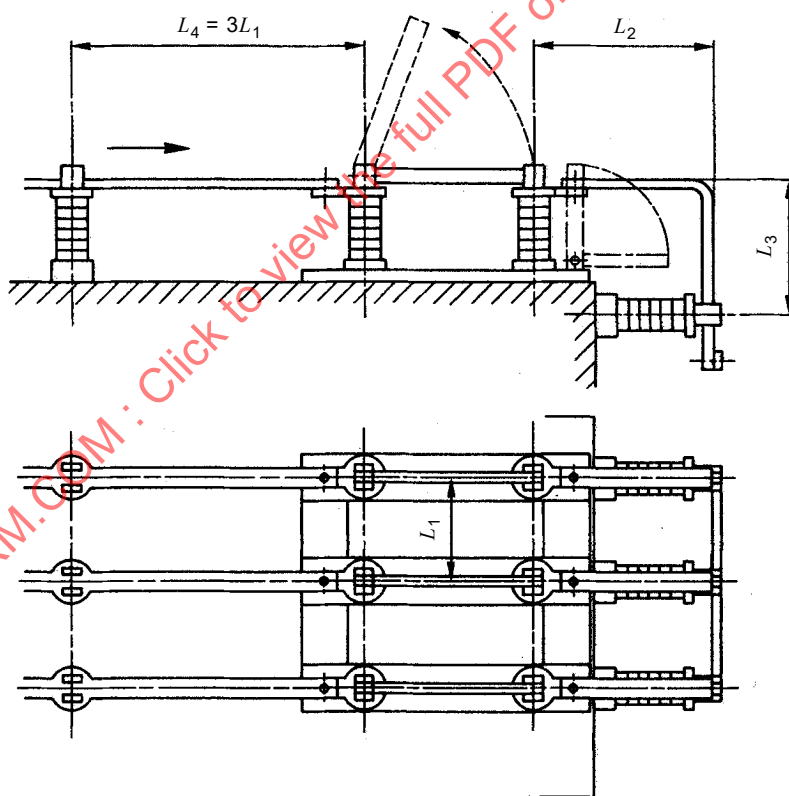
Disconnectors and earthing switches integrated in enclosed switchgear shall be tested as part of the switchgear assembly in accordance with IEC 62271-200, IEC 62271-201 or IEC 62271-203.

For divided support disconnectors and earthing switches, the vertical position of the contact in the contact zone shall be chosen to represent the most unfavourable condition with respect to the mounting of the fixed contact to flexible conductors or a rigid conductor. In case of doubt of the most unfavourable condition, the tests shall be performed in the highest and the lowest position of the contact within the rated contact zone.

All tests should preferably be performed three-phase. If a single-phase test is performed, the test should preferably be performed on two adjacent poles. If the test is performed on one pole, the return conductor shall be at phase distance from the tested pole. The return conductor shall be parallel to the main current path of the disconnector or earthing switch and at the same elevation above the base, or the equivalent, for disconnectors and earthing switches with vertical moving contact. The length of the return conductor shall be as given in Figures 2 to 5, as appropriate.

7.6.2.102 Disconnectors and earthing switches of $U_r \leq 52$ kV

The test arrangement given in Figure 2 shall be used for open type disconnectors and earthing switches of $U_r \leq 52$ kV. Hereby the distances L_2 and L_3 are as small as possible, but not smaller than L_1 .



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Figure 3 – Three-phase test arrangement for disconnectors and earthing switches

The represented disposition covers:

- unsupported distances equal or smaller than L_4 for rigid conductors;
- phase-distance equal or larger than L_1 .

If L_1 has a range the phase distance of the test setup shall be the shortest. L_4 shall be the longest distance given by the manufacturer but not less than three times the shortest L_1 .

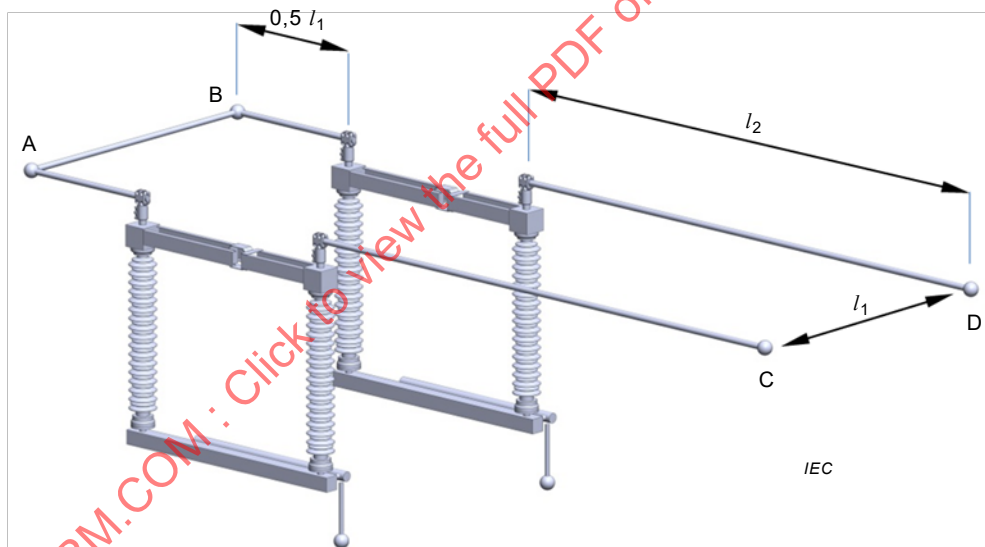
Avoid introduction of forces not representative of service conditions by the connections to the supply.

7.6.2.103 Disconnectors and earthing switches of $U_r > 52$ kV

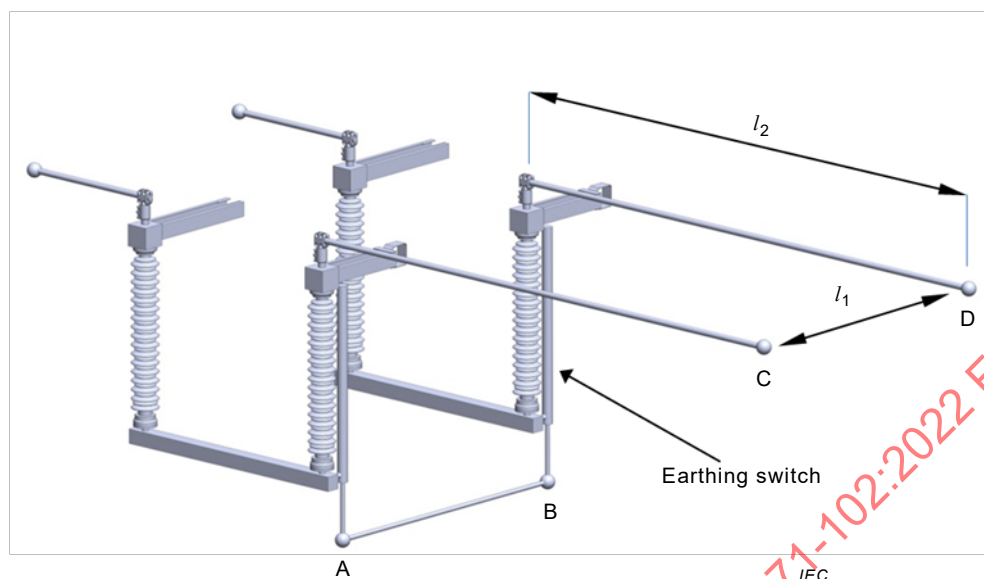
The single-phase test arrangement given in Figure 3 shall be used for disconnectors with a horizontal isolating distance and the relevant earthing switches; the test arrangement given in Figure 4 and Figure 5 shall be used for divided support disconnectors with a vertical isolating gap and the relevant earthing switches. Test results obtained on a disconnector or earthing switch placed in a certain position (e.g. horizontal or vertical) are valid only for the position of the disconnector or earthing switch during this test.

Three-phase test arrangements shall follow the same general pattern as the single-phase test arrangements of Figure 3 to Figure 5.

The short-circuit path between poles of the earthing switch schematically represented in Figure 3 shall reproduce during tests the installation conditions stated by the manufacturer. In particular, the position and fixing method of the conductors used to connect the poles between them and to the earth shall be considered.



a) Test arrangement for disconnectors



b) Test arrangement for earthing switches

Key

A–B Short-circuit connection

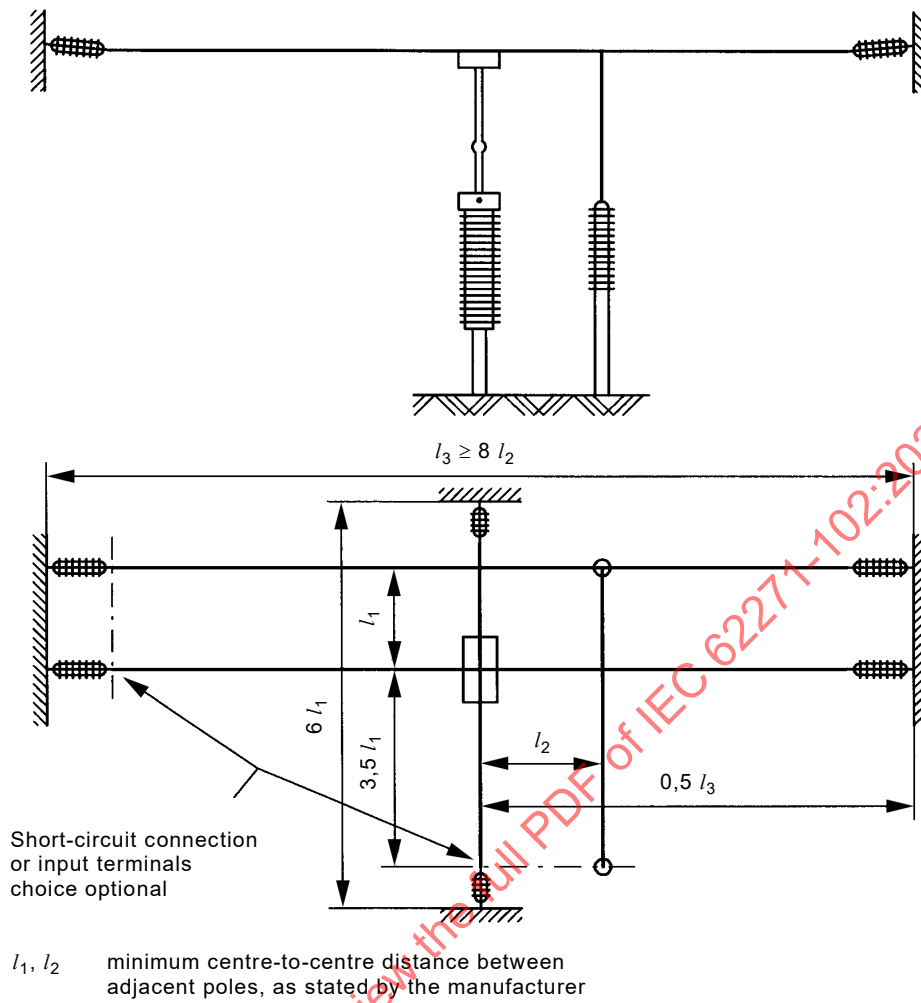
C–D Input

l_1 Minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

$l_2 = 2 \times l_1$ For $52 \text{ kV} < U_r \leq 550 \text{ kV}$

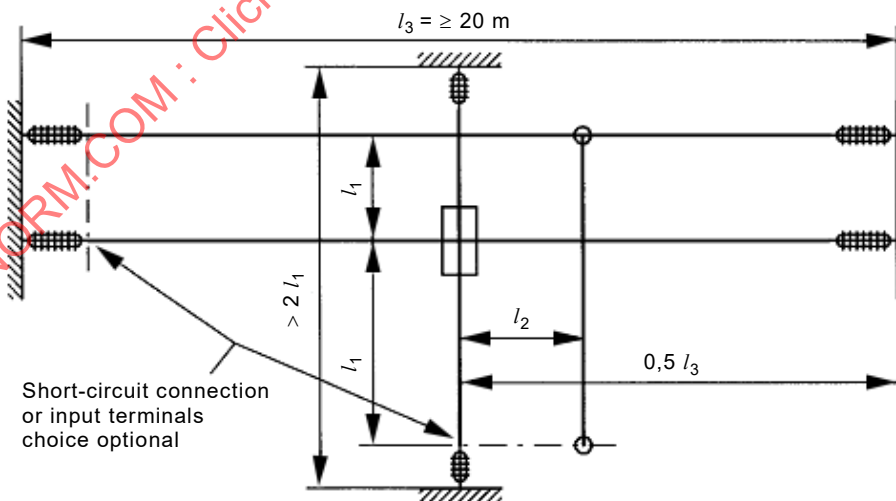
$l_2 = 0,5 \times l_1$ For $U_r > 550 \text{ kV}$, with a minimum of 7 m

Figure 4 – Single-phase test arrangement for disconnectors with a horizontal isolating distance and for earthing switches of $U_r > 52 \text{ kV}$, to be used with flexible or with rigid conductors



IEC

a) Test arrangement for disconnectors of $52 \text{ kV} < U_r \leq 550 \text{ kV}$

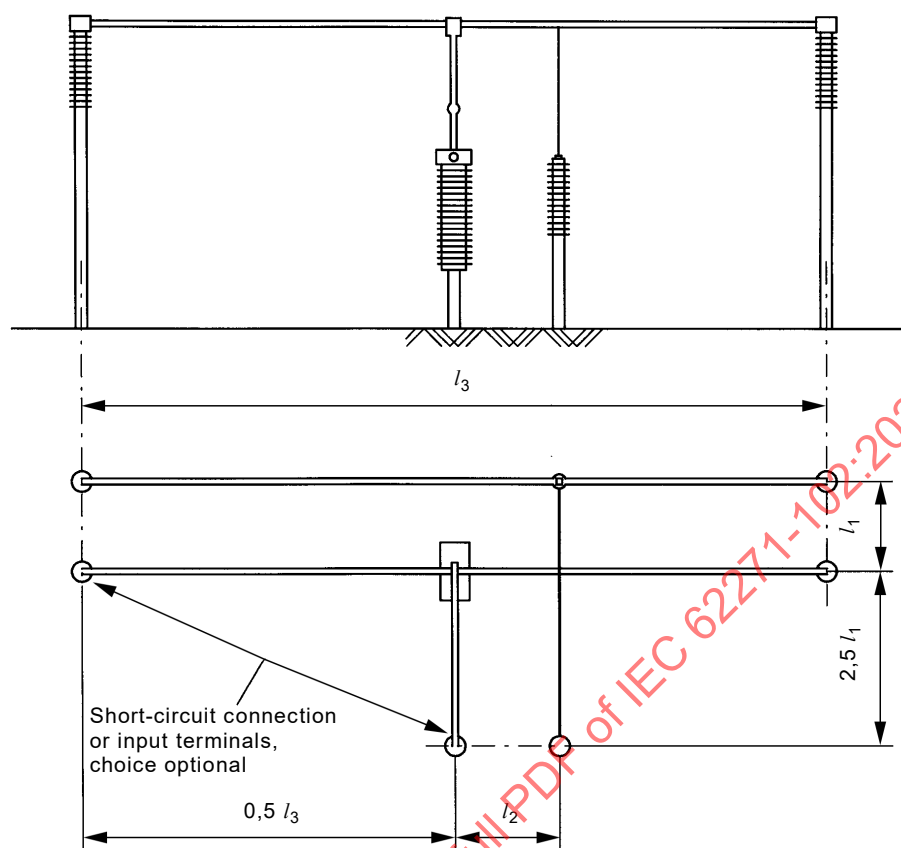


l_1, l_2 min. 10 m and max. centre-to-centre distance between
adjacent poles as stated by the manufacturer

IEC

b) Test arrangement for disconnectors of $U_r > 550 \text{ kV}$

Figure 5 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52 \text{ kV}$ with a vertical isolating distance, to be used with flexible conductors

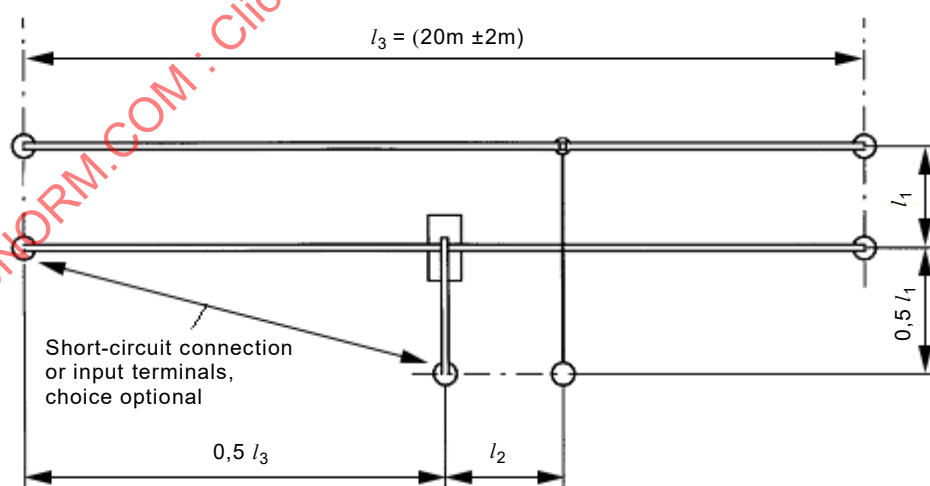


l_1, l_2 minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

IEC

For $U_r \leq 145$ kV $l_3 \geq 4l_1$
For $U_r \geq 170$ kV $l_3 = (20 \pm 2)$ m

a) Test arrangement for disconnectors of $52 \text{ kV} < U_r \leq 550 \text{ kV}$



l_1, l_2 minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

IEC

b) Test arrangement for disconnectors of $U_r > 550 \text{ kV}$

Figure 6 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52 \text{ kV}$ with a vertical isolating distance, to be used with rigid conductors

Disconnectors and earthing switches to be connected in the substation to flexible or rigid conductors, according to their documentation, shall be tested using flexible conductors with their rated static mechanical terminal load (e.g. longitudinal direction F_{a1} or F_{a2} in Figure 8 and F_{a1} , and F_{a2} in Figure 9) in a test setup with the dimensions given in Figure 3 or Figure 4 respectively. Disconnectors and earthing switches, according to their documentation, to be connected only to rigid conductors shall be tested with rigid conductors in a test arrangement with the same dimensions and without intentional static mechanical terminal load except the one given by the weight of rigid conductors. The dimensions and material of the conductors used shall be stated in the test report.

After applying 50 % of the longitudinal rated static terminal load, the disconnector or earthing switch may be adjusted, before the 100 % load is applied

All details referring to the test arrangement are mandatory, the details of the disconnector and earthing switch shown are given as an example.

For standardization of tests when they are performed with flexible conductors, where the rated currents of the equipment are larger than 1 250 A continuous current or 31,5 kA short-time withstand current for a duration of 1 s, two flexible conductors shall be used having a centre line distance of (70 ± 30) mm without spacers. Disconnectors and earthing switches of $U_r \geq 300$ kV shall also be tested with these two flexible conductors.

Unless the tested disconnector or earthing switch is solidly fixed to the foundation, the spring constant of the support structure has to be taken into consideration (IEC 60865-1).

The test report shall provide clear details of the mounting arrangements used for the tests or record that the disconnector was solidly fixed to the foundations.

Avoid introduction of forces not representative of service conditions by the connections to the supply, and static terminal loads larger than the rated static mechanical terminal loads of the test object.

If, in the test setup, the short side of the low-level conductor cannot be supported, it may be supported by the disconnector. This may result in a higher dynamic mechanical terminal load.

NOTE 1 In principle, Figure 3 can be used for testing earthing switches with an appropriate arrangement of the earth conductor.

NOTE 2 In principle, Figure 4 can be used for testing integrated earthing switches with an appropriate arrangement of the earth conductor.

7.6.3 Test current and duration

The AC component of the test current shall be equal to the AC component of the rated short-time withstand current (I_k) of the switchgear and controlgear with the tolerances and alternatives given below. The peak current (for a three-phase circuit, the highest value in one of the outer phases) shall be not less than the rated peak withstand current (I_n) and shall not exceed it by more than 5 % without the consent of the manufacturer.

For three-phase tests, the AC component of the test current in any phase shall not vary from the average of the currents in the three phases by more than 10 %. The average of the RMS values of the AC component of the test currents shall be not less than the rated value.

Either of two methods may be used:

Method 1: the test current I_t shall be applied for a time t_t equal to the rated duration t_k of short-circuit with a tolerance of the AC component of $^{+5}_{0}$ %.

Method 2: the value of the Joule integral $\int I^2 dt$ of the AC component along the test shall be not less than the value of $I_k^2 \times t_k$ calculated from the rated short-time current (I_k) and the rated duration of short-circuit (t_k), and shall not exceed this value by more than 10 % without the consent of the manufacturer, refer to Annex B (informative).

The following deviations are permitted:

- a) if the decrement of the short-circuit of the test laboratory is such that the specified RMS value cannot be obtained for the rated duration without applying initially an excessively high current, the RMS value of the test current may be permitted to fall below the specified value during the test and the duration of the test may be increased appropriately, provided that the value of the peak current is not less than that specified and the time is not extended to more than 5 s;
- b) if, in order to obtain the required peak current, the RMS value of the current is increased above the specified value, the duration of the test may be reduced accordingly;
- c) separation of the peak withstand current test and the short-time withstand current test is permissible:
 - for the peak withstand current test, the time during which the short-circuit current is applied shall be not less than 0,3 s;
 - for the short-time withstand current test, the time during which the short-circuit current is applied shall be equal to the rated duration. However, deviation in time according to item a) is permitted.for switching devices the test object shall be kept in closed position between the tests;
- d) when the characteristics of the test laboratory are such that the frequency of the test current cannot be kept within its specified tolerance for the specified duration, the frequency at the beginning of the test shall be within the specified tolerance and a decrease down to 80 % of the specified frequency is allowed.

7.6.4 Conditions of disconnectors and earthing switches after test

After the test, the test object shall not show significant deterioration, shall be capable of operating normally and carrying its rated continuous current.

If the mechanical switching device has a rated making and/or breaking capacity, then the condition of the contacts shall not be such as to affect the performance materially at any making and/or breaking current up to its rated value.

The following steps are used to check these requirements:

- a) a no-load opening operation of the mechanical switching device shall be performed in the same conditions as stated in 7.6.2 immediately after the test, and the contacts shall open at the first attempt;
- b) visual inspection of the test object and the contacts (if not detrimental);
- c) except for earthing switches, the variation of the resistance of the main circuit shall be checked according to 7.4.4.

The rated peak withstand current and the rated short-time withstand current, carried by a disconnector or earthing switch in the closed position during the rated duration of short-circuit, shall not cause:

- mechanical damage to any part of the disconnector or earthing switch;
- separation of the contacts.

After the test, a no-load operation shall be made with the rated value of power supply for independent power-operated devices, with minimum value of power supply for dependent power-operated devices, and for manually (dependent or independent) operated devices with

a force no higher than the values given for manually operated devices in 6.105. The disconnecter or earthing switch shall open at the first attempt.

In the case of performing the short-circuit withstand test with a single-phase test on one pole of a three-pole disconnecter or earthing switch operated by a common driving mechanism or shaft, exact details of the test procedure and the measured torque/force at the exit of the driving mechanism during the no-load operation shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus after a three phase short circuit occur. This test method may require the insertion of a torque/force measurement device in the power kinematic chain for testing. The measured torque/force in the power kinematic chain to open the pole under test of the disconnecter or earthing switch tested shall be not more than the value given by the driving mechanism when blocking the exit of the driving mechanism divided by the number of poles of the switching device under test.

After the no-load operation, for earthing switches, sound earth connection and sound insulation shall be verified by the following:

- visual inspection shall be made (if possible). Significant contact erosion or significant contact welding should not be observed. Light welding of contacts is permitted;
- when significant contact erosion is suspected or if visual inspection is not possible without dismantling the contacts, sound earth connection shall be verified by checking the electrical continuity according to 7.4.3 of IEC 62271-1:2017;
- in case of doubt of insulating properties or if visual inspection is not possible without dismantling, 7.2.12 is applicable to verify the dielectric conditions across the isolating gap and to earth.

After the no-load operation(s), for disconnectors:

- to verify the current carrying capacity main circuit resistance measurement shall be made as close as possible to the contacts. The increase of resistance after the test shall not exceed 20 % of the value measured before the test;
- when the contact resistance exceeds this value a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the contacts;
- visual inspection shall be made (if possible). In case of doubt of insulating properties or if visual inspection is not possible without dismantling, 7.2.12 is applicable to verify the dielectric conditions across the isolating gap and to earth.

7.7 Verification of the protection

7.7.1 Verification of the IP coding

In accordance with the requirements specified in Clauses 11, 12, 13 and 15 of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013, tests shall be performed, to demonstrate performances as required in 6.14, on the enclosures of switchgear and controlgear fully assembled as under service conditions. As real cable connections entering the enclosures are not normally installed for type tests, corresponding filler pieces shall be used. Transport units of switchgear shall be closed for the tests by covers providing identical protection qualities as for the joints.

The tests shall, however, be made only if there are doubts regarding the compliance with these requirements, they shall be performed in each position of the relevant parts as deemed necessary.

When the supplementary letter W is used, test method given in Annex C (normative) shall be applied.

7.7.2 Verification of the IK coding

The requirements specified in 6.14.4 shall be demonstrated according to IEC 62262:2002; tests shall be performed on the enclosures of switchgear and controlgear fully assembled as under service conditions.

After the test, the enclosure shall show no breaks and the deformation of the enclosure shall not affect the normal function of the equipment, reduce the insulating and/or creepage distances or reduce the specified degree of protection against access to hazardous parts below the permitted values. Superficial damage, such as removal of paint, breaking of cooling ribs or of similar parts, or depression of small dimension can be ignored.

The tests shall, however, be made only if there are doubts regarding the compliance with these requirements, they shall be performed in each position of the relevant parts deemed necessary.

Auxiliary equipment such as meters, relays etc., which may form part of the enclosure is exempted from receiving impacts in this test.

7.8 Tightness tests

7.8.1 General

The purpose of tightness tests is to demonstrate that the absolute leakage rate F does not exceed the specified value of the permissible leakage rate F_p at standardized ambient temperature of 20 °C. Acceptable test condition is an ambient temperature in a range of 15 °C up to 30 °C.

If tightness tests at the temperature limits of the service condition are required in the relevant product standards, an increased leakage rate is permissible. The increased temporary leakage rate shall not exceed the values given in Table 15.

Tightness test shall be performed with the same fluid and under the same pressure (density) as used in service. If the fluid itself is not traceable additional traceable fluids may be added, for example helium. The leakage test method shall have sufficient sensitivity; reference is made to IEC TR 62271-306 [4].

Where possible, the tests should be performed on a complete system. If this is not practical, the tests may be performed on parts, components or subassemblies. In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart (refer to IEC TR 62271-306 [4]). The possible leakages between subassemblies of different pressures shall also be taken into account.

The tightness test of switchgear and controlgear containing a mechanical switching device shall be performed both in the closed and open position of the device, unless the leakage rate is independent of the position of the main contacts.

Cumulative leakage measurement, which takes into account all the leaks from a given assembly to determine the leakage rate, shall be used in the calculation of leakage rates.

The type test report should include such information as:

- description of the object under test, including its internal volume and the nature of the filling gas or liquid;
- whether the object under test is in the closed or open position (if applicable);
- the pressures and temperatures recorded at the beginning and end of the test and the number of replenishments (if any needed);

- the value of the ambient temperature during the test.
- the cut-in and cut-off pressure settings of the pressure (or density) control or monitoring device;
- an indication of the calibration of the meters used to detect leakage rates;
- the results of the measurements;
- the test gas and if applicable the conversion factor to assess the results.

In general, for the application of an adequate test method, reference is made to IEC 60068-2-17:1994 [31].

Table 29 – Permissible leakage rates for gas systems

Temperature °C	Permissible leakage rate
Maximum service temperature (≥ 40 °C)	$3F_p$
Standardized ambient temperature (20 °C)	F_p
Minimum service temperature (any value down to and including -40 °C)	$3F_p$
Minimum service temperature (any value below -40 °C)	$6F_p$

7.8.2 Controlled pressure systems for gas

Preferred method for checking the relative leakage rate F_{rel} is by measuring the pressure drop Δp over a time period t that is of sufficient duration to permit a determination of the pressure drop (within the filling and replenishing pressure range). A correction shall be made to take into account the variation of ambient air temperature during the course of the test. During this period the replenishment device shall be inoperative.

$$F_{rel} = \frac{\Delta p}{p_r} \times \frac{24}{t} \times 100 (\% \text{ per day})$$

$$N = \frac{\Delta p}{p_r - p_m} \times \frac{24}{t}$$

where

t is the test duration (h);

p_r is the filling pressure (Pa);

p_m is the measured pressure after time t (Pa);

Δp is the pressure drop between p_r and p_m after time t (Pa);

N is the number of replenishments per day.

NOTE The linearity of the formula is considered to be maintained provided that Δp is of the same order of magnitude as $p_r - p_m$.

7.8.3 Closed pressure systems for gas

The test Q_m (Test method 1: cumulative test) described in IEC 60068-2-17:1994 is the preferred method to determine the relative leakage rate F_{rel} in gas systems and calculate the time between replenishments t_r . Detailed information about test procedure, sensitivity of measurement and example of calculation are also given in IEC TR 62271-306 [4].

Alternative methods of leak detection are also given in IEC TR 62271-306 [4] that may be used to measure the leakage rate, which allows in combination with the tightness coordination chart, the calculation of:

- the relative leakage rate;
- the time between replenishments (without considering extreme temperature conditions of number of operations).

The tightness test is considered to be successful when the measured leakage rate does not exceed the permissible leakage rate stated in Table 15 within the limits of +10 %. This inaccuracy of the measurement shall be taken into account when calculating the period of time between replenishments.

7.8.4 Sealed pressure systems

Tightness tests on sealed pressure systems shall be as follows

a) Switchgear using gas

The tests shall be performed according to the preferred method of 7.8.3.

b) Switchgear using vacuum interrupters

No specific tightness tests are required for vacuum interrupters since their tightness is verified during manufacturing process and because they are considered to have a zero leakage rate during their life. Nevertheless, instead of a tightness test, the vacuum integrity needs to be verified where specific standards ask for a tightness test as condition check (for example mechanical test, low and high temperature tests, etc.).

The integrity of the vacuum may be verified by the dielectric condition check test, refer to 7.2.12.

7.8.5 Liquid tightness tests

The purpose of tightness tests is to demonstrate that the total system leakage rate F_{lin} does not exceed the specified value $F_{\text{p(liq)}}$.

The object under test shall be as in service conditions with all its accessories and its normal fluid, mounted as close as possible as in service.

An increased leakage rate at extreme temperatures (if such tests are required in the relevant standards) and/or during operations is acceptable, provided that this rate resets to the initial value after the temperature is returned to normal ambient air temperature and/or after the operations are performed. The increased temporary leakage rate shall not impair the safe operation of the switchgear and controlgear.

The switchgear shall be observed over a period sufficient to determine a possible leak or the pressure drop Δp_{liq} . In this case, the calculations given in 7.8.2 are valid.

As an alternative, using liquids different from those in service or gas for the test is possible but requires justification by the manufacturer.

The test report shall include such information as:

- a general description of the object under test;
- the number of operations performed;
- the nature and pressure(s) of the liquid;
- the ambient air temperature during test;
- the results with the switchgear device in closed and in open position (where applicable).

7.9 Electromagnetic compatibility tests (EMC)

7.9.1 Emission tests

7.9.1.1 Emission tests from the main circuits (radio interference voltage test, RIV)

Radio interference voltage tests apply only to switchgear and controlgear having a rated voltage of 245 kV and above, when specified in the relevant product standard.

Test object shall be installed as stated in 7.2.4.

The test voltage shall be applied as follows.

- a) in closed position, between the terminals and the earthed frame;
- b) in open position, if any, between one terminal and the other terminals connected to the earthed frame and then with the connections reversed if the switching device is not symmetrical.

The case, tank, frame and other normally earthed parts shall be connected to earth.

The test object shall be dry and clean and at approximately the same temperature as the room in which the test is made. During the tests the test object shall be equipped with all accessories such as grading capacitors, corona rings, high-voltage connectors, etc. which may influence the radio interference voltage.

The measuring circuit (refer to Figure 3) shall comply with CISPR TR 18-2. The measuring circuit shall preferably be tuned to a frequency within 10 % of 0,5 MHz, but other frequencies in the range 0,5 MHz to 2 MHz may be used, the measuring frequency being recorded. The results shall be expressed in μV .

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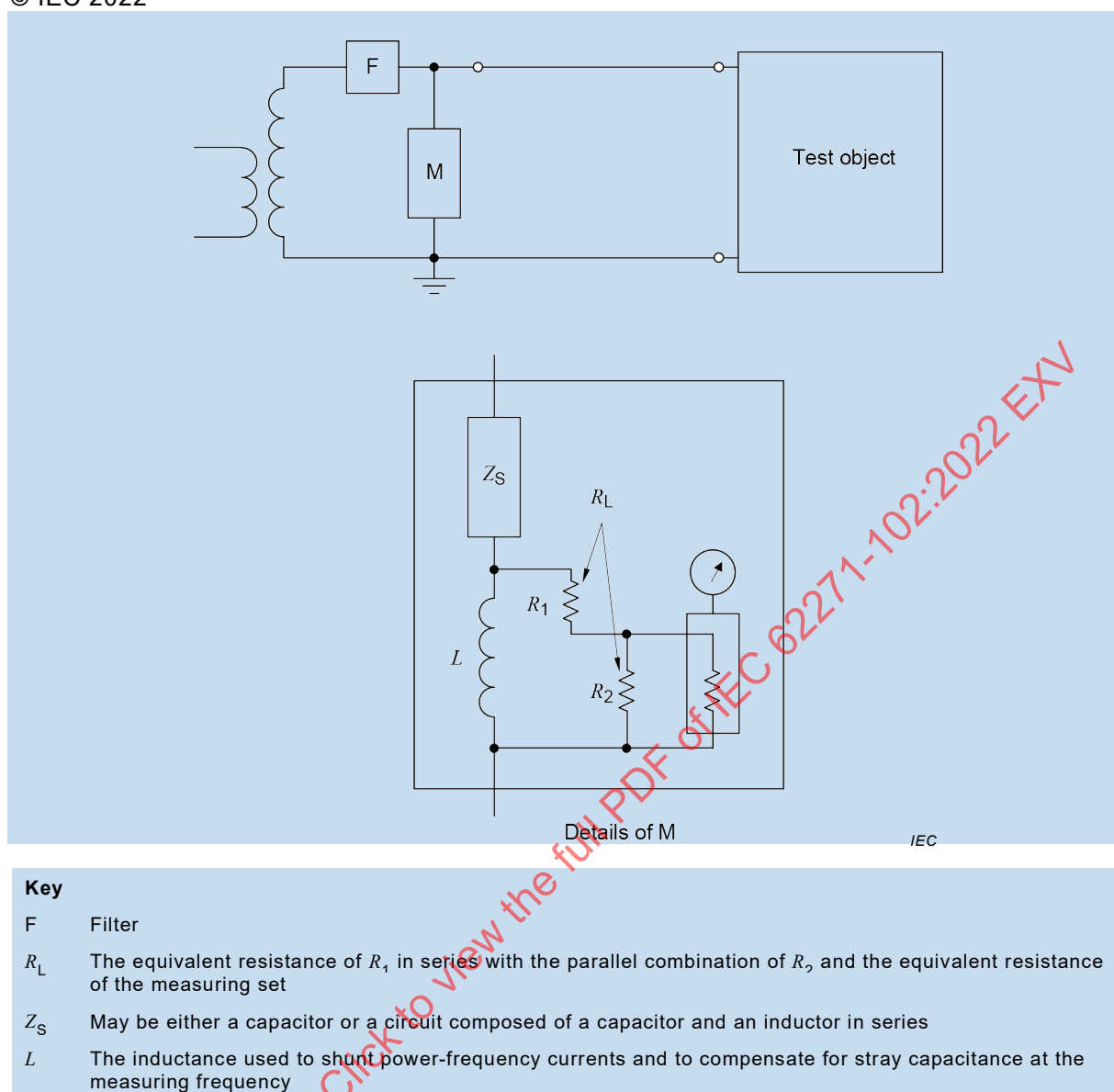


Figure 7 – Diagram of a test circuit for the radio interference voltage test

The preferred measuring impedances are those specified in CISPR publications. If measuring impedances different from those specified in CISPR publications are used as an alternative, they shall be not more than 600 Ω nor less than 30 Ω ; in any case the phase angle shall not exceed 20°. The equivalent radio interference voltage referred to 300 Ω can be calculated, assuming the measured voltage to be directly proportional to the resistance, except for test pieces of large capacitance, for which a correction made on this basis may be inaccurate. Therefore, a 300 Ω resistance is recommended for switchgear and controlgear with bushings with earthed flanges (for example dead tank switchgear and controlgear).

The filter F shall have high impedance at the measuring frequency, so that the impedance between the high-voltage conductor and earth is not shunted as seen from the switchgear and controlgear under test.

NOTE This filter also reduces circulating radiofrequency currents in the test circuit, generated by the high-voltage transformer or picked up from extraneous sources. A suitable value for its impedance has been found to be 10 000 Ω to 20 000 Ω at the measuring frequency.

It shall be ensured by suitable means that the radio interference background level (radio interference level caused by external field and by the high-voltage transformer when magnetized at the full test voltage) is at least 6 dB below the specified radio interference level

of the test object. Calibration methods for the measuring instrument and for the measuring circuits are given in CISPR 16-1 (all parts) [32] and CISPR TR 18-2 respectively.

The following test procedure shall be followed.

A voltage of $1,1 \times U_r / \sqrt{3}$ shall be applied to the test object and maintained for at least 5 min, U_r being the rated voltage of the switchgear and controlgear.

The test is passed, if the radio interference level does not exceed 2 500 μ V.

As the radio interference level may be affected by fibres or dust settling on the insulators, it is permitted to wipe the insulators with a clean cloth before taking a measurement. The atmospheric conditions during the test shall be recorded. If the measured RIV value is above the limit and the relative humidity is above 80 %, the test is not conclusive and shall be repeated with a relative humidity lower than 80 %.

7.9.1.2 Emission tests from the auxiliary and control circuits

Auxiliary and control circuits of switchgear and controlgear shall be subjected to electromagnetic emission tests if they include electronic equipment or components. In other cases no tests are required.

For auxiliary and control circuits of switchgear and controlgear, the EMC requirements and tests specified in this document have precedence over other EMC specifications.

The test shall be performed only on a representative auxiliary and control circuit, because the single components are tested according to their relevant standards, if any.

Electronic equipment, which is part of the auxiliary and control circuits, shall fulfil the requirements with regard to radiated emission, as defined in CISPR 11:2015 for group 1, class A equipment. No other tests are specified. A 10 m measuring distance may be used instead of 30 m, by increasing the limit values by 10 dB.

7.9.2 Immunity tests on auxiliary and control circuits

7.9.2.1 General

Auxiliary and control circuits of switchgear and controlgear shall be subjected to electromagnetic immunity tests if they include electronic equipment or components. In other cases no tests are required.

The tests shall be performed on a typical auxiliary and control circuit. Components shall comply with their relevant standards, if any.

The following immunity tests are specified:

- electric fast transient/burst test (refer to 7.9.2.2). The test simulates the conditions caused by switching in the auxiliary and control circuit;
- oscillatory wave immunity test (refer to 7.9.2.3). The test simulates the conditions caused by switching in the main circuit.

NOTE Other EMC immunity tests do exist, but are not specified in this case.

Electromagnetic immunity tests shall be made on complete auxiliary and control circuits or subassemblies. The tests may be made on

- the complete auxiliary and control circuits;
- subassemblies, such as central control cubicle, drive mechanism cubicle, etc.;

- subassemblies within a cubicle, such as metering or monitoring system.

Individual testing of subassemblies is strongly recommended in cases where long lengths of interconnections are needed, or where significant interference voltages are expected between the subassemblies. Individual testing is mandatory for each interchangeable subassembly.

The test voltage shall be applied to the interface of the auxiliary and control circuits or tested subassembly.

The type test report shall clearly state what system or subassembly has been tested.

7.9.2.2 Electrical fast transient/burst test

An electrical fast transient/burst test shall be performed in accordance with IEC 61000-4-4, with a repetition rate of 5 kHz. The ports and interfaces shall be chosen in accordance with IEC 61000-6-2. The test voltage and coupling shall be chosen according to Table 16.

Table 30 – Application of voltages at the fast transient/burst test

Interface	Relevance for equipment	Test voltage kV	Coupling
Power port	AC and DC power lines	2	CDN
Cabinet earth port		2	CDN
Signal port	Shielded and unshielded lines, carrying analogue and/or digital signals control lines communication lines (for example data buses) measuring lines (for example CT, VT)	2	CCC or equivalent coupling methods
Key CDN: Coupling decoupling network. CCC: Capacitive coupling clamp.			

7.9.2.3 Oscillatory wave immunity test

An oscillatory wave immunity test shall be performed, with shape and duration of the test voltage in accordance with IEC 61000-4-18.

The ports and interfaces shall be chosen in accordance with IEC 61000-6-2.

Damped oscillatory wave tests shall be made at 100 kHz and 1 MHz, with a relative tolerance of $\pm 30\%$.

Tests shall be made for both common and differential mode. The test voltage and coupling method shall be chosen according to Table 17.

Table 31 – Application of voltage at the damped oscillatory wave test

Interface	Relevance for equipment	Test voltage kV	Coupling
Power port	AC and DC power lines	Differential mode: 1,0 Common mode: 2,5	CDN CDN
Signal port	Shielded and unshielded lines, carrying analogue and/or digital signals control lines communication lines (for example data buses) measuring lines (for example CT, VT)	Differential mode: 1,0 Common mode: 2,5	CDN CDN Or equivalent coupling method
Key CDN: Coupling decoupling network.			

7.9.2.4 Behaviour of the secondary equipment during and after tests

The auxiliary and control circuits shall withstand each of the tests specified in 7.9.2.2 and 7.9.2.3 without permanent damage. After the tests it shall still be fully operational. Temporary loss of parts of the functionality is permitted according to Table 18.

Table 32 – Assessment criteria for transient disturbance immunity

Function	Criterion
Protection, tele protection	A
Alarm	B
Supervision	B
Command and control	A
Measurement	B
Counting	A
Data processing for high-speed protective system	A
for general use	B
Information	B
Data storage	A
Processing	B
Monitoring	B
Man-machine interface	B
Self-diagnostics	B
Processing, monitoring and self-diagnostic functions which are on-line connected, and are part of command and control circuits, shall fulfil criterion A.	
Key A: Normal performance within the specification limits; B: Temporary degradation or loss of function or performance which is self-recoverable.	

7.9.3 Additional EMC tests on auxiliary and control circuits

7.9.3.1 General

The objective of the tests described below is to qualify the whole assembly without repeating individual test on components. Therefore, tests on components which comply with their relevant IEC standards and with relevant rated values need not be repeated.

7.9.3.2 Ripple on DC input power port immunity test

This test shall be performed according to IEC 61000-4-17:2009. The test level shall be level 2, and the frequency of the ripple is equal to three times the rated frequency (f_r).

The assessment criterion is: "normal performance within the specification limits" (criterion A).

7.9.3.3 Voltage dips, short interruptions and voltage variations on input power port immunity tests

Voltage dips, short interruptions and voltage variations tests on AC power ports shall be performed according to IEC 61000-4-11 and on DC power ports according to IEC 61000-4-29.

The relevant acceptance criteria are present in 6.4.1.

7.10 Additional tests on auxiliary and control circuits

7.10.1 General

Tests on components, which comply with their relevant IEC standards and with relevant rated values, need not be repeated.

7.10.2 Functional tests

A functional test of all auxiliary and control circuits shall be made to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the auxiliary and control circuits of the device. They shall be performed with the upper and lower value limits of the supply voltage defined in 6.4.1.

For auxiliary and control circuits, sub-assemblies and components, operation tests can be omitted if they have been fully performed during a test applied to the whole switchgear and controlgear or in relevant circumstances.

7.10.3 Verification of the operational characteristics of auxiliary contacts

7.10.3.1 General

Auxiliary contacts, which are contacts included in auxiliary circuits, shall be submitted to the following tests unless the equipment has passed the whole type tests as a functional unit.

7.10.3.2 Auxiliary contact rated continuous current

This test verifies the rated value of current which a previously closed auxiliary contact is capable of carrying continuously.

The circuit shall be closed and opened by means independent from the contact under test. Test procedures are described in 7.5.3.2. The contact shall carry its class rated continuous current according to Table 8 without exceeding the temperature rise in Table 14 based on the contact material and the working environment.

7.10.3.3 Auxiliary contact rated short-time withstand current

This test verifies the value of current which a previously closed auxiliary contact is capable of carrying for a specified short period.

The circuit shall be closed and opened by means independent from the contact under test. The contact shall carry its class rated short-time withstand current according to Table 8 for 30 ms, with a resistive load. The current value to be obtained shall be reached within 5 ms after current initiation. The tolerance on the test current amplitude is $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ % and the tolerance on the test current duration is $\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %.

This test shall be repeated 20 times with a 1 min interval between each test. The contact resistance value shall be taken before and after the tests at 50 % of the rated continuous current in Table 8, with the contacts at ambient temperature for both measurements.

The test is passed:

- if the resistance increase is less than 20 %;
- or, when the increase exceeds 20 %, if the continuous current test according to 7.5.3.2 is performed successfully.

7.10.3.4 Auxiliary contact breaking capacity

This test verifies the breaking capacity of an auxiliary contact.

The circuit shall be closed by means independent from the contact under test. The contact shall carry for 5 s and shall break the current associated with its class according to Table 8, with an inductive load. The tolerance on the test voltage is $\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ % and the tolerance on the test current amplitude is $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ %.

For all classes, the circuit time constant shall be 20 ms with a tolerance of $\begin{smallmatrix} +20 \\ 0 \end{smallmatrix}$ %.

This test shall be repeated 20 times with a 1 min interval between each test. The recovery voltage shall be maintained during each 1 min interval and for 300 ms $\pm$ 30 ms after the last operation. The contact resistance value shall be taken before and after the tests at 50 % of the rated continuous current in Table 8, with the contacts at ambient temperature for both measurements. The resistance increase shall be less than 20 %. If the increase exceeds 20 % then the continuous current test according to 7.5.3.2 shall be performed.

7.10.4 Environmental tests

7.10.4.1 General

Heating elements, if any, shall be ready to operate except where otherwise stated.

The following tests are independent type tests.

Auxiliary and control circuits shall be energised, and shall remain in the operating condition during and after the test until the functional checks have been performed. At the end of the test duration, except for the vibration response test, auxiliary and control circuits shall be checked to ascertain whether they are capable of functioning in accordance with their design intent.

If other environmental tests than indicated under 7.10.4 are requested, due to special environmental conditions, then these tests should be performed according to IEC 60068-2 (all parts) [75] where applicable.

7.10.4.2 Cold test

A cold test shall be performed according to test Ad of IEC 60068-2-1:2007, under the service conditions specified in Clause 4. The test temperature shall be the minimum ambient air temperature and the test duration shall be 16 h.

7.10.4.3 Dry heat test

A dry heat test shall be performed according to test Be of IEC 60068-2-2:2007 according to the configuration of auxiliary circuits, under the service conditions specified in Clause 4. The test temperature shall be the maximum ambient air temperature and the test duration shall be 16 h.

7.10.4.4 Cyclic humidity test

A cyclic humidity test shall be performed according to test Db of IEC 60068-2-30:2005. The upper temperature shall be the maximum ambient air temperature specified in Clause 4 and the number of temperature cycles shall be two. Variant 2 may be used for the temperature fall period and recovery shall take place under standard atmospheric conditions. No special precautions shall be taken regarding the removal of surface moisture.

7.10.4.5 Vibration tests

Vibrations due to operation of the associated switchgear or controlgear are checked as follows.

- A test is performed according to IEC 60255-21-1:1988. Vibration response test parameters are those corresponding to severity class 1;
- or the auxiliary and control equipment assembly is subjected to the relevant mechanical endurance tests in the complete switchgear and controlgear.

The auxiliary and control circuits shall withstand the vibration response test without permanent damage. After the test, it shall still be fully operational. Temporary loss of parts of the functionality is permitted during the test according to criteria stated in Table 17.

7.10.4.6 Condition check

The power-frequency voltage withstand tests according to 7.10.5 shall be performed after each type test, to confirm that there has been no reduction of performance during testing.

In the case the type tests of 7.10.4 are performed as test sequence on the same test object, this condition check may be performed only once at the end.

7.10.5 Dielectric test

Auxiliary and control circuits of switchgear and controlgear shall be subjected to short-duration power-frequency voltage withstand tests. Each test shall be performed:

- a) between the auxiliary and control circuits connected together as a whole and the frame of the switching device;
- b) if practicable, between each part of the auxiliary and control circuits, which in normal use may be insulated from the other parts, and the other parts connected together and to the frame.

The power frequency tests shall be performed according to IEC 61180. The test voltage shall be 2 kV with duration of 1 min.

A DC test is acceptable by agreement of the manufacturer, the test voltage shall be 2,8 kV, with a duration of 1 min.

The auxiliary and control circuits of switchgear and controlgear shall be considered to have passed the tests if no disruptive discharge occurs during each test.

If motors and other devices such as electronic equipment used in the auxiliary and control circuits have already been tested in accordance with their own specification, they shall be disconnected for these tests.

7.11 X-ray radiation test for vacuum interrupters

7.11.1 General requirements

7.11.1.1 Condition of interrupter to be tested

Tests on the X-radiation emission levels shall be performed on new vacuum interrupters.

There is no requirement to test switchgear and controlgear for X-radiation emission, where the vacuum interrupter type has been successfully tested as a component.

7.11.1.2 Mounting of specimen

The interrupter shall be mounted in a test fixture, designed so that the open contact spacing may be set at the minimum distance when installed in the switchgear and controlgear. Interrupters designed for operation in an insulating medium other than air (such as oil or SF₆) may be tested in such a medium, if necessary, to withstand the test voltage.

The container for the insulating medium shall be of an insulating material having radiation attenuation no greater than that afforded by 9,5 mm thick methyl methacrylate. The insulating medium between the interrupter and radiation survey instrument shall be the minimum required for dielectric purposes.

7.11.1.3 Radiation survey instrument

A radiofrequency shielded radiation survey instrument having the following minimum specifications shall be used.

- accuracy: capable of measuring from 5 µSv/h up to 150 µSv/h with an accuracy of ±25 % along this range and with a response time not to exceed 15 s;
- energy response range: at least 25 keV to 0,5 MeV.

NOTE The selection of the radiation survey measuring instrument is related to the test voltage and sensitivity of the detector across the specified energy response range.

7.11.1.4 Location of radiation survey instrument

The sensing element of the radiation survey instrument shall be positioned in the plane of the separable contacts and pointed at the contacts. The preferred distance between the measuring instrument and the wall of the vacuum interrupter is 1 m. However any distance up to 15 m may be used in which case the instrument reading shall be adjusted by applying the inverse square law as follows:

$$R(1\text{m}) = R(d) \times d^2$$

where $R(d)$ is the radiation level measured, at the distance d (in m) from the external surface of the vacuum interrupter.

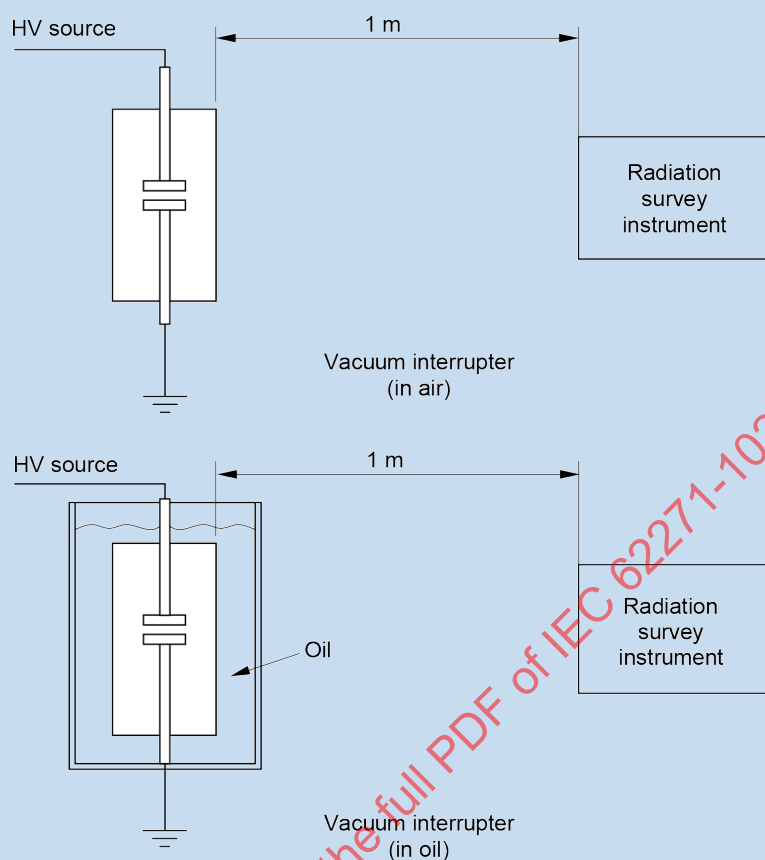


Figure 8 – Test location of radiation survey instrument

7.11.2 Test voltage and measurement procedure

With the interrupter mounted in a test fixture, with the contacts blocked open at the minimum contact spacing specified, and with the radiation survey instrument in place (refer to Figure 4), a voltage shall be applied across the interrupter contacts equal the rated voltage U_r of the switchgear and controlgear. After a minimum of 15 s, the X-radiation level on the radiation survey instrument shall be according to 7.11.3.

Next, the voltage across the interrupter contacts shall be raised to a value equal to the common value of rated short-duration power-frequency withstand voltage U_d shown in Table 1 or Table 2 as appropriate. After a minimum of 15 s, the X-radiation level on the radiation survey instrument shall be recorded in the test report.

7.11.3 Acceptance criteria

The X-radiation emitted from vacuum interrupters shall not exceed 5 $\mu\text{Sv/h}$ at 1 m distance at the rated voltage U_r .

For vacuum interrupters used in switchgear and controlgear that have a rated short-duration power-frequency withstand voltage less than or equal to 160 kV, the X-radiation emitted at the short-duration rated power-frequency withstand voltage U_d shall not exceed 150 $\mu\text{Sv/h}$ at 1 m distance.

For vacuum interrupters in switchgear and controlgear that have a rated short-duration power-frequency withstand voltage greater than 160 kV, the X-radiation emitted at the short-duration rated power-frequency withstand voltage U_d shall be measured. If the measured value exceeds 150 $\mu\text{Sv/h}$ at 1 m distance, then the actual value shall be declared by the manufacturer.

NOTE The declared value can be used to develop a safe working environment in accordance with local regulations when performing a power frequency withstand test across open contact gaps of vacuum interrupters.

7.101 Test to prove the short-circuit making performance of earthing switches

7.101.1 General test conditions

Earthing switches, having a short-circuit making current capability, shall be subjected to two (class E1) or five (class E2) making operations respectively, in a making test series in accordance with the procedures of 7.101.7.

The following test methods are applicable for combined function earthing switches that have short-circuit making capability in the other function:

- the short-circuit making tests shall first be performed on the other functions, in accordance with the relevant standards, followed by the short-circuit making tests on the earthing function, without intermediate maintenance;
- alternatively, the short-circuit making tests on the combined function earthing switch may be performed on a new combined function earthing switch preceded by at least one short-circuit making test on the other function followed by the short-circuit making tests on the earthing function without intermediate maintenance. This test method verifies only the short-circuit making capability of the earthing switch.

7.101.2 Arrangement of the earthing switch for tests

The earthing switch shall be tested under the representative conditions of installation and use, concerning the connections, support, enclosure and dimensions, in accordance with 7.6.2.

Its operating device shall be operated in the manner prescribed and in particular, if it is electrically, hydraulically or pneumatically operated, it shall be operated at the minimum supply voltage or pressure.

For gas-filled earthing switches, the tests shall be performed at the minimum functional pressure for insulation and/or switching.

For convenience of testing:

- the supply voltage to the coil for the closing operation may be increased to obtain a consistent closing time, provided it does not increase the closing speed of the contacts;
- in order to obtain accurate closing times an electrically or pneumatically released latch may be introduced at the toggle point.

Earthing switches with independent manual operation may be operated by an arrangement provided for the purpose of making remote control possible.

NOTE For testing purposes, it can be necessary to measure the travel characteristics, for example by using a travel recorder.

7.101.3 Test frequency

Earthing switches shall be tested at rated frequency, with a tolerance of $\pm 10\%$.

However, tests with a peak factor of 2,6 or above, at a supply frequency of 50 Hz or 60 Hz cover the requirements of both frequencies.

7.101.4 Test voltage

The test voltage shall be as follows:

- a) for three-phase tests, the average value of the applied voltage phase-to-phase shall not be less than the rated voltage U_r and shall not exceed this value by more than 10 % without the consent of the manufacturer. The differences between the average value and the applied voltages of each pole shall not exceed 5 %;
- b) for single-phase tests, the applied voltage shall not be less than the phase-to-earth value $U_r/\sqrt{3}$, and shall not exceed this value by more than 10 % without the consent of the manufacturer, with the exceptions given below:

for single-phase tests on three-pole operated earthing switches which have a spread between the first and second contact touch during closing exceeding half a cycle of the rated frequency, the applied voltage phase-to-earth shall not be less than U_r .

7.101.5 Test short-circuit making current

The short-circuit current during making test shall be expressed in terms of the peak current and the symmetrical RMS current. The symmetrical RMS value of current in each phase at 0,2 s shall be at least 80 % of the rated short-time withstand current. The prospective peak current shall be equal to the rated short-circuit making current (I_{ma}) with the tolerance of 0 % and +5 %.

The duration of the short-circuit current shall be at least 0,2 s.

The earthing switch shall be tested under the two extreme cases specified as follows:

- a) making at the peak of the voltage wave, (with a tolerance of –30 electrical degrees to +15 electrical degrees) leading to a symmetrical short-circuit current and the longest pre-arcing time. For convenience of testing, alternative test methods may be followed. The alternative test methods are given in Annex D;
- b) making at the zero of the voltage wave, without pre-arcing, leading to a fully asymmetrical short-circuit current. For convenience of testing, the test may be carried out at reduced applied voltage to obtain the rated short-circuit making current (I_{ma}). It may happen that the making operation does not occur exactly at the zero of the voltage wave. However, the extreme case b) is considered met if the rated short-circuit making current has been obtained.

7.101.6 Test circuits

Making tests shall be performed using the three-phase test circuit or the single-phase test circuit.

Three-phase tests cover:

- the interaction between the different phases;
- the stresses on the operating mechanism (in the case of a common operating mechanism).

Three-pole earthing switches shall be tested in a three-phase circuit in order to cover applications in both effectively and non-effectively earthed neutral systems. For testing purposes, the severity of making tests in circuits with unearthed neutral or solidly earthed neutral are considered to be equivalent. However, single-phase testing of earthing switches of $U_r > 52$ kV is allowed in the following cases:

- a) multi-enclosure type or open-air type earthing switches with separately stored closing energy for each pole;
- b) earthing switches operated pole-after-pole.

7.101.7 Test procedures

For class E1, the tests shall be performed with a sequence of two C operations with one single no-load O in between, i.e. C – O (no-load) – C, unless the test laboratory needs more no-load operations between the closing operations.

For class E2 earthing switches, the test sequence is $2C - x - 2C - y - 1C$, where x and y represent arbitrary number of no-load operations. The 2C operations consists of C – O (no-load) – C, unless the test laboratory needs more no-load operations between the closing operations. There is no requirement on the time interval between the two closing operations.

No maintenance is allowed during a test sequence.

For combined function earthing switches, the arbitrary number of no-load operations represented by x and y in the test sequence for class E2 may be replaced by switching operations.

Due to non-simultaneity of poles or different instants of initiation of pre-arcs in the different poles, a peak making current, which is higher than the rated value, may occur in one pole. This is particularly the case if, in one pole, the current begins to flow a few milliseconds later than in the other two poles. If the earthing switch fails during such an event, this is considered to be a failure of the earthing switch.

The requirements with regard to the instant of making as specified in Table 15 shall be achieved during the tests.

Table 33 – Requirements on the instant of making

Class E1	Class E2
2 tests	5 tests
At least 1 test fulfilling the requirements of 7.101.5 a)	At least 2 tests fulfilling the requirements of 7.101.5 a)
At least 1 test fulfilling the requirements of 7.101.5 b)	At least 2 tests fulfilling the requirements of 7.101.5 b)
NOTE Normally the speed of closing of the contacts of the earthing switches with short-circuit making capability is high enough that both maximum pre-arcing and maximum peak current can be reached within a same test, however at different phases.	

7.101.8 Behaviour of earthing switches when making short-circuit currents

The following applies during the making tests:

- enclosed earthing switches having a rated short-circuit making current shall, when making the short-circuit, not project flames, liquids, gases nor particles outside the enclosure;
- from open type earthing switches, flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.101.9 Condition of earthing switch after short-circuit making tests

After performing the specified operations, mechanical parts, parts related to the electrical field control (for example field electrodes of a GIS earthing switch) and insulators of the earthing switch shall be practically in the same condition as before. The insulating properties shall not be degraded. The short-circuit making performance and short-time current withstand performance may be impaired.

NOTE The useful life of the earthing switch with regard to short-circuit making and short-time current withstand capability is normally considered to be at the end, after the specified number of making operations necessitating maintenance or replacement.

To verify this requirement, the earthing switch shall meet the following inspection conditions:

- a) mechanical conditions: After each operation only light welding of contacts is permitted. However, the earthing switch shall be able to open and close under the conditions given in 6.5 and 6.6, with the rated values for power operated devices or with 120 % of the values given for manually operated devices in 6.105 using the normal operating handle;
- b) electrical continuity: Visual inspection after the no-load operation is usually sufficient for checking the electrical continuity of the earthing switch. In case of doubt the electrical continuity shall be measured according to 7.4.3 of IEC 62271-1:2017;
- c) dielectric requirements: Visual inspection is usually sufficient for checking the above requirement. In case of doubt, a voltage test as a condition check according to 7.2.12 is to be performed. As an alternative, 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For earthing switches that are sealed for life, the voltage test as a condition check is mandatory.

7.101.10 Invalid tests

In the case of an invalid test, it may become necessary to perform a greater number of short-circuit making tests than required by this document. An invalid test is one where one or more test parameters demanded by the document are not met. This includes, for example, current, voltage and time factors as well as point-on-wave requirements (if specified) and the additional features in synthetic testing.

The deviation from the document could make the test less or more severe. Four different cases are considered in Table 16.

Table 34 – Invalid tests

Test conditions related to standard	Earthing switch passed	Earthing switch failed
More severe	Test valid, result accepted	Test to be repeated with correct parameters Modification of the design of the earthing switch not required
Less severe	Test to be repeated with correct parameters Modification of the design of the earthing switch not required	Modification of the design of the earthing switch required, aiming for improvement of the making capability All tests to be repeated on the modified earthing switch
NOTE "More severe" is considered to be a test performed with voltage and/or current above the tolerances and additionally for the alternative test methods a test with longer prearcing time.		

In the case of less severe test conditions, the invalid part of the test-duty may be repeated without reconditioning of the earthing switch. In those cases, the test report shall include reference to the invalid test. However, in the case of a failure of the earthing switch during such additional tests, or at the discretion of the manufacturer, the earthing switch may be reconditioned and the complete test-duty repeated. If any record of an individual operation cannot be produced for technical reasons, individual operations are not considered invalid, provided that evidence can be given in another manner that the earthing switch did not fail and the required testing values were fulfilled.

In the case of three-phase direct testing (single power source), even if the requirements in 7.101.5 a) and/or 7.101.5 b) are still not met during the repetition of the complete test duty, the earthing switch is considered to have passed the test if the requirements specified in 7.101.8 and 7.101.9 are fulfilled.

7.101.11 Type test reports

The results of the type test shall be recorded in type-test reports containing sufficient data to prove compliance with the rated short-circuit making current performance requirements. Sufficient information should be included so that the essential parts of the earthing switch tested can be identified. Refer to 7.1.2 of IEC 62271-1:2017.

The test report shall contain the information about the test arrangements, test circuits and test procedures.

General information concerning the supporting structure of the earthing switch should be included. Information regarding the operating devices employed during the tests should, where applicable, be recorded.

Typical oscillographic or similar records shall be provided so that the following can be determined:

- the making current expressed as a peak value and the RMS value at 0.2 s;
- the applied voltages;
- instantaneous value of voltages at the moment of the making;
- pre-arcing time.

7.102 Operating and mechanical endurance tests

7.102.1 General test conditions

The test shall be made at the ambient air temperature of the test location. During the test, the ambient temperatures shall be recorded and maximum and minimum values included in the test report.

The supply voltage shall be measured at the terminals of the operating devices with full current flowing. Auxiliary equipment forming part of the operating device shall be included.

For three-phase disconnectors and earthing switches operated by one mechanism, where the application of terminal load is required, it shall be applied to all terminals simultaneously.

7.102.2 Contact zone test

This test shall be made in order to prove satisfactory operation of divided support disconnectors or divided support earthing switches, in the various positions of the fixed contact within the limits of the rated contact zone defined according to 5.103 and Figures 6 and/or 7. With the device in the open position, the fixed contact shall be placed in the following positions:

- a) at a height of h on the vertical axis of the assembly;
- b) at a height of $h - z_r$ on the same axis;
- c) at a height equal to h and displaced from the vertical axis horizontally by $+y_r/2$;
- d) at a height equal to h and displaced from the vertical axis horizontally by $-y_r/2$;
- e) positions a) to d) at a distance equal to $+x_r/2$;
- f) positions a) to d) at a distance equal to $-x_r/2$,

where

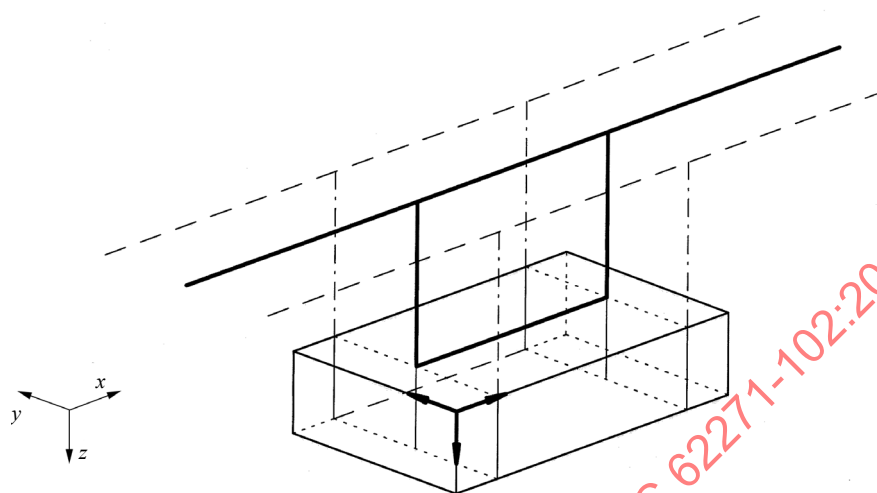
h is the highest position (stated by the manufacturer) of the fixed contact above the mounting plane;

x_r is the total amplitude of movement of the fixed contact in the x -direction;

y_r is the total amplitude of movement of the fixed contact in the y -direction;

the subscript, r, indicates the rated value assigned to the disconnector or earthing switch by the manufacturer.

In each position, the device shall close and open correctly.

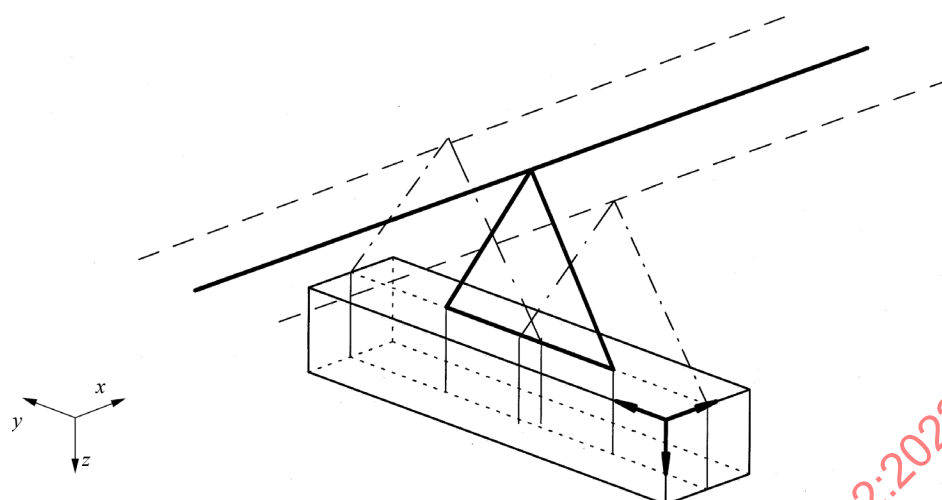


IEC

Key

- x Longitudinal to support (influence of temperature)
- y Perpendicular to support (influence of wind)
- z Vertical deflection (temperature and ice)

Figure 9 – Fixed contact parallel to support

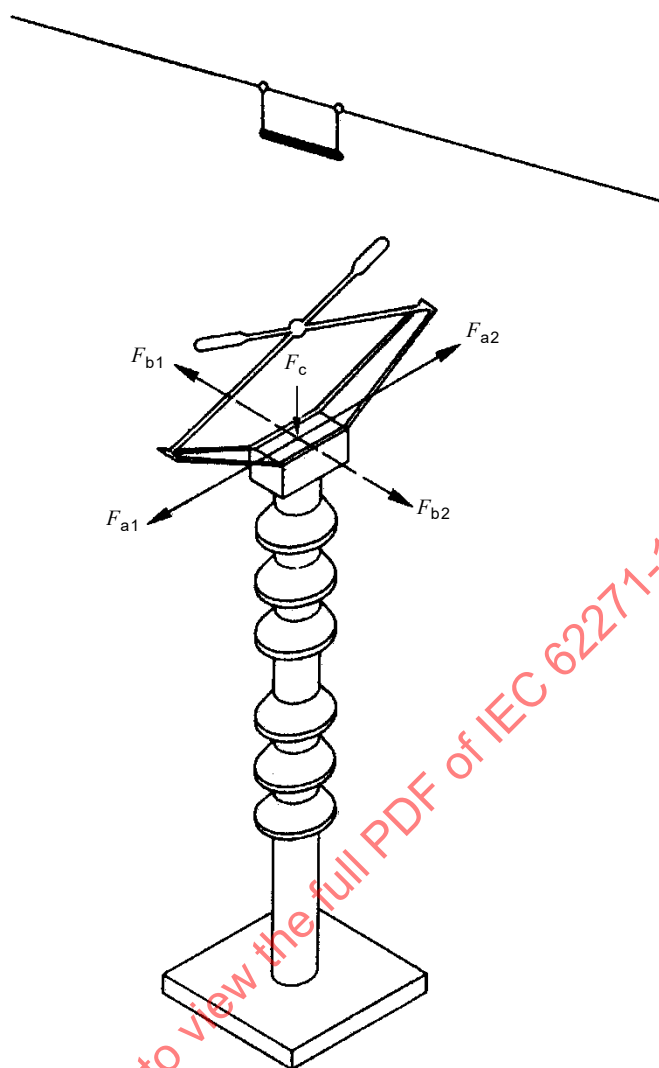


IEC

Key

- x Longitudinal to support (influence of temperature)
- y Perpendicular to support (influence of wind)
- z Vertical deflection (temperature and ice)

Figure 10 – Fixed contact perpendicular to support



IEC

NOTE Above the pantograph, the fixed contact is shown.

Figure 11 – Example of the application of rated static mechanical terminal loads to a (divided support) pantograph disconnector (or earthing switch)

7.102.3 Mechanical endurance test

7.102.3.1 Test procedure

The tests defined in 7.102.3.1 and in 7.102.3.2 shall be performed on disconnectors and earthing switches of class M0.

The mechanical endurance test shall consist of 1 000 operating cycles. For disconnectors or earthing switches having a rated terminal load, 50 % of the rated static terminal load shall be applied during the test in direction F_{a1} or F_{a2} (Figure 8 and Figure 9), without voltage on, or current through, the main circuit. For disconnectors having two or three insulators and a normally horizontal isolating gap, the 50 % rated static terminal load shall be applied at both sides of the disconnector, but in opposite directions. For disconnectors and earthing switches with one insulator (operating insulators not being taken into consideration), the terminal load shall be applied to only one side of the disconnector or earthing switch. After applying 50 % of the rated static terminal load, the disconnector or earthing switch may be adjusted before performing the tests.

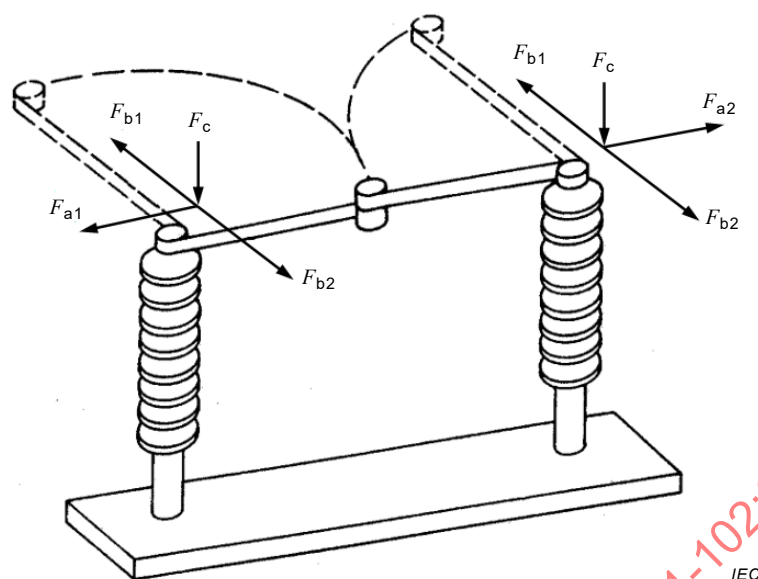


Figure 12 – Example of the application of rated static mechanical terminal loads to a two-column disconnecter

The closed and open positions shall be attained during each operating cycle.

During the test, the operation of the control and auxiliary contacts and position-signalling devices (if any) shall meet the requirements expressed in 6.104 and 6.4 of IEC 62271-1:2017. The test is considered failed if any of the control and auxiliary contacts and position-signalling devices do not operate at one of the close-open operating cycles.

The test shall be made on disconnectors and earthing switches equipped with their own operating mechanisms. During the test, lubrication in accordance with the manufacturer's instructions is permitted, but no mechanical adjustment or other maintenance is allowed.

On a disconnector or earthing switch having a power-operated mechanism:

- 900 close-open operating cycles shall be made at the rated supply voltage and/or rated pressure of compressed gas supply;
- 50 close-open operating cycles at the specified minimum supply voltage and/or minimum pressure of compressed gas supply;
- 50 close-open operating cycles at the specified maximum supply voltage and/or maximum pressure of compressed gas supply.

No specific time intervals between operating cycles or between closing and opening operations are required. These tests shall be made, however, at a rate such that the temperature rises of the energised electrical control components do not exceed the specified values. For the same purpose, external cooling may be applied during the test.

For manually operated disconnectors and earthing switches, the handle may, for convenience of testing, be replaced by an external power-operated device. In this case, it is not necessary to vary the power parameters.

7.102.3.2 Verification of successful operation

For the evaluation of the operating characteristics, before and after the mechanical endurance test programme, the following operations shall be performed without the static terminal load applied:

- five close-open operating cycles at the rated supply voltage and/or pressure (if any);
- five close-open operating cycles at the minimum supply voltage and/or pressure (if any);
- five close-open operating cycles at the maximum supply voltage and/or pressure (if any);
- five close-open manual operations if the switching device can be operated manually.

During these operating cycles, the operating characteristics, such as, if applicable, operating times, power consumption, maximum forces for manual operation, shall be recorded. Satisfactory operation of control and auxiliary contacts and position-indicating devices (if any) shall be verified. It is not necessary to include all the oscillograms recorded in the type test report.

The variation between the average values of each parameter, measured before and after the mechanical endurance test, shall be within the tolerances specified by the manufacturer.

After the test, all parts, including contacts, shall be visually inspected to check their good condition and they shall not show undue wear; see also 7.5.6.2, point 6, of IEC 62271-1:2017. The main circuit resistance, i.e. on disconnectors, shall be measured before and after the mechanical endurance test, as close as possible to the contacts. The resistance shall not increase by more than 20 % from the value measured before the test. If this limit is exceeded, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the contacts.

For earthing switches where contacts are visible, the fully closed and open positions during operation after the mechanical endurance test shall be verified by visual inspection.

For earthing switches where contacts are not visible, the fully closed and open positions during operation after the mechanical endurance test shall be verified by using the travel records or other appropriate methods.

For gas-insulated disconnectors and earthing switches, a tightness test according to 7.8 shall be performed before and after the mechanical endurance test.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % from the value measured before the test.

7.102.4 Operation during the application of rated static mechanical terminal loads

Twenty operating cycles with the rated power supply shall be made with the rated mechanical static terminal loads applied at each terminal in the directions specified by the manufacturer. When more than one load configuration is specified by the manufacturer, the 20 operating cycles shall be repeated for each configuration. The three components of each terminal load may be applied by a conductor pulling in the resultant direction and with the resultant force of the three vectors.

NOTE Any possible combination of the resultant forces applied at the terminals corresponds to one load configuration.

Examples of terminal loads applied at different types of disconnectors are shown in Figure 8 and Figure 9.

One example of possible configurations for a two columns disconnector is given here below:

- longitudinal (straight) load applied in direction F_{a1} at one terminal and F_{a2} at the opposite terminal;
- transversal (cross) load applied in direction F_{b1} or F_{b2} , at both terminals in the same direction;

- vertical load applied in direction F_c at both terminals (except for disconnectors specified to be connected to flexible conductors).

For only manually operated disconnectors and earthing switches the number of operating cycles is reduced to 10.

The loads shall be applied on both terminals at the same time.

The disconnector or earthing switch may be adjusted before the test and after having been loaded with 50 % of the rated longitudinal or perpendicular mechanical terminal force.

During each operation, the disconnector or earthing switch shall close and open correctly.

For verification, before and after the complete sequence of operating cycles, 7.102.3.2 and the appropriate comparators as required in 7.102.3.1 for mechanical endurance tests, are applicable (i.e. without static mechanical terminal loads applied).

7.102.5 Extended mechanical endurance tests

The tests defined in this subclause shall be performed on disconnectors class M1 and M2 and on earthing switches class M1.

In the case of disconnectors and earthing switches in GIS, the enclosure shall not be opened during the test.

Tests shall be carried out as follows:

- a) The extended mechanical endurance tests programme shall consist of a number of close-open operations carried out in accordance with 7.102.1 and 7.102.3.1.

According to the class assigned, one of the following number of operating cycles shall be performed:

- 2 000 (for class M1);
- 10 000 (for class M2).

After the first series of 1 000 operating cycles, some maintenance such as lubrication and mechanical adjustment is allowed and shall be performed in accordance with the manufacturer's instructions, and its reference included in the test report. Change of parts in the main circuit and in the kinematic chain is not permitted.

After each next series of 1 000 operating cycles, or at maintenance intervals (if of less than 1 000 operating cycles), the operating characteristics shall be recorded and evaluated (if power operated) at the rated pressure or voltage.

The programme of maintenance shall be defined by the manufacturer before the tests and recorded in the test report.

- b) Before and after the total test programme, verification of successful operation shall be performed as required in 7.102.3.2.

- c) In addition, after the total test programme, checks and tests shall be performed as follows:

- contact zone test (7.102.2), if applicable;
- verification of operation during application of rated static mechanical terminal loads (7.102.4), if applicable;
- verification of satisfactory operation with the minimum duration of the operating signal specified in the manufacturer's documentation;
- verification of operation of the mechanical strain-limiting devices, if any.

7.102.6 Testing of mechanical interlocking devices.

Disconnectors and earthing switches which are not covered by switchgear and controlgear assembly standards (e.g. IEC 62271-200, IEC 62271-201 and IEC 62271-203) shall be tested as follows, if mechanical interlocking devices are provided blocking the operating shaft or power kinematic chain.

All interlocking devices shall be submitted to 5 attempts to perform close and/or open operation for any interlocked position of disconnector and/or earthing switch, in order to prove compliance with requirements in 6.12.

Before each attempt, the interlocking devices shall be set in the position intended to prevent the operation of the switching device and then one attempt shall be made to operate the interlocked switching device. Operating forces given in 6.12 shall be employed and no adjustment shall be made to the switching devices or interlocking devices.

The tests are considered satisfactory if the interlocked switching devices and the interlocking devices are in proper working order and if the forces required to operate the switching devices are practically the same before and after the tests.

The operating forces are considered the same if the average value measured after the test is within the maximum and minimum values measured before the test. At least three close/open operations should be performed before the test to fix the minimum and maximum values for acceptance of the close or open operation after the test.

7.103 Operation under severe ice conditions

7.103.1 General

The tests defined in this subclause shall be made only if the manufacturer claims the suitability of disconnectors and earthing switches for operation under severe ice conditions (i. e. 10 mm ice coating and above).

Disconnectors and earthing switches having accessories to accommodate a bus-transfer current switching capability (disconnectors only) and a switching capability of induced currents (earthing switches only) shall be tested with these devices mounted.

NOTE Formation of ice may produce difficulties in the operation of electric power systems. Under certain atmospheric conditions, a deposit of ice can build up to a thickness that sometimes makes the operation of outdoor switching equipment difficult.

7.103.2 Test arrangement

- a) All parts of the disconnector or earthing switch to be tested shall be assembled, together with their operating mechanism, in a room which can be cooled to a temperature according to the requirements given in 7.103.3. The energizing of heating elements of the control mechanism is permitted during the test. Supports, operating insulators and other operating members may be shortened to reduce the height of the assembly to suit the test facilities available, provided the angle of rotation of the parts affected and the bending of thrust linkages remain unchanged.

In choosing the refrigeration capacity required, the heat content of the water with which the apparatus under test is sprayed should be taken into account.

- b) A single-pole of a three-pole apparatus may be tested if each pole has a separate operating mechanism. In the case of a three-pole apparatus up to and including 52 kV having one common operating mechanism for the three poles, the complete three-pole device shall be tested. In the case of voltages above 52 kV and if the testing laboratory cannot accommodate complete standard three-pole apparatus, modifications of mounting structures, post insulators or spacing, wherever possible, in order to enable the three-pole

test to be made are permitted. If the tests are not possible even in this configuration, tests with a single-pole apparatus operated by the common mechanism are permitted. In this last case, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus. In all cases, it is not allowed to change the original isolating distance for the disconnecter or the gap for the earthing switch.

- c) The disconnecter or earthing switch shall be tested for operation from the open position and the closed position separately.
- d) Prior to the test, any trace of oil or grease on parts that do not need to be lubricated in service shall be removed with an appropriate solvent. This is because thin films of oil or grease prevent ice from adhering and greatly change the results of tests.
- e) For measurement of ice thickness, a copper bar or tube 30 mm in diameter and 1 m in length shall be mounted in a horizontal position in a place where it will receive the same general rainfall as the apparatus under test.
- f) The arrangement shall allow the entire apparatus to be sprayed with artificial rain falling from above at various angles, from the vertical to 45°. The water used in the spray should be cooled to a temperature between 0 °C and 3 °C and shall reach the test object in the liquid state.

7.103.3 Test procedure

7.103.3.1 Checks before the formation of ice coating

Before testing, the disconnecter/earthing switch shall be subjected to:

- 5 close-open operating cycles at the rated supply and/or pressure (if any);
- 5 close-open manual operations if the switching device can only be operated manually;
- the measurement of the resistance of the main circuit in accordance with 7.4.4.

During the operating cycles, operating characteristics such as, if applicable, operating times, power consumption, maximum forces for manual operations, shall be recorded. Satisfactory operation of control and auxiliary contacts, and position-indicating device (if any) shall be verified. It is not necessary to include all the oscillograms recorded in the type test report.

7.103.3.2 Formation of ice coating

Nature produces ice coatings which may be divided into two general categories:

- a) clear ice, generally resulting from rain falling through air somewhat below the freezing point of water;
- b) rime ice, characterized by a white appearance, formed for example from atmospheric moisture condensing on cold surfaces.

For type tests a coating of solid clear ice of the required thickness shall be produced according to the procedure described below.

- a) Lower the room temperature down to 2 °C and start the spray of pre-cooled water. Continue this spray for a minimum of 1 h while holding the room temperature between 0,5 °C and 3 °C.
- b) Lower the room temperature down to the range between –7 °C and –3 °C while continuing the water spray. The rate of temperature change is not critical and may be whatever is obtainable with available refrigeration apparatus.
- c) Hold the room temperature within –7 °C and –3 °C and continue to spray until the specified thickness of ice can be measured on the top surface of the test bar. The amount of water should be controlled to cause ice to build up at the rate of approximately 6 mm/h.

NOTE 1 If the specific thermal capacities per unit surface area of test bar and apparatus under test differ considerably, even identical spraying conditions may produce very different ice coatings. These differences in thickness may be minimized by short periods of spraying alternating with longer periods of cooling.

NOTE 2 As a guide, it has been observed that between 20 l and 80 l per hour per m² of area sprayed is required to cause ice to be deposited at a rate of approximately 6 mm/h.

- d) Discontinue the spray and maintain the room temperature within $-7\text{ }^{\circ}\text{C}$ and $-3\text{ }^{\circ}\text{C}$ for a period of at least 4^{+2}_0 h. This ensures that all parts of the disconnector/earthing switch and the ice coating have reached a constant temperature.

7.103.3.3 Checks after the formation of ice coating

After the formation of ice coating, the satisfactory operation of the disconnector/earthing switch shall be checked:

- if the disconnector or earthing switch is manually operated, the operation will be considered as satisfactorily completed if the apparatus has been operated to its final closed or open position applying normal operating forces (being permissible to remove the ice from the insertion point of the handle);
- if the disconnector or earthing switch is electrically, pneumatically or hydraulically operated, the operation will be considered as satisfactorily completed if the apparatus has been operated on the first attempt up to its final closed or open position by the operating device supplied at its rated voltage or pressure.

Immediately after the closing operation, the electrical continuity across the contacts shall be checked.

When the disconnector/earthing switch is ice-free, it shall be subjected to the same checks of 7.103.3.1, with the room temperature restored to normal ambient temperature (above $10\text{ }^{\circ}\text{C}$). The apparatus shall be considered to have passed the test if its mechanical and electrical performance is not affected; this condition shall be considered as met if:

- the resistance measured before the formation of ice coating has not increased by more than 20 %;
- the variation between the average values of each parameter, measured before the formation of ice coating, is within the tolerances given by the manufacturer.

The complete ice coating procedure and subsequent checks shall be performed for each position (i.e. closed/open) on each disconnector and/or earthing switch. Ice coating shall be naturally removed between tests, for example by leaving the apparatus enough time at adequate room temperature.

7.104 Low- and high-temperature tests

7.104.1 General

If the temperature limits for the service conditions of the apparatus (defined by the manufacturer) are above $+40\text{ }^{\circ}\text{C}$ or below $-5\text{ }^{\circ}\text{C}$, the following procedure shall be applied:

Single poles of three-pole apparatus may be tested individually if each pole has a separate operating mechanism. In the case of three-pole apparatus of $U_r \leq 52\text{ kV}$ having one common operating mechanism for the three poles, the complete three-pole device shall be tested.

In the case of $U_r > 52\text{ kV}$ and if the testing laboratory cannot accommodate complete standard three-pole apparatus, modifications of mounting structures, post insulators or spacing, wherever possible, are permitted to enable tests on all three poles. If the tests are not possible even in this configuration, tests with a single-pole apparatus operated by the common mechanism are permitted. In this last case, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus. In all cases, changing the original isolating distance for the disconnector or the gap for the earthing switch is not allowed.

If heat sources are required, they shall be in operation.

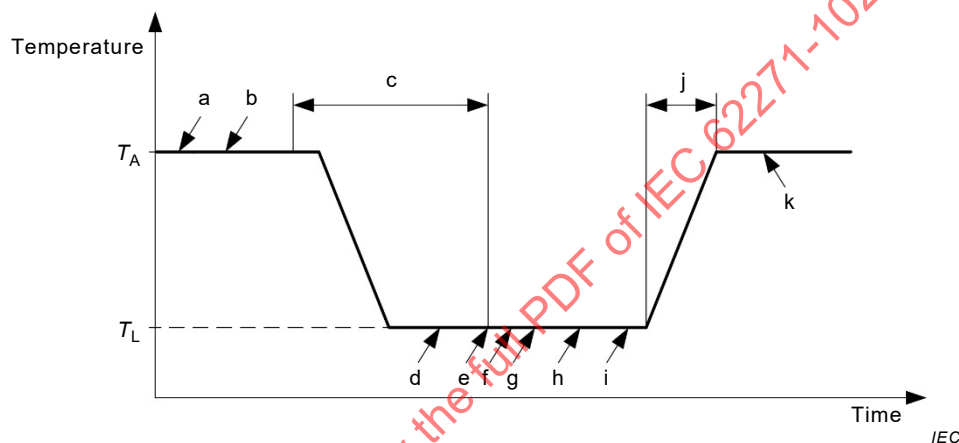
No maintenance, replacement of parts, lubrication or readjustment of the apparatus is permissible during the tests. For insulation pressure systems the tests shall be performed at rated filling pressure for insulation and/or switching. The characteristics recorded shall be within the tolerances specified by the manufacturer.

7.104.2 Measurement of ambient air temperature

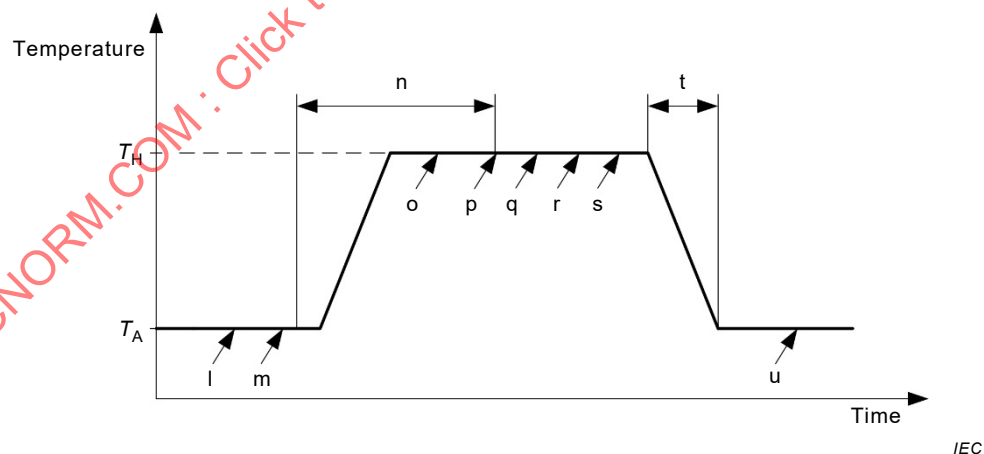
The maximum temperature deviation over the height of the apparatus shall not exceed 5 K, measured at a distance of 1 m from the apparatus.

7.104.3 Low-temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 10 a).



a) Low temperature test



b) High temperature test

NOTE Letters a to u identify application points of tests specified in 7.104.3 and 7.104.4.

Figure 13 – Test sequences for low and high temperature tests

If the low-temperature test is performed immediately after the high-temperature test and using the same sample, the low-temperature test can proceed after completion of item (t) of the high-temperature test. In this case, items (a) and (b) are omitted.

a) The test object shall be adjusted in accordance with the manufacturer's instructions.

- b) Characteristics and settings of the test object shall be recorded in accordance with 7.102.3.2 and at an ambient air temperature of $(20 \pm 5) ^\circ\text{C}$ (T_A). The tightness test for insulation pressure systems shall be performed according to 7.8.
- c) With the disconnecter in close position and/or the earthing switch in open position, the air temperature shall be decreased to the appropriate, minimum ambient air temperature (T_L), according to the service conditions defined by the manufacturer and in accordance with Clause 2, at a rate of change of approximately 10 K per hour. The disconnecter shall be kept in close position and/or the earthing switch in open position for a minimum of 12 h after the ambient air temperature stabilises at T_L .
- d) During the 12-h period with the disconnecter in the closed position and/or the earthing switch in the open position at temperature T_L , a tightness test shall be performed on insulation pressure systems. An increased leakage rate is acceptable, provided that it returns to the original value when the apparatus is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate should not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017. This tightness test shall be integral and performed by the accumulation method with appropriate apparatus for measurement of SF_6 concentration at the low temperature of the air in the testing room. For uniform diffusion of the SF_6 leaked inside the control volume, the use of a mixer or fan is highly recommended.
- e) After 12 h at temperature T_L , the disconnecter shall be opened and closed and/or the earthing switch shall be closed and opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- f) The low-temperature behaviour of the apparatus shall be verified, if applicable, by disconnecting the supply of all heating devices, including also the anti-condensation heating elements, for a duration t_x . At the end of the interval t_x , an operating order, at rated values of supply voltage and operating pressure, shall be given, if applicable. Then the disconnecter shall open and/or the earthing switch shall close. The operating characteristics shall be recorded.

The value of t_x up to which the apparatus is still operable without auxiliary power to the heaters, is stated by the manufacturer (not less than 2 h). In the absence of such a statement, the value is equal to 2 h.
- g) The disconnecter shall be left in open position and/or the earthing switch shall be left in close position for minimum 4 h.
- h) During the 4-h period with the disconnecter in open position and/or the earthing switch in closed position at temperature T_L , a tightness test shall be performed according to 7.8 for insulation pressure systems using a cumulative leakage method as indicated in item (d).
- i) After 4 h at temperature T_L , the disconnecter shall be closed and/or the earthing switch shall be opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- j) After completing the three closing and the three opening operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.
- k) After the apparatus has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the apparatus settings, and the operating characteristics shall be recorded and verified according to 7.102.3.2. A tightness test shall be made as in item b) for comparison with the initial characteristics.

For combined function earthing switches including a disconnecter function, the operation of the disconnecter and the operation of the earthing switch as described in items (e) and (i) shall be spaced by 4 h or by $t_x + 4$ h in case of heating devices are switched off. For insulation pressure systems a tightness test shall be performed at least once when both disconnecter and earthing switch are in the open position.

After the complete low temperature test the pressure shall not be under the minimum functional pressure.

7.104.4 High-temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 10 b).

If the high-temperature test is performed immediately after the low-temperature test and using the same sample, the high-temperature test can proceed after completion of item (j) of the low-temperature test. In this case, items (l) and (m) below are omitted.

- a) The test object shall be adjusted in accordance with the manufacturer's instructions.
- b) Characteristics and settings of the test object shall be recorded in accordance with 7.102.3.2 and at an ambient air temperature of $(20 \pm 5) ^\circ\text{C}$ (T_A). The tightness test for insulation pressure systems shall be performed according to 7.8.
- c) With the disconnecter in closed position and/or the earthing switch in open position, the air temperature shall be increased to the maximum ambient air temperature (T_H), declared by the manufacturer, at a rate of change of approximately 10 K per hour. The disconnecter shall be kept in close position and/or the earthing switch in open position for 12 h after the ambient air temperature stabilises at T_H .
- d) During the 12 h period with the disconnecter in close position and/or the earthing switch in open position at temperature T_H , a tightness test shall be performed for insulation pressure systems.
- e) After 12 h at temperature T_H , the disconnecter shall be opened and/or the earthing switch shall be closed three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- f) The disconnecter shall be left in open position and/or the earthing switch shall be left in the closed position for 4 h.
- g) During the 4-h period with the disconnecter in the open position and/or the earthing switch in the closed position at temperature T_H , a tightness test shall be performed for insulation pressure systems using a cumulative leakage method as indicated in item (d) of subclause 7.104.3.
- h) After 4 h at temperature T_H , the disconnecter shall be closed and/or the earthing switch shall be opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- i) After completing the three closing and the three opening operations, the air temperature shall be decreased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.
- j) After the apparatus has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the apparatus settings, operating characteristics and tightness as in items (l) and (m) for comparison with the initial characteristics.

For combined function earthing switches including a disconnecter function, the operation of the disconnecter and the operation of the earthing switch as described in items (p) and (s) shall be spaced by 4 h. A tightness test shall be performed at least once when both disconnecter and earthing switch are in the open position.

After the complete high-temperature test the pressure shall not be under the minimum functional pressure.

7.105 Tests to verify the proper functioning of the position-indicating device

7.105.1 General

These tests apply, when a position indicator according to 6.104.3.2 is used.

The equipment shall pass all the tests defined in 7.105.2, in order to verify both the sufficient strength of the power kinematic chain and the reliability of the position-indicating kinematic chain.

One specimen may be used for each operation mode.

7.105.2 Tests on the power kinematic chain and the position-indicating kinematic chain

The moving contact is locked in closed position for a disconnector and in open position for an earthing switch.

In the case of a three phase disconnector or earthing switch operated by a common operating device, only the moving contact of the pole located farthest from the point of transmission of the energy from the power source along the power kinematic chain is locked.

The tests consist of three attempts performed on the switching device with its own complete operating device equipped with a strain limiting device (if any) and/or with a torque (force) controlling system (if any).

- For manual operation (for dependent and for independent), the normal operation handle shall be used to perform the attempts. During the tests, double the normal forces shall be employed, with a minimum of 200 N, but limited to a force of 750 N or to the operation of a strain-limiting device or torque (force) controlling system. This force shall be applied halfway along the length of the gripping part of the operating handle. Where the operating handle or the operating device incorporates a feature which limits the operating torque (force), the switching device shall be operated until the strain-limiting device operates, provided that the operating handle with strain-limiting device is not interchangeable with other handles.
- For power operation (for dependent and for independent), the maximum supply voltage or pressure for operation (if power operated or if release operated) as defined in 5.9 and 5.11.102 shall be applied respectively during the attempts. In the case of the presence of a strain-limiting device or torque (force) controlling system, the switching device shall be operated until the strain-limiting device or torque (force) controlling system operates.

No adjustment or replacement shall be made along the position indicating chain between the attempts. No break on the mechanical kinematic chain shall be produced during the test, except for strain limiting devices designed to break, which will have to be replaced after they break. The test is considered passed if after each attempt the three moving contacts remain in the same position and the position-indicating device indicates correctly the position of the moving contacts.

If the position-indicating device is marked directly on a mechanical part of the power kinematic chain no additional test is required.

The enclosure providing protection to the position-indicating kinematic chain shall be tested for its IP and IK (in accordance with 6.104.3.1). The blows shall be applied to the points of the enclosure that are likely to be the weakest in relation to the protection of the indicating kinematic chain.

7.106 Bus-transfer current switching tests on disconnectors

7.106.1 General

These tests shall be performed only on disconnectors with a rated bus-transfer current switching capability.

7.106.2 Making and breaking tests

7.106.2.1 Arrangement of the disconnector for tests

The disconnector under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be used in the manner prescribed and in

particular, if it is power operated either electrically or pneumatically, it shall be operated at the minimum supply voltage or minimum functional pressure for operation, respectively.

Before commencing making and breaking tests, no-load operations shall be made to establish the mechanical operating characteristics of the disconnecter such as speed of travel, closing time and opening time.

For gas-insulated disconnectors, tests shall be performed at the minimum functional pressure for switching.

Disconnectors having an independent manual operation may be operated by remote control, using a power operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

Consideration shall be given to the effects of energization of both terminals of the disconnecter. When the physical arrangement of one side of the disconnecter differs from that of the other side, the supply side of the test circuit shall be connected to the side which represents the most severe condition. In case of doubt, 50 % of the breaking and making tests shall be carried out with the supply side of the test circuit connected to one side of the disconnecter and 50 % with the supply connected to the other side.

Only single-phase tests on one pole of a three-pole disconnecter need to be performed provided that the pole is not in a more favourable condition than the complete three-pole disconnecter with respect to:

- speed of make;
- speed of break;
- influence of adjacent phases.

Single-phase tests are adequate to demonstrate the making and breaking performance of a disconnecter, provided that it can be demonstrated that the arcing time and arc reach are such that there is no possibility of involvement of an adjacent phase. If, on the basis of a single-phase test, it is shown that the arc may reach an adjacent phase, then three-phase tests shall be performed using the specific disconnecter configuration.

7.106.2.2 Earthing of the test circuit and disconnecter

The frame of the disconnecter shall be earthed as well as the test circuit, see 7.106.2.6.

7.106.2.3 Test frequency

Disconnectors shall be tested at rated frequency, however disconnectors rated 50 Hz or 60 Hz may be tested with either of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of $\pm 10\%$ in accordance with Table C.1.

7.106.2.4 Test voltage

The test voltage U_{BT} shall be set so as to yield the required rated bus-transfer voltage ($^{+10}_0\%$) and shall be measured during the test across the open disconnecter terminals.

As noted in 7.106.2.1, only single-phase tests are normally required. If three-phase tests are required, then the test voltage of each phase shall not differ from the average test voltage by more than 10 %.

The power frequency recovery voltage shall be maintained for at least 0,3 s after interruption.

7.106.2.5 Test current

The test current shall be equal to the rated bus-transfer current ($^{+10}_0$ %) as defined in 5.108.1.

The current to be interrupted shall be symmetrical. The contacts of the disconnector shall not be separated until transient currents, due to the closing of the circuit, have subsided.

If three-phase tests are performed, the test current is the average of the current in all three phases. The test current in each phase shall not differ from the average test current by more than 10 %.

7.106.2.6 Test circuits

The test circuit as shown in Figure 11 shall have a power factor not exceeding 0,5. Two examples of test circuit are shown in Figure 11.

If three-phase tests are required, the neutral of the supply circuit and the load-side circuit shall be earthed.

Phase-to-earth insulation is not verified during the test when using the circuit given in Figure 11. If insulation performance has to be verified, other test circuits providing the rated phase-to-earth voltage are necessary.

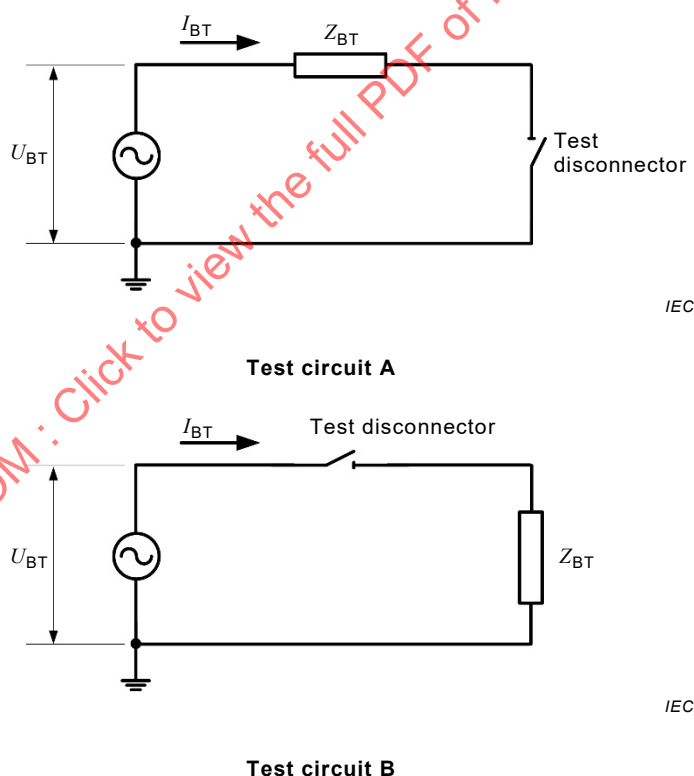


Figure 14 – Example of test circuit for bus-transfer current switching tests

7.106.2.7 Test duty

One hundred make-break operating cycles shall be made.

NOTE These 100 operating cycles are not considered adequate to demonstrate electrical life but they do provide an indication of contact erosion.

The opening operation shall follow the closing operation with a time delay between the two operations at least sufficient for any transient currents to subside. As well, the time between

operations shall be sufficient to cool down the disconnecter if specified by the manufacturer instructions.

The tests shall be performed without reconditioning of the disconnecter during the test duty.

7.106.2.8 Behaviour of the disconnecter during tests

The disconnecter shall perform successfully without undue mechanical or electrical distress.

Outward emission of flame or metallic particles from the disconnecter during operation is permitted, if this does not impair its insulation level. Flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.106.2.9 Condition of disconnecter after tests

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the disconnecter shall be essentially in the same condition as before the test.

It is recognized that mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, will impair the switching capability of the disconnecter. However, the current-carrying capability and the isolating properties of the disconnecter shall not be impaired. The quality of the material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level.

The isolating properties of a disconnecter in the open position shall not be reduced below what corresponds to normal wear and ageing, by deterioration of insulating parts.

No-load operation and visual inspection of the disconnecter after tests are usually sufficient for verification of the isolating properties and the current-carrying capability of the disconnecter. In case of doubt, it can be necessary to perform the appropriate tests as mentioned below.

- If the isolating properties are doubted, a voltage test as condition check according to 7.2.12 is to be performed to verify the insulating properties. Alternative test methods given in 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For disconnectors that are sealed-for-life, the voltage test as a condition check is mandatory;
- If the current-carrying capacity is doubted, main circuit resistance measurement may be used where ever it is possible to measure the resistance close to the contacts. The increase in main circuit resistance after test shall not exceed 20 %. If the contact resistance exceeds this value, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the main contacts.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % from the value measured before the test. A visual inspection of the resistor shall be made after the type tests. No evidence of flashover across the resistor or any mechanical damage shall be observed. It can be necessary to disassemble the disconnecter for the visual inspection.

7.106.2.10 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017 the type test report shall contain the following information:

- a) typical oscillographic or similar records of the tests performed (at least one oscillogram for each 10 operations);
- b) test circuit;
- c) test currents;
- d) test voltages;
- e) power frequency recovery voltages;
- f) void;
- g) arcing times;
- h) number of making and breaking operations;
- i) condition of the contacts after test (see 7.106.2.9).

General information concerning the supporting structure of the disconnector should be included. The operating time of the disconnector and the type of operating devices employed during the tests shall be recorded.

7.107 Induced current switching tests on earthing switches

7.107.1 General

Type tests for earthing switches having a rated induced current switching capability shall include:

- tests to prove the electromagnetically induced current making and breaking capability;
- tests to prove the electrostatically induced current making and breaking capability.

7.107.2 Arrangement of the earthing switch for tests

The earthing switch under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be operated in the manner prescribed and, in particular, if it is electrically or pneumatically operated, it shall be operated either at the minimum supply voltage or supply pressure, respectively.

Before commencing making and breaking tests, no-load operations shall be made and details of the operating characteristics of the earthing switch, such as speed of travel, closing time and opening time, shall be recorded (see 7.102.3.2).

For gas-insulated earthing switches, tests shall be performed at the minimum functional gas pressure (density) for switching.

Earthing switches having a manual operating device may be operated by remote control using a power-operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

Only single-phase tests on one pole of a three-pole earthing switch need to be performed provided that it is not in a more favourable condition than the complete three-pole earthing switch with respect to:

- speed of closing;
- speed of opening;
- influence of adjacent poles or proximity of energized phases.

Single-phase tests are adequate to demonstrate the making and breaking performance of an earthing switch provided that it can be demonstrated that the arcing time and arc-reach are such that there is no possibility that involvement of an adjacent energized phase can occur. If, on the basis of a single-phase test, it is determined that the arc may reach an adjacent

energized phase, then three-phase tests shall be performed using the specific earthing switch configuration.

7.107.3 Earthing of test circuit and earthing switch

The test circuit shall be earthed through the terminal of the earthing switch which is normally connected to earth.

7.107.4 Test frequency

Earthing switches shall be tested at rated frequency, however earthing switches rated 50 Hz or 60 Hz may be tested with any of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of $\pm 10\%$ according Table C.1.

7.107.5 Test voltage

The test voltages shall be set so as to yield the voltage specified in Table 9 before making and after breaking, and shall be measured across the earthing switch terminals during the test.

As noted in 7.107.2, only single-phase tests are normally required. If three-phase tests are required, then the test voltage of each phase shall not be different from the average test voltage by more than 10 %.

The power frequency test voltage shall be maintained for at least 0,3 s after interruption.

7.107.6 Test currents

The test currents shall be equal to the rated induced currents ($^{+10}_0\%$). The current to be interrupted shall be symmetrical. The contacts of the earthing switch shall not be separated until transient currents due to closing of the circuit have subsided.

If three-pole making and breaking tests are performed, the test current shall be measured as the average of the current in all three poles. The test current for each phase shall not be different from the average test current by more than 10 %.

Before contact separation, the waveform of the test current for electrostatically induced current breaking tests should be, as nearly as possible, sinusoidal (see IEC/TR 62271-305). This condition is considered to be met if the ratio of the RMS value of the total current to the RMS value of the fundamental component does not exceed 1,2. The test current shall not go through zero more than once per half cycle of power frequency before contact separation.

7.107.7 Test circuits

7.107.7.1 General

For type tests, the transmission lines may be replaced by elements consisting of capacitors, inductors and resistors.

If three-phase tests are required, the test circuit shall incorporate the same elements in each phase as for the single-phase test circuit in order to yield the appropriate test voltages and currents. The neutral of the supply circuit shall be earthed.

As an alternative, other test circuits than those specified may be used provided they fulfil the requirements for test currents, voltages and the transient recovery voltage parameters.

7.107.7.2 Test circuit for electromagnetically induced current making and breaking tests

The single-phase test circuit (Figure 12) consists of a supply circuit yielding the appropriate test voltage and test current such that the circuit power factor does not exceed 0,15. The components R and C are selected to yield the appropriate transient recovery voltage parameters. The damping resistance R may be connected in series or in parallel with the capacitance C .

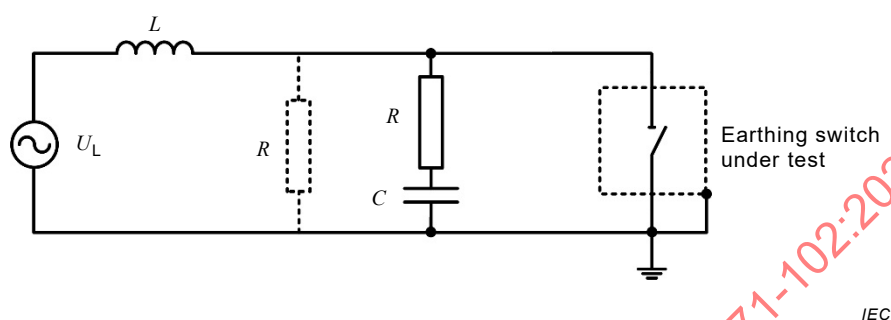


Figure 15 – Test circuit for electromagnetically induced current switching tests

The values of supply voltage (U_L) and inductance (L) can be calculated from the values of voltage and current given in Table 9, so as to produce the proper values of test current and power frequency recovery voltage.

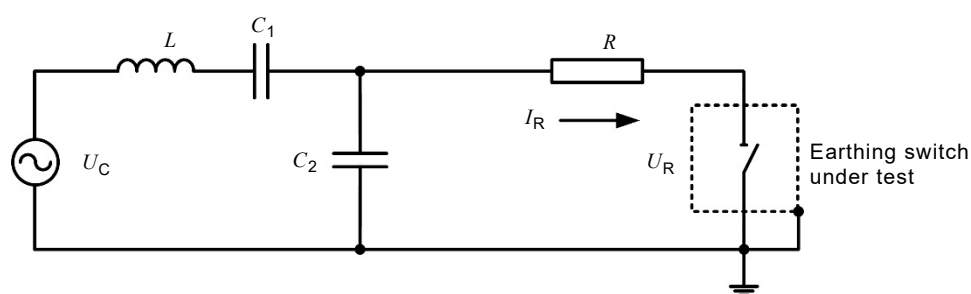
The prospective transient recovery voltage waveforms should have the form of a triangular wave due to the surge impedance of the connected transmission lines. As an alternative, transient recovery voltages having a $(1 - \cos)$ form may be used. Values of R and C may be selected to yield the proper transient recovery voltage parameters specified in Table 17.

Table 35 – Standard values of recovery voltages for electromagnetically induced current breaking tests

Rated voltage U_r kV	Class A			Class B				
	Power frequency recovery voltage	TRV peak	Time to peak	Power frequency recovery voltage	TRV peak	Time to peak		
	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} 0 \\ -10 \end{smallmatrix}$ %)	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} 0 \\ -10 \end{smallmatrix}$ %)		
	kV RMS	kV	μ s	kV RMS	kV	μ s		
72,5	0,5	1,1	100	2	4,5	300		
100								
123								
145	1	2,3	200			10	23	1 000
170								
245	1,4	3,2						
300								
362	2	4,5	325	65	145	2 400		
420								
550								
800								
1 100	5	11,3	750	65	145	2 400		
1 200								

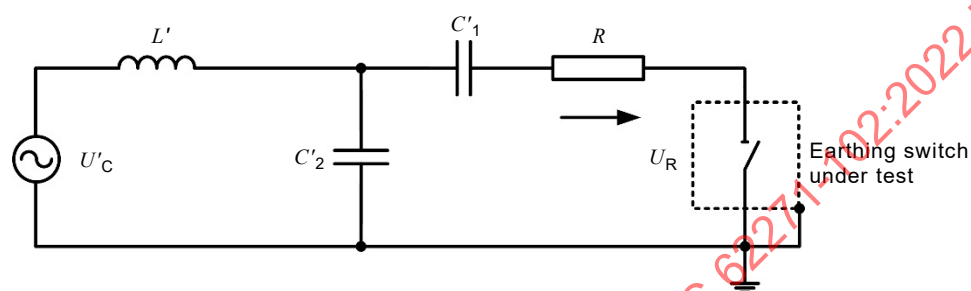
NOTE 1 Recovery voltages are valid for single-phase or three-phase tests.

NOTE 2 The prospective TRV waveform may be of a triangular or (1 – cos) form (see 7.107.7.2). The time to peak is valid for either waveform type.



Test circuit 1

IEC



Test circuit 2

IEC

$$L = Z_0^2 \times C_1$$

$$L' = L \times \left[\frac{C_1}{C_1 + C_2} \right]^2$$

$$u_C = \frac{i_R}{\omega C_1}$$

$$u'_C = \left[\frac{C_1}{C_1 + C_2} \right] \times u_C, \text{ or } u'_C = u_R$$

$$C_2 = C_1 \times \left[\frac{u_C}{u_R} - 1 \right]$$

$$C'_1 = C_1 + C_2 \quad C'_2 = C_2 \left(1 + \frac{C_2}{C_1} \right)$$

where

Z_0 is the surge impedance of the line:

- 425 Ω for 52 kV < $U_r \leq 170$ kV;
- 380 Ω for 245 kV $\leq U_r \leq 300$ kV;
- 325 Ω for 362 kV $\leq U_r \leq 800$ kV;
- 290 Ω for 1 100 kV $\leq U_r \leq 1\,200$ kV.

Key

i_R is the rated induced current from Table 9

u_R is the rated induced voltage from Table 9

C_1 is the test circuit capacitance given in Table 18

Figure 16 – Test circuits for electrostatically induced current-switching tests

7.107.7.3 Test circuits for electrostatically induced current switching tests

Either test circuit 1 or 2 in Figure 13 shall be selected as suitable for the test laboratory, since they are equivalent, as long as the equations within the circuit parameters are satisfied.

The power factor of the test circuit shall not exceed 0,15. The values of supply voltage (U_C), inductance L and capacitance C_2 for test circuit 1 can be calculated from the given values of C_1 in Table 18 and the rated current and voltage values in Table 9, by using the equations noted in Figure 13. This will result in the appropriate values of test current and voltage as well as the proper inrush current frequency and test-circuit surge impedance. Values for test circuit 2 can be calculated from the values derived for test circuit 1.

A resistance (R), not exceeding 10 % of the capacitive impedance [$1 / \omega (C_1 + C_2) = 1 / \omega C_1'$], as seen from the earthing switch, may be inserted in the circuits as shown in Figure 13. The value chosen, however, should not be greater than the surge impedance of the transmission line considered (see Table 18), nor lead to an aperiodic damping of the inrush current when closing the earthing switch.

Table 36 – Test circuit capacitances (C_1 values) for electrostatically induced current switching tests

Rated voltage U_r kV	Test circuit capacitance	
	Class A μF	Class B μF
72,5 – 100 – 123	0,07	0,27
145 – 170	0,13	
245	0,15	
300		0,80
362 – 420	0,29	1,18
550 – 800	0,35	1,47
1 100 – 1 200	0,8	2,63

NOTE Values of C_1 can be calculated from the expression:

$$C_1 = (6D) / (\pi Z_0)$$

where

D is the line length, in km;

Z_0 is the line surge impedance, in Ω .

Surge impedance assumed:

- 72,5 kV $\leq U_r \leq$ 170 kV: 425 Ω ;
- 245 kV $\leq U_r \leq$ 300 kV: 380 Ω ;
- 362 kV $\leq U_r \leq$ 800 kV: 325 Ω ;
- 1 100 kV $\leq U_r \leq$ 1 200 kV: 290 Ω .

7.107.7.4 Test duties

Ten make-break operating cycles shall be made for each of the electrostatically and electromagnetically induced current-switching tests.

NOTE Ten operating cycles are not considered adequate to demonstrate electrical life, but will provide an indication of contact erosion.

The opening operation shall follow the closing operation with sufficient time delay between the two operations for any transient currents to subside.

The tests shall be performed without reconditioning of the earthing switch during the test programme.

7.107.7.5 Behaviour of earthing switch during tests

The earthing switch shall perform successfully without undue mechanical or electrical distress.

Outward emission of flame or metallic particles from the earthing switch during operation is permitted, if this does not impair its insulation level. Flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.107.7.6 Condition of earthing switch after tests

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the earthing switch shall be essentially in the same condition as before the test. The earthing switch shall be capable of carrying its rated peak withstand current and its rated short-time withstand current.

Mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, are acceptable.

Visual inspection and no-load operation of the earthing switch after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests as mentioned below.

If the isolating properties are doubted, a voltage test as condition check according to 7.2.12 is to be performed to verify the isolating properties. As an alternative, 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For earthing switches that are sealed for life, the voltage test as a condition check is mandatory.

7.107.7.7 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017, the type test report shall contain the following information:

- a) typical oscillographic or similar records;
- b) test circuits;
- c) test currents;
- d) test voltages;
- e) power frequency recovery voltages;
- f) prospective transient recovery voltages;
- g) arcing times;
- h) number of making and breaking operations;
- i) condition of earthing switch after test.

General information concerning the supporting structure of the earthing switch should be included. The operating time of the earthing switch and the type of operating devices employed during the tests shall be recorded.

7.108 Bus-charging current switching tests on disconnectors

7.108.1 General

These tests shall be performed on disconnectors forming part of gas-insulated switchgear classified for bus-charging current switching.

NOTE The limit of 300 kV is derived from SF₆-insulated switchgear experience. The dielectric performance of disconnectors during bus-charging current switching and the performance against VFTO during the switching depends on the insulating gas used. For more information, refer to CIGRE Technical Brochure No. 260, 2004 [7].

7.108.2 Test duties

Three test duties are defined:

- *test duty 1*: switching of a very short section of busbar duct, this test duty shall be performed on disconnectors of $U_r \geq 300$ kV;
- *test duty 2*: switching of parallel capacitors of circuit-breakers under 180° out-of-phase condition; this test duty is not mandatory;
- *test duty 3*: current-switching capability test; this test duty is not mandatory.

NOTE 1 Test duty 2 is a special type test for disconnectors placed close to circuit-breakers that are equipped with parallel capacitors.

NOTE 2 Test duty 3 is a special type test to be carried out according to this specification by agreement between the manufacturer and the user. It serves to demonstrate the current interruption capability of the disconnector when de-energizing long busbars. Typical current values are given in Table 11.

7.108.3 Arrangement of the disconnector for tests

The operating device of the disconnector under test shall be operated in the manner specified by the manufacturer and, in particular, if it is power operated, it shall be operated at the specified minimum supply voltage and/or minimum supply pressure. The time delay between operations shall be sufficient to cool down the disconnector if specified by the manufacturer instructions.

Before commencing the making and breaking tests, no-load operations shall be made and details of the operating characteristics of the disconnector such as closing time and opening time shall be recorded (see 7.102.3.2).

Tests shall be performed at the minimum functional gas pressure (density) for switching of the disconnector under test. Associated compartments shall be at their minimum functional gas pressure (density) as well.

In most cases the design of the disconnector involves asymmetries (for example asymmetrical shields, or moving contact/fixed contact differences, etc.). For these cases, the test arrangement of the disconnector shall be such as to perform the test under the most severe conditions. For test duty 1, the most severe test arrangement is considered to be that which results in maximum pre-striking distance for the closing operation. For test duty 2 and test duty 3, the test arrangement of the disconnector is considered to be of minor importance.

Only single-phase tests on one pole of a three-pole operated disconnector need to be performed, provided that this does not mean a change of operating speed of more than ± 15 %.

For disconnectors having three poles in one enclosure, a three-phase test arrangement is required. One phase is connected to the testing circuit, and the two remaining poles not involved in the switching process shall be grounded at both terminals.

7.108.4 Test frequency

Disconnectors shall be tested at rated frequency, however disconnectors rated 50 Hz or 60 Hz may be tested with any of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of ± 10 % in accordance with Table C.1.

7.108.5 Test voltages for making and breaking tests

During making and breaking tests, the power frequency voltage shall be applied and maintained for at least 0,3 s before and after the switching operation. In the case of a DC pre-charge voltage at the load side (test duty 1), the DC voltage shall be applied according to the specified level for about 1 min before the close operation. The load side shall not be grounded between the open and close operations. The test circuit should not contain elements that cause a decay of the trapped charge.

With reference to Figures 14, 16 and 17, the test voltages at source side and load side of the test arrangement shall be applied as given in Table 19.

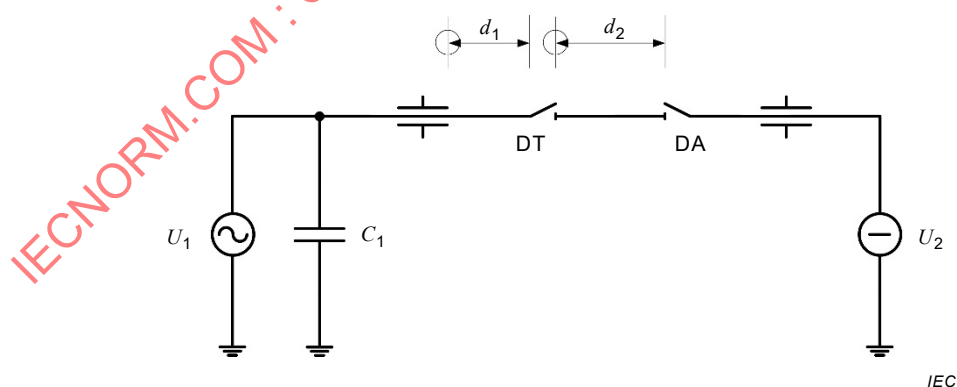
The test voltages in Table 19 are valid for the disconnector in the open position.

NOTE In the case of test duty 3, the test voltage can be considerably higher when the disconnector is in the closed position. This is caused by resonance phenomena, especially if the impedance of the supplying transformer is high, which is normal for transformers used for dielectric AC voltage tests. This voltage will increase severity of the test conditions. It will normally not be more than 10 %.

Table 37 – Test voltages for making and breaking tests

Test duty	Test voltage	
	Source side U_1	Load side U_2
1	$1,1 \times U_r / \sqrt{3}$	Pre-charge with negative DC voltage $-1,1 \times U_r \times \sqrt{2} / \sqrt{3}$
2	$1,1 \times U_r / \sqrt{3}$	AC voltage in phase opposition $1,1 \times U_r / \sqrt{3}$
3	$U_r / \sqrt{3}$	–

NOTE The factor 1,1 has been chosen to take into account statistical effects which are inherent in this kind of switching phenomena, and to restrict the number of test operations to those specified in Table 20. As test duty 3 should only indicate the switching capability of the disconnector, this increase of the test voltage is not necessary.



Key

DT Disconnector under test

DA Auxiliary disconnector

Busbar lengths d_1 and d_2 are understood to be taken as the following distances:

d_1 : open contact of the disconnector under test (DT) to the bushing connection;

d_2 : open contact of the disconnector under test (DT) to the open contact of the auxiliary disconnector (DA).

Figure 17 – Test circuit for test duty 1

7.108.6 Test circuits for making and breaking tests

7.108.6.1 Switching of a very short section of busbar duct, test duty 1

7.108.6.1.1 General

Figure 14 shows the test circuit for test duty 1. The load side shall be represented by a section of busbar, d_2 3 m to 5 m in length. The connection to the supply side shall be realised by another section of busbar, d_1 in length. In order to obtain representative very fast transient (VFT) conditions, the ratio d_2/d_1 , shall be in the range of 0,36 to 0,52. The source-side circuit shall have an added lumped capacitance, C_1 . The value of C_1 shall be chosen so that the peak value of the voltage to earth at the disconnector terminals is met as defined in 7.108.6.1.2.

Before starting a closing operation, the load side shall be charged by DC voltage according to Table 18, and the DC voltage source disconnected by the auxiliary disconnector, DA.

7.108.6.1.2 Transient voltage values

The voltage transients at the disconnector location during a close operation are used to characterize the behaviour of the test circuit and to ensure consistent overvoltage characteristics under test conditions. Two distinct aspects of transient voltages are of importance: these are the very fast transient (VFT) phenomena and the fast transient (FT) phenomena. The VFT phenomena are determined by the circuit arrangement as described in 7.108.6.1.1. The circuit response for the fast transient phenomena shall be verified at least once for the test arrangement by direct measurement (see 7.108.11) under the following conditions:

- source-side test voltage: $U_r/\sqrt{3}$;
- load-side voltage: 0 (no pre-charge).

For these conditions, the maximum peak value of the transient voltage to earth U_{TVE} at the first prestrike during a close operation shall be not less than $1,4 \times U_r \sqrt{2}/\sqrt{3}$ (for practical purposes a variation of 5 % is considered acceptable) and the time to maximum peak shall be less than 500 ns, (Figure 15).

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear the resistor shall be short-circuited or replaced by a solid conductor before the tests in order to verify the test circuit conditions described above.

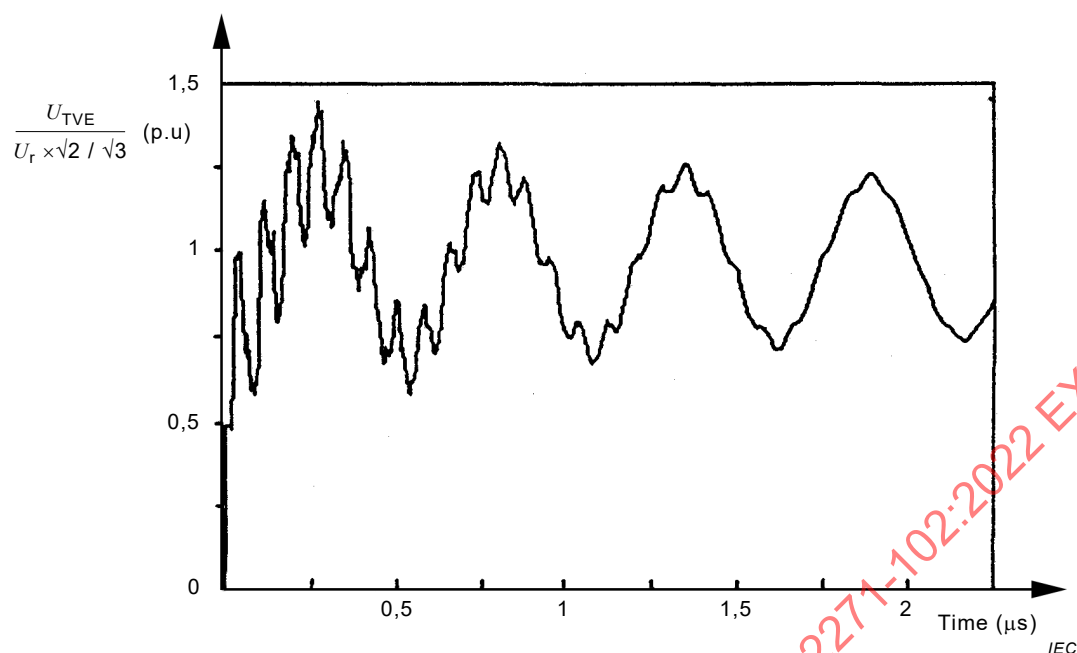


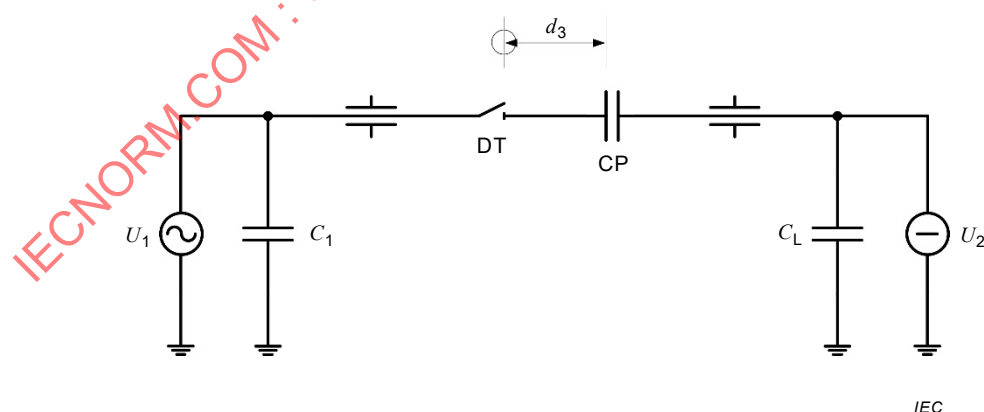
Figure 18 – Typical voltage waveform (Including VFT and FT components)

7.108.6.2 Out-of-phase switching, test duty 2

Figure 16 shows the test circuit for out-of-phase switching. The parallel capacitor CP of a circuit-breaker may be represented by the actual circuit-breaker with its own capacitor or by an adequate capacitance of equal or higher value than the capacitance used in service.

The shortest possible distance d_3 between capacitor CP and disconnector shall be established. The lengths of the other test circuit parts are not specified, but they should be as short as possible in order to minimize their influence on the capacitance of the test circuit.

The lumped capacitance C_L (Figure 16) shall be of a value not less than 400 pF. The ratio C_1/C_L shall be in the range of 4 to 6.



Key

- DT Disconnector under test
- CP Circuit-breaker parallel capacitor or equivalent capacitor

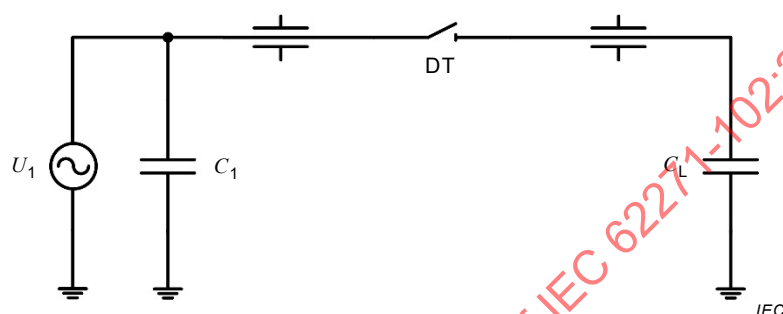
Figure 19 – Test circuit for test duty 2

7.108.6.3 Current switching capability test, test duty 3

The test circuit shown in Figure 17 applies. For this type of switching, the specific lengths of the busbar sections are of no significance. On the load side, a lumped capacitance C_L should be added in order to achieve the bus-charging current as given in Table 11 with a tolerance of $\pm 10\%$.

In order to reduce resonance effects, which can be caused due to a high source impedance, connection of a lumped capacitance C_1 of any value is acceptable to the source side.

Further testing conditions that affect the transient recovery conditions are subject to agreement between the manufacturer and the user.



Key

DT Disconnector under test

Figure 20 – Test circuit for test duty 3

7.108.7 Performance of making and breaking tests

During each test duty, the test series shall be performed without reconditioning the disconnector. The number of tests is given in Table 20.

Table 38 – Number of tests

Test duty	Number of make and break operations	
	Standard disconnector	Fast-acting disconnector ^a
1	50 ^b	200 ^{a, c}
2	50	200
3	50	50
^a Disconnectors having a contact speed in the range of 1 m/s or higher at the moment of contact separation. ^b If the most severe disconnector arrangement cannot be determined clearly (with reference to 7.108.3), test duty 1 shall be repeated with reversed disconnector terminals. ^c Reduction of the number of tests down to 50 is acceptable if the test voltage is increased (to cover statistical effects) to the following values: – source side: $U_r \times 1,2/\sqrt{3}$; – load side: (DC pre-charge): $-U_r \times 1,2 \sqrt{2}/\sqrt{3}$.		

7.108.8 Behaviour of the disconnector during making and breaking tests

The disconnector shall perform successfully without mechanical or electrical damage.

Disruptive discharges from phase to earth or from phase to phase are not permitted. Additionally, for resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear disruptive discharges are not permitted across the resistor.

NOTE It is essential that disruptive discharges to earth or between phases can be detected properly by adequate measuring or detecting equipment.

7.108.9 Condition after test

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the disconnector shall be essentially in the same condition as before the test.

Mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, are acceptable. However, the current-carrying capability and the isolating properties of the disconnector shall not be impaired. The quality of the material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level. There may be deposits on the insulators caused by the decomposition of the arc extinguishing medium.

The isolating properties of a disconnector in the open position shall not be reduced below what corresponds to normal wear and ageing, by deterioration of insulating parts.

No-load operation and visual inspection of the disconnector after tests are usually sufficient for verification of the isolating properties and the current-carrying capability of the disconnector. In case of doubt, it can be necessary to perform the appropriate tests as mentioned below. For disconnectors that are sealed for life, it is mandatory to perform the voltage test as a condition check.

If the isolating properties are doubted, a voltage test as condition check in accordance with 7.2.12 is to be performed to verify the insulating properties. Alternative test methods given in 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable.

In case of doubt of current-carrying capacity, main circuit resistance measurement may be used where ever it is possible to measure the resistance close to the contacts. The increase in main circuit resistance after test shall not exceed 20 %. If the contact resistance exceeds this value, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017 by monitoring the temperature at the points as close as possible to the main contacts.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % of the value measured before the test. A visual inspection of the resistor shall be made after the type tests. No evidence of flashover across the resistor or any mechanical damage shall be observed. It can be necessary to disassemble the disconnector for the visual inspection.

7.108.10 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017, the type test report shall contain the following information:

- a) representative oscillographic record of one make and one break operation;
- b) test circuit(s);
- c) steady-state test current (only for test duty 3);
- d) test voltage(s);
- e) transient voltage characteristics;

- f) record of operating characteristics;
- g) insulating-gas pressure during the tests;
- h) number of make and break switching operations;
- i) condition after test;
- j) type of fault detection system;
- k) supply voltage or pressure of mechanism operated.

7.108.11 Requirements for U_{TVE} measurements

Requirements for the measurements:

- U_{TVE} verification shall be carried out at least once during each performed test-duty. Configurational changes such as different connecting lead length, equipment orientation, etc., are considered as changes to the test circuit and will require additional measurements;
- U_{TVE} measurements shall be made within 1 m of the arcing contacts of the disconnecter. If this is not possible, U_{TVE} verification may be done by computer calculation, provided that other measurements (within the test section but outside the 1 m zone) are performed at least once to check the validity of the calculation technique;
- care shall be taken to ensure that possible stray power frequency interference is taken into account;
- U_{TVE} measurement shall be made with sufficient bandwidth to properly record the VFT component.

8 Routine tests

8.1 General

The routine tests are for the purpose of revealing faults in material or construction. They do not impair the properties and reliability of a test object. The routine tests shall be made wherever reasonably practicable at the manufacturer's works on each apparatus manufactured. By agreement, any routine test may be made on site.

The routine tests given in this document comprise:

- a) dielectric test on the main circuit in accordance with 8.2;
- b) tests on auxiliary and control circuits in accordance with 8.3;
- c) measurement of the resistance of the main circuit in accordance with 8.4;
- d) tightness test in accordance with 8.5;
- e) design and visual checks in accordance with 8.6.
- f) mechanical operating tests in accordance with 8.101.
- g) verification of earthing function in accordance with 8.102

Disconnectors and earthing switches integrated in enclosed switchgear shall be tested as part of the switchgear assembly in accordance with IEC 62271-200, IEC 62271-201 or IEC 62271-203.

Additional routine tests may be necessary and are, when needed, specified in the relevant IEC standards.

When switchgear and controlgear is not completely assembled before transport, separate tests shall be made on all transport units. In this event, the manufacturer shall demonstrate the validity of this test (for example, leakage rate, test voltage, resistance of part of the main circuit).

Test reports of the routine tests are not required unless otherwise agreed upon between the manufacturer and the user.

8.2 Dielectric test on the main circuit

A dry, short-duration power-frequency voltage test shall be applied. The test procedure shall be according to IEC 60060-1:2010 and to 7.2, except that each pole or transport unit shall be tested. For sealed pressure systems, the test shall be made at the filling pressure for insulation.

The test voltage shall be the rated short-duration power-frequency withstand voltage specified in column 2 of Tables 1 through 4.

When the insulation of switchgear and controlgear is provided only by solid-core insulators and air at ambient pressure, the power-frequency voltage withstand test may be omitted if the dimensions between the conductive parts – between phases, across open switching devices and between conductive parts and the frame – are checked by dimensional measurements.

Bases for the checking of dimensions are the dimensional (outline) drawings, which are part of the type test report (or are referred to in it) of the particular switchgear and controlgear. Therefore, in these drawings all information necessary for dimensional checking including the permissible tolerances shall be given.

In case of disconnectors or earthing switches placed

- inside sealed pressure systems, the dielectric test may be performed at rated filling pressure for insulation;
- inside controlled or closed pressure systems, the dielectric test shall be performed at minimum functional pressure for insulation.

If the conditions indicated in the third paragraph of 8.2 of IEC 62271-1:2017 are not fulfilled, the following applies:

- for testing of disconnectors the test conditions shall be in accordance with Table 21. For an explanation of the reference designations for connections, see Figure 2 of IEC 62271-1:2017;

Table 39 – Power frequency voltage tests

Test condition no.	Disconnector position	Voltage applied to	Earth connected to
1 ^a	Closed	Aa	BbCcF
2 ^a	Closed	Bb	AaCcF
3 ^a	Closed	Cc	AaBbF
4	Open	ABC	abcF
5	Open	abc	ABCF
6 ^b	Open	ABC or abc	Earthing switch

^a If the insulation between poles is air at atmospheric pressure and if the dimensions are checked, test conditions nos. 1, 2 and 3 may be combined, the test voltage being applied between all parts of the main circuit connected together and the base.

^b Earthing switch in the position resulting in the shortest gap between its moving parts and ABC or abc. The test is applicable only to disconnectors with integrated earthing switch.

- for testing of earthing switches, the test voltage shall be applied with the earthing switch in the open position:
 - 1) between adjacent insulated terminals with the bases earthed (e.g. A to B with F earthed);

- 2) between all the insulated terminals connected together and the bases earthed (e.g. ABC to F earthed).

8.3 Tests on auxiliary and control circuits

8.3.1 Inspection of auxiliary and control circuits, and verification of conformity to the circuit diagrams and wiring diagrams

The nature of the materials, the quality of assembly, the finish and, if necessary, the protective coatings against corrosion shall be checked. A visual inspection is also necessary to check the satisfactory installation of the thermal insulation, if any.

A visual inspection of actuators, interlocks, locks, etc., shall be made.

Components for auxiliary and control circuits inside enclosures shall be checked for proper mounting. The location of the means provided for connecting external wiring shall be checked to ensure that there is sufficient wiring space for spreading of the cores of multi-core cables and for the proper connection of the conductors.

The conductors and cables shall be checked for proper routing. Special attention shall be given to ensure that no mechanical damage can occur to conductors and cables due to the proximity of sharp edges or heating elements, or to the movement of moving parts.

Furthermore, the identification of components and terminals and, if applicable, the identification of cables and wiring shall be verified. In addition, the conformity of auxiliary and control circuits to the circuit diagrams and wiring diagrams shall be checked.

8.3.2 Functional tests

Functional tests are specified, where relevant, in the relevant IEC product standards. When specified, they shall be made on all auxiliary and control circuits to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the auxiliary and control circuits of the device.

Operation tests on auxiliary and control circuits, subassemblies and components may be omitted if they have been fully tested during a test applied to the whole switchgear and controlgear.

8.3.3 Verification of protection against electrical shock

Protection against direct contact with the main circuit and safe accessibility to the auxiliary and control equipment parts liable to be touched during normal operation shall be checked. The preferred method is by visual inspection.

Where visual inspection cannot provide confirmation of the electrical continuity of earthed metallic parts, the alternative procedure defined in 7.4.3 shall be applied.

8.3.4 Dielectric tests

Only power frequency tests shall be performed. This test shall be made under the same conditions as those detailed in 7.10.5.

The test voltage shall be 1 kV with duration of 1 s.

8.4 Measurement of the resistance of the main circuit

For the routine test, the DC voltage drop or resistance of each pole of the main circuit shall be measured under conditions as nearly as possible similar, with regard to ambient air

temperature and points of measurement, to those under which the corresponding measurement before the continuous current test was made. The test current shall be within the range stated in 7.4.4.

The measured resistance shall not exceed $1,2 \times R_{11}$, where R_{11} is equal to the resistance measured before the continuous current test.

In the case of assemblies it may be necessary to calculate the expected resistance based on relevant type tests.

Subclause 8.4 of IEC 62271-1:2017 is applicable only to disconnectors.

8.5 Tightness test

8.5.1 General

Routine tests shall be performed to demonstrate the tightness criteria according to 6.16 at ambient temperature with the switchgear parts, components or subassemblies at or above the minimum functional pressure (or density) for insulation.

8.5.2 Controlled pressure systems for gas

The test procedure corresponds to 7.8.2.

8.5.3 Closed pressure systems for gas

The test may be performed at different stages of the manufacturing process or of assembling on site, on parts, components and subassemblies.

For parts or subassemblies tested in factory, the cumulative test is the preferred method.

For gas-filled systems tested in factory, the probing test using a sniffing device may be used. If any leak is detected, the test shall be considered to be failed or the leak shall be quantified by using a cumulative method.

For routine tests at site, the probing test using a sniffing device is the preferred method.

The sensitivity of the sniffing device shall be at least $10^{-8} \text{ Pa} \times \text{m}^3/\text{s}$.

8.5.4 Sealed pressure systems

Depending on the insulation medium two situations are considered:

a) Switchgear using gas

The preferred test procedure corresponds to 7.8.4, item a).

An alternative test procedure corresponds to the sealing tracer gas test with mass spectrometer, refer to IEC 60068-2-17:1994 [31].

b) Switchgear using vacuum interrupters

The vacuum tightness shall be demonstrated by a dielectric test according to 7.2.12 carried out after the mechanical routine test specified in the relevant product standards.

8.5.5 Liquid tightness tests

Routine tests shall be performed at normal ambient air temperature with the completely assembled switchgear and controlgear device. Testing of subassemblies is also permissible. In this case, a final check shall be performed at site.

The test methods correspond to those of the type tests (refer to 7.8.5).

8.6 Design and visual checks

The switchgear and controlgear shall be checked to verify its compliance with the purchase specification, if any.

8.101 Mechanical operating tests

Operating tests are made to ensure that the disconnectors or earthing switches show the specified operating behaviour within the specified supply voltage, if any, and supply pressure limits, if any, of their operating mechanisms.

During these tests, which are performed without voltage on, or current flowing through the main circuit, it shall be verified that:

- the disconnectors or earthing switches open and close correctly when their operating mechanisms are energized;
- the interlocks work properly in any interlocked position;
- the position-indicating and -signalling devices indicate correctly the open and closed positions.

The disconnector or earthing switch shall be subjected to the following tests:

- at specified minimum supply voltage and/or pressure (if any): five operating cycles;
- at specified maximum supply voltage and/or pressure (if any): five operating cycles;
- if a disconnector or earthing switch can be operated manually: five manual operating cycles.

During these operating cycles, the operating characteristics such as, if applicable, operating times, power consumption, maximum forces for manual operation, shall be verified. Satisfactory operation of control and auxiliary contacts, and position-indicating devices (if any) shall be verified. The values of each parameter shall be within the tolerances specified by the manufacturer.

During these tests no adjustment shall be made and the operation shall be faultless. The closed and open position shall be reached with the specified indication and signalling during each operating cycle.

After these tests, no parts of the disconnector or earthing switch shall be damaged.

For disconnectors and earthing switches of $U_r > 52$ kV, the mechanical operating routine tests may be performed on sub-assemblies.

Where mechanical routine tests are performed on separate components, they shall be repeated at site on a complete assembled disconnector during the commissioning tests. The same total number of operations as specified in 7.102.3.2 shall be performed.

8.102 Verification of earthing function

The earthing function shall be verified according to the manufacturer's specification. However, test of electrical continuity shall be performed. Some examples of other routine tests that can be specified are as follows:

- contact resistance;
- contact pressure;
- visual inspection;

- dimension check;
- electrical continuity.

9 Guide to the selection of disconnectors and earthing switches (informative)

9.1 General

Clause 9 gives general guidance on the appropriate selection of ratings and parameters depending on the application to be covered by high-voltage switchgear and controlgear. A summary of the considerations for specifying the ratings of switchgear and controlgear is provided in Annex F (informative).

For the selection of disconnectors and earthing switches, the following conditions and requirements at site should be considered:

- continuous current load and overload conditions;
- existing fault conditions;
- static and dynamic terminal loads resulting from the substation design;
- use of rigid or flexible conductors to be connected to the disconnector or earthing switch or to which the separated contact is mounted;
- environmental conditions (climate, pollution, etc.);
- altitude of the substation site;
- required operational performance (mechanical endurance);
- switching requirements (bus-transfer current switching by disconnectors, induced current switching by earthing switches, short-circuit making capacity of earthing switches).

NOTE See Annex B for more information about current-switching capabilities of disconnectors and earthing switches

When selecting a disconnector or earthing switch, due allowance should be made for the likely future development of the system as a whole so that the disconnector or earthing switch is suitable not merely for immediate requirements, but also for those of the future.

9.2 Selection of rated values

The rated values should be chosen in accordance with this document having regard for the characteristics of the system as well as its anticipated future development. A list of ratings is given in Clause 5.

For most of the rated voltages, several rated insulation levels exist to allow for application of different performance criteria or overvoltage patterns. The choice should be made considering the degree of exposure to fast-front and slow-front overvoltage, the type of neutral earthing of the system and the type of overvoltage limiting devices (see IEC 60071-2:1996). Other parameters, such as local atmospheric and climatic conditions and the use at altitudes exceeding 1 000 m, should also be considered.

The duty imposed by fault conditions should be determined by calculating the fault currents at the place where the switchgear and controlgear is to be located in the system. Reference is made to IEC 60909-0 [33] and IEC TR 60909-1 [34] in this regard.

9.2.101 General

All rated characteristics and classes of a disconnector or earthing switch given in Clause 5 should be considered, as far as applicable, together with subclauses 9.2.102 to 9.2.110.

9.2.102 Selection of rated voltage and rated insulation level

The rated voltage of the disconnector or earthing switch should be chosen so as to be at least equal to the highest voltage of the system at the point where the disconnector or earthing switch is to be installed.

The rated voltage of a disconnector or earthing switch should be selected from the standard values and their related insulation levels given in 5.2 and 5.3 of IEC 62271-1:2017.

For disconnectors and earthing switches installed at high altitudes, refer to 4.2.2 of IEC 62271-1:2017.

9.2.103 Selection of rated continuous current

The rated continuous current of a disconnector should be selected from the standard values given in 5.5 of IEC 62271-1:2017.

It should be noted that disconnectors have no standardized continuous overcurrent capability. When selecting a disconnector, therefore, the rated continuous current should be such as to make it suitable for any load current that may occur in service. Where intermittent overcurrents are expected to be frequent and severe, the manufacturer should be consulted.

9.2.104 Selection of rated contact zone

For proper function of a divided support disconnector or earthing switch, the user should ensure that the fixed contact stays within the limits given in Table 2 by considering the service conditions when specifying the substation design and the cantilever strength of the insulators.

When selecting the rated contact zone, the user should verify that the rated contact zone specified by the manufacturer is not exceeded in its specific application for the following additional constraints, if applicable:

- a longitudinal deflection resulting from wind acting on other connected components that are perpendicular to the bus work and from equipment movement;
- a perpendicular deflection resulting from forces from wind on other connected components that are perpendicular to the bus work and from equipment movement;
- a vertical deflection resulting from other vertical loads hung from the bus and from operating loads imposed by the operation of other equipment connected to the bus.

9.2.105 Selection of rated static mechanical terminal load

The rated static mechanical terminal load should be selected based on the requirements of 5.104 and the definitions of 3.7.119. The most disadvantageous conditions should be considered by the user when specifying the rated static terminal loads.

To calculate the required static terminal loads as well as the required strength of insulators, the forces resulting from the conductors connected to the disconnector or earthing switch, including the forces of wind and ice (if applicable) and minimum specified ambient air temperature on these conductors should be considered.

9.2.106 Selection of a bus-transfer current switching capability for disconnectors of $U_r > 52$ kV

Although disconnectors are, by definition, only capable of opening and closing a circuit when either negligible current is broken or made or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs, disconnectors in some applications are used for load transfer from one bus system to a parallel bus. Even if a bus coupling is closed, the load transfer can be a more or less severe switching operation for the

disconnecter, depending on the dimensions of the substation and the current to be transferred.

If a bus-transfer current switching capability is required, the values of transfer current and expected recovery voltage should be specified in the enquiry (see Clause 10).

9.2.107 Selection of an induced-current switching capability for earthing switches of $U_r > 52$ kV

An earthing switch is normally used for opening and closing a connection to earth from an isolated section of an electrical installation or line.

In high-voltage networks, tower configurations are sometimes used with more than one system being mounted on the same line tower. In such cases, induced currents have to be switched when earthing or unearthing one of the lines whilst the other line is connected to the system and can be carrying load current. The magnitude of the induced currents to be switched by the earthing switch depends on the capacitive and inductive coupling factors between the lines, and on the voltage, load and length of the parallel system.

Usually, higher voltage networks are characterised by longer loop distances and higher load currents resulting in higher values of induced currents.

If a switching capability is required, the values given in Table 9 can be used for most of the cases to be specified in the enquiry (see Clause 10).

9.2.108 Selection of rated short-time withstand current and of rated duration of short-circuit

Subclauses 5.6 and 5.8 of IEC 62271-1:2017 are applicable.

The test arrangements represented in Figures 3, 4 and 5 are for type test purposes. It cannot be excluded that electrical installation designs exist in which the disconnecter or earthing switch undergoes higher stresses.

NOTE For short-time currents it can be considered that the thermal stress is constant when $I^2t = \text{constant}$.

9.2.109 Selection of rated peak withstand current and of rated short-circuit making current for earthing switches

The selected disconnecter or earthing switch should have a rated peak withstand current not less than the highest peak value of the fault current occurring in the actual system (by considering the actual value of the time constant of the network).

Subclause 5.6 should be considered.

This applies also to the rated short-circuit making current of an earthing switch (where applicable).

9.2.110 Selection of short-circuit making capability for earthing switches

The selection should be done according to the classification mentioned in subclause 5.102. The selection of class E1 or E2 depends on operational procedures of the electrical network. Usually, this ability is not requested for earthing switches forming part of air-insulated switchgears of $U_r > 52$ kV.

9.3 Cable-interface considerations

For connection to cables, the maximum temperature at the terminals at full continuous current should be below the temperature limits of the cable insulation and cable termination.

9.4 Continuous or temporary overload due to changed service conditions

Equipment could be required to carry a load current above its rated continuous current during a short period of time or when ambient temperatures are favourable to do it provided the temperature does not exceed the maximum temperature value specified in Table 14; reference is made to IEC TR 62271-306 [4].

NOTE For certain devices (e.g. load break switches) the temporary overload could result in a load current that exceeds the switching capability of the switchgear.

9.5 Environmental aspects

9.5.1 Service conditions

Selected switchgear and controlgear and its associated operating devices and auxiliary equipment should be designed and validated to comply with at least the specific service conditions required by the user or appropriate arrangements should be made.

9.5.2 Clearances affected by service conditions

Where clearances may be compromised by environmental related changes in the service access level (for example accumulation of snow, sand, etc.) the use of increased clearances should be considered.

9.5.3 High humidity

For the normal service conditions present in 4.1.2 e), condensation may occasionally occur on, or in, indoor switchgear and controlgear.

To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed for such conditions should be used.

Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear.

High humidity may also be due to ground level rainwater or for cable-connected applications of underground network applications from incoming cable raceways connected to switchgear.

9.5.4 Solar radiation

Under certain levels of solar radiation, appropriate measures, for example roofing, forced ventilation etc., may be necessary, or derating may be used, in order not to exceed the specified temperature and pressure rise limits. Tests with simulated solar gain may be used to demonstrate if measures or derating are needed.

9.5.101 Local environmental conditions

For the normal and special service conditions for disconnectors and earthing switches, Clause 4 of IEC 62271-1:2017 applies.

For disconnectors and earthing switches, pollution conditions in certain areas both outdoors and indoors are unfavourable on account of smoke, chemical fumes, salt-laden spray, etc. Where such adverse conditions are known to exist, special consideration should be given to the design and materials used with the disconnector or earthing switch. In these conditions,

care should be taken when considering the performance of parallel insulation. Pollution tests could be necessary to be performed on the disconnector or the earthing switch.

For insulators normally exposed to the atmosphere, refer to 6.15 of IEC 62271-1:2017. The performance of an insulator in polluted atmospheres also depends on the frequency with which artificial washing or other pollution control methods are carried out or natural cleaning occurs.

NOTE Insulator designs which have been proved by testing to fulfil the requirements of the user, can have a nominal creepage distance smaller than that given by the product of the rated voltage and the minimum specific creepage distance.

For open-terminal, indoor installations in coastal areas where salt deposit is a problem, it is recommended, for $U_r > 52$ kV, to use equipment with outdoor insulation as this is more readily available than special indoor insulation. The use of GIS installations is also possible.

If a disconnector or earthing switch is to be located where the wind speed exceeds 34 m/s, this should be stated in the enquiry.

If a disconnector or earthing switch is to be located in a surrounding where an ice-coating with a thickness exceeding 1 mm is expected, this should be stated in the enquiry, taking 7.103 into consideration.

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

The intention of this clause is to define information, which is necessary to enable the user to make an appropriate enquiry for equipment and to enable the supplier to give an adequate tender.

Furthermore, it enables the user to make a comparison and evaluation of offers from different suppliers.

NOTE The supplier can either be a manufacturer or a contractor.

When enquiring about or ordering an installation of switchgear and controlgear the following information as a minimum should be supplied by the enquirer.

Annex F (informative) provides similar information items in a tabular form for ease of use.

For disconnectors and earthing switches used in gas-insulated and/or metal-enclosed switchgear, Clause 9 of IEC 62271-200:2011 or IEC 62271-203:2011 is applicable.

10.2 Information with enquiries and orders

When enquiring for or ordering a disconnector or an earthing switch, the following information, where applicable, should be supplied by the enquirer:

- particulars of system, i.e. nominal and highest voltages, frequency, number of phases and details of neutral earthing;
- service conditions, including minimum and maximum ambient air temperatures if different from the normal values (refer to Clause 9), altitude if over 1 000 m, ice and any special conditions likely to exist or arise, for example unusual exposure to steam or vapour, moisture, fumes, explosive gases, excessive dust or salt air (see 9.5.101);
- characteristics of the disconnector or earthing switch. The following information should be given:

- 1) indoor or outdoor installation;
 - 2) number of phases;
 - 3) rated voltage;
 - 4) rated frequency;
 - 5) rated insulation level where a choice exists between different insulation levels corresponding to a given rated voltage or, if other than standard, desired insulation level (see Tables 1 to 4 of IEC 62271-1:2017);
 - 6) rated continuous current (for disconnectors only);
 - 7) rated short-time withstand current (I_k);
 - 8) rated duration of short-circuit (if different from 1 s);
 - 9) rated peak withstand current (if different from 2,5 I_k);
 - 10) rated short-circuit making current, if any (for earthing switches only) (see 5.101);
 - 11) rated static mechanical terminal loads, if applicable (see 5.104);
 - 12) use of rigid or flexible conductors to be connected to the disconnector or earthing switch or to which the separated contact is mounted, if applicable (see 5.104);
 - 13) mounting conditions and HV connections, for example hanging arrangement of the fixed contact of the disconnector and earthing switch, support structure to be supplied with the equipment or not, if applicable;
 - 14) requirements for insulators (if applicable) to be used with the disconnector and earthing switch:
 - class of pollution taken from IEC/TS 60815-1 [4];
 - profile of the sheds (if applicable); taken from IEC/TS 60815 (all parts) [3];
 - see item 11);
 - 15) required contact zone; if applicable;
 - 16) operation under severe ice conditions, if applicable;
 - 17) rated bus-transfer current switching (disconnectors only), if applicable;
 - 18) rated induced current switching (earthing switches only), if applicable;
 - 19) rated mechanical endurance class, if different from M0;
 - 20) rated short-circuit making capability class, if different from E0 (earthing switches only);
 - 21) bus-charging current switching capability;
 - 22) degree of protection for the enclosure and partitions (if any of both);
 - 23) circuit diagrams;
- d) characteristics of the operating mechanism and associated equipment, in particular:
- 1) method of operation, whether manual and/or power dependent;
 - 2) for independent manual operation of earthing switches: the duration of a time delay;
 - 3) the operating height above servicing level;
 - 4) for power operation, the type of available supply energy (e.g. compressed air, or electrical DC or AC) and its ratings (pressure, voltage, frequency);
 - 5) number and type of auxiliary contacts to be available;
 - 6) degree of protection if higher than that specified in 6.14;
 - 7) interlocking requirements;
 - 8) minimum duration of the operating signal;
 - 9) maximum operating time for power operation;
- e) requirements concerning the use of compressed gas and requirements for design and tests of pressure vessels;

- f) any routine tests or additional checks required to be witnessed by the user;
- g) any other information concerning special conditions not included above that might influence the tender or the order, such as, for example, special mounting or installation conditions, the location of the external high-voltage connections or requirements for cable testing;
- h) request for type test documentation or any specific request about conformity assessment material.

10.3 Information with tenders

The information given by the manufacturer with tenders should cover the requirements specified in 10.2 as applicable, and should state compliance with and deviations from the enquiry details. The dimensions given in drawings of disconnectors and earthing switches are subject to tolerances as standardized by ISO 2768-1 unless otherwise specified. National requirements enforcing deviation from IEC 62271-1 should be stated in the tender documents.

The information given by the manufacturer with tenders should include, where applicable:

- a) rated values and characteristics as enumerated in item c) of 10.2, and Clause 5;
- b) constructional features, when applicable:
 - 1) mass of complete disconnector or earthing switch;
 - 2) overall dimensions in closed and open position (if different);
 - 3) arrangement of the external connections;
 - 4) facilities necessary for transport and mounting;
 - 5) mounting provisions;
 - 6) accessible sides;
 - 7) type of gas-pressure or liquid-pressure system (if any);
 - 8) minimum clearances in air:
 - between poles;
 - to earth;
 - for isolating distance (for disconnectors only);
 - 9) for divided support disconnectors and earthing switches, the rated contact zone;
 - 10) corrosion protection;
 - 11) for disconnectors having a fixed contact requiring reaction forces when closing and opening the contact, these forces and their direction shall be stated by the manufacturer in the documentation;
 - 12) where applicable, the dielectric losses (mW) of the insulation system of the external grounding connection shall be given;
- c) operating mechanism and associated equipment:
 - 1) type of operating mechanism;
 - 2) rated supply voltage and/or pressure of operating mechanism;
 - 3) current required at rated supply voltage to operate the disconnector or earthing switch; maximum current and maximum voltage at the terminals of the operating mechanism;
 - 4) quantity of free gas required to operate the disconnector or earthing switch at the rated supply pressure, as applicable;
 - 5) number and type of available auxiliary contacts;
 - 6) design of the device or description of means for securing the position;
 - 7) design of indicating and signalling device;
 - 8) operating times.

11 Transport, storage, installation, operating instructions, and maintenance

11.1 General

It is essential that the transport, storage and installation of switchgear and controlgear, as well as their operation and maintenance in service, is performed in accordance with instructions given by the manufacturer.

Consequently, the manufacturer shall provide the appropriate version of the instruction manual for the transport, storage, installation, operation and maintenance of switchgear and controlgear. The instructions for the transport and storage should be given at a convenient time before delivery, and the instructions for the installation, operation and maintenance should be given by the time of delivery at the latest. It is preferable that the operation manual be a separate document from the installation and maintenance manual.

It is impossible, here, to cover in detail the complete rules for the installation, operation and maintenance of each one of the different types of apparatus manufactured, but the following information is given relative to the most important points to be considered for the instructions provided by the manufacturer.

For disconnectors and earthing switches used in gas-insulated and/or metal-enclosed switchgear, Clause 10 of IEC 62271-200:2011 or of IEC 62271-203:2011 is applicable.

11.2 Conditions during transport, storage and installation

A special agreement should be made between manufacturer and user if the service conditions of temperature and humidity defined in the order cannot be guaranteed during transport, storage and installation. Special precautions may be essential for the protection of insulation during transport, storage and installation, and prior to energizing, to prevent moisture absorption due, for instance, to rain, snow or condensation. Vibrations during transport should be considered. Appropriate instructions should be given by the manufacturer.

Special packaging should be proposed by the manufacturer for long term storage of parts for maintenance needs according to customer specifications.

11.3 Installation

Disconnectors and earthing switches shall be packed, as far as it is practicable, as one unit.

Packages and crates containing more than one unit or more than one component (insulators, drive rods, operating mechanisms and similar components) should be clearly identified and accompanied by a list of content.

11.3.1 General

For each type of switchgear and controlgear the instructions provided by the manufacturer shall include at least the items listed below.

11.3.2 Unpacking and lifting

Each complete equipment shall be provided with adequate lifting facilities and labelled (externally) to show the correct method of lifting. The equipment shall be labelled (externally) to indicate its maximum mass, in kg, when fully equipped. Special lifting devices shall be capable of lifting the mass of each transport unit and special precautions shall be detailed in the installation manual (for example lifting brackets/bolts that are not intended to be left outdoors shall be removed at site).

Required information for unpacking should be given.

11.3.3 Assembly

When the switchgear and controlgear is not fully assembled for transport, all transport units should be clearly marked. Drawings showing assembly of these parts should be provided with the switchgear and controlgear.

11.3.4 Mounting

Instructions for the mounting of switchgear and controlgear, operating device and auxiliary equipment should include sufficient details of locations and foundations to enable site preparation to be completed.

These instructions should also indicate:

- the total mass of the apparatus inclusive of extinguishing or insulating fluids;
- the mass of extinguishing or insulating fluids;
- the mass of each unit to be lifted separately.

11.3.5 Connections

Instructions should include information on:

- connection of conductors, comprising the necessary advice to prevent overheating and unnecessary strain on the switchgear and controlgear and to provide adequate clearance distances;
- connection of auxiliary circuits;
- connection of liquid or gas systems, if any, including size and arrangement of piping;
- connection for earthing;
- auxiliary contacts available to the user.

11.3.6 Information about gas and gas mixtures for controlled and closed pressure systems

For controlled and closed pressure systems filled with gas mixture, the percentage of the different gases and their associated tolerances shall be defined by the manufacturer taking into account handling and uncertainty of measurement. Appropriate gas filling procedures are defined in IEC 62271-4.

During commissioning or maintenance, the maximum allowable humidity content within gas-filled switchgear and controlgear filled with gas at the filling pressure (density) for insulation shall be checked by dew point measurement. Appropriate correction factors shall be used for measurements performed at temperatures other than 20 °C according to the manufacturer's instruction manual.

The maximum allowable humidity content for equipment filled or re-filled with new or used gas should be such that the dew point inside the switchgear compartment is not higher than

- –10 °C for equipment with adsorber material;
- –15 °C for equipment without adsorber material

during commissioning or after maintenance for a measurement at filling pressure (density) for insulation and at 20 °C.

NOTE 1 These dew point values during commissioning are expected to give a dew point value lower than -5 °C during service life, for a measurement at 20 °C.

NOTE 2 The measurement of the dew point is specified at a given temperature due to the possible exchange of water between gas and solid materials when the temperature changes, which could change the measured value.

NOTE 3 An example of measurement and determination of the dew point is given in IEEE C37.122.5 [35].

11.3.7 Final installation inspection

Instructions should be provided for inspection and tests which should be made after the switchgear and controlgear has been installed and all connections have been completed.

These instructions should include:

- a schedule of recommended site tests to establish correct operation;
- procedures for carrying out any adjustment that may be necessary to obtain correct operation;
- recommendations for any relevant measurements that should be made and recorded to help with future maintenance decisions;
- a procedure for qualitative gas tightness test at site (sniffing test) on all field assembled connections for closed pressure systems, reference is made to 8.5.3;
- instructions for final inspection and putting into service.

Guidance for electromagnetic compatibility site measurements is given in Annex H (informative).

11.3.8 Basic input data by the user

These data should include:

- a) access limitations to the local site;
- b) local working conditions and any restrictions that may apply (for example, safety equipment, normal working hours, union requirements for supervisor, manufacturer's and local installation crew, etc.);
- c) availability and capacity of lifting and handling equipment;
- d) availability, number and experience of local personnel;
- e) specific pressure vessel rules and procedures that may apply during installation and commissioning tests;
- f) interface requirements for high-voltage cables and transformers;
- g) in the case of extensions to existing switchgear and controlgear:
 - 1) provisions for the extension available within existing primary and secondary equipment;
 - 2) in-service conditions or operating restrictions that apply;
 - 3) safety regulations that locally apply.

11.3.9 Basic input data by the manufacturer

These data should include:

- a) space necessary for installation and assembly;
- b) size and weight of components and testing equipment;
- c) site conditions regarding cleanliness and temperature for clean installation and preparation area;
- d) number and experience of local personnel required for installation;
- e) time and activity schedules for installation and commissioning;
- f) electric power, lighting, water and other needs for installation and commissioning;
- g) proposed training of installation and service personnel;
- h) in case of extension to existing switchgear and controlgear:

- 1) out-of-service requirements of existing components related to the installation schedule;
- 2) safety precautions.

i) gas filling procedure (mixed gases) and dew point verification, if necessary.

11.4 Operation

The operating instructions given by the manufacturer shall contain the following information:

- a general description of the equipment with particular attention to the technical description of its characteristics and operation so that the user has an adequate understanding of the main principles involved;
- a description of the safety features of the equipment and the operation of the interlocks and padlocking facilities;
- as relevant, a description of the action to be taken to manipulate the equipment for operation isolation, earthing, maintenance, and testing;
- as relevant, measures against corrosion should be given.

11.5 Maintenance

For disconnectors and earthing switches with any switching capability, the number of operations needs to be taken into account in order to estimate the maintenance intervals.

For maintenance purposes, the disconnector in gas-insulated switchgear shall be considered to have its full isolating properties only if the gas pressure is not lower than its minimum functional pressure (density).

11.5.1 General

The effectiveness of maintenance depends mainly on the way instructions are prepared by the manufacturer and implemented by the user.

11.5.2 Information about fluids and gas to be included in maintenance manual

Where applicable, the following information shall be provided by the manufacturer:

- a) type and required quantity and quality of liquid to be used in switchgear and controlgear;
- b) type and required quantity and quality of gas to be used in switchgear and controlgear.

11.5.3 Recommendations for the manufacturer

The manufacturer should be responsible for ensuring the continued availability of spare parts required for maintenance for a period of not less than 10 years from the date of final manufacture of the switchgear and controlgear.

The manufacturer should inform the purchasers of a particular type of switchgear and controlgear about corrective actions required by systematic defects and failures detected in service.

The manufacturer's maintenance manual should include the following information listed below.

- a) Extent and frequency of maintenance. For this purpose the following factors should be considered:

- 1) switching operations (current and number);
- 2) total number of operations;
- 3) time in service (periodic intervals);

- 4) environmental conditions;
- 5) activity after a seismic event (if applicable);
- 6) measurements and diagnostic tests, (if any).

b) Detailed description of the maintenance work:

- 1) recommended place for the maintenance work (indoor, outdoor, in factory, on site, etc.);
- 2) procedures for inspection, diagnostic tests, examination, overhaul;
- 3) reference to drawings;
- 4) reference to part numbers;
- 5) use of special equipment or tools;
- 6) precautions to be observed (for example cleanliness and possible effects of harmful arcing by-products);
- 7) lubrication procedures.

c) Comprehensive drawings of the details of the switchgear and controlgear important for maintenance, with clear identification (part number and description) of assemblies, subassemblies and significant parts.

NOTE Expanded detail drawings which indicate the relative position of components in assemblies and subassemblies are a common illustration method.

d) Limits of values, which can be measured during operation or routine maintenance and tolerances which, when exceeded, make corrective action necessary, for example:

- 1) pressures, density levels, gas mixtures tolerance;
- 2) resistance and/or capacitance (of the main circuit);
- 3) operating times;
- 4) resistance of the main circuits;
- 5) insulating liquid or gas characteristics;
- 6) quantities and quality of liquid or gas (see IEC 60480 and IEC 62271-4 for SF₆);
- 7) dew point inside gas-filled switchgear compartment according to 11.3.6;
- 8) permissible erosion of parts subject to wear;
- 9) torques;
- 10) important dimensions.

e) Specifications for auxiliary maintenance materials, including warning of known non-compatibility of materials:

- 1) grease;
- 2) oil;
- 3) fluid;
- 4) cleaning and degreasing agents.

f) List of special tools, lifting and access equipment.

g) Tests after the maintenance work.

h) List of the recommended spare parts (description, reference number, quantities) and advice for storage.

i) Estimate of active scheduled maintenance time, carried out in accordance with an established time schedule.

j) How to proceed with the equipment at the end of its operating life, taking into consideration environmental requirements.

11.5.4 Recommendations for the user

If the user wishes to perform maintenance, the maintenance manual of the manufacturer should be followed.

The user should record the following information:

- the serial number and the type of the switchgear and controlgear;
- the date when the switchgear and controlgear is put in service;
- the results of all measurements and tests including diagnostic tests carried out during the life of the switchgear and controlgear;
- dates and extent of the maintenance work carried out;
- the history of service, periodical records of the operation counters and other indications (for example short-circuit operations);
- references to any failure report.

In case of failure and defects, the user should make a failure report and should inform the manufacturer by stating the special circumstances and measures taken. Depending upon the nature of the failure, an analysis of the failure should be made in collaboration with the manufacturer.

11.5.5 Failure report

The purpose of the failure report is to standardize the recording of the switchgear and controlgear failures with the following objectives:

- to describe the failure using a common terminology;
- to provide data for the user statistics;
- to provide a meaningful feedback to the manufacturer.

The following gives guidance on how to make a failure report.

A failure report should include the points listed below.

a) Identification of the switchgear which failed:

- 1) substation name;
- 2) identification of the switchgear (manufacturer, type, serial number, ratings);
- 3) switchgear technology (air blast, minimum oil, SF₆, vacuum);
- 4) location (indoor, outdoor);
- 5) enclosure;
- 6) drive mechanism, if applicable (hydraulic, pneumatic, spring, motor, manual).

b) History of the switchgear:

- 1) date of commissioning of the equipment;
- 2) date of failure/defect;
- 3) total number of operating cycles, if applicable;
- 4) date of last maintenance;
- 5) details of any changes made to the equipment since manufacture;
- 6) total number of operating cycles since last maintenance;
- 7) condition of the switchgear when the failure/defect was discovered (in service, maintenance, etc.).

c) Identification of the subassembly/component responsible for the primary failure/defect:

- 1) high-voltage stressed components;
- 2) electrical control and auxiliary circuits;
- 3) drive mechanism, if applicable;
- 4) other components.

d) Stresses presumed to contribute to the failure/defect:

- 1) operation mistake or misuse of the equipment;
- 2) environmental conditions (temperature, wind, rain, snow, ice, pollution, lightning, etc.).

e) Classification of the failure/defect:

- 1) major failure;
- 2) minor failure;
- 3) defect.

f) Origin and cause of the failure/defect:

- 1) origin (mechanical, electrical, tightness if applicable);
- 2) cause (design, manufacture, inadequate instructions, incorrect mounting, incorrect maintenance, stresses beyond those specified, etc.);
- 3) operation mistake or misuse.

g) Consequences of the failure or defect:

- 1) switchgear down-time, which is time interval during which an item is in a down state;
- 2) time consumption for repair;
- 3) labour cost;
- 4) cost of spare parts.

A failure report may include the following information:

- drawings, sketches;
- photographs of defective components;
- single-line station diagram;
- operation and timing sequences;
- records or plots;
- references to maintenance or operating manuals.

12 Safety

12.1 General

High-voltage switchgear and controlgear, complying with the applicable IEC standards, can be considered safe when installed in accordance with the relevant installation rules including instructions provided by the manufacturers and used and maintained in accordance with the manufacturer's instructions (see Clause 11).

High-voltage switchgear and controlgear is normally only accessible by instructed persons. Performing operations and maintenance is only allowed to skilled persons. When unrestricted access is available to switchgear and controlgear, additional safety features may be required.

High-voltage switchgear and controlgear in accordance with IEC offers a high level of safety with regard to external effects that might harm personnel, mainly because the high-voltage parts may be surrounded by an enclosure. Nevertheless, high power equipment, can comprise some potential risks, some examples are:

- the enclosures, if any, may be pressurized with gas;

- pressure-relief devices may open due to exceptional conditions, e.g. resulting from an internal arc. In extreme circumstances, the arc can burn through the enclosures. Both result in the sudden release of hot gas;
- sudden events, which are in themselves with low risk to humans, may alarm personnel and lead to accidents (for example, a fall);
- commissioning, maintenance and extension activities may require special attention due to the complexity of the equipment and its internal parts which are mostly not visible.

Experience has shown that human error is a factor that shall be considered (for example, closing an earthing switch on an energized conductor).

NOTE The terms "skilled person" and "instructed person" are defined in IEC 826-09-01 and IEC 826-09-02, respectively. The requirements for "skilled person" and "instructed person" can deviate depending on local safety rules.

For actuating principles, refer to IEC 60447:2004 [5].

12.2 Precautions by manufacturers

The following list provides examples of precautions usually implemented by manufacturers.

- design and test pressurized enclosures, pressure relief devices and relevant switchgear elements to international established standards;
- provide adequate and easy means to check interlocking systems (the most reasonable way to avoid human error);
- explain safe operation of the switchgear and controlgear clearly in instruction manuals. Explain precautions to prevent improper operation and the consequences of improper operation;
- provide the user and/or contractor with appropriate information related to design of the surrounding area, possibly ventilation and gas detection information, to minimize personnel risks in case a failure occurs;
- provide safe procedures for dismantling and disposal.

12.3 Precautions by users

The following list provides examples of precautions that may be taken by users:

- limit access to the installation to people who are trained and authorized;
- keep operators and other personnel instructed regarding risks and safety requirements including local regulations;
- keep switchgear and controlgear maintained and up to date in terms of technical standards, especially interlocking and protection devices;
- use remote control and have the interlocking system working as intended;
- select equipment that minimizes the risk to personnel from improper operation (for example earthing switches with short-circuit making capacity on lines, motor actuators to allow remote operation);
- coordinate the protection system with product properties (for example, do not reclose on internal faults);
- prepare earthing procedures considering the difficulty of referring to and understanding the complex arrangement and operation of the switchgear and controlgear;
- label equipment clearly for easy identification of individual devices and gas compartments.

Especially during maintenance, repair or extension work:

- ensure that maintenance, repair and extension work is carried out only by qualified and trained personnel;

- prepare a safety and protection plan for the work. Indicate who is responsible for planning, implementing and enforcing safety and protection measures;
- check interlocking and protection devices before starting;
- pay special attention to manual operations, especially when the switchgear and controlgear is energized;
- inform personnel who may be near the switchgear and controlgear before operating the equipment (for example, a horn or flashing light);
- mark emergency exits and keep passages clear of obstructions;
- instruct the people involved how to work safely in a switchgear and controlgear environment and what to do in an emergency.

13 Influence of the product on the environment

Documentation shall include the following relevant information about the environmental impact of the switchgear:

- a) When fluids are used in switchgear and controlgear, instructions shall be provided in order to allow the user to:
 - 1) minimize the leakage rate as far as is practicable;
 - 2) control the handling of the new and used fluids. IEC 62271-4 is referred to for SF₆ and its mixtures refer to IEC 62271-4.
- b) Instructions concerning disassembly and end-of-life procedures for the different materials of the equipment and indicate the possibility to recycle.

Annex A (normative)

Identification of test objects

A.1 General

For identification of a test object, the following topics shall be covered.

A.2 Data

- Manufacturer's name;
- Type designation, ratings and serial number of apparatus;
- Outline description of apparatus (including number of poles, interlocking system, busbar system, earthing system, and the arc extinguishing process);
- Make, type, serial numbers, ratings of essential parts, where applicable (for example, drive mechanisms, interrupters, shunt impedances, relays, fuse links, insulators);
- Rated characteristics of fuse links and protective devices;
- Whether the apparatus is intended for operation in the vertical and horizontal plane.

A.3 Drawings

Drawings to be submitted	Drawing content (as applicable)
Single-line diagram of main circuit	Type designation of principal components
General layout NOTE For an assembly it may be necessary to provide drawings of the complete assembly and of each switching device.	Overall dimensions Supporting structure and mounting points Enclosure(s) Pressure-relief devices Conducting parts of main circuit Earthing conductors and earthing connections Electrical clearances: – to earth, between open contacts; – between poles. Location and dimensions of barriers between poles Location of earthed metallic screens, shutters or partitions in relation to live parts Liquid insulation level Location and type designation of insulators Location and type designation of instrument transformers
Detailed drawings of insulators	Material Dimensions (including profile and creepage distances)
Arrangement drawings of cable boxes	Electrical clearances Principal dimensions Terminals Level or quantity and specifications of insulant in filled boxes Cable termination details

Drawings to be submitted	Drawing content (as applicable)
Detailed drawings of parts of the main circuit and associated components	Dimensions and material of principal parts Cross-sectional view through the axis of main and arcing contacts Travel of moving contacts Electrical clearance between open contacts Distance between point of contact separation and end of travel Assembly of fixed and moving contacts Details of terminals (dimensions, materials) Identity of springs Material and creepage distances of insulating parts
Detailed drawings of mechanisms (including coupling and drive mechanisms)	Arrangement and identity of main components of the kinematic chains to: – main contacts; – auxiliary switches; – pilot switches; – position indication. Latching device Assembly of drive mechanism Interlocking devices Identity of springs Control and auxiliary devices
Electrical diagram of auxiliary and control circuits (if applicable)	Type designation of all components

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Annex B (informative)

Determination of the equivalent RMS value of a short-time current during a short-circuit of a given duration

The method illustrated in Figure B.1 could be used to determine the short-time current, if no digital equipment provides the proper computation (refer to 7.6.3).

The total time t_t of the test is divided into 10 equal parts by verticals 0 – 0,1... 1 and the RMS value of the AC component of the current is measured at these verticals.

These values are designated: $Z_0, Z_1... Z_{10}$

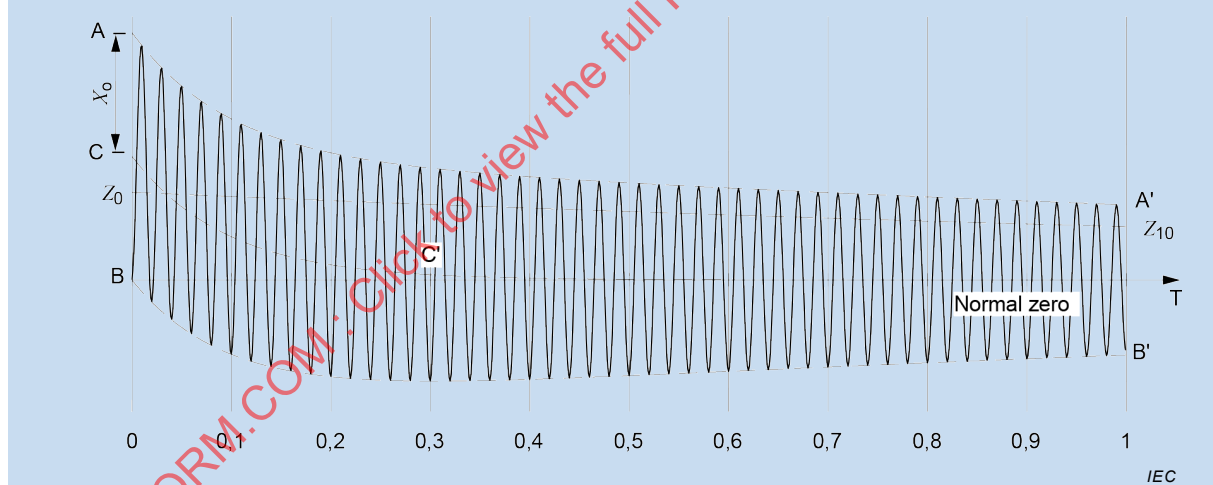
where

$Z = X/\sqrt{2}$ and X is the peak value of AC component of current.

The equivalent RMS current during the time t_t is given by:

$$I_t = \sqrt{\frac{1}{30} \left[Z_0^2 + 4(Z_1^2 + Z_3^2 + Z_5^2 + Z_7^2 + Z_9^2) + 2(Z_2^2 + Z_4^2 + Z_6^2 + Z_8^2) + Z_{10}^2 \right]}$$

The DC component of current represented by CC' is not taken into account.



Key

AA'	Envelopes of current wave
BB'	
CC'	Displacement of current wave zero line from normal zero line at any instant
$Z_0...Z_{10}$	RMS value of AC component of current at any instant measured from normal zero
X_0	Peak value of AC component of current at instant of initiating short-circuit
BT	Duration of short-circuit, t_t

Figure B.1 – Determination of short-time current

Annex C (normative)

Method for the weatherproofing test for outdoor switchgear and controlgear

The switchgear and controlgear to be tested shall be fully equipped and complete with all covers, screens, bushings, etc., and placed in the area to be subjected to with artificial precipitation. For switchgear and controlgear comprising several functional units a minimum of two units shall be used to test the joints between them.

The artificial precipitation shall be supplied by a sufficient number of nozzles to produce a uniform spray over the surfaces under test. The various parts of the switchgear and controlgear may be tested separately, provided that a uniform spray is simultaneously applied also to both of the following:

- a) the top surfaces from nozzles located at a suitable height;
- b) the floor outside the equipment for a distance of 1 m in front of the parts under test with the equipment located at the minimum height above the floor level specified by the manufacturer.

Where the width of the equipment exceeds 3 m, the spray may be applied to 3 m wide sections in turn. Pressurized enclosures need not be submitted to artificial precipitation.

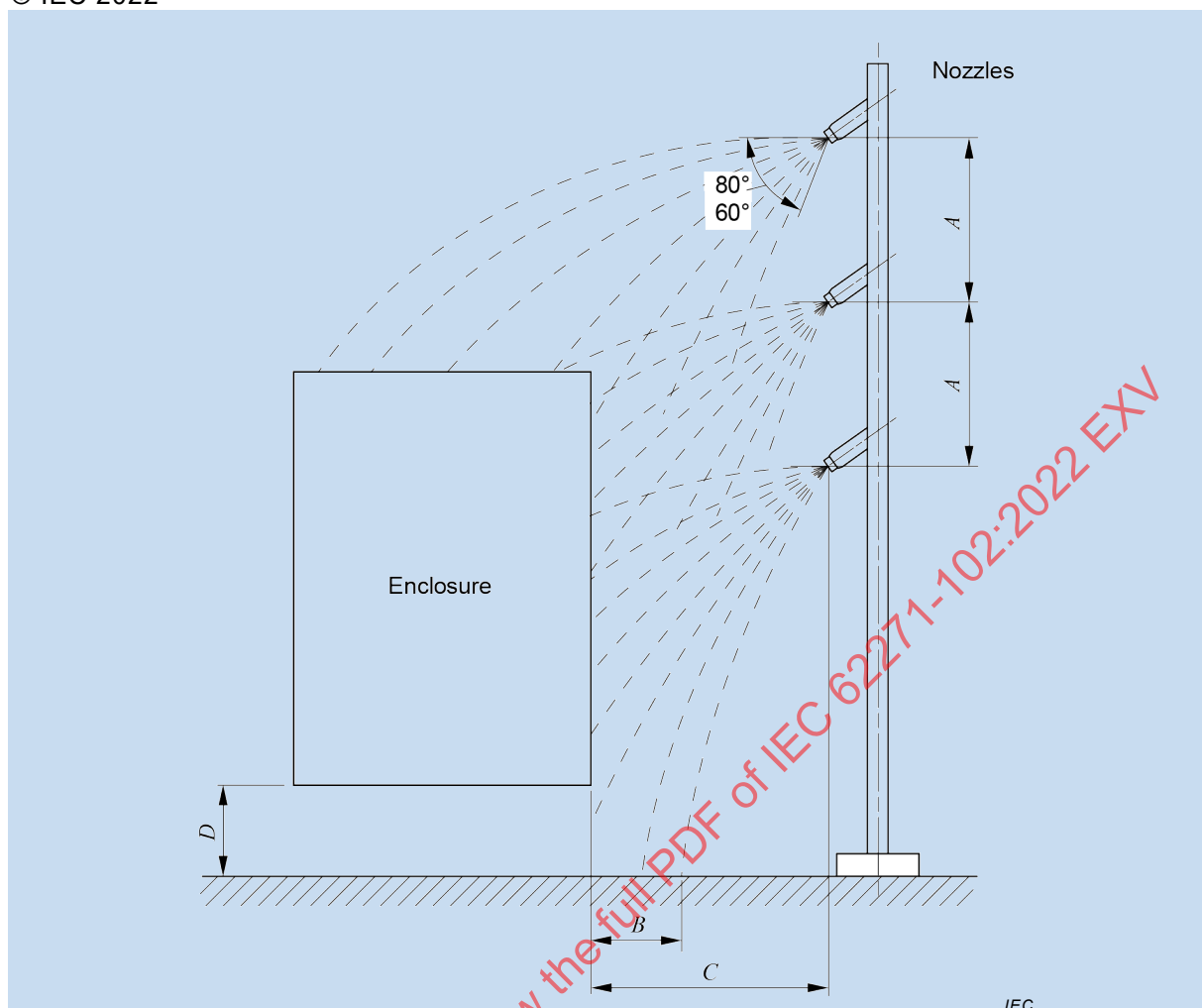
Each nozzle used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of $30 \text{ l/min} \pm 3 \text{ l/min}$ at a pressure of $460 \text{ kPa} \pm 46 \text{ kPa}$ and a spray angle of 60° to 80° . The centre lines of the nozzles shall be inclined downwards so that the top of the spray is horizontal as it is directed towards the surfaces being tested. It is convenient to arrange the nozzles on a vertical stand-pipe and to space them about 2 m apart (refer to test arrangement in Figure C.1).

The pressure in the feed pipe of the nozzles shall be $460 \text{ kPa} \pm 46 \text{ kPa}$ under flow conditions. The rate at which water is applied to each surface under test shall be about 5 mm/min, and each surface so tested shall receive this rate of artificial precipitation for duration of 5 min. The spray nozzles shall be at a distance between 2,5 m and 3 m from the nearest vertical surface under test.

NOTE When a nozzle in accordance with Figure C.2 is used, the quantity of water is considered to be in accordance with this standard when the pressure is $460 \text{ kPa} \pm 10 \%$.

After the test is completed, the equipment shall be inspected promptly to determine whether the following requirements have been met:

- a) no water shall be visible on the insulation of the main and auxiliary circuits;
- b) no water shall be visible on any internal electrical components and drive mechanisms of the equipment;
- c) no significant accumulation of water shall be retained by the structure or other non-insulating parts (to minimize corrosion).



<i>A</i>	About 2 m
<i>B</i>	1 m
<i>C</i>	2,5 m to 3 m
<i>D</i>	Minimum height above floor

Figure C.1 – Arrangement for weatherproofing test

Dimensions in millimetres

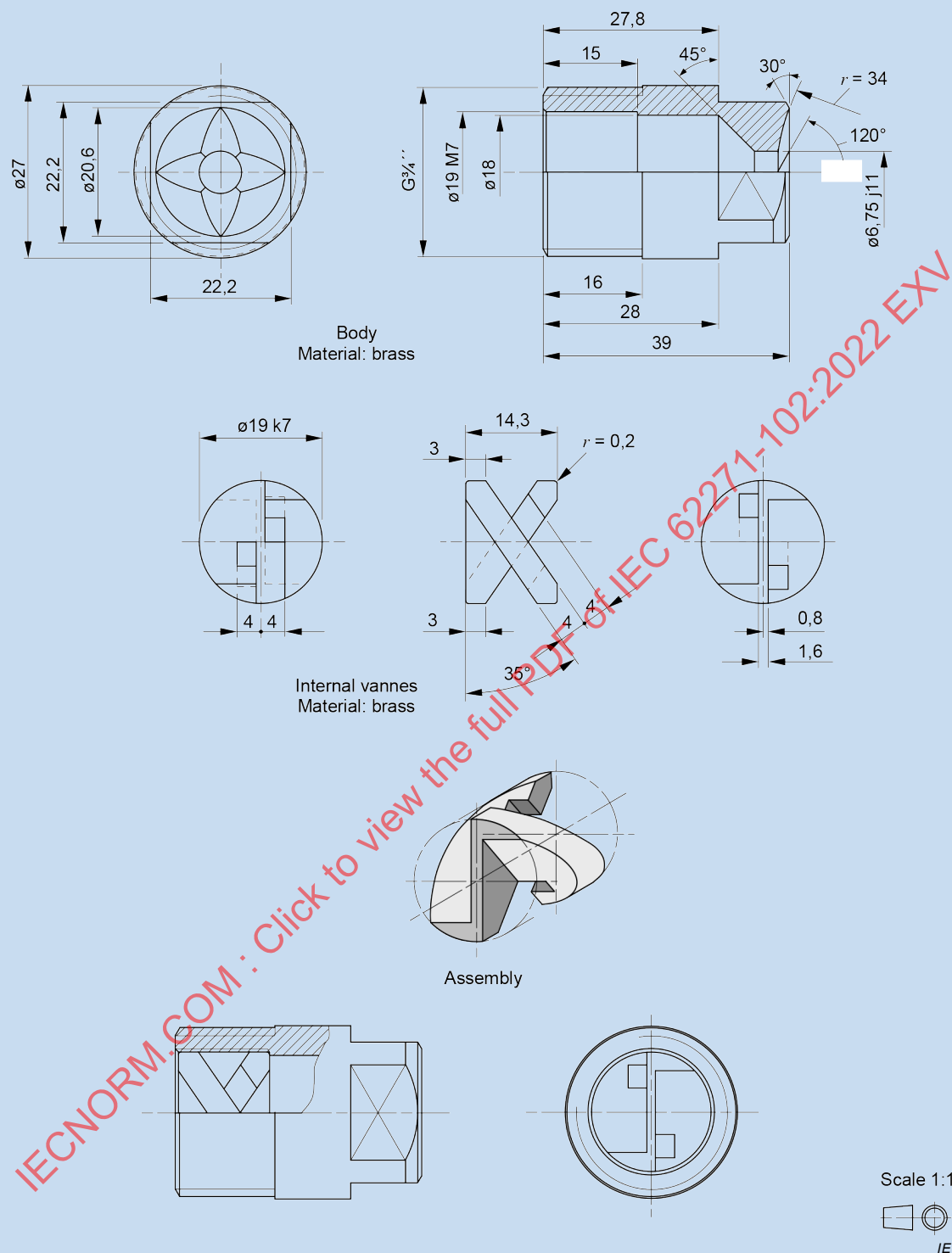


Figure C.2 – Nozzle for weatherproofing test

Annex D (informative)

References for auxiliary and control circuit components

Table D.1 is provided as a quick reference to many of the component standards. The latest editions should be used.

Table D.1 – List of reference documents for auxiliary and control circuit components (1 of 2)

Device		IEC standard
Cables and wiring	Insulation of PVC wiring	IEC 60227 (all parts) [36]
	Size and area of conductors	IEC 60228 [37]
	Insulation of rubber cable	IEC 60245 (all parts)[38]
	Identification	IEC 60445 [39]
Terminals	Terminal blocks for round wire	IEC 60947-7-1 [40]
	Protective terminal blocks for round wire	IEC 60947-7-2 [41]
	Identification	IEC 60445 [39]
Relays	All-or-nothing relays	IEC 61810 (all parts) [42]
	Voltage ratings and operating range of all-or-nothing relays	IEC 61810-1 [43]
	Performance of relay contacts	IEC 61810-2 [44]
Contactors and motor starters	Electromechanical contactors for closing and opening electrical circuit	IEC 60947-4-1 [45]
	Electromechanical contactors combined with relay for short-circuit protection	IEC 60947-2 [46]
	Motor starters (AC)	IEC 60947-4-1 [45]
	AC semiconductor motor controllers	IEC 60947-4-2 [47]
	Motor protective overload relays	IEC 60947-4-1 [45]
Low-voltage switches	Low-voltage switches for motor circuits and distribution circuits	IEC 60947-3 [48]
	Manual control switches and push-buttons	IEC 60947-5-1 [49]
	Pilot switches: pressure, temperature switches etc.	IEC 60947-5-1 [49]
	Household humidity sensing controls	IEC 60730-2-13 [50]
	Household switches	IEC 60669-1 [51]
	Household thermostats	IEC 60730-2-9 [52]
	Lever (toggle) switch	IEC 61020-1 [53]
	Graphical symbols for manual switches	IEC 60417 [26]
	Colours of lights for manual switches	IEC 60073 [25]

Table D.1 (2 of 2)

Device		IEC standard
Low-voltage circuit-breakers and low-voltage circuit-breakers with residual current protection	Requirements	IEC 60947-2 [46]
Low-voltage fuses	General requirements	IEC 60269-1 [54]
	Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K	IEC 60269-2 [55]
Low-voltage disconnectors	Requirements	IEC 60947-3 [48]
Motors	Requirements	IEC 60034-1 [56]
Meters	Analogue meters	IEC 60051-1 [57]
	Ammeters and voltmeters	IEC 60051-2 [58]
	Frequency meters	IEC 60051-4 [59]
	Phase-angle and power-factor meters	IEC 60051-5 [60]
Lamp used as an indicator	Requirements	IEC 60947-5-1 [49]
	Graphical symbols	IEC 60417 [26]
	Colour lights	IEC 60073 [25]
Plugs, socket-outlets, and couplers	Requirements for plugs, sockets-outlet, industrial cable couplers, appliance couplers	IEC 60309-1 [61]
	Dimensional and interchangeability	IEC 60309-2 [62]
	Household plugs, socket-outlets and couplers	IEC TR 60083 [63]
	Other couplers and plugs	IEC 60130 (all parts) [64]
Printed circuit-boards	Requirements	IEC 62326-1 [65]
Resistors	Potentiometers	IEC 60393-1 [66]
	Resistors 1 W to 1 000 W	IEC 60115-4 (all parts) [67]
Illumination	Illumination fluorescents	IEC 60081 [68]
	Tungsten filament lamps	IEC 60064 [69]
NOTE For electronic components used in auxiliary and control equipment additional information can be found in IEC TR 62063 [70].		

Annex E (normative)

Tolerances on test quantities during tests

During type tests, the following types of tolerances may normally be distinguished:

- tolerances on test quantities which directly determine the stress of the test object;
- tolerances concerning features or the behaviour of the test object before and after the test;
- tolerances on test conditions;
- tolerances concerning parameters of measurement devices to be applied.

A tolerance is defined as the range of the test value specified in the standard within which the measured test value shall lie for a test to be valid. In certain cases the test may remain valid even if the measured value falls outside the range: this is the case when it results in a more severe test condition.

Any deviation between the measured test value and the true test value caused by the uncertainty of the measurement are not taken into account in this respect.

The basic rules for application of tolerances on test quantities during type tests are as follows:

- a) testing stations shall aim wherever possible for the test value specified;
- b) the tolerances on test quantities specified shall be observed by the testing station. Higher stresses exceeding those tolerance are permitted only with the consent of the manufacturer;
- c) where, for any test quantity, no tolerance is given within this standard, or the standard to be applied, the type test shall be not less severe than specified. The upper stress limits are subject to the consent of the manufacturer.

Table E.1 – Tolerances on test quantities for type test

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.2 up to 7.2.12	Dielectric tests				
7.2.7.2, 7.2.8.2, 7.2.12, 7.10.5	Power-frequency voltage tests	Test voltage (RMS value)	Rated short-duration power frequency withstand voltage	±1 %	IEC 60060-1:2010
		Frequency	–	45 Hz to 65 Hz	
		Wave shape	Peak value / RMS value = $\sqrt{2}$	±5 %	
7.2.7.3 and 7.2.8.4	Lightning impulse voltage tests	Peak value	Rated lightning impulse withstand voltage	±3 %	IEC 60060-1:2010
		Front time	1,2 µs	±30 %	
		Time to half-value	50 µs	±20 %	
7.2.8.3	Switching impulse voltage tests	Peak value	Rated switching impulse withstand voltage	±3 %	IEC 60060-1:2010
		Front time	250 µs	±20 %	
		Time to half-value	2 500 µs	±60 %	
7.3 and 7.9.1.1	Radio interference voltage tests	Test voltage		±1 %	
		Tune frequency of measurement circuit		Within +10 % of 0,5 MHz or between 0,5 MHz to 2 MHz	
7.4.4	Measurement of the resistance of circuits	DC test current, I_{DC}	–	50 A < I_{DC} ≤ rated continuous current , or –20 %, +0 % of I_r ≤ 50 A	
7.5	Continuous current tests	Ambient air velocity	–	≤ 0,5 m/s	
		Test current frequency	Rated frequency	–5 %, +2 %	
		Test current	Rated continuous current	–0 %, +2 % These limits shall be kept only for the last two hours of testing period	
		Ambient air temperature T_a	--	10 °C < T_a ≤ 40 °C	
7.6	Short-time withstand current and peak withstand current tests	Test frequency	Rated frequency	±10 % at the beginning of the test, –20 %, +10 % at the end	
		Peak current (in one of the outer phases)	Rated peak withstand current	–0 %, +5 %	

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
		Average of AC component of three-phase test current	Rated short-time withstand current	See tolerances for I^2t in 7.6.3	7.6.3
		Ratio of AC component of test current in any phase versus average of the three phases	1	±10 %	
		Short-circuit current duration	Rated short-circuit duration	Maximum 5 s	7.6.3
		Value of I^2t	Value I^2t Derived from rated values short-time withstand current and duration.	–0 %, +10 %	
7.9.2.3	Oscillatory wave immunity test	Damped oscillatory wave tests	Test frequency 100 kHz, 1 MHz	±30 %	IEC 61000-4-18
7.10.3.3	Auxiliary contact rated short-time withstand current	Test current amplitude		–0 %, +5 %	
		Test current duration		–0 %, +10 %	
7.10.3.4	Auxiliary contact breaking capability	Test voltage amplitude		–0 %, +10 %	
		Test current amplitude		–0 %, +5 %	
		Circuit time constant		–0 %, +20 %	
7.10.4.2	Cold tests	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-1: 2007
7.10.4.3	Dry heat test	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-2: 2007
7.10.4.4	Cyclic humidity test	Minimum temperature of cycle		±3 K	IEC 60068-2-30: 2005
		Maximum temperature of cycle		± 2 K	
7.10.4.5	Vibration response and seismic tests				IEC 60255-21-1: 1988
7.11.1.3	Radiation instrument	Accuracy measurement of radiation		±25 %	
	Energy response	Accuracy measurement of energy		±15 %	

Annex F (informative)

Information and technical requirements to be given with enquiries, tenders and orders

F.1 General

This annex provides a list of useful technical information items in a tabular form to be considered for possible exchange between user and supplier during contracting stage.

When in the table "supplier information" is mentioned, this means that only the supplier needs to deliver this information.

Attention should be paid to the fact that such table should be complemented with information and characteristics relevant for the type of switchgear and controlgear considered; see product standards.

F.2 Normal and special service conditions (refer to Clause 4)

		User requirements	Supplier proposals
Service condition	Indoor or outdoor		
Ambient air temperature:			
Minimum	°C		
Maximum	°C		
Solar radiation	W/m ²		
Altitude	m		
Pollution	Class		
Excessive dust or salt			
Ice coating	mm		
Wind	m/s		
Humidity	%		
Condensation or precipitation			
Vibration	Class		
Induced electromagnetic disturbance in auxiliary and control circuits	kV		

F.3 Ratings (refer to Clause 5)

		User requirements	Supplier proposals
Rated voltage for equipment (U_r)	kV		
Rated insulation levels phase to earth and between phases			
Rated short-duration power-frequency withstand voltage (U_d)	kV		
Rated switching impulse withstand voltage (U_s)	kV		
– phase to earth	kV		
– between phases	kV		
Rated lightning impulse withstand voltage (U_p)	kV		
Rated frequency (f_r)	Hz		
Rated continuous current (I_r)	A	According single line	
Rated short-time withstand current (I_k)	kA		
Rated peak withstand current (I_p)	kA		
Rated duration of short-circuit (t_k)	s		
Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)	V		
Rated supply frequency of closing and opening devices and of auxiliary circuits	Hz	DC or 50 or 60	

F.4 Design and construction (refer to Clause 6)

To be complemented with information provided by relevant product standards.

		User requirements	Supplier proposals
Number of phases	Three- or single-phase encapsulation		
Mass of the heaviest transport unit			
Mounting provisions			
Type of gas-pressure or liquid-pressure system			
Overall dimensions of the installation			
Description by name and category of the various compartments			
Rated filling level and minimum functional level			
Low- and high-pressure interlocking and monitoring devices			
Interlocking devices			
Degrees of protection			
Arrangement of the external connections			
Accessible sides			
Volume of liquid or mass of gas or liquid for the different compartments			

		User requirements	Supplier proposals
Facilities for transport and mounting			
Instructions for operation and maintenance			
Specification of gas or liquid condition			

F.5 System information

		User information
Nominal voltage of system	kV	
Highest voltage of system	kV	
Number of phases		
Type of system neutral earthing		Effectively or non-effectively

F.6 Documentation for enquiries and tenders

	User requirements	Supplier proposals
Scope of supply (training, technical and layout studies and requirements for co-operation with other parties)		
Single-line diagram		
General arrangement drawings of substation layout		
Provisions for transport and mounting to be given by the user		
Foundation loading	Supplier information	
Gas schematic diagrams	Supplier information	
List of type test reports	Supplier information	
List of recommended spare parts	Supplier information	

Annex G (informative)

List of symbols

Description	Symbol	Subclause
Absolute leakage rate	F	3.6.6.4
Absolute leakage rate	F_{liq}	3.6.7.1
Alarm pressure (or density) for insulation and/or switching	$p_{\text{ae}} (\rho_{\text{ae}})$	3.6.5.3
Alarm pressure for operation (or density)	$p_{\text{am}} (\rho_{\text{am}})$	3.6.5.4
Filling pressure	p_{r}	7.8.2
Filling pressure (or density) for insulation and/or switching	$p_{\text{re}} (\rho_{\text{re}})$	3.6.5.1
Filling pressure (or density) for operation	$p_{\text{rm}} (\rho_{\text{rm}})$	3.6.5.2
Main circuit resistance measured before continuous current test	R_{u}	8.4
Measured pressure	p_{m}	7.8.2
Minimum functional pressure (or density) for insulation and/or switching	$p_{\text{me}} (\rho_{\text{me}})$	3.6.5.5
Minimum functional pressure for operation (or density)	$p_{\text{mm}} (\rho_{\text{mm}})$	3.6.5.6
Number of replenishments per day	N	3.6.6.8
Number of replenishments per day	N_{liq}	3.6.7.3
Partial voltage with respect to earth	U_{f}	7.2.6.3 b)
Permissible leakage rate	F_{p}	3.6.6.5
Permissible leakage rate	$F_{\text{p(liqu)}}$	3.6.7.2
Pressure drop	Δp	3.6.6.9
Pressure drop	Δp_{liq}	3.6.7.4
Protection against ingress of water coding	IP	6.14.3
Protection of equipment against mechanical impact under normal service conditions coding	IK	6.14.4
Radio interference voltage test	RIV	7.3
Rated continuous current	I_{r}	5.5
Rated duration of short-circuit	t_{k}	5.8
Rated frequency	f_{r}	5.4
Rated lightning impulse withstand voltage	U_{p}	5.3
Rated peak withstand current	I_{p}	5.7
Rated short-duration power-frequency withstand voltage	U_{d}	5.3
Rated short-time withstand current	I_{k}	5.6
Rated supply voltage	U_{a}	5.9.2
Rated supply voltage of closing and opening devices and of auxiliary and control circuits	U_{a}	5.9
Rated switching impulse withstand voltage	U_{s}	5.3
Rated voltage	U_{r}	5.2
Relative leakage rate	F_{rel}	3.6.6.6
Time between replenishments	t_{r}	3.6.6.7
Total test voltage	U_{t}	7.2.6.3 b)

Annex H **(informative)**

Electromagnetic compatibility on site

EMC site measurements are not type tests but may be performed in special situations:

- where it is deemed necessary to verify that actual stresses are covered by the EMC severity class of the auxiliary and control circuits;
- in order to evaluate the electromagnetic environment;
- in order to apply proper mitigation methods, if necessary;
- to record the electromagnetically induced voltages in auxiliary and control circuits, due to switching operations both in the main circuit and in the auxiliary and control circuits. It is not considered necessary to test all auxiliary and control circuits in a substation under consideration. A typical configuration should be chosen.

Measurement of the induced voltages should be made at representative ports in the interface between the auxiliary and control circuits and the surrounding network, for example, at the input terminals of control cubicles, without disconnection of the system. Instrumentation for recording induced voltages should be connected as outlined in IEC TR 60816 [71].

Switching operations should be carried out at normal operating voltage, both in the main circuit and in the auxiliary and control circuits. Induced voltages will vary statistically and thus a representative number of both making and breaking operations should be chosen, with random operating instants.

The switching operations in the main circuit are to be made under no-load conditions. The tests will thus include the switching of parts of the substation but no switching of load currents and no fault currents.

The making operations in the main circuit should be performed with trapped charge on the load side corresponding to normal operating voltage. This condition may be difficult to obtain at testing, and, as an alternative, the test procedure may be as follows:

- discharge the load side before the making operation, to assure that the trapped charge is zero;
- multiply recorded voltage values at the making operation by 2, in order to simulate the case with trapped charge on the load side.

The switching device in the primary system shall preferably be operated at rated pressure and auxiliary voltage.

NOTE 1 The most severe cases, with regard to induced voltages, will normally occur when only a small part of a substation is switched.

NOTE 2 The most severe electromagnetic disturbances are expected to occur at disconnector switching, especially for GIS installations.

The recorded or calculated peak value of induced common-mode voltage, due to switching in the main circuit, should not exceed 1,6 kV for interfaces of the auxiliary and control circuits.

Annex I
(informative)

List of notes concerning certain countries

With reference to Annex SC of *IEC/ISO Directives Supplement – Procedures specific to IEC*, (2016), an IEC National Committee may provide a statement to be included in an International Standard, informing the user of the standard of particular conditions existing in its country.

Clause	Text
6.14.1	NOTE In addition to IEC 60529 enclosures are to be designed to prevent unauthorized access by provided provisions for locking or requiring a special tool to open doors. Doors hinges and access panels are not externally removable (US).
6.14.2	NOTE The minimum default code is IP2XB (US)
7.2.12	NOTE The required test voltage for disconnectors and switch disconnectors of all rated voltages is 100 % of the tabulated voltage in columns (3) of Tables 1 or 2 and 3 or 4 (Canada).

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Annex J (informative)

Extension of validity of type tests

J.1 General

An individual type test need not be repeated in some situations e.g.:

- for a change of construction detail, if the manufacturer can establish that this change does not influence the result of that individual type test;
- for a change in the installation instructions, provided that the test conditions are not invalidated by the new instructions (e.g. see J.2);
- for covering other values of ratings for the same switchgear and controlgear, if these new ratings are covered by the tests already performed (e.g. see J.3 or when lower performances are requested).

Particular examples where extension of a type test may be used to validate design changes or other similar equipment, without repeating type tests, are given in the following subclauses. It should be noted that supporting evidence should be provided to validate such extensions of type tests.

More details may be given in the product standards and/or technical reports, e.g. IEC TR 62271-307 [72].

J.2 Dielectric tests

For non-enclosed conductors, the dielectric tests performed cover other dispositions having equal or higher clearances to surroundings (e.g. height above ground) and between conductors, if the insulating materials and shapes of conductors and insulators are the same.

J.3 Short-time withstand current tests

Short-time withstand current and peak withstand current tests performed at 50 Hz or 60 Hz, using a peak factor of 2,6, cover both frequencies for networks having a DC time constant of 45 ms or smaller.

Short-time withstand current and peak withstand current tests performed at 50 Hz or 60 Hz using a peak factor of 2,7, cover both frequencies for any DC time constants.

J.4 Continuous current test

A test performed on a single pole, or on a single unit, covers larger arrangements (i.e. three pole or multiple units) provided that the influence with other poles or other units is negligible, as it is generally the case for non-enclosed switchgear and controlgear; this provision is applicable, for instance, to some outdoor transmission devices.

As stated in 7.5.3.1:

- for switchgear and controlgear rated for both frequencies at 50 Hz and 60 Hz and having no ferrous components adjacent to the current-carrying parts, test can be performed at 50 Hz and cover both frequencies provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values;
- tests performed at 60 Hz cover both frequencies.

J.5 Electromagnetic immunity test on auxiliary and control circuits

Subassemblies may be positioned in different places within the auxiliary and control circuits, without invalidating the type test of the complete system, provided that the overall wiring length and the number of individual wires connecting the subassembly to the auxiliary and control circuits is not greater than in the tested system.

Interchangeable subassemblies may be replaced by similar subassemblies, without invalidating the original type test, provided that:

- rules for design and installation given in IEC 61000-6-5 are followed;
- type tests have been performed on the most complete subassembly applicable to the type of switchgear and controlgear;
- manufacturer's design rules are the same as for the type-tested subassembly.

J.6 Environmental tests on auxiliary and control circuits

Environmental tests on auxiliary and control circuits need not be repeated if performance requirements are validated during environmental tests on a whole switchgear and controlgear.

Parts, or pieces of equipment, of auxiliary and control circuits validated in a given arrangement are validated also when used in a different arrangement of auxiliary and control circuits belonging to the same range of switchgear and controlgear equipment.

Tests performed with a given supply voltage for auxiliary and control circuit cover similar auxiliary and control circuits designed for lower supply voltages.

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Annex K (informative)

Exposure to pollution

K.1 General

The quality of ambient air with respect to pollution by dust, smoke, corrosive and/or flammable gases, vapours, or salt is a consideration under normal and special service conditions (refer to Clause 4 of this document). This annex defines levels of pollution as well as recommendations for the minimum specific creepage distance across external insulation.

K.2 Pollution levels

For purposes of standardization, the levels of pollution, very light, light and medium, are qualitatively defined. The qualitative examples given in Table K.1 are approximate descriptions of some typical corresponding environments. Other more extreme environmental conditions may merit further consideration, e.g., snow and ice in heavy pollution, heavy rain, and arid areas. For these special conditions, reference is given to IEC TS 60815-1:2008, IEC TS 60815-2:2008 and IEC TS 60815-3:2008.

K.3 Minimum requirements for switchgear

The minimum creepage distance expressed as a specific creepage in mm/kV are for the normal service conditions of atmospheric contamination and altitudes up to 1 000 m. This minimum creepage provides generally satisfactory service operation under these conditions.

For each level of pollution described in Table K.1, the corresponding minimum recommended nominal unified specific creepage distance (USCD) in mm/kV across the insulator is given in Table K.2.

NOTE The information in Table K.1 is adapted from IEC TS 60815-1:2008; the values in Table K.2 are taken from IEC TS 60815-2:2008.

Table K.1 – Environmental examples by site pollution severity (SPS) class

SPS Class	Example of typical environments
Very light	Example 1: > 50 km^a from any sea, desert, or open dry land > 10 km from man-made pollution sources ^b Within a shorter distance than mentioned above of pollution sources, but: - prevailing wind not directly from these pollution sources - and/or with regular monthly rain washing
Light	Example 2: 10 km to 50 km^a from the sea, a desert, or open dry land 5 km to 10 km from man-made pollution sources ^b Within a shorter distance than example 1 from pollution sources, but: - prevailing wind not directly from these pollution sources - and/or with regular monthly rain washing
Medium	Example 3: 3 km to 10 km^c from the sea, a desert, or open dry land 1 km to 5 km from man-made pollution sources ^b Within a shorter distance than mentioned above of pollution sources, but: - prevailing wind not directly from these pollution sources - and/or with regular monthly rain washing Example 4: Further away from pollution sources than mentioned in example 3, but: - dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season - and/or heavy, high conductivity rain occurs - and/or there is a high non-soluble deposit level (refer to IEC TS 60815-1:2008)
Heavy and Very heavy	Refer to IEC TS 60815-1:2008.
^a During a storm, the ESDD level at such a distance from the sea may reach a much higher level. ^b The presence of a major city will have an influence over a longer distance, i.e. the distance specified for sea, desert and dry land. ^c Depending on the topography of the coastal area and the wind intensity.	

Table K.2 – Minimum nominal specific creepage distance by pollution level

SPS class	Minimum recommended nominal unified specific creepage distance (USCD) ^a mm/kV
Very light	22
Light	27,8
Medium	34,7
Heavy and Very heavy	Refer to IEC TS 60815-1:2008, IEC TS 60815-2:2008, and IEC TS 60815-3:2008
^a The unified specific creepage distance (USCD) is the creepage distance of an insulator divided by the RMS value of the highest operating voltage across the insulator. [SOURCE: IEC TS 60815-2:2008, 3.2]	

Annex A (informative)

Test voltage for the most disadvantageous dielectric position of an earthing switch during operation (minimum temporary clearance)

For standardization of dielectric strength in the most disadvantageous dielectric position of an earthing switch during operation, it has to be taken into consideration that:

- for $52 \text{ kV} < U_r \leq 170 \text{ kV}$, different types of neutral systems exist;
- for $U_r > 170 \text{ kV}$, the solid earthing of the neutral is the typical one.

Therefore:

- for the lower voltage range ($52 \text{ kV} < U_r \leq 170 \text{ kV}$), even if different neutral systems exist, it is reasonable to standardize only one test voltage, considering the most severe condition, which is the one of unearthed neutral systems;
- for the higher voltage range ($U_r > 170 \text{ kV}$), only the solid earthing of the neutral is considered for standardizing the test voltage.

Furthermore, for $U_r \geq 300 \text{ kV}$ the proportion of the power frequency withstand voltage to the system voltage is reduced compared with the proportion of the test voltage to the system voltage below 300 kV (in the higher range, switching impulse tests are standardized).

Because of the relatively low power-frequency withstand voltage for systems of 300 kV and above, the disconnectors and earthing switches of $U_r = 245 \text{ kV}$ have a singular position. On the one hand, they belong to the range with solidly earthed systems; on the other hand, they belong to the test voltage range below 300 kV . This makes it necessary, therefore, to consider whether to relate the required dielectric strength to the standardized power frequency withstand voltage (line-to-earth) or to the rated voltage.

A fixed relation to the line-to-earth withstand voltage would give too high a value for the lower rated voltages and too low a value for the higher rated voltages.

Since the safety distances in substations are not related to the dielectric test voltages but to the rated voltage, the dielectric strength for the minimum temporary clearance should also be related to the rated voltage and the earthing condition of the network. Also the fact should be considered that the test voltages might be changed once in a while, and this should not result in a change of the test voltage for the minimum temporary clearance.

For standardization, the following values are therefore suggested:

- a) for $52 \text{ kV} < U_r \leq 170 \text{ kV}$: $1,3 \times U_r$;
- b) for $U_r > 170 \text{ kV}$: $2 \times U_r / \sqrt{3}$.

For disconnectors with integrated earthing switches, the suggested test voltages with the earthing switch in the most disadvantageous dielectric position are given in Table 14 after taking into consideration the above-mentioned details. An impulse voltage test is not required because of the very low probability of a lightning or switching impulse during the earthing procedure.

Annex B (informative)

Current-switching capability required of disconnectors and earthing switches

B.1 Bus-transfer current switching capability of disconnectors

For disconnectors used to transfer load currents from one bus system to another, a capability to make and break bus-transfer currents is required. This requirement is applied to disconnectors of $U_r > 52$ kV.

The bus-transfer currents and voltages depend upon the magnitude of the load current and upon the size of the loop between the location(s) of the bus coupling and the location of the disconnector to be operated.

The values of the rated bus-transfer voltages in Table 7 are based on calculations of the bus-transfer current corresponding to the rated continuous current of the disconnector taking into account impedances as shown in Table B.1 and typical loop lengths as follows:

- loop length for gas-insulated installations: 65 m for $52 \text{ kV} < U_r < 245 \text{ kV}$ and 130 m for $U_r \geq 245 \text{ kV}$;
- loop length for air-insulated installations: 200 m for $52 \text{ kV} < U_r < 245 \text{ kV}$ and 400 m for $U_r \geq 245 \text{ kV}$.

Table B.1 – Average impedances

Rated voltage U_r kV	Average impedance $\mu\Omega/\text{m}$	
	Gas-insulated installations	Air-insulated installations
72,5	63	314
100		
123		
145		
170		
245 / 300	67	346
420		
550		361
800	76	355
1 100	80	388

B.2 Bus-charging current switching capability of disconnectors

Energizing or de-energizing unloaded sections of busbar duct or parallel capacitors of circuit-breakers is considered as capacitive switching. Very fast transient overvoltage (VFTO) phenomena occur as an inherent part of capacitive switching with disconnectors in gas-insulated metal-enclosed switchgear. Since the VFTO might cause disruptive discharges to earth, correct design of the disconnector is required to avoid disruptive discharges to earth. This requirement is normally applied to disconnectors of $U_r \geq 300$ kV.

For $U_r < 300$ kV, the VFTO does not become so high compared with the specified lightning impulse withstand voltage (LIWV) because the ratios between the LIWV and rated voltage are

sufficiently high. Simultaneous switching of several disconnectors in the same circuit is not advisable and thus not considered in this document.

As a special case for disconnectors used to de-energize long busbars or other energized parts, for example short lengths of cables, a capability of current-switching is required. This requirement can be applied not only to disconnectors of $U_r \geq 300$ kV but also of $U_r < 300$ kV.

With $U_r \geq 800$ kV the maximum VFTO in GIS systems can reach the insulation level of lightning impulse withstand voltage in certain cases. In such cases, resistor-fitted disconnectors may be used to mitigate the VFTO. Three different types of resistor-fitted disconnectors are given as examples in Figure B.1. The resistor can be positioned in parallel or in series to the switching gap. In the arc-commutation method, the current is switched to the parallel resistor during an opening operation by commutation of the arc from the main contact to the resistor contact.

Typical resistors of values 200Ω to $1\,000 \Omega$ are used. The overvoltage damping factor depends on the ratio of the resistance of the resistor and the system impedance.

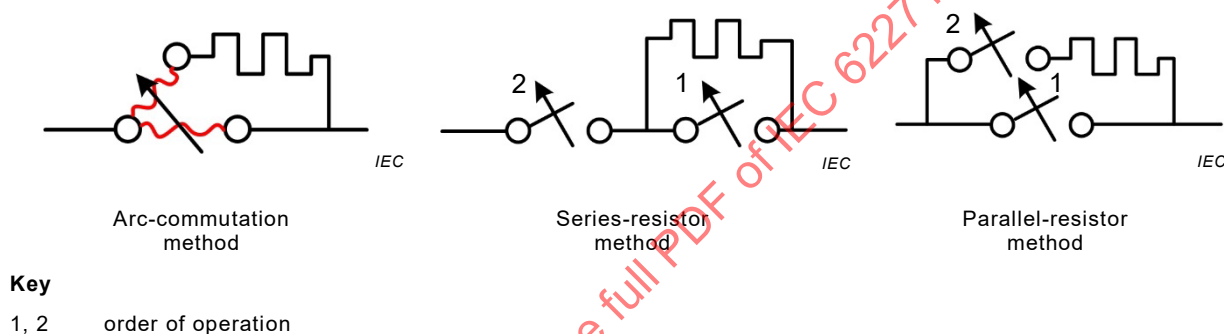


Figure B.1 – Examples of resistor-fitted disconnectors

B.3 Induced current-switching capability of earthing switches

For earthing switches used to earth multiple configurations of overhead transmission lines, a capability to make and break induced currents is required. This requirement is applied to earthing switches of $U_r > 52$ kV.

In the case of multiple configurations of overhead transmission lines, current can circulate in de-energized and earthed lines as a result of capacitive and inductive coupling with adjacent energized lines. Earthing switches applied to earth these lines shall therefore be capable of assuring the following service conditions:

- making and breaking of a capacitive current when the earth connection is open at one termination and earthing switching is performed at the other termination;
- making and breaking of an inductive current when the line is earthed at one termination and earthing switching is performed at the other termination;
- carrying continuously the capacitive and inductive currents.

Annex C (normative)

Tolerances on test quantities for type tests

A tolerance is defined as the range of the test values specified in the document within which the measured test value shall lie for a test to be valid.

Any deviation between the measured test value and the true test value caused by the uncertainty of the measurement are not taken into account in this respect.

Table C.1 states tolerances on test quantities for type tests.

Table C.1 – Tolerances on test quantities for type tests (1 of 2)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference
7.101	Short-circuit making tests of earthing switches	Test frequency	f_r	$\pm 10 \%$	7.101.3
		Test voltage (average phase to phase)	U_r	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4
		Any phase voltage / average (three-phase)	1	$\pm 5 \%$	7.101.4 a)
		Test voltage (average, single phase)	$U_r / \sqrt{3}$	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4 b)
		Test voltage (average, three-phase)	U_r	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4 b)
		Short-circuit current at 200 ms	I_k	$\geq 80 \%$	7.101.5
		Short-circuit making current (peak, prospective)	I_{ma}	$\left(\begin{smallmatrix} +5 \\ 0 \end{smallmatrix} \right) \%$	7.101.5
7.106	Bus-transfer current switching	Test frequency	f_r	$\pm 10 \%$	7.106.2.3
		Test voltage	U_{bt}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.106.2.4
		Test current	I_{bt}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.106.2.5
		Any phase current / average	1	$\pm 10 \%$	7.106.2.5
		Power factor of test circuit		$\leq 0,5$	7.106.2.6

Table C.1 (2 of 2)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference
7.107	Induced current switching	Test frequency	f_r	$\pm 10 \%$	7.107.4
		Test voltage	U_{im}, U_{is}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.5
		Any phase voltage / average	1	$\pm 10 \%$	7.107.5
		Test current	I_{im}, I_{is}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.6
		Any phase current / average	1	$\pm 10 \%$	7.107.6
		Power factor of supply circuit		$\leq 0,15$	7.107.7.2
		TRV peak (electromagnetically induced current)		$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.7.2
		Time to peak (electromagnetically induced current)		$\left(\begin{smallmatrix} 0 \\ -10 \end{smallmatrix} \right) \%$	7.107.7.2
7.108	Bus-charging current switching test	Test frequency	f_r	$\pm 10 \%$	7.108.4
		Test voltage	U_1, U_2	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.108.5
	Current switching capability test duty 3	Bus-charging current		$\pm 10 \%$	7.108.5

Annex D (normative)

Alternative test methods for short-circuit current making tests

D.1 General

In this annex applying to 7.101.5 a), alternative test methods are given to obtain the conditions corresponding to correct making current with correct pre-arcing time.

For the tests using alternative methods in which the required pre-arcing time is obtained, the making angle can be extended to -40 electrical degrees and $+15$ electrical degrees with reference to the voltage peak of the current source.

NOTE At -40 electrical degrees, the pre-arc energy is higher than within the limitation of -30 electrical and $+15$ electrical degrees.

For convenience of testing in a three-phase circuit it is allowed to have the maximum pre-arcing time only in one phase, while at the other two phases the current is applied at reduced voltage.

D.2 Alternative methods

D.2.1 Synthetic test method with both rated voltage and rated short-circuit current

The synthetic test methods as given in Clause 5 of IEC 62271-101:2012 may be applied.

The test circuit and specific requirements shall fulfil the requirement a) of 7.101.5.

D.2.2 Test methods with reduced voltage

D.2.2.1 General

To obtain comparable results between tests with rated voltage and alternative tests with reduced voltages, the pre-arcing time obtained during the making test with reduced voltage shall not be less than the pre-arcing time in the test with the rated voltage.

The test is split up in two parts:

- part 1: a test at rated voltage and reduced current to determine the pre-arcing time of the earthing switch;
- part 2: a test at reduced voltage and rated short-circuit making current, with the required pre-arcing time.

D.2.2.2 Part 1: determination of pre-arcing time

The pre-arcing time shall be determined by performing making tests at rated voltage and reduced current. The arrangement of the earthing switch shall be as described in 7.101.2. The current shall be low enough that the contact surface is not influenced by contact erosion. The pre-arcing time shall be determined at each of these tests.

Ten making tests performed to evaluate the pre-arcing time shall result in a current initiation instant corresponding to an angle of -15 electrical degrees to $+15$ electrical degrees on the peak of the applied AC voltage wave-shape. The average value of these valid pre-arcing times measured and the standard deviation (σ) shall be calculated to be applied in Part 2 (see D.2.2.3).

As an alternative, DC voltage may be used. The DC voltage shall correspond to the peak value of the test voltage. The pre-arcing time can differ depending on the polarity of the voltage at making. Therefore, 10 making tests shall be divided into 5 operations with positive polarity and 5 operations with negative polarity. The longest average pre-arcing time out of the two polarities and its standard deviation (σ) shall be calculated and applied in Part 2.

NOTE A travel transducer or an equivalent device can be used for the measurement of the pre-arcing time. In a three-phase device, one phase can be used for evaluating the pre-arcing time and the other phases can be used to measure the actual contact touch. A no-load operation with contact timing measurement on all three poles can be used to compensate time spread between poles.

D.2.2.3 Part 2: short-circuit current making tests at reduced voltage

During making tests with rated short-circuit current at reduced voltage, the pre-arcing time (see 7.101.5 a) shall be at least equal to the average of the pre-arcing time plus 2σ determined in the tests as described in Part 1 (see D.2.2.2).

The short-circuit current obtained during tests at reduced voltage shall be at least equal to the rated short-circuit current.

In order to obtain the required pre-arcing time, the initiation of the current can be achieved by the three methods listed below.

Method 1: A current source at reduced voltage and a voltage source of any wave form, high enough to initiate the pre-arcing at the correct point on the wave.

Method 2: For gas-insulated earthing switches, both the gas pressure and the applied voltage of the current source can be decreased such that the required pre-arcing time is still obtained.

Instead of just decreasing the gas pressure, the test object may also be filled with an alternative medium, such as air or nitrogen.

The speed at contact touch shall not change by more than 10 % due to the reduction of the gas pressure or replacing the gas by an alternative medium.

NOTE 1 It can be useful to estimate the required voltage at reduced pressure by the same method as described in Part 1 in order to obtain the correct pre-arcing time.

NOTE 2 In case that reduced pressure or alternative gas is used, the behaviour of the rupture disk cannot be verified, since the transient pressure can be lower or higher than expected in service conditions when service gas and rated filling pressure are used.

Method 3: A current source with reduced voltage and pre-arcing initiated by a fuse wire of maximum 0,5 mm diameter. The fuse wire is required in the pole to be tested for the short-circuit making current with the correct pre-arcing time.

NOTE 3 Some extra tests can be necessary to estimate the length of the fuse wire.

Annex E (informative)

Extension of validity of type tests

E.1 General

Annex J, except subclause J.2, of IEC 62271-1:2017 is applicable with the following addition:

Upon agreement between the manufacturer and the user, an individual type test does not need to be repeated for change of construction detail if the manufacturer can demonstrate that this change does not influence the result of that individual type test.

E.2 Dielectric tests

The rated voltage covers every voltage equal or less than the tested one.

E.3 Short-time withstand current tests

Test results obtained on a disconnector or earthing switch placed in a certain position (e.g. horizontal or vertical) are valid for the position of the disconnector or earthing switch during this test. However, in some cases, the position in which it is tested can validate other positions depending on the design and construction of the disconnector or earthing switch.

E.4 Short-circuit making performance of earthing switches

The rated voltage covers every network voltage equal or less than the tested one. The rated short-circuit making current covers every network short-circuit current equal or less than the tested one.

E.5 Operating and mechanical endurance tests

The test carried out on a given disconnector or earthing switch with a specified rated voltage and/or current covers lower rated voltage and/or current.

Interlocking devices of a given design may be used with other disconnectors and earthing switches, without repeating the type test, if the manufacturer can show the evidence that they work in the same way as they worked during the type test.

E.6 Bus-transfer current switching tests on disconnectors

Bus-transfer current switching elements of a given design may also be used within other disconnectors, without repeating the type test, if the manufacturer can show evidence that the bus-transfer current switching elements are operated by the other disconnector in the same way as by the disconnector with which the type test has been performed.

E.7 Induced current switching tests on earthing switches

Making and breaking elements of earthing switches having a rated induced current switching capability of a given design may also be used within other earthing switches without repeating the type test, if the manufacturer can show evidence that the making and breaking elements are operated by the other earthing switch in the same way as by the earthing switch with which the type test has been performed.

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**High-voltage switchgear and controlgear –
Part 102: Alternating current disconnectors and earthing switches**

**Appareillage à haute tension –
Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif**

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Part 102: Alternating current disconnectors and earthing switches**

**Appareillage à haute tension –
Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif**

6.4	Auxiliary and control equipment and circuits	35
6.5	Dependent power operation	35
6.6	Stored energy operation.....	35
6.7	Independent unlatched operation (independent manual or power operation)	35
6.8	Manually operated actuators	35
6.9	Operation of releases.....	35
6.10	Pressure/level indication	35
6.11	Nameplates.....	35
6.12	Locking devices	38
6.13	Position indication.....	38
6.14	Degree of protection provided by enclosures	38
6.15	Creepage distances for outdoor insulators	38
6.16	Gas and vacuum tightness.....	38
6.17	Tightness for liquid systems.....	38
6.18	Fire hazard (flammability)	38
6.19	Electromagnetic compatibility (EMC).....	38
6.20	X-ray emission	38
6.21	Corrosion	38
6.22	Filling levels for insulation, switching and/or operation.....	39
6.101	Particular requirements for earthing switches.....	39
6.102	Requirements in respect of the isolating distance of disconnectors	39
6.103	Mechanical strength.....	39
6.104	Operation of disconnectors and earthing switches – Position of the movable contact system and its indicating and signalling devices	40
6.104.1	Securing of position	40
6.104.2	Additional requirements for power-operated mechanisms	40
6.104.3	Indication and signalling of position	40
6.105	Maximum force required for manual (dependent or independent) operation.....	41
6.105.1	General	41
6.105.2	Operation requiring more than one revolution	42
6.105.3	Operation requiring up to one revolution	42
6.106	Dimensional tolerances.....	42
6.107	Earthing switches with short-circuit making current capability	42
7	Type tests	42
7.1	General.....	42
7.1.1	Basics	42
7.1.2	Information for identification of test objects.....	44
7.1.3	Information to be included in type test reports	44
7.2	Dielectric tests	44
7.2.1	General	44
7.2.2	Ambient air conditions during tests	44
7.2.3	Wet test procedure	44
7.2.4	Arrangement of the equipment.....	44
7.2.5	Criteria to pass the test	45
7.2.6	Application of the test voltage and test conditions.....	45
7.2.7	Tests of disconnectors and earthing switches of $U_T \leq 245$ kV.....	45
7.2.8	Test of disconnectors and earthing switches of $U_T > 245$ kV	45
7.2.9	Artificial pollution tests for outdoor insulators.....	45
7.2.10	Partial discharge tests	46

7.2.11	Dielectric tests on auxiliary and control circuits	46
7.2.12	Voltage test as condition check	46
7.3	Radio interference voltage (RIV) test	46
7.4	Resistance measurement	46
7.5	Continuous current tests	46
7.6	Short-time withstand current and peak withstand current tests	46
7.6.1	General	46
7.6.2	Arrangement of the disconnectors and earthing switches and of the test circuit	46
7.6.3	Test current and duration	52
7.6.4	Conditions of disconnectors and earthing switches after test	52
7.7	Verification of the protection	53
7.8	Tightness tests	53
7.9	Electromagnetic compatibility tests (EMC)	53
7.10	Additional tests on auxiliary and control circuits	53
7.11	X-ray radiation test for vacuum interrupters	53
7.101	Test to prove the short-circuit making performance of earthing switches	54
7.101.1	General test conditions	54
7.101.2	Arrangement of the earthing switch for tests	54
7.101.3	Test frequency	54
7.101.4	Test voltage	54
7.101.5	Test short-circuit making current	55
7.101.6	Test circuits	55
7.101.7	Test procedures	55
7.101.8	Behaviour of earthing switches when making short-circuit currents	56
7.101.9	Condition of earthing switch after short-circuit making tests	56
7.101.10	Invalid tests	57
7.101.11	Type test reports	57
7.102	Operating and mechanical endurance tests	58
7.102.1	General test conditions	58
7.102.2	Contact zone test	58
7.102.3	Mechanical endurance test	61
7.102.4	Operation during the application of rated static mechanical terminal loads	63
7.102.5	Extended mechanical endurance tests	64
7.102.6	Testing of mechanical interlocking devices	65
7.103	Operation under severe ice conditions	65
7.103.1	General	65
7.103.2	Test arrangement	65
7.103.3	Test procedure	66
7.104	Low- and high-temperature tests	67
7.104.1	General	67
7.104.2	Measurement of ambient air temperature	68
7.104.3	Low-temperature test	68
7.104.4	High-temperature test	70
7.105	Tests to verify the proper functioning of the position-indicating device	70
7.105.1	General	70
7.105.2	Tests on the power kinematic chain and the position-indicating kinematic chain	71
7.106	Bus-transfer current switching tests on disconnectors	71

7.106.1	General	71
7.106.2	Making and breaking tests	71
7.107	Induced current switching tests on earthing switches	75
7.107.1	General	75
7.107.2	Arrangement of the earthing switch for tests	75
7.107.3	Earthing of test circuit and earthing switch	76
7.107.4	Test frequency	76
7.107.5	Test voltage	76
7.107.6	Test currents	76
7.107.7	Test circuits	76
7.108	Bus-charging current switching tests on disconnectors	81
7.108.1	General	81
7.108.2	Test duties	82
7.108.3	Arrangement of the disconnector for tests	82
7.108.4	Test frequency	82
7.108.5	Test voltages for making and breaking tests	83
7.108.6	Test circuits for making and breaking tests	84
7.108.7	Performance of making and breaking tests	86
7.108.8	Behaviour of the disconnector during making and breaking tests	86
7.108.9	Condition after test	87
7.108.10	Type test reports	87
7.108.11	Requirements for U_{TVE} measurements	88
8	Routine tests	88
8.1	General	88
8.2	Dielectric test on the main circuit	88
8.3	Tests on auxiliary and control circuits	89
8.4	Measurement of the resistance of the main circuit	89
8.5	Tightness test	89
8.6	Design and visual checks	89
8.101	Mechanical operating tests	89
8.102	Verification of earthing function	90
9	Guide to the selection of disconnectors and earthing switches (informative)	90
9.1	General	90
9.2	Selection of rated values	91
9.2.101	General	91
9.2.102	Selection of rated voltage and rated insulation level	91
9.2.103	Selection of rated continuous current	91
9.2.104	Selection of rated contact zone	91
9.2.105	Selection of rated static mechanical terminal load	92
9.2.106	Selection of a bus-transfer current switching capability for disconnectors of $U_r > 52$ kV	92
9.2.107	Selection of an induced-current switching capability for earthing switches of $U_r > 52$ kV	92
9.2.108	Selection of rated short-time withstand current and of rated duration of short-circuit	92
9.2.109	Selection of rated peak withstand current and of rated short-circuit making current for earthing switches	93
9.2.110	Selection of short-circuit making capability for earthing switches	93
9.3	Cable-interface considerations	93

9.4	Continuous or temporary overload due to changed service conditions.....	93
9.5	Environmental aspects.....	93
9.5.101	Local environmental conditions.....	93
10	Information to be given with enquiries, tenders and orders (informative).....	94
10.1	General.....	94
10.2	Information with enquiries and orders	94
10.3	Information with tenders.....	95
11	Transport, storage, installation, operating instructions, and maintenance	96
11.1	General.....	96
11.2	Conditions during transport, storage and installation	96
11.3	Installation	96
11.4	Operation.....	97
11.5	Maintenance	97
12	Safety.....	97
12.1	General.....	97
12.2	Precautions by manufacturers.....	97
12.3	Precautions by users	97
13	Influence of the product on the environment	97
Annex A (informative)	Test voltage for the most disadvantageous dielectric position of an earthing switch during operation (minimum temporary clearance)	98
Annex B (informative)	Current-switching capability required of disconnectors and earthing switches.....	99
B.1	Bus-transfer current switching capability of disconnectors.....	99
B.2	Bus-charging current switching capability of disconnectors	99
B.3	Induced current-switching capability of earthing switches.....	100
Annex C (normative)	Tolerances on test quantities for type tests	101
Annex D (normative)	Alternative test methods for short-circuit current making tests.....	103
D.1	General.....	103
D.2	Alternative methods	103
D.2.1	Synthetic test method with both rated voltage and rated short-circuit current.....	103
D.2.2	Test methods with reduced voltage.....	103
Annex E (informative)	Extension of validity of type tests	105
E.1	General.....	105
E.2	Dielectric tests	105
E.3	Short-time withstand current tests.....	105
E.4	Short-circuit making performance of earthing switches.....	105
E.5	Operating and mechanical endurance tests.....	105
E.6	Bus-transfer current switching tests on disconnectors	105
E.7	Induced current switching tests on earthing switches	106
Bibliography		107
Figure 1	– Position indicating/signalling device(s).....	40
Figure 2	– Three-phase test arrangement for disconnectors and earthing switches	48
Figure 3	– Single-phase test arrangement for disconnectors with a horizontal isolating distance and for earthing switches of $U_T > 52$ kV, to be used with flexible or with rigid conductors	49

Figure 4 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52$ kV with a vertical isolating distance, to be used with flexible conductors	50
Figure 5 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52$ kV with a vertical isolating distance, to be used with rigid conductors	51
Figure 6 – Fixed contact parallel to support	59
Figure 7 – Fixed contact perpendicular to support	60
Figure 8 – Example of the application of rated static mechanical terminal loads to a (divided support) pantograph disconnector (or earthing switch)	61
Figure 9 – Example of the application of rated static mechanical terminal loads to a two-column disconnector	62
Figure 10 – Test sequences for low and high temperature tests	68
Figure 11 – Example of test circuit for bus-transfer current switching tests	73
Figure 12 – Test circuit for electromagnetically induced current switching tests	77
Figure 13 – Test circuits for electrostatically induced current-switching tests	79
Figure 14 – Test circuit for test duty 1	83
Figure 15 – Typical voltage waveform (Including VFT and FT components)	85
Figure 16 – Test circuit for test duty 2	85
Figure 17 – Test circuit for test duty 3	86
Figure B.1 – Examples of resistor-fitted disconnectors	100
Table 1 – Classification of earthing switches for short-circuit making	28
Table 2 – Preferred contact zones for "fixed" contacts supported by flexible conductors	29
Table 3 – Preferred contact zones for "fixed" contacts supported by rigid conductors	29
Table 4 – Preferred static mechanical terminal loads	30
Table 5 – Classification of disconnectors for mechanical endurance	31
Table 6 – Classification of earthing switches for mechanical endurance	31
Table 7 – Rated bus-transfer voltages of disconnectors	32
Table 8 – Classification of earthing switches for induced-current switching	32
Table 9 – Rated induced currents and voltages	33
Table 10 – Classification of disconnectors for bus-charging switching	34
Table 11 – Standard rated bus-charging currents	34
Table 12 – Product information	36
Table 13 – List of type tests	43
Table 14 – Power frequency withstand voltages	45
Table 15 – Requirements on the instant of making	56
Table 16 – Invalid tests	57
Table 17 – Standard values of recovery voltages for electromagnetically induced current breaking tests	78
Table 18 – Test circuit capacitances (C_1 values) for electrostatically induced current switching tests	80
Table 19 – Test voltages for making and breaking tests	83
Table 20 – Number of tests	86

Table 21 – Power frequency voltage tests	89
Table B.1 – Average impedances	99
Table C.1 – Tolerances on test quantities for type tests	101

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 102: Alternating current disconnectors and earthing switches

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 62271-102 edition 2.1 contains the second edition (2018-05) [documents 17A/1173/FDIS and 17A/1180/RVD] and its amendment 1 (2022-04) [documents 17A/1322/CDV and 17A/1337/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 62271-102 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

This second edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) new numbering according to IEC 17/1025/RQ to harmonize with ISO/IEC Directives, Part 2, and IEEE Std. C37.100.1;
- b) clause numbering has been aligned with IEC 62271-1:2017;
- c) the Scope has been extended to cover all indoor and outdoor installations. Consideration of switching devices having disconnecting and/or earthing switch functionalities, apart from other functions, are also covered by this document;
- d) ratings have been moved from Annexes B, C and E to Clause 5; the order of the subclauses now corresponds to the order of subclauses in Clause 7;
- e) new rating values for bus-transfer current and bus-transfer voltage have been assigned;
- f) new class of mechanical endurance for earthing switches has been added (M1);
- g) subclause "Rated values of electrical endurance for earthing switches" is now called "Classification of earthing switches for short-circuit making capability";
- h) new subclause with ratings for ice-coating has been added;
- i) new subclause with classification of bus-charging switching capability has been added;
- j) new withstand requirements for interlocking devices have been added;
- k) the way to comply with the requirements of the isolating distance of disconnectors has been modified;
- l) design and construction requirements for position-indicating devices have been modified, aligning the requirements for position indication and signalling;
- m) the value of the operating force has been changed;
- n) the test procedures and validation criteria have been revised and modified where necessary;
- o) requirements for applied voltage during single-phase test on non-simultaneous closing earthing switches have been changed;
- p) non-verifiable requirements have been deleted;
- q) a new subclause has been added for testing mechanical interlocking devices;
- r) the high- and low-temperature test is mandatory if the temperature limits for the service conditions of the apparatus (defined by the manufacturer) are above +40 °C or below –5 °C, and a more detailed testing procedure is given;
- s) the testing procedure to verify the proper functioning of the position-indicating device allows a more practicable testing for every technology used;
- t) a new Annex B has been added with title: "Current-switching capability required of disconnectors and earthing switches";
- u) a new Annex C has been added with title: "Tolerances on test quantities for type tests";
- v) a new Annex E has been added with title: "Extension of validity of type tests".

This standard is to be read in conjunction with IEC 62271-1:2017, to which it refers and which is applicable, unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses, except annexes, is used as in IEC 62271-1:2017. Additional subclauses are numbered from 101.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62271 series, published under the general title *High-voltage switchgear and controlgear*, can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 102: Alternating current disconnectors and earthing switches

1 Scope

This part of IEC 62271 applies to alternating current disconnectors and earthing switches, designed for indoor and outdoor installations for nominal voltages above 1 000 V and for service frequencies up to and including 60 Hz.

It also applies to the operating devices of these disconnectors and earthing switches and their auxiliary equipment.

Additional requirements for disconnectors and earthing switches in enclosed switchgear and controlgear are given in IEC 62271-200, IEC 62271-201 and IEC 62271-203.

NOTE Disconnectors in which the fuse forms an integral part are not covered by this standard.

This document is also applicable to switching devices having disconnecting and/or earthing functionalities apart from other functions, such as high-speed earthing switch, circuit-breaker and switch-disconnector.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-151, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-441, *International Electrotechnical Vocabulary – Chapter 441: Switchgear controlgear and fuses*

IEC 60050-471, *International Electrotechnical Vocabulary – Part 471: Insulators*

IEC 60050-614, *International Electrotechnical Vocabulary – Part 614: Generation, transmission and distribution of electricity – Operation*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

~~IEC 60071-2, *Insulation co-ordination – Part 2: Application guide*~~

IEC 60137, *Insulating bushings for alternating voltages above 1 000 V*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

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IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC/TR 62271-305, *High-voltage switchgear and controlgear – Part 305: Capacitive current switching capability of air-insulated disconnectors for rated voltages above 52 kV*

ISO 2768-1, *General tolerances – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-151, IEC 60050-441, IEC 60050-471, IEC 60050-614, and IEC 62271-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 General terms and definitions

3.1.101

indoor switchgear and controlgear

switchgear and controlgear designed solely for installation within a building or other housing, where the switchgear and controlgear is protected against wind, rain, snow, abnormal dirt deposits, abnormal condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-04]

3.1.102

outdoor switchgear and controlgear

switchgear and controlgear suitable for installation in the open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-05]

3.1.103

user

person or legal entity using the disconnectors or earthing switches

Note 1 to entry: This can include the purchaser (for example an electricity supplier), but it can also include the contracting company, the staff responsible for erection of installation, the maintenance or operating staff or anybody else temporarily or permanently responsible for the disconnector, earthing switch or electrical installation, or even the operation of the switchgear.

3.2 Assemblies of switchgear and controlgear

3.2.1

test object

equipment needed to represent the specimen for a particular type test

[SOURCE: IEC 62271-1:2017, 3.2.1, modified – "switchgear and controlgear" replaced by "specimen"]

3.3 Parts of assemblies

Subclause 3.3 of IEC 62271-1:2017 is applicable.

3.4 Switching devices

3.4.101

disconnector

mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

Note 1 to entry: A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time currents under abnormal conditions such as those of short-circuit.

Note 2 to entry: "Negligible current" implies currents such as the capacitive currents of bushings, busbars, connections, very short lengths of cable, currents of permanently connected grading impedances of circuit-breakers and currents of voltage transformers and dividers (see also IEC/TR 62271-305). For $U_r \leq 420$ kV, a current not exceeding 0,5 A is a negligible current for the purpose of this definition; for $U_r > 420$ kV and currents exceeding 0,5 A, the manufacturer should be consulted. "No significant change in voltage" refers to such applications as the by-passing of induction voltage regulators or circuit-breakers and bus transfer.

[SOURCE: IEC 60050-441:2000, 441-14-05, modified – Note 2 to entry has been added]

3.4.102

divided support disconnector

divided support earthing switch

disconnector (or earthing switch) in which the fixed and moving contacts of each pole are not supported by a common base or frame

Note 1 to entry: A typical example is the pantograph or semi-pantograph disconnector (or earthing switch).

[SOURCE: IEC 60050-441:2000, 441-14-06 and -07, modified – The term "earthing switch" is completed with "divided support" and the term "disconnector" substituted by "earthing switch" in Note 1 to entry when appropriate; Note 2 to entry deleted.]

3.4.103

centre-break disconnecter

disconnecter in which both contacts of each pole are movable and engage at a point substantially midway between their supports

Note 1 to entry: This term applies to high-voltage disconnectors only.

[SOURCE: IEC 60050-441:2000, 441-14-08]

3.4.104

double-break disconnecter

disconnecter that opens a circuit at two points

[SOURCE: IEC 60050-441:2000, 441-14-09]

3.4.105

resistor-fitted disconnecter

disconnecter fitted with resistor in series or in parallel to the switching contacts in order to mitigate the very fast transient overvoltage (VFTO) during both the opening and closing operation in metal-enclosed gas-insulated switchgear

3.4.106

earthing switch

mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time currents under abnormal conditions such as those of short-circuit, but not required to carry current under normal conditions of the circuit

Note 1 to entry: An earthing switch may have a short-circuit making capacity.

Note 2 to entry: An earthing switch of $U_r > 52$ kV may have a rating for switching and carrying induced currents.

Note 3 to entry: These devices may sometimes be operated against short-circuit. The different classes of earthing switches are related to the number of short-circuit making operations.

Note 4 to entry: In some cases, earthing switches are used as fault-initiating devices.

[SOURCE: IEC 60050-441:2000, 441-14-11, modified – the Notes 2, 3 and 4 to entry have been added]

3.4.107

combined function earthing switch

earthing switch having a common contact system for earthing and at least one of the following functions:

- disconnecting;
- making and/or breaking of currents up to the short-circuit current.

3.4.108

switch-disconnector

switch which, in the open position, satisfies the isolating requirements specified for a disconnector

[SOURCE: IEC 60050-441:2000, 441-14-12]

3.5 Parts of switching devices

3.5.101

pole of a switching device

portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.102

main circuit

<of a switching device> all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.103

contact

<of a mechanical switching device> conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.104

main contact

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.105

control contact

contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.106

"a" contact

make contact

control or auxiliary contact that is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.107

"b" contact

break contact

control or auxiliary contact that is open when the main contacts of a mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.108

position-indicating device

part of a mechanical switching device that indicates whether it is in the open, closed, or where appropriate, earthed position

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.109

position-signalling device

part of a disconnector or earthing switch which uses auxiliary energy to indicate whether the contacts of the main circuit are in the open or closed position

3.5.110

terminal

conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

[SOURCE: IEC 60050-151:2014, 151-12-12, modified – the note has been deleted.]

3.5.111

contact zone

<for divided support disconnectors and earthing switches> spatial region of positions the fixed contact may take up for correct engagement with the moving contact

3.5.112

power kinematic chain

mechanical connecting system between the operating mechanism and the moving contacts, both included

Note 1 to entry: Refer to Figure 1.

3.5.113

position-indicating kinematic chain

mechanical connecting system between the moving contacts and the position-indicating device(s), both included

3.5.114

position-signalling kinematic chain

mechanical connecting system between the moving contacts and the position of the signalling device(s)

3.5.115

connecting point

most upstream point (i.e. the closest to the source of energy) of the common part of the power and position-indicating/signalling kinematic chains

3.5.116

strain limiting device

device that limits to a defined value the torque or force transmitted to the downstream side of the device irrespective of the torque or force applied to the upstream side

3.5.117

torque (force) controlling system

system that monitors and controls the torque (force) transmitted to the downstream side of the device in comparison with defined value

3.5.118

bushing

device that enables one or several conductors to pass through a partition such as a wall or a tank, and insulate the conductors from it

[SOURCE: IEC 60050-471:2007, 471-02-01, modified – Notes 1 and 2 to entry deleted]

3.5.119

source of energy

origin of the energy released or of the force/torque applied to the power kinematic chain of a switching device during an operation or at any stable position of it

Note 1 to entry: The origin of the energy or force/torque can be human, electrical, hydraulics, pneumatics and mechanics i.e. springs, weights, etc. alone or in combination.

3.6 Operation

3.6.101

operation

<of a mechanical switching device> transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this may be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:2000, 441-16-01]

3.6.102

operating cycle

<of a mechanical switching device> succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:2000, 441-16-02]

3.6.103

closing operation

<of a mechanical switching device> operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:2000, 441-16-08]

3.6.104

opening operation

<of a mechanical switching device> operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:2000, 441-16-09]

3.6.105

dependent manual operation

<of a mechanical switching device> operation solely by means of directly applied manual energy, such that the speed and force of the operation are dependent upon the action of the operator

Note 1 to entry: Dependent manual operation may be performed by a crank or by a swing lever (horizontal or vertical).

Note 2 to entry: Switching devices with dependent manual operation have not any inherent switching capability.

[SOURCE: IEC 60050-441:2000, 441-16-13, modified – Notes 1 and 2 to entry have been added]

3.6.106

dependent power operation

<of a mechanical switching device> operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.107

stored energy operation

<of a mechanical switching device> operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

Note 1 to entry: This kind of operation may be subdivided according to:

- 1) the manner of storing the energy (spring, weight, etc.);
- 2) the origin of the energy (manual, electric, etc.);
- 3) the manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:2000, 441-16-15]

3.6.108

independent manual operation

<of a mechanical switching device> stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

[SOURCE: IEC 60050-441:2000, 441-16-16]

3.6.109

closed position

<of a mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

Note 1 to entry: Predetermined continuity means that the contacts are fully closed to carry the rated continuous and the rated short circuit currents, as applicable.

[SOURCE: IEC 60050-441:2000, 441-16-22, modified – Note to entry has been added]

3.6.110

open position

<of a mechanical switching device> position in which the predetermined clearance between open contacts in the main circuit of the device is secured

[SOURCE: IEC 60050-441:2000, 441-16-23]

3.6.111

toggle point

point beyond which any further movement of the charging mechanism causes the stored energy to be released

3.6.112

mechanical endurance

<of a disconnector or earthing switch> capability of a disconnector or earthing switch to perform a defined number of operations without voltage on or current through the circuit under specified operation conditions

3.7 Characteristic quantities

3.7.101

peak making current

<of an earthing switch> peak value of the first major loop of the current in a pole of the earthing switch during the transient period following the initiation of current during a making operation

Note 1 to entry: Where, for a three-phase circuit, a single value of (peak) making current is referred to, this is, unless otherwise stated, the highest value in any phase.

3.7.102

peak current

peak value of the first major loop of current during the transient period following initiation

3.7.103

short-time withstand current

current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-17]

3.7.104

peak withstand current

value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-18]

3.7.105

insulation level

set of withstand voltages specified which characterize the dielectric strength of the insulation

[SOURCE: IEC 60050-614:2016, 614-03-23]

3.7.106

power frequency withstand voltage

RMS value of sinusoidal power frequency voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

[SOURCE: IEC 60050-614:2016, 614-03-22]

3.7.107

lightning impulse withstand voltage

peak value of the lightning impulse voltage which the insulation of the disconnector or earthing switch withstands under specified test conditions

3.7.108

switching impulse withstand voltage

peak value of the switching impulse voltage which the insulation of the disconnector or earthing switch withstands under specified test conditions

3.7.109

external insulation

distances in atmospheric air, and along the surfaces in contact with atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin, etc.

Note 2 to entry: External insulation is either weather-protected or non-weather-protected, designed to operate inside or outside closed shelters, respectively.

[SOURCE: IEC 60050-614:2016, 614-03-02, modified – Note 2 to entry has been added]

3.7.110

internal insulation

internal distances of the solid, liquid or gaseous insulation of equipment which are protected from the effects of atmospheric and other external conditions

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.7.111

self-restoring insulation

insulation which completely recovers its insulating properties within a short time after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-04]

3.7.112

non-self-restoring insulation

insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge

Note 1 to entry: Definitions 3.7.111 and 3.7.112 apply only when the discharge is caused by the application of a test voltage during a dielectric test. However, discharges occurring in service can cause a self-restoring insulation to lose partially or completely its original insulating properties.

[SOURCE: IEC 60050-614:2016, 614-03-05, modified – Note to entry has been added]

3.7.113

parallel insulation

insulator arrangement with two insulators in parallel where the distance between the two insulators might influence the dielectric strength

Note 1 to entry: With open terminal disconnectors and earthing switches, parallel insulation is used when a drive insulator is situated next to a support insulator.

3.7.114

disruptive discharge

failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between electrodes to practically zero

Note 1 to entry: Non-sustained disruptive discharge in which the test object is momentarily bridged by a spark or arc may occur. During these events the voltage across the test object is momentarily reduced to zero or to a very small value. Depending on the characteristics of the test circuit and the test object, a recovery of dielectric strength may occur and may even allow the test voltage to reach a higher value. Such an event should be interpreted as a disruptive discharge unless otherwise specified by the relevant technical committee.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric the loss may be only temporary.

[SOURCE: IEC 60060-1:2010, 3.1.1]

3.7.115

clearance

distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:2000, 441-17-31]

3.7.116

clearance between poles

clearance between any conductive parts of adjacent poles

[SOURCE: IEC 60050-441:2000, 441-17-32]

3.7.117

clearance to earth

clearance between any conductive parts and any parts which are earthed or intended to be earthed

[SOURCE: IEC 60050-441:2000, 441-17-33]

3.7.118

clearance between open contacts

total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position

Note 1 to entry: The total clearance is the sum of the clearances existing between the contacts.

[SOURCE: IEC 60050-441:2000, 441-17-34, modified – Note to entry has been added]

3.7.119

mechanical terminal load

external load acting on each terminal

Note 1 to entry: The external load is the result of the combined mechanical forces which may be applied to the terminals of the switching device. Wind forces acting on the equipment itself are not included as they do not contribute to the external load acting on terminals.

Note 2 to entry: A disconnector or earthing switch can be subjected to several mechanical forces different in value, direction and point of action.

Note 3 to entry: The terminal loads as defined here do not usually apply to enclosed switchgear.

3.7.119.1

static mechanical terminal load

static mechanical terminal load at each terminal equivalent to the mechanical force to which this terminal of the disconnector or earthing switch is subjected by the flexible or rigid conductor connected to this terminal

Note 1 to entry: The static mechanical terminal load includes forces resulting from ice, wind and connected conductors.

3.7.119.2

dynamic mechanical terminal load

combination of the static mechanical load and the electromagnetic forces under short-circuit conditions

3.7.120

bus-transfer current switching

opening and closing of disconnectors under load when this load is not interrupted, but transferred from one bus to a parallel bus

3.7.121

bus-transfer current

current that flows when a load is transferred from one bus system to another

3.7.122

bus-transfer voltage

power frequency voltage across the open disconnector after breaking or before making the bus-transfer current

3.7.123

induced current switching

making or breaking of inductive or capacitive currents by an earthing switch, whereupon the currents are induced in an earthed or unearthed system by adjacent energized lines or cables

Note 1 to entry: When two or more transmission lines are mounted together, energy will be induced electrostatically and/or electromagnetically from a live system into a de-energized system resulting in capacitive or inductive currents flowing in this system, depending whether it is earthed at one or at both ends.

3.7.124

electromagnetically induced current

<on an earthing switch> inductive current that flows through an earthing switch when it connects to and disconnects from earth one termination of a de-energized transmission line, with the other termination earthed, and with an energized line carrying current in parallel with, and in proximity to, the earthed line

Note 1 to entry: The inductive current in a de-energized line earthed at both terminations is dependent upon the current in the energized line and the coupling factor to the energized line, as determined by the circuit configuration.

3.7.125

electrostatically induced current

<on an earthing switch> capacitive current that flows through an earthing switch when it connects to and disconnects from earth one termination of a de-energized transmission line, with the other termination open, and with an energized line in parallel with, and in proximity to, the earthed line

Note 1 to entry: The capacitive current in a de-energized line earthed at one termination is dependent upon the voltage of the energized line, the coupling factor to the energized line as determined by the circuit configuration, and the length of the earthed line between the earthed termination and the open termination.

3.7.126

bus-charging current switching

making or breaking of bus-charging currents by disconnectors

3.7.127

bus-charging current

capacitive current that flows when an isolated part of a busbar system is energised or de-energised

3.7.128

transient voltage to earth

U_{TVE}

voltage to earth which appears at the first prestrike during a closing operation of a disconnector

3.7.129

filling pressure for insulation and/or switching

filling density for insulation and/or switching

pressure in Pascal (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in

relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

[SOURCE: IEC 62271-1:2017, 3.6.5.1]

3.7.130

minimum functional pressure for insulation and/or switching minimum functional density for insulation and/or switching

pressure (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment becomes necessary

[SOURCE: IEC 62271-1:2017, 3.6.5.5]

3.8 Index of definitions

A – B

"a" contact.....	3.5.106
"b" contact.....	3.5.107
Bus-charging current.....	3.7.127
Bus-charging current switching.....	3.7.126
Bushing.....	3.5.118
Bus-transfer current.....	3.7.121
Bus-transfer current switching.....	3.7.120
Bus-transfer voltage.....	3.7.122

C

Centre-break disconnector.....	3.4.103
Clearance.....	3.7.115
Clearance between open contacts.....	3.7.118
Clearance between poles.....	3.7.116
Clearance to earth.....	3.7.117
Closed position (of a mechanical switching device).....	3.6.109
Closing operation (of a mechanical switching device).....	3.6.103
Combined function earthing switch.....	3.4.107
Connecting point.....	3.5.115
Contact (of a mechanical switching device).....	3.5.103
Contact zone (for divided support disconnectors and earthing switches).....	3.5.111
Control contact.....	3.5.105

D

Dependent manual operation (of a mechanical switching device).....	3.6.105
Dependent power operation (of a mechanical switching device).....	3.6.106
Disconnector.....	3.4.101
Disruptive discharge.....	3.7.114
Divided support disconnector.....	3.4.102
Divided support earthing switch.....	3.4.102

Double-break disconnecter.....	3.4.104
Dynamic mechanical terminal load.....	3.7.119.2

E

Earthing switch.....	3.4.106
Electromagnetically induced current (on an earthing switch).....	3.7.124
Electrostatically induced current (on an earthing switch).....	3.7.125
External insulation.....	3.7.109

I

Independent manual operation (of a mechanical switching device).....	3.6.108
Indoor switchgear and controlgear.....	3.1.101
Induced current switching.....	3.7.123
Insulation level.....	3.7.105
Internal insulation.....	3.7.110

L – N

Lightning impulse withstand voltage.....	3.7.107
Main circuit (of a switching device).....	3.5.102
Main contact.....	3.5.104
Mechanical endurance of a disconnecter or earthing switch.....	3.6.112
Mechanical terminal load.....	3.7.119
Minimum functional density for insulation.....	3.7.130
Minimum functional pressure for insulation.....	3.7.130
Non-self-restoring insulation.....	3.7.112

O

Open position (of a mechanical switching device).....	3.6.110
Opening operation (of a mechanical switching device).....	3.6.104
Operation (of a mechanical switching device).....	3.6.101
Operating cycle (of a mechanical switching device).....	3.6.102
Outdoor switchgear and controlgear.....	3.1.102

P

Parallel insulation.....	3.7.113
Peak current.....	3.7.102
Peak making current (of an earthing switch).....	3.7.101
Peak withstand current.....	3.7.104
Pole of a switching device.....	3.5.101
Position-indicating device.....	3.5.108
Position-indicating kinematic chain.....	3.5.113
Position-signalling device.....	3.5.109

Position-signalling kinematic chain	3.5.114
Power frequency withstand voltage	3.7.106
Power kinematic chain	3.5.112

R – U

Rated filling density for insulation	3.7.129
Rated filling pressure for insulation	3.7.129
Resistor-fitted disconnecter	3.4.105
Self-restoring insulation	3.7.111
Short-time withstand current	3.7.103
Source of energy	3.5.119
Static mechanical terminal load	3.7.119.1
Stored energy operation (of a mechanical switching device)	3.6.107
Strain limiting device	3.5.116
Switch-disconnector	3.4.108
Switching impulse withstand voltage	3.7.108
Terminal	3.5.110
Test object	3.2.1
Toggle point	3.6.111
Torque (force) controlling system	3.5.117
Transient voltage to earth	3.7.128
User	3.1.103

4 Normal and special service conditions

Clause 4 of IEC 62271-1:2017 is applicable.

5 Ratings

5.1 General

Clause 5 of IEC 62271-1:2017 is applicable for a disconnector or earthing switch, including their operating devices and auxiliary equipment. The list of ratings is complemented with the following items:

- k) rated short-circuit making current (for earthing switches only);
- l) rated contact zone;
- m) rated static mechanical terminal load;
- n) rated ice-coating;
- o) rated values of the bus-transfer current switching capability (for disconnectors only);
- p) rated values of the induced current switching capability (for earthing switches only);
- q) rated values of the bus-charging current switching capability (for disconnectors only).

In addition to the rated values given above, the following classifications may be assigned:

- r) short-circuit making class (for earthing switches only);
- s) mechanical endurance class;

- t) induced current switching class (for earthing switches only);
- u) bus-charging current switching class (for disconnectors only).

Disconnectors or earthing switches being classified for more than one switching capability may indicate their classification by combined class designations. For example, an earthing switch having short-circuit making capability class E1 and an induced current switching capability class B may be classified as class B+E1.

Ratings for making and breaking capabilities cannot be assigned to disconnectors and earthing switches with only manual dependent operation.

In the case of disconnectors and earthing switches with both dependent power and dependent manual operation, any making and breaking capability is not valid for dependent manual operation.

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:2017 is applicable.

5.3 Rated insulation level (U_d , U_p , U_s)

Subclause 5.3 of IEC 62271-1:2017 is applicable with the following addition:

For disconnectors rated above 52 kV and disconnectors having an isolating distance in parallel to the base of the disconnector and having integrated earthing switches, the insulation level between moving parts of the earthing switch and the opposite live parts, during operation of the earthing switch, shall be at least the short-duration power frequency withstand voltage for the smallest gap between them specified in 7.2.6.

If national safety regulations specify higher withstand values for earthing switches that have manual operating mechanisms only, this has to be agreed upon between the user and the manufacturer.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 is applicable.

5.5 Rated continuous current (I_r)

Subclause 5.5 of IEC 62271-1:2017 is applicable. This subclause applies only to disconnectors.

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 is applicable with the following addition.

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 is applicable with the following addition.

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 is applicable with the following addition:

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.9 Rated supply voltage of auxiliary and control circuits (U_a)

Subclause 5.9 of IEC 62271-1:2017 is applicable.

5.10 Rated supply frequency of auxiliary circuits and control circuits

Subclause 5.10 of IEC 62271-1:2017 is applicable.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is applicable with the following addition:

5.11.101 Rated pressure of compressed gas supply for insulation and/or switching

The limits of pressure shall be given by the manufacturer.

5.11.102 Rated pressure of compressed gas supply for operation

External pneumatic or hydraulic supply.

Unless otherwise specified by the manufacturer, the limits of the operating pressure are 85 % and 110 % of the rated pressure.

5.101 Rated short-circuit making current (I_{ma})

The rated short-circuit making current is applicable only to the earthing switches class E1 and E2. This shall be equal to the rated peak withstand current.

Subclause 5.102 provides a classification of earthing switches for short-circuit making capability.

5.102 Classification of earthing switches for short-circuit making

The short-circuit making capability of earthing switches to perform a defined number of short-circuit making operations, without major maintenance, shall correspond to one of the classes given in Table 1.

NOTE The increased number of making operations of Class E2 is typically related to voltages up to and including 52 kV depending on the operating conditions and the protection systems of such networks.

Table 1 – Classification of earthing switches for short-circuit making

Class	Type of earthing switch
E0	Earthing switch with no short-circuit making capability
E1	Earthing switch with capability to perform two short-circuit making operations

E2	Earthing switch with capability to perform five short-circuit making operations

5.103 Rated contact zone

In case of divided support disconnectors and divided support earthing switches the manufacturer shall state the rated values of the contact zone (indicated by x_r , y_r and z_r). Preferred values are given in Table 2 and Table 3. The rated values shall be specified by the manufacturer. This refers also to a tolerable angular displacement of the fixed contact.

Table 2 – Preferred contact zones for "fixed" contacts supported by flexible conductors

Rated voltage U_r kV	x mm	y mm	z_1 mm	z_2 mm
72,5 – 100	100	300	200	300
123 – 145		350		
170	200	400	250	450
245		500		
300				
362				
420			400	500
550				
800		250	650	450
1 100 – 1 200	300	700	500	600
x = total amplitude of longitudinal movement of the supporting conductor (temperature). y = total horizontal deflection (perpendicular to supporting conductor) (wind). z = vertical deflection (temperature and ice).				
NOTE z_1 are values for short-span, z_2 are values for long-span of the flexible conductors to which the fixed contacts are mounted.				

Table 3 – Preferred contact zones for "fixed" contacts supported by rigid conductors

Rated voltage U_r kV	x mm	y mm	z mm
72,5 – 100 – 123 – 145	100	100	100
170 – 245 – 300 – 362 – 420	150	150	150
550	175	175	175
800	200	200	200
1 100 – 1 200	250	250	250
x = total amplitude of longitudinal movement of the supporting conductor (temperature). y = total horizontal deflection (perpendicular to supporting conductor) (wind). z = vertical deflection (ice).			

5.104 Rated static mechanical terminal load

When disconnectors or earthing switches are intended to be directly connected to lines, i.e. flexible or rigid conductors, the rated static mechanical terminal load of each terminal shall be assigned, indicating the directions of application.

The maximum static mechanical terminal load to which a terminal of a disconnector or earthing switch is allowed to be subjected under the most disadvantageous conditions is the rated static mechanical terminal load.

Preferred values of static mechanical terminal loads are given in Table 4 and are intended to be used as a guide.

Table 4 – Preferred static mechanical terminal loads

Rated voltage U_r kV	Rated continuous current I_r A	Two- and three-column disconnectors or earthing switches		Divided support disconnectors or earthing switches		Vertical Force F_c^a N
		Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	
		In Figure 9		In Figure 8		
		N	N	N	N	
72,5	$\leq 1\,600$	400	130	800	200	500
	$> 1\,600$	500	170	800	200	
100 – 123 – 145	$\leq 1\,600$	500	170	800	200	1 000
	$> 1\,600$	600	200	1 000	300	
170	$\leq 1\,600$	600	200	1 000	300	
	$> 1\,600$	800	250	1 250	400	
245	$\leq 2\,500$	800	270	1 250	400	1 250
	$> 2\,500$	1 000	330	1 600	500	
300 – 362	$\leq 2\,500$	1 000	400	1 600	500	1 500
	$> 2\,500$	1 500	500	1 800	600	
420	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
550	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
800	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
1 100 – 1 200	$\leq 4\,000$	2 000	660	4 000	1 600	2 000
	$> 4\,000$	2 500	1 000	5 000	2 000	

^a F_c simulates the downward forces caused by the weight of the connecting conductors. F_c does not apply to flexible conductors.

NOTE The static mechanical terminal load includes forces resulting from ice, wind and connected conductors.

5.105 Classification of disconnectors for mechanical endurance

The mechanical endurance of disconnectors shall correspond to one of the classes given in Table 5. The performance is associated to a programme of maintenance defined by the manufacturer.

Table 5 – Classification of disconnectors for mechanical endurance

Class	Number of operating cycles	Mechanical endurance
M0	1 000	Normal
M1	2 000	Extended
M2	10 000	Extended

5.106 Classification of earthing switches for mechanical endurance

The mechanical endurance of earthing switches shall correspond to one of the classes given in Table 6. The performance is associated to a programme of maintenance defined by the manufacturer.

Table 6 – Classification of earthing switches for mechanical endurance

Class	Number of operating cycles	Mechanical endurance
M0	1 000	Normal
M1	2 000	Extended

5.107 Rated ice-coating

For disconnectors and earthing switches able to operate under ice-conditions a rated ice-coating shall be assigned by the manufacturer.

Preferred ratings of ice-coating are: 1 mm, 10 mm and 20 mm.

5.108 Rated values of disconnectors for bus-transfer current switching

5.108.1 Rated bus-transfer current

The rated bus-transfer current of disconnectors used in both air-insulated and gas-insulated installations is:

- for $52 \text{ kV} < U_r < 245 \text{ kV}$ 80 % of the rated continuous current of the disconnector, but limited to 1 600 A;
- for $245 \text{ kV} \leq U_r \leq 550 \text{ kV}$ 60 % of the rated continuous current of the disconnector, but limited to 4 000 A;
- for $U_r > 550 \text{ kV}$ 80 % of the rated continuous current of the disconnector, but limited to 4 000 A.

Rated bus-transfer currents greater than the values given above may be assigned by the manufacturer.

NOTE 1 It is recognised that disconnectors of $U_r \leq 52 \text{ kV}$ can also have bus-transfer switching capability. In this case, checking of the performance is subjected to an agreement between the user and the manufacturer.

NOTE 2 For more information refer to the following: for information about 60 % and 80 %, refer to CIGRE TB 570 – 2014 [1]¹ and CIGRE SC A3 third report, presented in Paris (FR), 2016, and about 4 000 A refer to CIGRE SC A3 and B3 colloquium in Nagoya (JP), paper no. 212, 2015.

¹ Numbers in square brackets refer to the Bibliography.

5.108.2 Rated bus-transfer voltage

Rated bus-transfer voltages are given in Table 7. Different bus-transfer voltages than the values given in Table 7 below may be assigned by the manufacturer.

Table 7 – Rated bus-transfer voltages of disconnectors

Rated continuous current I_r A	Rated voltage U_r			Rated voltage U_r		
	$52\text{ kV} < U_r < 245\text{ kV}$	$245\text{ kV} \leq U_r \leq 550\text{ kV}$	$U_r > 550\text{ kV}$	$52\text{ kV} < U_r < 245\text{ kV}$	$245\text{ kV} \leq U_r \leq 550\text{ kV}$	$U_r > 550\text{ kV}$
	Gas-insulated installations V (RMS value)			Air-insulated installations V (RMS value)		
2 000	10	15	20	100	175	250
2 500					220	310
3 150		20	30		275	390
4 000		25	42		350	500
5 000					435	625
6 300		35			550	
8 000					580	

NOTE The values in the table are based on calculations of a bus-transfer current corresponding to the rated continuous current of the disconnector taking into account typical loop lengths and impedances given in Annex B.

5.109 Classification and rated values of earthing switches for induced current switching

Rated induced current and voltage shall be assigned to earthing switches of $U_r > 52 \text{ kV}$ and designed for making or breaking of inductive or capacitive induced currents (see 3.7.124 and 3.7.125), hence requiring an induced current switching capability.

For this application, a classification for induced current switching (class A or B) shall be assigned to the earthing switch. This class depends upon the severity of the induced current switching duty. The classification of earthing switches for induced current switching is given in Table 8.

Table 8 – Classification of earthing switches for induced-current switching

Class	Type of earthing switch
A	Earthing switch designed to be used in circuits having relatively short sections of line or low coupling to adjacent energized circuits
B	Earthing switch designed to be used in circuits having relatively long sections of lines or high coupling to adjacent energized circuits

The values of rated induced current and voltage for the two classes of earthing switches are given in Table 9. These values represent the maximum switching capabilities for each rated voltage.

Table 9 – Rated induced currents and voltages

Rated voltage U_r kV	Electromagnetic coupling				Electrostatic coupling			
	Rated induced current A (RMS value)		Rated induced voltage kV (RMS value)		Rated induced current A (RMS value)		Rated induced voltage kV (RMS value)	
	Class		Class		Class		Class	
	A	B	A	B	A	B	A	B
72,5	50	80	0,5	2	0,4	2	3	6
100								
123			1			3		9
145								
170			1,4			10		5
245	80	160		2	20		7,5	
300								
362								
420								
550								
800	110	440	5	65	3	25	12	32
1 100								
1 200								

NOTE 1 In some situations (very long sections of the earthed line in proximity to an energized line; very high loading on the energized line; energized line having a service voltage higher than the earthed line, etc.), the induced current and voltage can be higher than the given values. For these situations, the rated values are subject to agreement between manufacturer and user.

NOTE 2 The rated induced voltages correspond to line-to-earth values for both single-phase and three-phase tests (see 7.107.5).

5.110 Classification and rated values of disconnectors for bus-charging current switching

Disconnectors forming part of the gas-insulated switchgear and controlgear of $U_r \geq 300$ kV shall be classified for bus-charging current switching performance. Tests for disconnectors of $U_r < 300$ kV are generally not necessary and are subject to agreement between the manufacturer and the user. In any case, for $52 \text{ kV} < U_r < 300 \text{ kV}$, the test for classification of BCS is not mandatory.

NOTE Bus-charging switching capability for air-insulated disconnectors is subject to agreement between the manufacturer and the user, refer to IEC/TR 62271-305.

Four classes are distinguished depending upon application. See Table 10, where the associated test duties are also indicated.

Table 10 – Classification of disconnectors for bus-charging switching

Class	Application	Associated test duties (see 7.108.2)
BCS	Switching of very short sections of busbar ducts of open circuits	TD ₁
BCB	BCS class + switching of parallel capacitors associated to circuit-breakers, under 180° out-of-phase condition of open circuits	TD ₁ & TD ₂
BCL	BCS class + switching of long sections of busbar ducts of open circuits	TD ₁ & TD ₃
BCT	BCS class + BCB class + BCL class	TD ₁ , TD ₂ & TD ₃

The rated bus-charging current is associated only to disconnectors classified as BCL or BCT. No rated bus-charging current can be assigned to TD₁ and TD₂, as they depend on the design, the physical construction of the installation, and rated voltage. The standard values for this rating are given in Table 11. These values are only associated to the de-energizing of long sections of busbar ducts in accordance with test duty 3 in 7.108.2. For more information, refer to Annex B.

Table 11 – Standard rated bus-charging currents

Rated voltage U_r kV (RMS value)	72,5	100	123	145	170	245	300	362	420	550	800	1 100	1 200
Rated bus-charging current A (RMS value)	0,1	0,1	0,1	0,1	0,1	0,25	0,25	0,5	0,5	0,5	0,8	1,0	1,0
NOTE The values are normally not exceeded in practice. They apply to 50 Hz as well as to 60 Hz. In the case of higher values in practice, other test values are considered by agreement between the manufacturer and the user.													

6 Design and construction

6.1 Requirements for liquids in disconnectors and earthing switches

Subclause 6.1 of IEC 62271-1:2017 is applicable.

6.2 Requirements for gases in disconnectors and earthing switches

Subclause 6.2 of IEC 62271-1:2017 is applicable with the following addition.

NOTE In general, the term "gas" for insulation and/or switching in this document refers to SF₆. However, the principles expressed could be also used for other gases.

6.3 Earthing of disconnectors and earthing switches

Subclause 6.3 of IEC 62271-1:2017 is applicable with the following additions.

For disconnectors and earthing switches used in enclosed switchgear and controlgear assemblies, 5.3 of IEC 62271-200:2011, IEC 62271-201:2014 or IEC 62271-203:2011 is applicable (as it corresponds).

Metallic enclosures and operating mechanisms not mounted together with and not electrically connected to the metallic frame of the disconnector or earthing switch, shall be provided with an earthing terminal marked with the protective earth symbol.

If, for testing purposes after installation (e.g. cable testing, contact resistance measurement), a removable connection for earthing the main circuit through the earthing switch exists, it shall be able to withstand the rated peak and short-time withstand current. The relevant insulation level (DC and AC) of this external connection – when removed – shall be stated by the manufacturer.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:2017 is applicable with the following addition.

Refer also to 6.104 of this document.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 is applicable with the following additions.

In case of disconnectors and earthing switches with both dependent power and dependent manual operation, the noncapability of making and breaking, when manually operated, shall be clearly stated in the instruction manual and close to the point of manual operation.

Disconnectors and earthing switches having a pneumatic or hydraulic operating device shall be capable of closing and opening when the supply pressure is between the minimum and the maximum supply pressure specified (refer to 5.11.102).

See also 6.105 for maximum manual operating forces.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is applicable with the following addition.

See also subclause 6.105 for maximum manual operating (storing energy) forces.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 is applicable with the following addition.

See also subclause 6.105 for maximum manual operating (storing energy) forces.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is applicable.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 is applicable.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is applicable with the following additions:

- Disconnectors, earthing switches and their operating devices that are designed to be:
 - used as stand alone or may be integrated as components for switchgear, shall be provided with nameplates that contain information in accordance with Table 12;

- integrated in a particular family of switchgear and controlgear shall integrate the information on the nameplate(s) and/or in the manufacturer instruction manual of the switchgear and controlgear, as indicated in Table 12.

Table 12 – Product information (1 of 2)

Information to be put on the nameplate	Abbreviation	Unit	Disconnecter	Earthing switch ^a	Operating device
Manufacturer			x	x	x
Manufacturer's type designation			x	x	x
Mechanical endurance class			x ^b	x ^b	x
Short-circuit making capability class				x ^b	
Instruction book reference			x	x	x
Year of manufacture			x	x	x
Reference of this standard			x	x	x
Serial number			x	x	x
Rated voltage	U_r	kV	x	x	
Rated frequency	f_r	Hz	x	x	
Rated lightning impulse withstand voltage	U_p	kV	x	x	
Rated switching impulse withstand voltage for $U_r \geq 300$ kV	U_s	kV	x	x	
Rated power-frequency withstand voltage	U_d	kV	x	x	
Rated continuous current	I_r	A	x		
Rated short-time withstand current	I_k	kA	x	x	
Rated duration of short-circuit	t_k	s	x ^c	x ^c	
Rated peak withstand current	I_p	kA	x	x	
Rated short-circuit making current	I_{ma}	kA		x ^d	
Insulating fluid and mass	M_f	kg	x ^e	x ^e	
Minimum and maximum ambient air temperature		°C	x ^f	x ^f	x ^f

Table 12 (2 of 2)

Information to be put either on the nameplate or in the instruction manual	Abbreviation	Unit	Disconnecter	Earthing switch ^a	Operating device
Rated bus-charging current	I_{bc}	A	x ^g		
Class of bus-charging current switching			x ^g		
Rated bus-transfer current	I_{bt}	A	x ^h		
Rated bus-transfer voltage	U_{bt}	V	x ^h		
Class of earthing switch (class A or B) ⁱ				x ⁱ	
Rated induced current (electromagnetic)	I_{im}	A		x ⁱ	
Rated induced voltage (electromagnetic)	U_{im}	V		x ⁱ	
Rated induced current (electrostatic)	I_{is}	A		x ⁱ	
Rated induced voltage (electrostatic)	U_{is}	V		x ⁱ	
Value of the resistor	R	Ω	x ^j		
Rated filling pressure for operation	P_{rm}	Pa			x
Minimum functional pressure for operation	p_{mm}	Pa			x
Alarm pressure for operation	P_{am}	Pa			x
Rated filling pressure for insulation	P_{re}	Pa	x	x	
Minimum functional pressure for insulation	p_{me}	Pa	x	x	
Alarm pressure for insulation	P_{ae}	Pa	x	x	
Minimum functional pressure for switching	p_{sw}	Pa	x	x	
Rated supply voltage of auxiliary and control circuits	U_a	V			x ^k
Rated static mechanical terminal load	F	N	x	x	
Mass (including liquid)	M	kg	x	x	x
Rated ice-coating		mm	x	x	x
Rated contact zone	x_r, y_r and z_r	mm	x ^l	x ^l	
NOTE 1 The marking of values indicated by x is mandatory (if applicable).					
NOTE 2 The word "rated" does not need to appear on the nameplate.					
^a One nameplate may be used for an earthing switch and disconnector assembled as a single unit. ^b The class marking is mandatory if different from M0 or E0. It may be included into the type designation to avoid additional space requirement. ^c Mandatory if t different from 1 s. ^d For earthing switches having short-circuit making capability. ^e Chemical formula for gas or commercial name for liquid (if any of both) shall be indicated. ^f Mandatory if different from –5 °C and/or +40 °C. ^g For disconnectors forming a part of gas-insulated switchgear and controlgear of $U_r \geq 300$ kV. ^h For disconnectors of $U_r > 52$ kV having bus-transfer current switching capability. ⁱ For earthing switches of $U_r > 52$ kV having induced current switching capability. ^j For resistor-fitted disconnectors. ^k Rated supply voltages of auxiliary and control circuits may have separate values which have to be indicated. Manufacturer shall also indicate if the supply is dc or ac source. ^l For divided support disconnectors and/or divided support earthing switches of $U_r > 52$ kV.					

6.12 Locking devices

Subclause 6.12 of IEC 62271-1:2017 is applicable with the following addition:

Disconnectors and earthing switches to be mechanically interlocked by blocking the operating shaft or power kinematic chain of the disconnector or earthing switch, and not integrated in switchgear and controlgear assemblies covered by the standards IEC 62271-200, IEC 62271-201 or IEC 62271-203, shall be designed to withstand:

- during motor-operation, the strain produced by the motor starting torque at the maximum motor supply voltage, or, if a strain limiting device is present, to its limiting value, and
- during manual-operation, 3 times the value of the corresponding maximum force given for manual operation in 6.105 (without considering peak value) or, if a strain limiting device is present, to 1,5 times its limiting value.

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 is applicable with the following addition. Refer also to 6.104 of this document.

6.14 Degree of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 is applicable with the following addition for enclosures containing auxiliary and control circuits:

The degree of protection provided by enclosures for outdoor installation shall be a minimum of IP3XDW of IEC 60529:1989 + AMD1:1999 + AMD2:2013.

For indoor installations the degree of protection shall be not less than IP2X of IEC 60529:2013.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 is applicable.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC 62271-1:2017 is applicable.

6.17 Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 is applicable.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 is applicable.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 is applicable.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 is applicable.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 is applicable.

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 is applicable with the following addition:

The pressure in Pa (or density) or liquid mass shall be assigned by the manufacturer referred to atmospheric air conditions of 20 °C at which the gas- or liquid-filled switchgear is filled before being put into service.

For operating devices having their own compressor or pump integral to them and with their own supplying pressure tank, the limits of filling (operating) pressure shall be stated by the manufacturer.

6.101 Particular requirements for earthing switches

Any material and any cross-section is allowed for connections between movable parts of an earthing switch and its frame, provided that the connections are able to withstand the electrical, mechanical and environmental stresses that occur in service.

6.102 Requirements in respect of the isolating distance of disconnectors

When the insulation across the isolating distance may be subjected to pollution in service, care shall be taken to ensure the suitability of insulator design (e.g. creepage distance, hydrophobicity, orientation of insulator). IEC/TS 60815 (all parts) [3] can be used for guidance selecting the appropriate insulator design. The satisfactory performance of the insulation across the isolating distance under polluted conditions should be verified with the appropriate voltage withstand level corresponding to the isolating distance for which the disconnector is intended.

The design has also to take into account the effects of contamination caused by wear and arcing by-products. The effectiveness of the design to withstand these effects is verified by the condition checks specified in Clause 7 after the relevant type tests.

NOTE 1 It is usual that the isolating gap of a disconnector is longer than the phase-to-ground insulating distance, since IEC 62271-1:2017 specifies higher voltage withstand levels across the isolating distance than for the phase-to-ground insulation. However, where a long creepage distance is required, the phase-to-ground insulation distance can become longer than the isolating gap of the disconnector. For such cases the use of protective devices such as surge arresters or rod gaps can be necessary.

NOTE 2 Test method for insulators can be found in IEC 60507 [2] and IEC/TS 60815 (all parts) [3]

6.103 Mechanical strength

The disconnector and earthing switch, including the insulators used, installed according to the manufacturer's instructions shall be able to:

- open and close correctly the main contacts under its rated static mechanical terminal loads;
- carry the rated continuous current (when applicable) under its rated static mechanical terminal loads;
- withstand the dynamic forces on its terminals under short-circuit conditions.

The required cantilever strength of an insulator shall be calculated taking into consideration the height of the terminal above the top of the insulator as well as additional forces acting on the insulator (see 3.7.119 and 9.102.4).

6.104 Operation of disconnectors and earthing switches – Position of the movable contact system and its indicating and signalling devices

6.104.1 Securing of position

Disconnectors and earthing switches, including their operating mechanisms, shall be designed in such a way that they cannot come out of their open or closed position by gravity, wind pressure, vibrations, reasonable shocks or accidental touching of the connecting rods of their operating system according to their service conditions as defined in Clause 4.

Disconnectors and earthing switches shall permit temporary mechanical locking in at least the open position (for disconnectors) and closed position (for earthing switches) except for disconnectors or earthing switches whose contacts are directly moved by a hook-stick.

6.104.2 Additional requirements for power-operated mechanisms

Power operated mechanisms shall also provide a manual operating facility. Connecting a hand-operating device (for instance a hand crank) to the power-operated mechanism shall ensure safe interruption of the control energy to the power-operated mechanism.

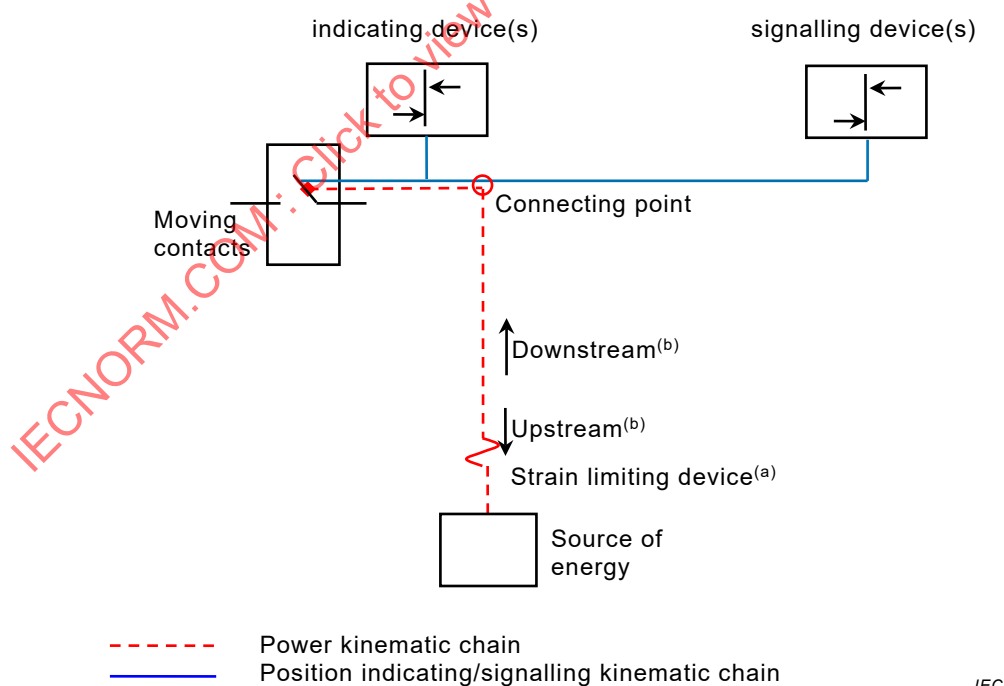
6.104.3 Indication and signalling of position

6.104.3.1 General requirements

Indication and signalling of the closed and open position shall not take place unless the moving contacts have reached their closed or open position, respectively.

NOTE For the definition of "closed" and "open" see 3.6.109 and 3.6.110.

Figure 1 represents the different elements involved in indication and signalling of positions, and some design conditions.



a) The strain limiting device (if any) can be an external device or an internal as part of the source of energy, e.g. torque (force) controlling system.

b) Upstream is the direction towards the source of energy, downstream is the direction towards the contacts.

Figure 1 – Position indicating/signalling device(s)

The strain limiting device (if any) may be placed at any point along the power kinematic chain between the source of energy and the connecting point, but it shall not be along the position indicating/signalling kinematic chain. See 6.104.3.2 and 6.104.3.3.

The position-indicating device(s) shall be fixed directly on a mechanical part of the power kinematic chain or mechanically connected to it through a separate position indicating/signalling kinematic chain. If the position indicator is not directly fixed on the mechanical part of the power kinematic chain, then the position-indicating kinematic chain from the connecting point shall be placed inside an enclosure providing a minimum degree of protection equivalent to IP2XC of IEC 60529:1989 + AMD1:1999 + AMD2:2013, and with an impact level IK 07 of IEC 62262:2002.

The position-signalling kinematic chain shall be placed inside an enclosure with the same levels of protection as defined for the position-indicating kinematic chain.

6.104.3.2 Indication of position

It shall be possible to know the position of the disconnector or earthing switch. The indication of the position of the disconnector or earthing switch is given if one of the following conditions is fulfilled:

- at least the position of the moving contacts of each pole is visible for disconnectors in open position and for earthing switches in closed position;
- both the open and closed positions of the moving contacts of each pole are indicated by a reliable position-indicating device. A common position-indicating device may be used only if all the poles of the disconnector or earthing switch are operated by a common operating mechanism.

NOTE In some countries the design of the disconnector is such that the isolating distance is visible (Canada).

The kinematic chain between the moving contacts and the position-indicating device shall be designed with sufficient mechanical strength to meet the requirements of the specified tests (7.105). The operation of the position-indicating kinematic chain shall be positively driven. The position-indicating device may be marked directly on a mechanical part of the power kinematic chain by suitable means. The strain-limiting device, if any, shall not form part of the position-indicating kinematic chain.

6.104.3.3 Signalling of position by auxiliary contacts

A common signal for all poles of a disconnector or earthing switch shall be given only if all poles of the disconnector or earthing switch are in a position in accordance with 6.104.3.1.

A common position-signalling device is permitted to be used only if the disconnector or earthing switch is three-pole operated by a common operating mechanism.

The kinematic chain between the moving contacts and the position-signalling device(s) shall be designed with sufficient mechanical strength to meet the requirements of the mechanical endurance tests. The position-signalling kinematic chain operation shall be positively driven. The strain-limiting device, if any, shall not form part of the position-signalling kinematic chain.

6.105 Maximum force required for manual (dependent or independent) operation

6.105.1 General

The values given in 6.105.2 and 6.105.3 also apply to maintenance manual operation of normally motor-operated disconnectors and earthing switches.

NOTE These values include ice-breaking, if applicable.

6.105.2 Operation requiring more than one revolution

The maximum force needed to operate or store energy in a disconnector or earthing switch with more than one revolution (hand crank for example) shall not exceed 80 N during 90 % of the total required revolutions and never exceed 120 N.

6.105.3 Operation requiring up to one revolution

The force needed to operate or store energy in a disconnector or earthing switch requiring up to one revolution (swing lever for example) should not exceed 250 N (refer to 6.6.4 of IEC 62271-1:2017). A maximum value of 450 N is accepted during a rotation of 15° maximum.

6.106 Dimensional tolerances

For disconnectors and earthing switches installed and/or connected by the user, the relevant mounting dimensions and the dimensions of high-voltage connections as well as the earthing connections of disconnectors and earthing switches, the tolerances given in ISO 2768-1 shall apply for linear and angular dimensions.

6.107 Earthing switches with short-circuit making current capability

Earthing switches assigned for short-circuit making current shall be capable of making at rated and lower voltage, any current up to and including the rated short-circuit making current. This requirement is considered to be satisfied if the earthing switch successfully demonstrates its electrical endurance class.

7 Type tests

7.1 General

7.1.1 Basics

Subclause 7.1.1 of IEC 62271-1:2017 is applicable with the following additions.

Disconnectors and earthing switches shall be tested to verify their rated characteristics, under the proper conditions of installation and use (e. g. they shall be tested as normally installed in the gas-insulated or metal-enclosed switchgear and controlgear) with all associated components, the arrangement of which may influence the performance, such as connections, supports, provisions for venting, resistors etc.

Disconnector and earthing switches that are different in construction or mounting arrangements as compared to the given examples in Clause 7 shall be tested in conditions that are representative of the actual installation.

NOTE Associated components are likely to influence the performance. Mechanical forces due to the short-circuit current, venting of arc-products, the possibility of disruptive discharges, etc., could characterise this influence. It is recognized that, in some cases, such influences may be quite negligible.

The same setting of the position-signalling device for closed and open positions shall be used for the dielectric test and the short-time withstand current and peak withstand current tests.

The type tests for disconnector and earthing switch are listed in Table 13. For the type tests, the tolerances on test quantities are given in Annex C.

Information regarding the extension of validity of type tests is given in Annex E (informative).

Table 13 – List of type tests

Type test, dependent upon application, rating or design	Condition	Related device		Subclauses
		Disconnector	Earthing switch	
Dielectric tests	a	x	x	7.2
Measurement of the resistance of the main circuit	a	x		7.4.4
Continuous current tests	a	x		7.5
Short-time withstand current and peak withstand current tests	a	x	x	7.6
Mechanical endurance tests	a	x	x	7.102.3
Verification of the degree of protection	Assigned IP- and/or IK-code	x	x	7.7
Radio interference voltage (RIV) test	$U_r \geq 245$ kV	x	x	7.3
Tightness tests	Controlled, sealed or closed pressure systems	x	x	7.8
EMC tests	Presence of electronic components	x	x	7.9
Additional tests on auxiliary and control circuits	Presence of auxiliary and control circuits	x	x	7.10
X- ray radiation test	Presence of vacuum interrupters	x	x	7.11
Test to prove the short-circuit making performance of earthing switches	Class E1 or E2		x	7.101
Contact zone test	Divided support	x	x	7.102.2
Operation during application of rated static mechanical terminal load	Assigned mechanical terminal load	x	x	7.102.4
Extended mechanical endurance tests	Class M1 or M2	x	x	7.102.5
Testing on mechanical interlocking devices	Presence of interlock blocking the operating shaft or power kinematic chain	x	x	7.102.6
Operation under severe ice conditions	10 mm and above	x	x	7.103
Low and high temperature tests	If maximum ambient temperature $> +40^\circ\text{C}$ or minimum ambient temperature $< -5^\circ\text{C}$	x	x	7.104
Tests to verify the proper functioning of the position-indicating device	Presence of position-indicating device	x	x	7.105
Bus-transfer current switching tests	Bus-transfer current switching capability ^b	x		7.106
Induced current switching tests	Class A or B ^c		x	7.107
Bus-charging current switching tests	Bus-charging current switching capability ^{d, e}	x		7.108
^a Mandatory without condition for the related device. ^b Applicable to disconnectors of $U_r > 52$ kV. ^c Applicable to earthing switches of $U_r > 52$ kV. ^d Applicable to disconnectors of $U_r > 52$ kV forming part of gas-insulated switchgear. For $U_r < 300$ kV, tests are generally considered not necessary and are subject to agreement between user and manufacturer. ^e Bus-charging switching capability for air-insulated disconnectors is subject to agreement between the manufacturer and the user, refer to IEC/TR 62271-305.				

7.1.2 Information for identification of test objects

Subclause 7.1.2 of IEC 62271-1:2017 is applicable with the following addition:

At the beginning of the type tests, the mechanical operating characteristics and their tolerances for the disconnector or earthing switch during opening and/or closing shall be given by the manufacturer, e.g. time between events during operation and no-load travel curves.

7.1.3 Information to be included in type test reports

Refer to 7.1.3 of IEC 62271-1:2017 with the following additions (where applicable):

When for testing purposes, the insulators are not provided by the manufacturer of the disconnector or earthing switch, the most important features of insulators used during type tests shall be included in the relevant test reports for comparison with those described in the manufacturer's documentation:

- rated cantilever strength;
- rated torsional strength of support insulators (and operating insulators, where applicable);
- height and number of elements;
- creepage length and shed-profile;
- deflection under load.

In the case of dielectric tests, information shall be included regarding the smallest gap at which the indicating or signalling device can signal the position OPEN. For air-insulated devices, the minimum size of the gap and the height above ground used for the test shall be stated (see 7.2.4). Also the distance of the lowest part of insulation to ground shall be given.

7.2 Dielectric tests

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 is applicable.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC 62271-1:2017 is applicable.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 is applicable.

7.2.4 Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is applicable with the following addition:

Dielectric tests on disconnectors or earthing switches when in the OPEN position shall be carried out with the minimum isolating distance for the disconnector or gap for the earthing switch at which the indicating or signalling device can signal the position OPEN or the minimum isolating distance compatible with the locking arrangements specified in 6.104.1, whichever is the smallest. This requirement does not apply to independent operated indoor disconnectors and earthing switches.

Where the design requires an adjustment of the position indicator or the position-signalling device, this shall be performed according to the instruction manual. No deviation of these devices is acceptable for dielectric tests.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable.

7.2.6 Application of the test voltage and test conditions

Subclause 7.2.6 of IEC 62271-1:2017 is applicable with the following additions.

Disconnectors of $U_r > 52$ kV having an isolating distance in parallel to the base of the disconnector and having integrated earthing switches, shall also be tested in open position, in dry conditions only, with the power frequency test voltage given in Table 14 in the most disadvantageous dielectric position of the earthing switch. If the minimum temporary clearance is larger than the clearances given in ~~IEC 60071-2~~ IEC 60071-1, no test is required.

Table 14 – Power frequency withstand voltages

Rated voltage U_r kV	Test voltage kV
72,5	94
100	130
123	160
145	188
170	221
245	283
300	346
362	418
420	484
550	635
800	924
1 100	1 270
1 200	1 386

NOTE See Annex A for rationale of the values given in Table 14.

For testing of earthing switches, the test voltage shall be applied with the earthing switch in the open position (see Table 21):

- between adjacent insulated terminals with the bases earthed (e.g. A to B with F earthed);
- between all the insulated terminals connected together and the bases earthed (e.g. ABC to F earthed).

7.2.7 Tests of disconnectors and earthing switches of $U_r \leq 245$ kV

Subclause 7.2.7 of IEC 62271-1:2017 is applicable.

7.2.8 Test of disconnectors and earthing switches of $U_r > 245$ kV

Subclause 7.2.8 of IEC 62271-1:2017 is applicable.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is applicable with the following addition.

NOTE The performance of parallel insulation can be affected under pollution and rain (additional pollution tests could be necessary).

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-1:2017 is applicable with the following addition:

Partial discharge tests are not required to be performed on the complete disconnector or earthing switch except when required by the assembly standards i.e. IEC 62271-200, IEC 62271-201 and IEC 62271-203. However, in the case of disconnectors and earthing switches using components for which a relevant IEC standard exists, including partial discharge measurements (for example, bushings, see IEC 60137), evidence shall be provided by the manufacturer showing that those components have passed the partial discharge tests as laid down in the relevant IEC standard. For partial discharge measurement, see IEC 60270.

NOTE 1 The measurement of partial discharge test is a suitable means of detecting certain defects in the equipment under test and is a useful complement to the dielectric tests. Experience shows that partial discharges can lead in particular arrangements to a degradation in the dielectric strength of the equipment, especially of solid insulation.

NOTE 2 Other methods, for example UHF or acoustic methods, for measuring or detecting the partial discharge other than the one considered in IEC 60270, can be employed by agreement.

7.2.11 Dielectric tests on auxiliary and control circuits

Subclause 7.2.11 of IEC 62271-1:2017 is applicable.

7.2.12 Voltage test as condition check

Subclause 7.2.12 of IEC 62271-1:2017 is applicable.

7.3 Radio interference voltage (RIV) test

Subclause 7.3 of IEC 62271-1:2017 is applicable.

7.4 Resistance measurement

Subclause 7.4 of IEC 62271-1:2017 is applicable.

7.5 Continuous current tests

Subclause 7.5 of IEC 62271-1:2017 is applicable.

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

Subclause 7.6.1 of IEC 62271-1:2017 is applicable.

7.6.2 Arrangement of the disconnectors and earthing switches and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is applicable with the following additions:

7.6.2.101 General test conditions

The disconnectors or earthing switches under test shall be installed with their own operating mechanism as far as necessary to make the test representative.

Disconnectors having accessories to accommodate a bus-transfer current switching capability, and earthing switches having accessories to accommodate induced current switching capability, shall be tested with these devices mounted.

Tests shall be carried out employing the least favourable position of the operating mechanism and the main contacts. Consideration should be given to 6.104.3 and, where applicable, to 7.105.

Where the design requires an adjustment of the position indicator or the position-signalling device, this shall be performed according to the instruction manual. No deviation of these devices is acceptable for short-circuit tests.

If the design allows tolerances, these shall be declared by the manufacturer prior to the test. The short-time withstand current and peak withstand current tests shall be performed with the signalling device set at the maximum or minimum specified tolerance giving the least favourable status of the main contacts indicated by the signalling device. This requirement does not apply to independently operated indoor disconnectors and earthing switches.

NOTE The least favourable status of the main contacts is the first position at which during closing operation the "CLOSED" signal appears.

Open type disconnectors and earthing switches shall be tested with one of the appropriate test arrangements as specified in Figures 2, 3, 4 or 5. Where flexible conductors are used in the test setup, the terminals of the disconnectors or earthing switches under test shall be loaded with their longitudinal rated static mechanical terminal loads applied in the directions indicated by the manufacturer.

The test arrangement shall also be representative of the least favourable conditions of electromagnetic forces tending to open the disconnector or earthing switch. The tests on an earthing switch integral to a disconnector shall be made with the same test connections as for the disconnector test.

Single phase tests on disconnector or earthing switches having one common operating mechanism for three poles shall be performed on a single pole farthest from the operating mechanism.

Earthing switches not forming an integral part of a disconnector shall be tested in an arrangement that fulfils the same requirements as for disconnectors.

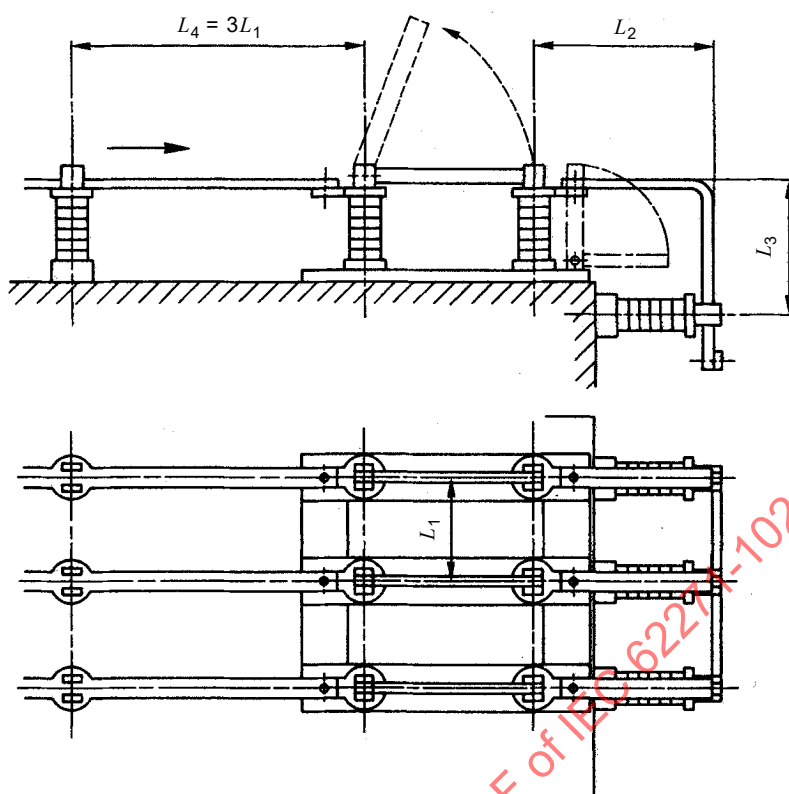
Disconnectors and earthing switches integrated in enclosed switchgear shall be tested as part of the switchgear assembly in accordance with IEC 62271-200, IEC 62271-201 or IEC 62271-203.

For divided support disconnectors and earthing switches, the vertical position of the contact in the contact zone shall be chosen to represent the most unfavourable condition with respect to the mounting of the fixed contact to flexible conductors or a rigid conductor. In case of doubt of the most unfavourable condition, the tests shall be performed in the highest and the lowest position of the contact within the rated contact zone.

All tests should preferably be performed three-phase. If a single-phase test is performed, the test should preferably be performed on two adjacent poles. If the test is performed on one pole, the return conductor shall be at phase distance from the tested pole. The return conductor shall be parallel to the main current path of the disconnector or earthing switch and at the same elevation above the base, or the equivalent, for disconnectors and earthing switches with vertical moving contact. The length of the return conductor shall be as given in Figures 2 to 5, as appropriate.

7.6.2.102 Disconnectors and earthing switches of $U_r \leq 52$ kV

The test arrangement given in Figure 2 shall be used for open type disconnectors and earthing switches of $U_r \leq 52$ kV. Hereby the distances L_2 and L_3 are as small as possible, but not smaller than L_1 .



IEC

Figure 2 – Three-phase test arrangement for disconnectors and earthing switches

The represented disposition covers:

- unsupported distances equal or smaller than L_4 for rigid conductors;
- phase-distance equal or larger than L_1 .

If L_1 has a range the phase distance of the test setup shall be the shortest. L_4 shall be the longest distance given by the manufacturer but not less than three times the shortest L_1 .

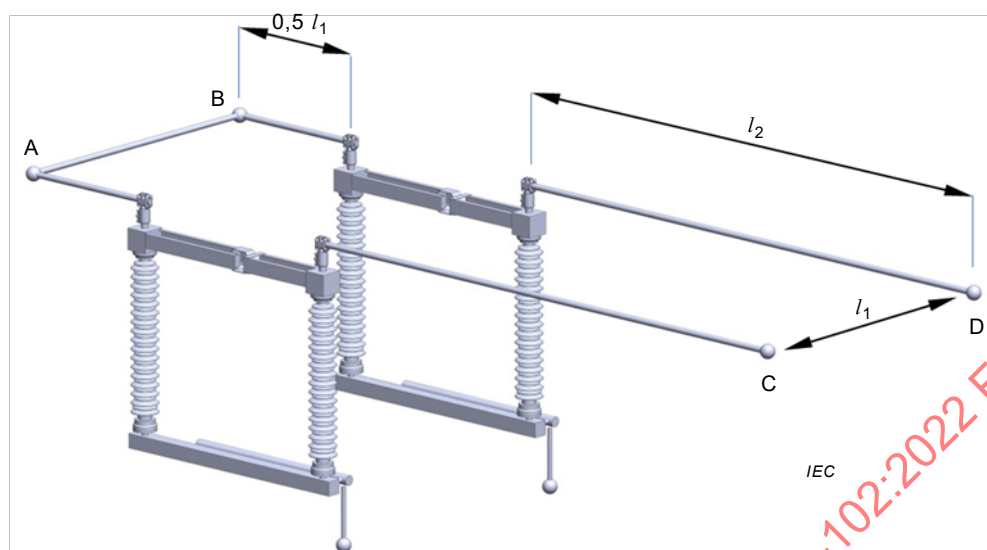
Avoid introduction of forces not representative of service conditions by the connections to the supply.

7.6.2.103 Disconnectors and earthing switches of $U_r > 52$ kV

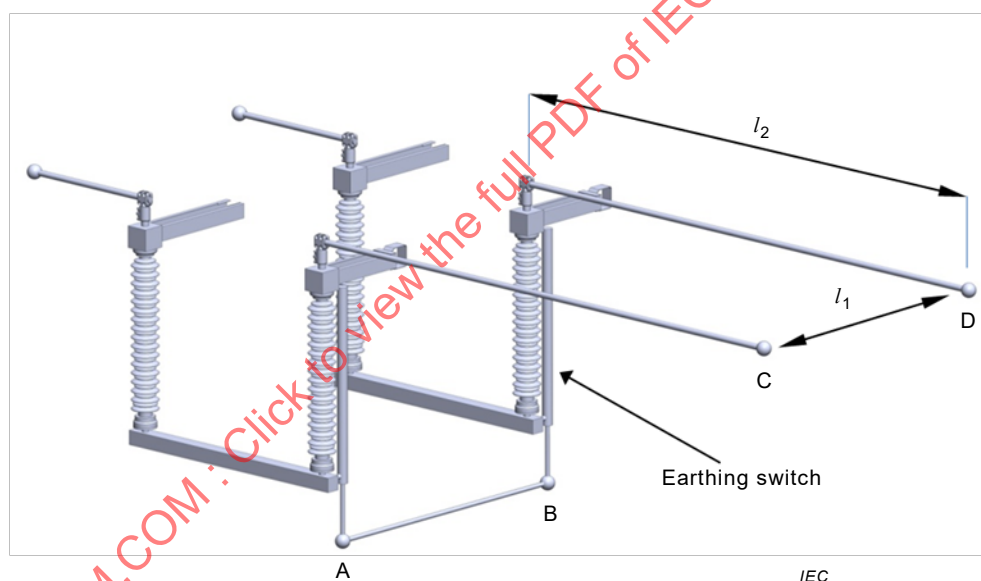
The single-phase test arrangement given in Figure 3 shall be used for disconnectors with a horizontal isolating distance and the relevant earthing switches; the test arrangement given in Figure 4 and Figure 5 shall be used for divided support disconnectors with a vertical isolating gap and the relevant earthing switches. Test results obtained on a disconnector or earthing switch placed in a certain position (e.g. horizontal or vertical) are valid only for the position of the disconnector or earthing switch during this test.

Three-phase test arrangements shall follow the same general pattern as the single-phase test arrangements of Figure 3 to Figure 5.

The short-circuit path between poles of the earthing switch schematically represented in Figure 3 shall reproduce during tests the installation conditions stated by the manufacturer. In particular, the position and fixing method of the conductors used to connect the poles between them and to the earth shall be considered.



a) Test arrangement for disconnectors



b) Test arrangement for earthing switches

Key

A–B Short-circuit connection

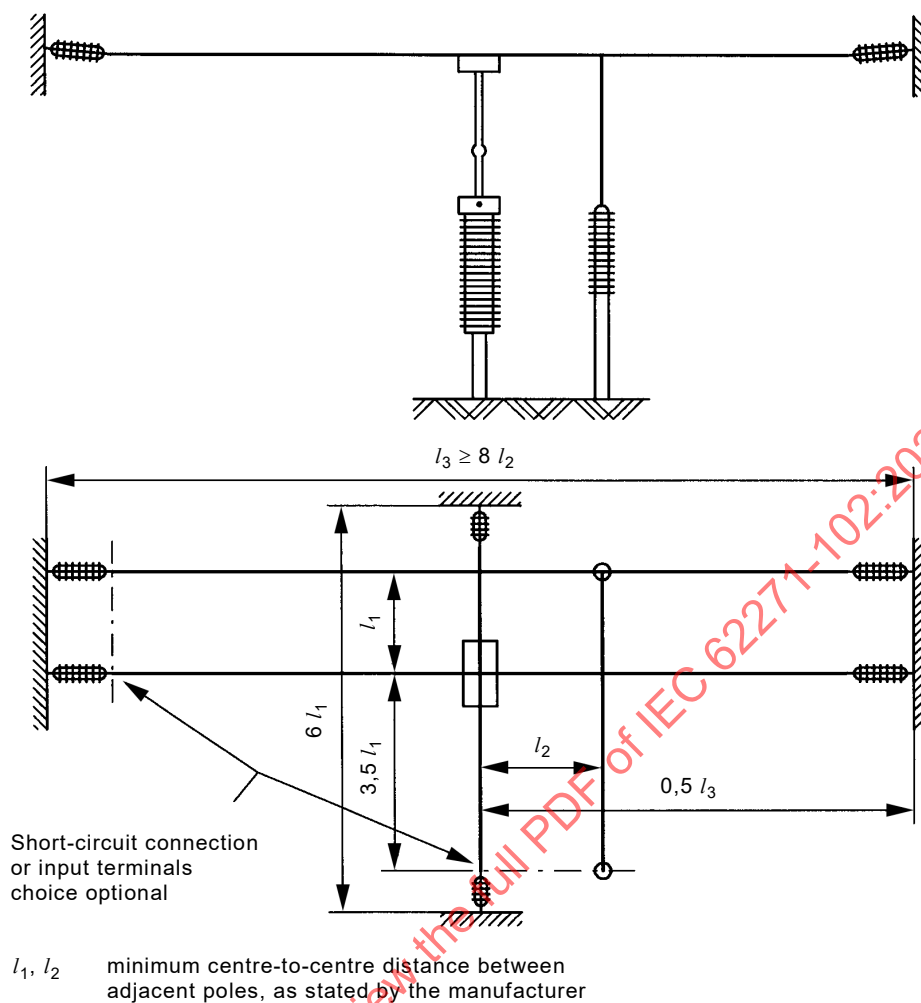
C–D Input

l_1 Minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

$l_2 = 2 \times l_1$ For $52 \text{ kV} < U_r \leq 550 \text{ kV}$

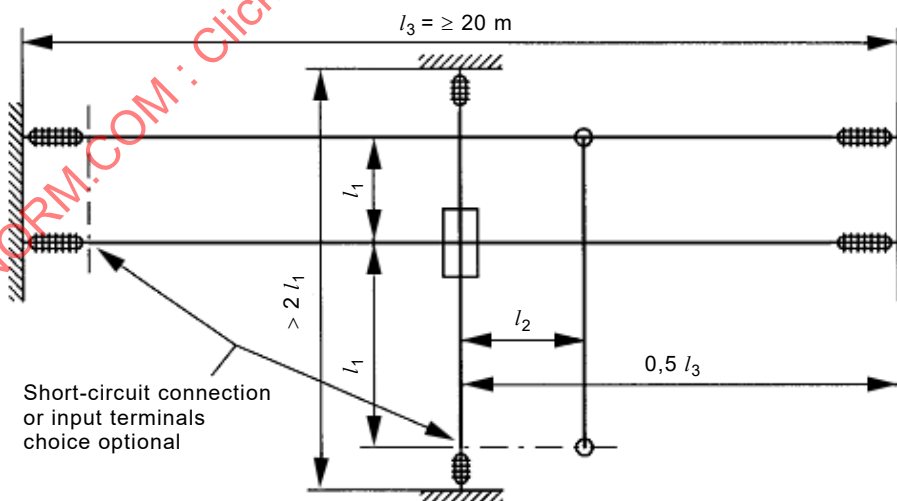
$l_2 = 0,5 \times l_1$ For $U_r > 550 \text{ kV}$, with a minimum of 7 m

Figure 3 – Single-phase test arrangement for disconnectors with a horizontal isolating distance and for earthing switches of $U_r > 52 \text{ kV}$, to be used with flexible or with rigid conductors



IEC

a) Test arrangement for disconnectors of $52 \text{ kV} < U_r \leq 550 \text{ kV}$

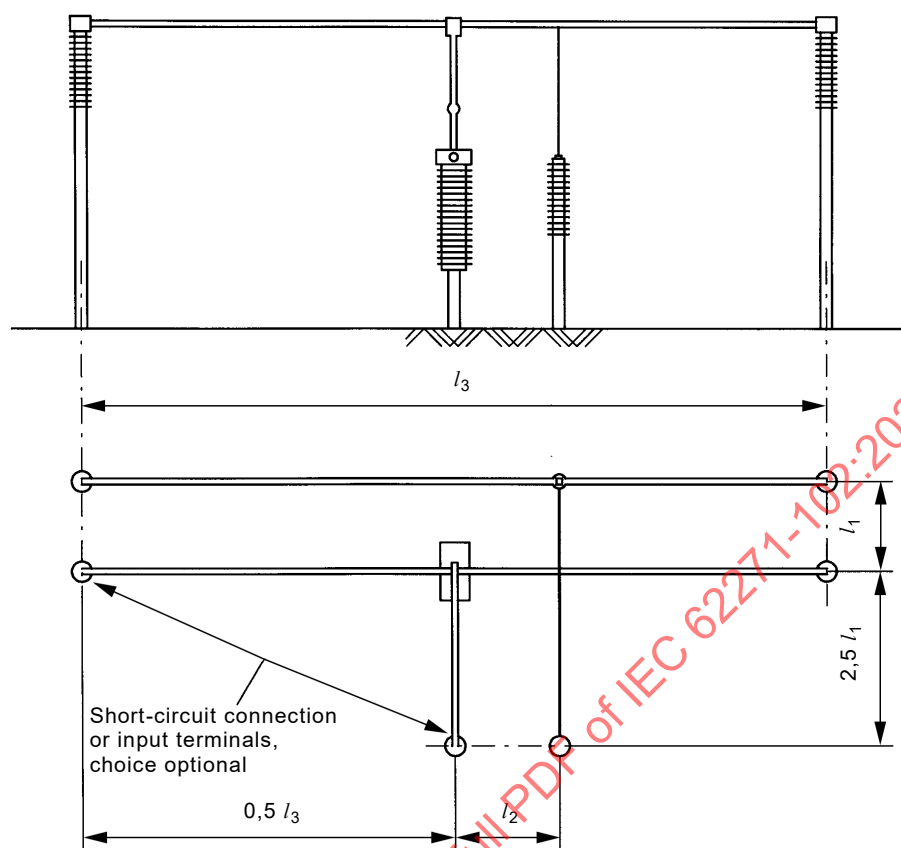


l_1, l_2 min. 10 m and max. centre-to-centre distance between
adjacent poles as stated by the manufacturer

IEC

b) Test arrangement for disconnectors of $U_r > 550 \text{ kV}$

Figure 4 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52 \text{ kV}$ with a vertical isolating distance, to be used with flexible conductors

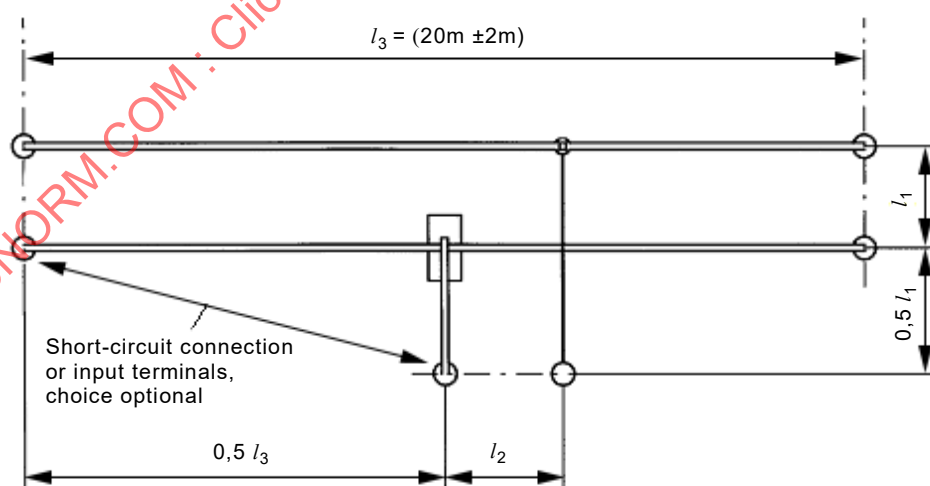


l_1, l_2 minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

IEC

For $U_r \leq 145$ kV $l_3 \geq 4l_1$
For $U_r \geq 170$ kV $l_3 = (20 \pm 2)$ m

a) Test arrangement for disconnectors of $52 \text{ kV} < U_r \leq 550 \text{ kV}$



l_1, l_2 minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

IEC

b) Test arrangement for disconnectors of $U_r > 550 \text{ kV}$

Figure 5 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52 \text{ kV}$ with a vertical isolating distance, to be used with rigid conductors

Disconnectors and earthing switches to be connected in the substation to flexible or rigid conductors, according to their documentation, shall be tested using flexible conductors with their rated static mechanical terminal load (e.g. longitudinal direction F_{a1} or F_{a2} in Figure 8 and F_{a1} , and F_{a2} in Figure 9) in a test setup with the dimensions given in Figure 3 or Figure 4 respectively. Disconnectors and earthing switches, according to their documentation, to be connected only to rigid conductors shall be tested with rigid conductors in a test arrangement with the same dimensions and without intentional static mechanical terminal load except the one given by the weight of rigid conductors. The dimensions and material of the conductors used shall be stated in the test report.

After applying 50 % of the longitudinal rated static terminal load, the disconnector or earthing switch may be adjusted, before the 100 % load is applied

All details referring to the test arrangement are mandatory, the details of the disconnector and earthing switch shown are given as an example.

For standardization of tests when they are performed with flexible conductors, where the rated currents of the equipment are larger than 1 250 A continuous current or 31,5 kA short-time withstand current for a duration of 1 s, two flexible conductors shall be used having a centre line distance of (70 ± 30) mm without spacers. Disconnectors and earthing switches of $U_r \geq 300$ kV shall also be tested with these two flexible conductors.

Unless the tested disconnector or earthing switch is solidly fixed to the foundation, the spring constant of the support structure has to be taken into consideration (IEC 60865-1).

The test report shall provide clear details of the mounting arrangements used for the tests or record that the disconnector was solidly fixed to the foundations.

Avoid introduction of forces not representative of service conditions by the connections to the supply, and static terminal loads larger than the rated static mechanical terminal loads of the test object.

If, in the test setup, the short side of the low-level conductor cannot be supported, it may be supported by the disconnector. This may result in a higher dynamic mechanical terminal load.

NOTE 1 In principle, Figure 3 can be used for testing earthing switches with an appropriate arrangement of the earth conductor.

NOTE 2 In principle, Figure 4 can be used for testing integrated earthing switches with an appropriate arrangement of the earth conductor.

7.6.3 Test current and duration

Subclause 7.6.3 of IEC 62271-1:2017 is applicable.

7.6.4 Conditions of disconnectors and earthing switches after test

Subclause 7.6.4 of IEC 62271-1:2017 is applicable with the following addition.

The rated peak withstand current and the rated short-time withstand current, carried by a disconnector or earthing switch in the closed position during the rated duration of short-circuit, shall not cause:

- mechanical damage to any part of the disconnector or earthing switch;
- separation of the contacts.

After the test, a no-load operation shall be made with the rated value of power supply for independent power-operated devices, with minimum value of power supply for dependent power-operated devices, and for manually (dependent or independent) operated devices with

a force no higher than the values given for manually operated devices in 6.105. The disconnector or earthing switch shall open at the first attempt.

In the case of performing the short-circuit withstand test with a single-phase test on one pole of a three-pole disconnector or earthing switch operated by a common driving mechanism or shaft, exact details of the test procedure and the measured torque/force at the exit of the driving mechanism during the no-load operation shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus after a three phase short circuit occur. This test method may require the insertion of a torque/force measurement device in the power kinematic chain for testing. The measured torque/force in the power kinematic chain to open the pole under test of the disconnector or earthing switch tested shall be not more than the value given by the driving mechanism when blocking the exit of the driving mechanism divided by the number of poles of the switching device under test.

After the no-load operation, for earthing switches, sound earth connection and sound insulation shall be verified by the following:

- visual inspection shall be made (if possible). Significant contact erosion or significant contact welding should not be observed. Light welding of contacts is permitted;
- when significant contact erosion is suspected or if visual inspection is not possible without dismantling the contacts, sound earth connection shall be verified by checking the electrical continuity according to 7.4.3 of IEC 62271-1:2017;
- in case of doubt of insulating properties or if visual inspection is not possible without dismantling, 7.2.12 is applicable to verify the dielectric conditions across the isolating gap and to earth.

After the no-load operation(s), for disconnectors:

- to verify the current carrying capacity main circuit resistance measurement shall be made as close as possible to the contacts. The increase of resistance after the test shall not exceed 20 % of the value measured before the test;
- when the contact resistance exceeds this value a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the contacts;
- visual inspection shall be made (if possible). In case of doubt of insulating properties or if visual inspection is not possible without dismantling, 7.2.12 is applicable to verify the dielectric conditions across the isolating gap and to earth.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1:2017 is applicable.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 is applicable.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 is applicable.

7.10 Additional tests on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:2017 is applicable.

7.11 X-ray radiation test for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 is applicable.

7.101 Test to prove the short-circuit making performance of earthing switches

7.101.1 General test conditions

Earthing switches, having a short-circuit making current capability, shall be subjected to two (class E1) or five (class E2) making operations respectively, in a making test series in accordance with the procedures of 7.101.7.

The following test methods are applicable for combined function earthing switches that have short-circuit making capability in the other function:

- the short-circuit making tests shall first be performed on the other functions, in accordance with the relevant standards, followed by the short-circuit making tests on the earthing function, without intermediate maintenance;
- alternatively, the short-circuit making tests on the combined function earthing switch may be performed on a new combined function earthing switch preceded by at least one short-circuit making test on the other function followed by the short-circuit making tests on the earthing function without intermediate maintenance. This test method verifies only the short-circuit making capability of the earthing switch.

7.101.2 Arrangement of the earthing switch for tests

The earthing switch shall be tested under the representative conditions of installation and use, concerning the connections, support, enclosure and dimensions, in accordance with 7.6.2.

Its operating device shall be operated in the manner prescribed and in particular, if it is electrically, hydraulically or pneumatically operated, it shall be operated at the minimum supply voltage or pressure.

For gas-filled earthing switches, the tests shall be performed at the minimum functional pressure for insulation and/or switching.

For convenience of testing:

- the supply voltage to the coil for the closing operation may be increased to obtain a consistent closing time, provided it does not increase the closing speed of the contacts;
- in order to obtain accurate closing times an electrically or pneumatically released latch may be introduced at the toggle point.

Earthing switches with independent manual operation may be operated by an arrangement provided for the purpose of making remote control possible.

NOTE For testing purposes, it can be necessary to measure the travel characteristics, for example by using a travel recorder.

7.101.3 Test frequency

Earthing switches shall be tested at rated frequency, with a tolerance of $\pm 10\%$.

However, tests with a peak factor of 2,6 or above, at a supply frequency of 50 Hz or 60 Hz cover the requirements of both frequencies.

7.101.4 Test voltage

The test voltage shall be as follows:

- a) for three-phase tests, the average value of the applied voltage phase-to-phase shall not be less than the rated voltage U_r and shall not exceed this value by more than 10 % without the consent of the manufacturer. The differences between the average value and the applied voltages of each pole shall not exceed 5 %;

- b) for single-phase tests, the applied voltage shall not be less than the phase-to-earth value $U_r/\sqrt{3}$, and shall not exceed this value by more than 10 % without the consent of the manufacturer, with the exceptions given below:

for single-phase tests on three-pole operated earthing switches which have a spread between the first and second contact touch during closing exceeding half a cycle of the rated frequency, the applied voltage phase-to-earth shall not be less than U_r .

7.101.5 Test short-circuit making current

The short-circuit current during making test shall be expressed in terms of the peak current and the symmetrical RMS current. The symmetrical RMS value of current in each phase at 0,2 s shall be at least 80 % of the rated short-time withstand current. The prospective peak current shall be equal to the rated short-circuit making current (I_{ma}) with the tolerance of 0 % and +5 %.

The duration of the short-circuit current shall be at least 0,2 s.

The earthing switch shall be tested under the two extreme cases specified as follows:

- a) making at the peak of the voltage wave, (with a tolerance of -30° electrical degrees to $+15^\circ$ electrical degrees) leading to a symmetrical short-circuit current and the longest pre-arcing time. For convenience of testing, alternative test methods may be followed. The alternative test methods are given in Annex D;
- b) making at the zero of the voltage wave, without pre-arcing, leading to a fully asymmetrical short-circuit current. For convenience of testing, the test may be carried out at reduced applied voltage to obtain the rated short-circuit making current (I_{ma}). It may happen that the making operation does not occur exactly at the zero of the voltage wave. However, the extreme case b) is considered met if the rated short-circuit making current has been obtained.

7.101.6 Test circuits

Making tests shall be performed using the three-phase test circuit or the single-phase test circuit.

Three-phase tests cover:

- the interaction between the different phases;
- the stresses on the operating mechanism (in the case of a common operating mechanism).

Three-pole earthing switches shall be tested in a three-phase circuit in order to cover applications in both effectively and non-effectively earthed neutral systems. For testing purposes, the severity of making tests in circuits with unearthed neutral or solidly earthed neutral are considered to be equivalent. However, single-phase testing of earthing switches of $U_r > 52$ kV is allowed in the following cases:

- a) multi-enclosure type or open-air type earthing switches with separately stored closing energy for each pole;
- b) earthing switches operated pole-after-pole.

7.101.7 Test procedures

For class E1, the tests shall be performed with a sequence of two C operations with one single no-load O in between, i.e. C – O (no-load) – C, unless the test laboratory needs more no-load operations between the closing operations.

For class E2 earthing switches, the test sequence is $2C - x - 2C - y - 1C$, where x and y represent arbitrary number of no-load operations. The 2C operations consists of

C – O (no-load) – C, unless the test laboratory needs more no-load operations between the closing operations. There is no requirement on the time interval between the two closing operations.

No maintenance is allowed during a test sequence.

For combined function earthing switches, the arbitrary number of no-load operations represented by x and y in the test sequence for class E2 may be replaced by switching operations.

Due to non-simultaneity of poles or different instants of initiation of pre-arcs in the different poles, a peak making current, which is higher than the rated value, may occur in one pole. This is particularly the case if, in one pole, the current begins to flow a few milliseconds later than in the other two poles. If the earthing switch fails during such an event, this is considered to be a failure of the earthing switch.

The requirements with regard to the instant of making as specified in Table 15 shall be achieved during the tests.

Table 15 – Requirements on the instant of making

Class E1	Class E2
2 tests	5 tests
At least 1 test fulfilling the requirements of 7.101.5 a)	At least 2 tests fulfilling the requirements of 7.101.5 a)
At least 1 test fulfilling the requirements of 7.101.5 b)	At least 2 tests fulfilling the requirements of 7.101.5 b)
NOTE Normally the speed of closing of the contacts of the earthing switches with short-circuit making capability is high enough that both maximum pre-arcing and maximum peak current can be reached within a same test, however at different phases.	

7.101.8 Behaviour of earthing switches when making short-circuit currents

The following applies during the making tests:

- enclosed earthing switches having a rated short-circuit making current shall, when making the short-circuit, not project flames, liquids, gases nor particles outside the enclosure;
- from open type earthing switches, flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.101.9 Condition of earthing switch after short-circuit making tests

After performing the specified operations, mechanical parts, parts related to the electrical field control (for example field electrodes of a GIS earthing switch) and insulators of the earthing switch shall be practically in the same condition as before. The insulating properties shall not be degraded. The short-circuit making performance and short-time current withstand performance may be impaired.

NOTE The useful life of the earthing switch with regard to short-circuit making and short-time current withstand capability is normally considered to be at the end, after the specified number of making operations necessitating maintenance or replacement.

To verify this requirement, the earthing switch shall meet the following inspection conditions:

- mechanical conditions: After each operation only light welding of contacts is permitted. However, the earthing switch shall be able to open and close under the conditions given in 6.5 and 6.6, with the rated values for power operated devices or with 120 % of the values given for manually operated devices in 6.105 using the normal operating handle;

- b) electrical continuity: Visual inspection after the no-load operation is usually sufficient for checking the electrical continuity of the earthing switch. In case of doubt the electrical continuity shall be measured according to 7.4.3 of IEC 62271-1:2017;
- c) dielectric requirements: Visual inspection is usually sufficient for checking the above requirement. In case of doubt, a voltage test as a condition check according to 7.2.12 is to be performed. As an alternative, 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For earthing switches that are sealed for life, the voltage test as a condition check is mandatory.

7.101.10 Invalid tests

In the case of an invalid test, it may become necessary to perform a greater number of short-circuit making tests than required by this document. An invalid test is one where one or more test parameters demanded by the document are not met. This includes, for example, current, voltage and time factors as well as point-on-wave requirements (if specified) and the additional features in synthetic testing.

The deviation from the document could make the test less or more severe. Four different cases are considered in Table 16.

Table 16 – Invalid tests

Test conditions related to standard	Earthing switch passed	Earthing switch failed
More severe	Test valid, result accepted	Test to be repeated with correct parameters Modification of the design of the earthing switch not required
Less severe	Test to be repeated with correct parameters Modification of the design of the earthing switch not required	Modification of the design of the earthing switch required, aiming for improvement of the making capability All tests to be repeated on the modified earthing switch
NOTE "More severe" is considered to be a test performed with voltage and/or current above the tolerances and additionally for the alternative test methods a test with longer prearcing time.		

In the case of less severe test conditions, the invalid part of the test-duty may be repeated without reconditioning of the earthing switch. In those cases, the test report shall include reference to the invalid test. However, in the case of a failure of the earthing switch during such additional tests, or at the discretion of the manufacturer, the earthing switch may be reconditioned and the complete test-duty repeated. If any record of an individual operation cannot be produced for technical reasons, individual operations are not considered invalid, provided that evidence can be given in another manner that the earthing switch did not fail and the required testing values were fulfilled.

In the case of three-phase direct testing (single power source), even if the requirements in 7.101.5 a) and/or 7.101.5 b) are still not met during the repetition of the complete test duty, the earthing switch is considered to have passed the test if the requirements specified in 7.101.8 and 7.101.9 are fulfilled.

7.101.11 Type test reports

The results of the type test shall be recorded in type-test reports containing sufficient data to prove compliance with the rated short-circuit making current performance requirements. Sufficient information should be included so that the essential parts of the earthing switch tested can be identified. Refer to 7.1.2 of IEC 62271-1:2017.

The test report shall contain the information about the test arrangements, test circuits and test procedures.

General information concerning the supporting structure of the earthing switch should be included. Information regarding the operating devices employed during the tests should, where applicable, be recorded.

Typical oscillographic or similar records shall be provided so that the following can be determined:

- the making current expressed as a peak value and the RMS value at 0,2 s;
- the applied voltages;
- instantaneous value of voltages at the moment of the making;
- pre-arcing time.

7.102 Operating and mechanical endurance tests

7.102.1 General test conditions

The test shall be made at the ambient air temperature of the test location. During the test, the ambient temperatures shall be recorded and maximum and minimum values included in the test report.

The supply voltage shall be measured at the terminals of the operating devices with full current flowing. Auxiliary equipment forming part of the operating device shall be included.

For three-phase disconnectors and earthing switches operated by one mechanism, where the application of terminal load is required, it shall be applied to all terminals simultaneously.

7.102.2 Contact zone test

This test shall be made in order to prove satisfactory operation of divided support disconnectors or divided support earthing switches, in the various positions of the fixed contact within the limits of the rated contact zone defined according to 5.103 and Figures 6 and/or 7. With the device in the open position, the fixed contact shall be placed in the following positions:

- a) at a height of h on the vertical axis of the assembly;
- b) at a height of $h - z_r$ on the same axis;
- c) at a height equal to h and displaced from the vertical axis horizontally by $+y_r/2$;
- d) at a height equal to h and displaced from the vertical axis horizontally by $-y_r/2$;
- e) positions a) to d) at a distance equal to $+x_r/2$;
- f) positions a) to d) at a distance equal to $-x_r/2$,

where

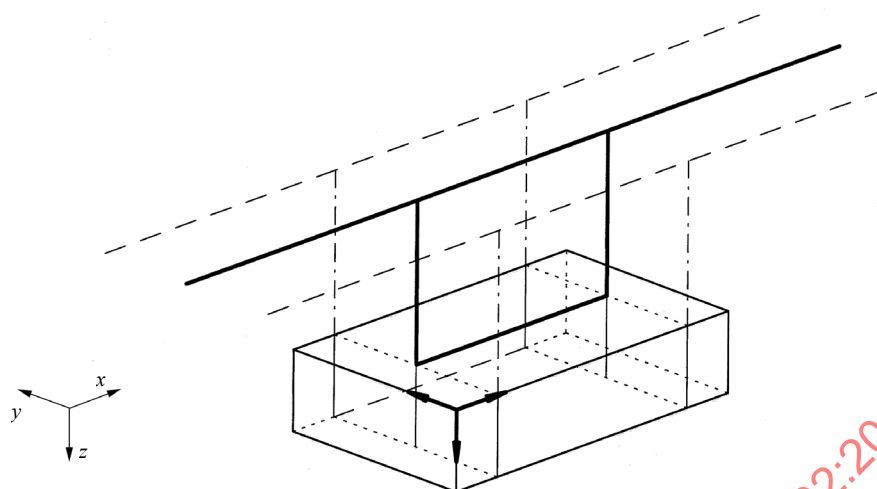
h is the highest position (stated by the manufacturer) of the fixed contact above the mounting plane;

x_r is the total amplitude of movement of the fixed contact in the x -direction;

y_r is the total amplitude of movement of the fixed contact in the y -direction;

the subscript, r , indicates the rated value assigned to the disconnector or earthing switch by the manufacturer.

In each position, the device shall close and open correctly.



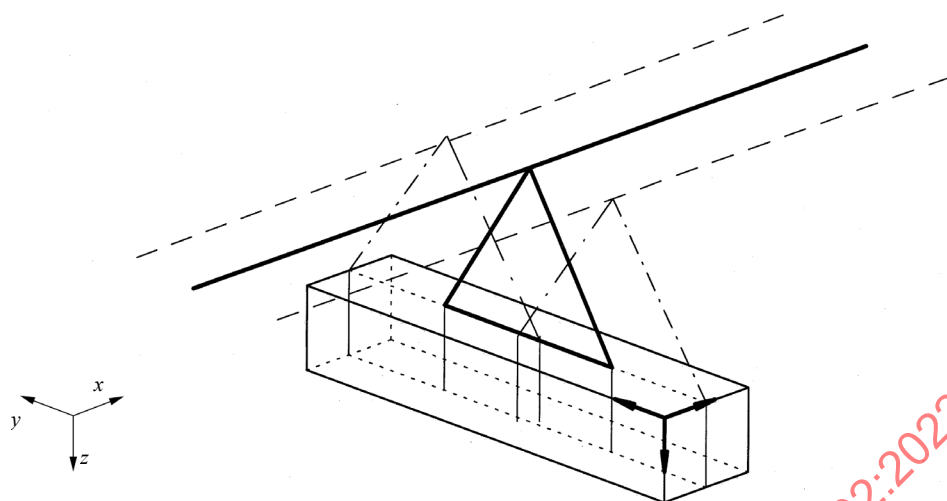
Key

- x Longitudinal to support (influence of temperature)
- y Perpendicular to support (influence of wind)
- z Vertical deflection (temperature and ice)

Figure 6 – Fixed contact parallel to support

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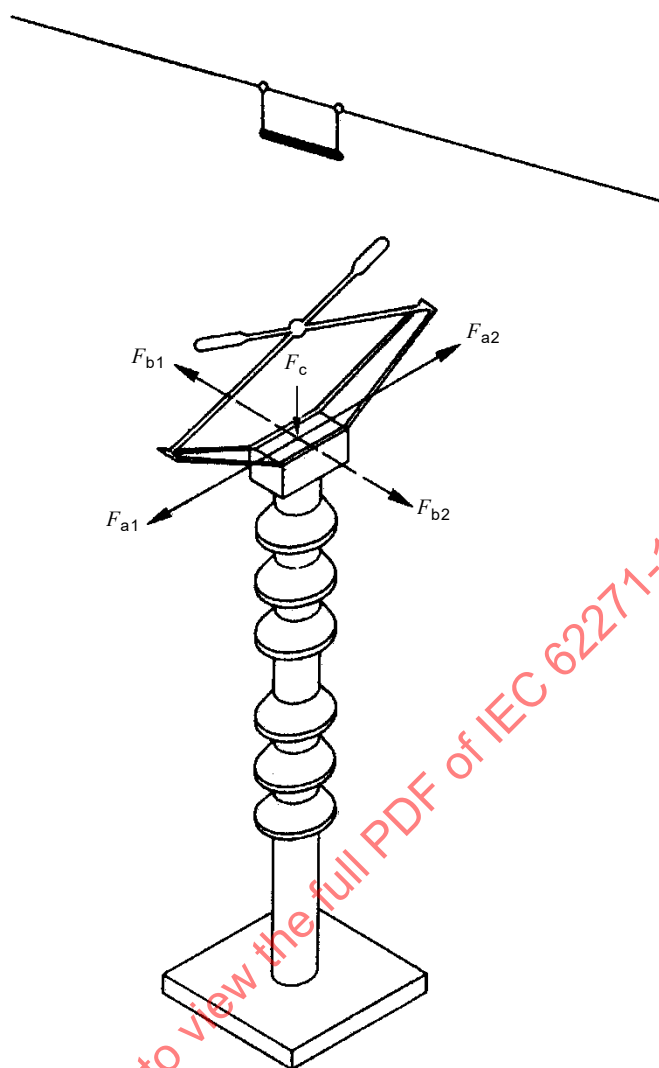
IEC

Key

- x Longitudinal to support (influence of temperature)
- y Perpendicular to support (influence of wind)
- z Vertical deflection (temperature and ice)

Figure 7 – Fixed contact perpendicular to support

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NOTE Above the pantograph, the fixed contact is shown.

Figure 8 – Example of the application of rated static mechanical terminal loads to a (divided support) pantograph disconnector (or earthing switch)

7.102.3 Mechanical endurance test

7.102.3.1 Test procedure

The tests defined in 7.102.3.1 and in 7.102.3.2 shall be performed on disconnectors and earthing switches of class M0.

The mechanical endurance test shall consist of 1 000 operating cycles. For disconnectors or earthing switches having a rated terminal load, 50 % of the rated static terminal load shall be applied during the test in direction F_{a1} or F_{a2} (Figure 8 and Figure 9), without voltage on, or current through, the main circuit. For disconnectors having two or three insulators and a normally horizontal isolating gap, the 50 % rated static terminal load shall be applied at both sides of the disconnector, but in opposite directions. For disconnectors and earthing switches with one insulator (operating insulators not being taken into consideration), the terminal load shall be applied to only one side of the disconnector or earthing switch. After applying 50 % of the rated static terminal load, the disconnector or earthing switch may be adjusted before performing the tests.

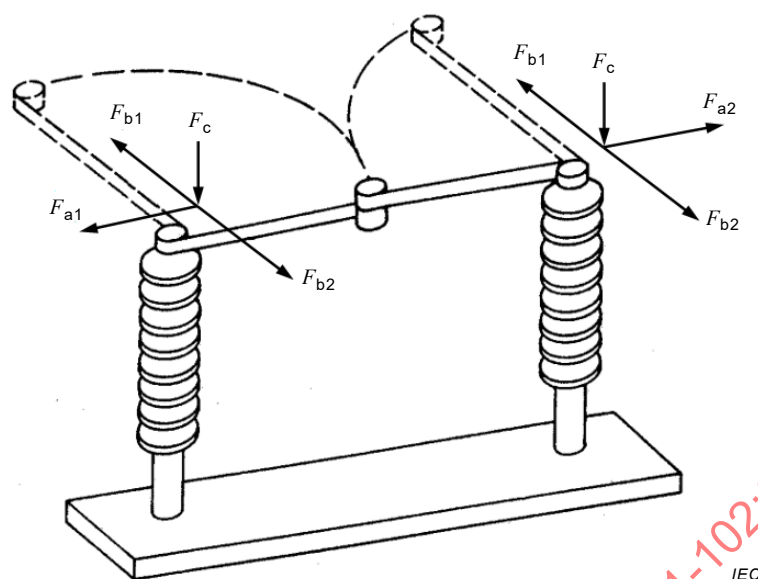


Figure 9 – Example of the application of rated static mechanical terminal loads to a two-column disconnecter

The closed and open positions shall be attained during each operating cycle.

During the test, the operation of the control and auxiliary contacts and position-signalling devices (if any) shall meet the requirements expressed in 6.104 and 6.4 of IEC 62271-1:2017. The test is considered failed if any of the control and auxiliary contacts and position-signalling devices do not operate at one of the close-open operating cycles.

The test shall be made on disconnectors and earthing switches equipped with their own operating mechanisms. During the test, lubrication in accordance with the manufacturer's instructions is permitted, but no mechanical adjustment or other maintenance is allowed.

On a disconnector or earthing switch having a power-operated mechanism:

- 900 close-open operating cycles shall be made at the rated supply voltage and/or rated pressure of compressed gas supply;
- 50 close-open operating cycles at the specified minimum supply voltage and/or minimum pressure of compressed gas supply;
- 50 close-open operating cycles at the specified maximum supply voltage and/or maximum pressure of compressed gas supply.

No specific time intervals between operating cycles or between closing and opening operations are required. These tests shall be made, however, at a rate such that the temperature rises of the energised electrical control components do not exceed the specified values. For the same purpose, external cooling may be applied during the test.

For manually operated disconnectors and earthing switches, the handle may, for convenience of testing, be replaced by an external power-operated device. In this case, it is not necessary to vary the power parameters.

7.102.3.2 Verification of successful operation

For the evaluation of the operating characteristics, before and after the mechanical endurance test programme, the following operations shall be performed without the static terminal load applied:

- five close-open operating cycles at the rated supply voltage and/or pressure (if any);
- five close-open operating cycles at the minimum supply voltage and/or pressure (if any);
- five close-open operating cycles at the maximum supply voltage and/or pressure (if any);
- five close-open manual operations if the switching device can be operated manually.

During these operating cycles, the operating characteristics, such as, if applicable, operating times, power consumption, maximum forces for manual operation, shall be recorded. Satisfactory operation of control and auxiliary contacts and position-indicating devices (if any) shall be verified. It is not necessary to include all the oscillograms recorded in the type test report.

The variation between the average values of each parameter, measured before and after the mechanical endurance test, shall be within the tolerances specified by the manufacturer.

After the test, all parts, including contacts, shall be visually inspected to check their good condition and they shall not show undue wear; see also 7.5.6.2, point 6, of IEC 62271-1:2017. The main circuit resistance, i.e. on disconnectors, shall be measured before and after the mechanical endurance test, as close as possible to the contacts. The resistance shall not increase by more than 20 % from the value measured before the test. If this limit is exceeded, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the contacts.

For earthing switches where contacts are visible, the fully closed and open positions during operation after the mechanical endurance test shall be verified by visual inspection.

For earthing switches where contacts are not visible, the fully closed and open positions during operation after the mechanical endurance test shall be verified by using the travel records or other appropriate methods.

For gas-insulated disconnectors and earthing switches, a tightness test according to 7.8 shall be performed before and after the mechanical endurance test.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % from the value measured before the test.

7.102.4 Operation during the application of rated static mechanical terminal loads

Twenty operating cycles with the rated power supply shall be made with the rated mechanical static terminal loads applied at each terminal in the directions specified by the manufacturer. When more than one load configuration is specified by the manufacturer, the 20 operating cycles shall be repeated for each configuration. The three components of each terminal load may be applied by a conductor pulling in the resultant direction and with the resultant force of the three vectors.

NOTE Any possible combination of the resultant forces applied at the terminals corresponds to one load configuration.

Examples of terminal loads applied at different types of disconnectors are shown in Figure 8 and Figure 9.

One example of possible configurations for a two columns disconnector is given here below:

- longitudinal (straight) load applied in direction F_{a1} at one terminal and F_{a2} at the opposite terminal;
- transversal (cross) load applied in direction F_{b1} or F_{b2} , at both terminals in the same direction;

- vertical load applied in direction F_c at both terminals (except for disconnectors specified to be connected to flexible conductors).

For only manually operated disconnectors and earthing switches the number of operating cycles is reduced to 10.

The loads shall be applied on both terminals at the same time.

The disconnector or earthing switch may be adjusted before the test and after having been loaded with 50 % of the rated longitudinal or perpendicular mechanical terminal force.

During each operation, the disconnector or earthing switch shall close and open correctly.

For verification, before and after the complete sequence of operating cycles, 7.102.3.2 and the appropriate comparators as required in 7.102.3.1 for mechanical endurance tests, are applicable (i.e. without static mechanical terminal loads applied).

7.102.5 Extended mechanical endurance tests

The tests defined in this subclause shall be performed on disconnectors class M1 and M2 and on earthing switches class M1.

In the case of disconnectors and earthing switches in GIS, the enclosure shall not be opened during the test.

Tests shall be carried out as follows:

- a) The extended mechanical endurance tests programme shall consist of a number of close-open operations carried out in accordance with 7.102.1 and 7.102.3.1.

According to the class assigned, one of the following number of operating cycles shall be performed:

- 2 000 (for class M1);
- 10 000 (for class M2).

After the first series of 1 000 operating cycles, some maintenance such as lubrication and mechanical adjustment is allowed and shall be performed in accordance with the manufacturer's instructions, and its reference included in the test report. Change of parts in the main circuit and in the kinematic chain is not permitted.

After each next series of 1 000 operating cycles, or at maintenance intervals (if of less than 1 000 operating cycles), the operating characteristics shall be recorded and evaluated (if power operated) at the rated pressure or voltage.

The programme of maintenance shall be defined by the manufacturer before the tests and recorded in the test report.

- b) Before and after the total test programme, verification of successful operation shall be performed as required in 7.102.3.2.
- c) In addition, after the total test programme, checks and tests shall be performed as follows:
- contact zone test (7.102.2), if applicable;
 - verification of operation during application of rated static mechanical terminal loads (7.102.4), if applicable;
 - verification of satisfactory operation with the minimum duration of the operating signal specified in the manufacturer's documentation;
 - verification of operation of the mechanical strain-limiting devices, if any.

7.102.6 Testing of mechanical interlocking devices.

Disconnectors and earthing switches which are not covered by switchgear and controlgear assembly standards (e.g. IEC 62271-200, IEC 62271-201 and IEC 62271-203) shall be tested as follows, if mechanical interlocking devices are provided blocking the operating shaft or power kinematic chain.

All interlocking devices shall be submitted to 5 attempts to perform close and/or open operation for any interlocked position of disconnector and/or earthing switch, in order to prove compliance with requirements in 6.12.

Before each attempt, the interlocking devices shall be set in the position intended to prevent the operation of the switching device and then one attempt shall be made to operate the interlocked switching device. Operating forces given in 6.12 shall be employed and no adjustment shall be made to the switching devices or interlocking devices.

The tests are considered satisfactory if the interlocked switching devices and the interlocking devices are in proper working order and if the forces required to operate the switching devices are practically the same before and after the tests.

The operating forces are considered the same if the average value measured after the test is within the maximum and minimum values measured before the test. At least three close/open operations should be performed before the test to fix the minimum and maximum values for acceptance of the close or open operation after the test.

7.103 Operation under severe ice conditions

7.103.1 General

The tests defined in this subclause shall be made only if the manufacturer claims the suitability of disconnectors and earthing switches for operation under severe ice conditions (i. e. 10 mm ice coating and above).

Disconnectors and earthing switches having accessories to accommodate a bus-transfer current switching capability (disconnectors only) and a switching capability of induced currents (earthing switches only) shall be tested with these devices mounted.

NOTE Formation of ice may produce difficulties in the operation of electric power systems. Under certain atmospheric conditions, a deposit of ice can build up to a thickness that sometimes makes the operation of outdoor switching equipment difficult.

7.103.2 Test arrangement

- a) All parts of the disconnector or earthing switch to be tested shall be assembled, together with their operating mechanism, in a room which can be cooled to a temperature according to the requirements given in 7.103.3. The energizing of heating elements of the control mechanism is permitted during the test. Supports, operating insulators and other operating members may be shortened to reduce the height of the assembly to suit the test facilities available, provided the angle of rotation of the parts affected and the bending of thrust linkages remain unchanged.

In choosing the refrigeration capacity required, the heat content of the water with which the apparatus under test is sprayed should be taken into account.

- b) A single-pole of a three-pole apparatus may be tested if each pole has a separate operating mechanism. In the case of a three-pole apparatus up to and including 52 kV having one common operating mechanism for the three poles, the complete three-pole device shall be tested. In the case of voltages above 52 kV and if the testing laboratory cannot accommodate complete standard three-pole apparatus, modifications of mounting structures, post insulators or spacing, wherever possible, in order to enable the three-pole

test to be made are permitted. If the tests are not possible even in this configuration, tests with a single-pole apparatus operated by the common mechanism are permitted. In this last case, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus. In all cases, it is not allowed to change the original isolating distance for the disconnecter or the gap for the earthing switch.

- c) The disconnecter or earthing switch shall be tested for operation from the open position and the closed position separately.
- d) Prior to the test, any trace of oil or grease on parts that do not need to be lubricated in service shall be removed with an appropriate solvent. This is because thin films of oil or grease prevent ice from adhering and greatly change the results of tests.
- e) For measurement of ice thickness, a copper bar or tube 30 mm in diameter and 1 m in length shall be mounted in a horizontal position in a place where it will receive the same general rainfall as the apparatus under test.
- f) The arrangement shall allow the entire apparatus to be sprayed with artificial rain falling from above at various angles, from the vertical to 45°. The water used in the spray should be cooled to a temperature between 0 °C and 3 °C and shall reach the test object in the liquid state.

7.103.3 Test procedure

7.103.3.1 Checks before the formation of ice coating

Before testing, the disconnecter/earthing switch shall be subjected to:

- 5 close-open operating cycles at the rated supply and/or pressure (if any);
- 5 close-open manual operations if the switching device can only be operated manually;
- the measurement of the resistance of the main circuit in accordance with 7.4.4.

During the operating cycles, operating characteristics such as, if applicable, operating times, power consumption, maximum forces for manual operations, shall be recorded. Satisfactory operation of control and auxiliary contacts, and position-indicating device (if any) shall be verified. It is not necessary to include all the oscillograms recorded in the type test report.

7.103.3.2 Formation of ice coating

Nature produces ice coatings which may be divided into two general categories:

- a) clear ice, generally resulting from rain falling through air somewhat below the freezing point of water;
- b) rime ice, characterized by a white appearance, formed for example from atmospheric moisture condensing on cold surfaces.

For type tests a coating of solid clear ice of the required thickness shall be produced according to the procedure described below.

- a) Lower the room temperature down to 2 °C and start the spray of pre-cooled water. Continue this spray for a minimum of 1 h while holding the room temperature between 0,5 °C and 3 °C.
- b) Lower the room temperature down to the range between –7 °C and –3 °C while continuing the water spray. The rate of temperature change is not critical and may be whatever is obtainable with available refrigeration apparatus.
- c) Hold the room temperature within –7 °C and –3 °C and continue to spray until the specified thickness of ice can be measured on the top surface of the test bar. The amount of water should be controlled to cause ice to build up at the rate of approximately 6 mm/h.

NOTE 1 If the specific thermal capacities per unit surface area of test bar and apparatus under test differ considerably, even identical spraying conditions may produce very different ice coatings. These differences in thickness may be minimized by short periods of spraying alternating with longer periods of cooling.

NOTE 2 As a guide, it has been observed that between 20 l and 80 l per hour per m² of area sprayed is required to cause ice to be deposited at a rate of approximately 6 mm/h.

- d) Discontinue the spray and maintain the room temperature within $-7\text{ }^{\circ}\text{C}$ and $-3\text{ }^{\circ}\text{C}$ for a period of at least 4^{+2}_0 h. This ensures that all parts of the disconnector/earthing switch and the ice coating have reached a constant temperature.

7.103.3.3 Checks after the formation of ice coating

After the formation of ice coating, the satisfactory operation of the disconnector/earthing switch shall be checked:

- if the disconnector or earthing switch is manually operated, the operation will be considered as satisfactorily completed if the apparatus has been operated to its final closed or open position applying normal operating forces (being permissible to remove the ice from the insertion point of the handle);
- if the disconnector or earthing switch is electrically, pneumatically or hydraulically operated, the operation will be considered as satisfactorily completed if the apparatus has been operated on the first attempt up to its final closed or open position by the operating device supplied at its rated voltage or pressure.

Immediately after the closing operation, the electrical continuity across the contacts shall be checked.

When the disconnector/earthing switch is ice-free, it shall be subjected to the same checks of 7.103.3.1, with the room temperature restored to normal ambient temperature (above $10\text{ }^{\circ}\text{C}$). The apparatus shall be considered to have passed the test if its mechanical and electrical performance is not affected; this condition shall be considered as met if:

- the resistance measured before the formation of ice coating has not increased by more than 20 %;
- the variation between the average values of each parameter, measured before the formation of ice coating, is within the tolerances given by the manufacturer.

The complete ice coating procedure and subsequent checks shall be performed for each position (i.e. closed/open) on each disconnector and/or earthing switch. Ice coating shall be naturally removed between tests, for example by leaving the apparatus enough time at adequate room temperature.

7.104 Low- and high-temperature tests

7.104.1 General

If the temperature limits for the service conditions of the apparatus (defined by the manufacturer) are above $+40\text{ }^{\circ}\text{C}$ or below $-5\text{ }^{\circ}\text{C}$, the following procedure shall be applied:

Single poles of three-pole apparatus may be tested individually if each pole has a separate operating mechanism. In the case of three-pole apparatus of $U_r \leq 52\text{ kV}$ having one common operating mechanism for the three poles, the complete three-pole device shall be tested.

In the case of $U_r > 52\text{ kV}$ and if the testing laboratory cannot accommodate complete standard three-pole apparatus, modifications of mounting structures, post insulators or spacing, wherever possible, are permitted to enable tests on all three poles. If the tests are not possible even in this configuration, tests with a single-pole apparatus operated by the common mechanism are permitted. In this last case, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus. In all cases, changing the original isolating distance for the disconnector or the gap for the earthing switch is not allowed.

If heat sources are required, they shall be in operation.

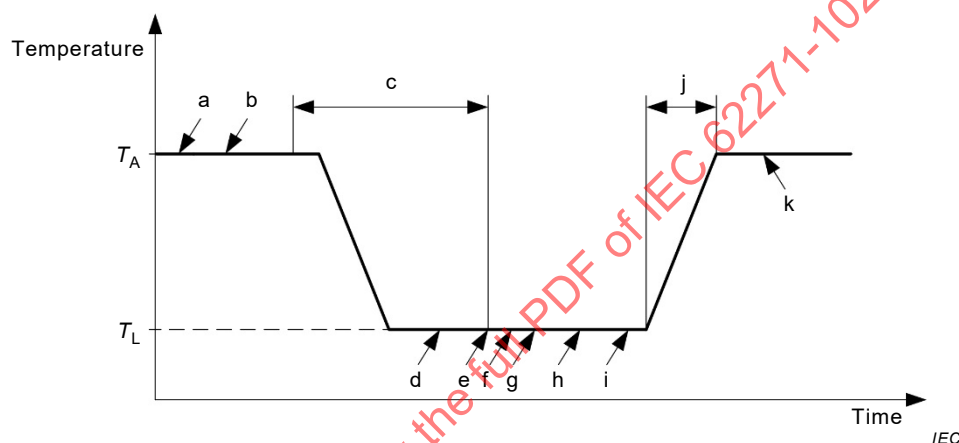
No maintenance, replacement of parts, lubrication or readjustment of the apparatus is permissible during the tests. For insulation pressure systems the tests shall be performed at rated filling pressure for insulation and/or switching. The characteristics recorded shall be within the tolerances specified by the manufacturer.

7.104.2 Measurement of ambient air temperature

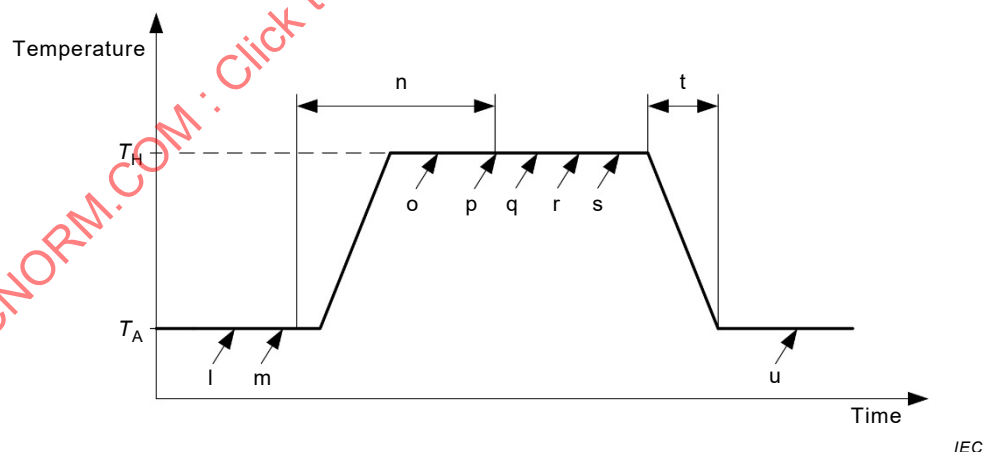
The maximum temperature deviation over the height of the apparatus shall not exceed 5 K, measured at a distance of 1 m from the apparatus.

7.104.3 Low-temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 10 a).



a) Low temperature test



b) High temperature test

NOTE Letters a to u identify application points of tests specified in 7.104.3 and 7.104.4.

Figure 10 – Test sequences for low and high temperature tests

If the low-temperature test is performed immediately after the high-temperature test and using the same sample, the low-temperature test can proceed after completion of item (t) of the high-temperature test. In this case, items (a) and (b) are omitted.

a) The test object shall be adjusted in accordance with the manufacturer's instructions.

- b) Characteristics and settings of the test object shall be recorded in accordance with 7.102.3.2 and at an ambient air temperature of $(20 \pm 5) ^\circ\text{C}$ (T_A). The tightness test for insulation pressure systems shall be performed according to 7.8.
- c) With the disconnecter in close position and/or the earthing switch in open position, the air temperature shall be decreased to the appropriate, minimum ambient air temperature (T_L), according to the service conditions defined by the manufacturer and in accordance with Clause 2, at a rate of change of approximately 10 K per hour. The disconnecter shall be kept in close position and/or the earthing switch in open position for a minimum of 12 h after the ambient air temperature stabilises at T_L .
- d) During the 12-h period with the disconnecter in the closed position and/or the earthing switch in the open position at temperature T_L , a tightness test shall be performed on insulation pressure systems. An increased leakage rate is acceptable, provided that it returns to the original value when the apparatus is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate should not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017. This tightness test shall be integral and performed by the accumulation method with appropriate apparatus for measurement of SF_6 concentration at the low temperature of the air in the testing room. For uniform diffusion of the SF_6 leaked inside the control volume, the use of a mixer or fan is highly recommended.
- e) After 12 h at temperature T_L , the disconnecter shall be opened and closed and/or the earthing switch shall be closed and opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- f) The low-temperature behaviour of the apparatus shall be verified, if applicable, by disconnecting the supply of all heating devices, including also the anti-condensation heating elements, for a duration t_x . At the end of the interval t_x , an operating order, at rated values of supply voltage and operating pressure, shall be given, if applicable. Then the disconnecter shall open and/or the earthing switch shall close. The operating characteristics shall be recorded.

The value of t_x up to which the apparatus is still operable without auxiliary power to the heaters, is stated by the manufacturer (not less than 2 h). In the absence of such a statement, the value is equal to 2 h.
- g) The disconnecter shall be left in open position and/or the earthing switch shall be left in close position for minimum 4 h.
- h) During the 4-h period with the disconnecter in open position and/or the earthing switch in closed position at temperature T_L , a tightness test shall be performed according to 7.8 for insulation pressure systems using a cumulative leakage method as indicated in item (d).
- i) After 4 h at temperature T_L , the disconnecter shall be closed and/or the earthing switch shall be opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- j) After completing the three closing and the three opening operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.
- k) After the apparatus has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the apparatus settings, and the operating characteristics shall be recorded and verified according to 7.102.3.2. A tightness test shall be made as in item b) for comparison with the initial characteristics.

For combined function earthing switches including a disconnecter function, the operation of the disconnecter and the operation of the earthing switch as described in items (e) and (i) shall be spaced by 4 h or by $t_x + 4$ h in case of heating devices are switched off. For insulation pressure systems a tightness test shall be performed at least once when both disconnecter and earthing switch are in the open position.

After the complete low temperature test the pressure shall not be under the minimum functional pressure.

7.104.4 High-temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 10 b).

If the high-temperature test is performed immediately after the low-temperature test and using the same sample, the high-temperature test can proceed after completion of item (j) of the low-temperature test. In this case, items (l) and (m) below are omitted.

- l) The test object shall be adjusted in accordance with the manufacturer's instructions.
- m) Characteristics and settings of the test object shall be recorded in accordance with 7.102.3.2 and at an ambient air temperature of $(20 \pm 5) ^\circ\text{C}$ (T_A). The tightness test for insulation pressure systems shall be performed according to 7.8.
- n) With the disconnecter in closed position and/or the earthing switch in open position, the air temperature shall be increased to the maximum ambient air temperature (T_H), declared by the manufacturer, at a rate of change of approximately 10 K per hour. The disconnecter shall be kept in close position and/or the earthing switch in open position for 12 h after the ambient air temperature stabilises at T_H .
- o) During the 12 h period with the disconnecter in close position and/or the earthing switch in open position at temperature T_H , a tightness test shall be performed for insulation pressure systems.
- p) After 12 h at temperature T_H , the disconnecter shall be opened and/or the earthing switch shall be closed three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- q) The disconnecter shall be left in open position and/or the earthing switch shall be left in the closed position for 4 h.
- r) During the 4-h period with the disconnecter in the open position and/or the earthing switch in the closed position at temperature T_H , a tightness test shall be performed for insulation pressure systems using a cumulative leakage method as indicated in item (d) of subclause 7.104.3.
- s) After 4 h at temperature T_H , the disconnecter shall be closed and/or the earthing switch shall be opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- t) After completing the three closing and the three opening operations, the air temperature shall be decreased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.
- u) After the apparatus has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the apparatus settings, operating characteristics and tightness as in items (l) and (m) for comparison with the initial characteristics.

For combined function earthing switches including a disconnecter function, the operation of the disconnecter and the operation of the earthing switch as described in items (p) and (s) shall be spaced by 4 h. A tightness test shall be performed at least once when both disconnecter and earthing switch are in the open position.

After the complete high-temperature test the pressure shall not be under the minimum functional pressure.

7.105 Tests to verify the proper functioning of the position-indicating device

7.105.1 General

These tests apply, when a position indicator according to 6.104.3.2 is used.

The equipment shall pass all the tests defined in 7.105.2, in order to verify both the sufficient strength of the power kinematic chain and the reliability of the position-indicating kinematic chain.

One specimen may be used for each operation mode.

7.105.2 Tests on the power kinematic chain and the position-indicating kinematic chain

The moving contact is locked in closed position for a disconnector and in open position for an earthing switch.

In the case of a three phase disconnector or earthing switch operated by a common operating device, only the moving contact of the pole located farthest from the point of transmission of the energy from the power source along the power kinematic chain is locked.

The tests consist of three attempts performed on the switching device with its own complete operating device equipped with a strain limiting device (if any) and/or with a torque (force) controlling system (if any).

- For manual operation (for dependent and for independent), the normal operation handle shall be used to perform the attempts. During the tests, double the normal forces shall be employed, with a minimum of 200 N, but limited to a force of 750 N or to the operation of a strain-limiting device or torque (force) controlling system. This force shall be applied halfway along the length of the gripping part of the operating handle. Where the operating handle or the operating device incorporates a feature which limits the operating torque (force), the switching device shall be operated until the strain-limiting device operates, provided that the operating handle with strain-limiting device is not interchangeable with other handles.
- For power operation (for dependent and for independent), the maximum supply voltage or pressure for operation (if power operated or if release operated) as defined in 5.9 and 5.11.102 shall be applied respectively during the attempts. In the case of the presence of a strain-limiting device or torque (force) controlling system, the switching device shall be operated until the strain-limiting device or torque (force) controlling system operates.

No adjustment or replacement shall be made along the position indicating chain between the attempts. No break on the mechanical kinematic chain shall be produced during the test, except for strain limiting devices designed to break, which will have to be replaced after they break. The test is considered passed if after each attempt the three moving contacts remain in the same position and the position-indicating device indicates correctly the position of the moving contacts.

If the position-indicating device is marked directly on a mechanical part of the power kinematic chain no additional test is required.

The enclosure providing protection to the position-indicating kinematic chain shall be tested for its IP and IK (in accordance with 6.104.3.1). The blows shall be applied to the points of the enclosure that are likely to be the weakest in relation to the protection of the indicating kinematic chain.

7.106 Bus-transfer current switching tests on disconnectors

7.106.1 General

These tests shall be performed only on disconnectors with a rated bus-transfer current switching capability.

7.106.2 Making and breaking tests

7.106.2.1 Arrangement of the disconnector for tests

The disconnector under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be used in the manner prescribed and in

particular, if it is power operated either electrically or pneumatically, it shall be operated at the minimum supply voltage or minimum functional pressure for operation, respectively.

Before commencing making and breaking tests, no-load operations shall be made to establish the mechanical operating characteristics of the disconnecter such as speed of travel, closing time and opening time.

For gas-insulated disconnectors, tests shall be performed at the minimum functional pressure for switching.

Disconnectors having an independent manual operation may be operated by remote control, using a power operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

Consideration shall be given to the effects of energization of both terminals of the disconnecter. When the physical arrangement of one side of the disconnecter differs from that of the other side, the supply side of the test circuit shall be connected to the side which represents the most severe condition. In case of doubt, 50 % of the breaking and making tests shall be carried out with the supply side of the test circuit connected to one side of the disconnecter and 50 % with the supply connected to the other side.

Only single-phase tests on one pole of a three-pole disconnecter need to be performed provided that the pole is not in a more favourable condition than the complete three-pole disconnecter with respect to:

- speed of make;
- speed of break;
- influence of adjacent phases.

Single-phase tests are adequate to demonstrate the making and breaking performance of a disconnecter, provided that it can be demonstrated that the arcing time and arc reach are such that there is no possibility of involvement of an adjacent phase. If, on the basis of a single-phase test, it is shown that the arc may reach an adjacent phase, then three-phase tests shall be performed using the specific disconnecter configuration.

7.106.2.2 Earthing of the test circuit and disconnecter

The frame of the disconnecter shall be earthed as well as the test circuit, see 7.106.2.6.

7.106.2.3 Test frequency

Disconnectors shall be tested at rated frequency, however disconnectors rated 50 Hz or 60 Hz may be tested with either of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of $\pm 10\%$ in accordance with Table C.1.

7.106.2.4 Test voltage

The test voltage U_{BT} shall be set so as to yield the required rated bus-transfer voltage ($^{+10}_0\%$) and shall be measured during the test across the open disconnecter terminals.

As noted in 7.106.2.1, only single-phase tests are normally required. If three-phase tests are required, then the test voltage of each phase shall not differ from the average test voltage by more than 10 %.

The power frequency recovery voltage shall be maintained for at least 0,3 s after interruption.

7.106.2.5 Test current

The test current shall be equal to the rated bus-transfer current ($+10\%$ to 0%) as defined in 5.108.1.

The current to be interrupted shall be symmetrical. The contacts of the disconnector shall not be separated until transient currents, due to the closing of the circuit, have subsided.

If three-phase tests are performed, the test current is the average of the current in all three phases. The test current in each phase shall not differ from the average test current by more than 10 %.

7.106.2.6 Test circuits

The test circuit as shown in Figure 11 shall have a power factor not exceeding 0,5. Two examples of test circuit are shown in Figure 11.

If three-phase tests are required, the neutral of the supply circuit and the load-side circuit shall be earthed.

Phase-to-earth insulation is not verified during the test when using the circuit given in Figure 11. If insulation performance has to be verified, other test circuits providing the rated phase-to-earth voltage are necessary.

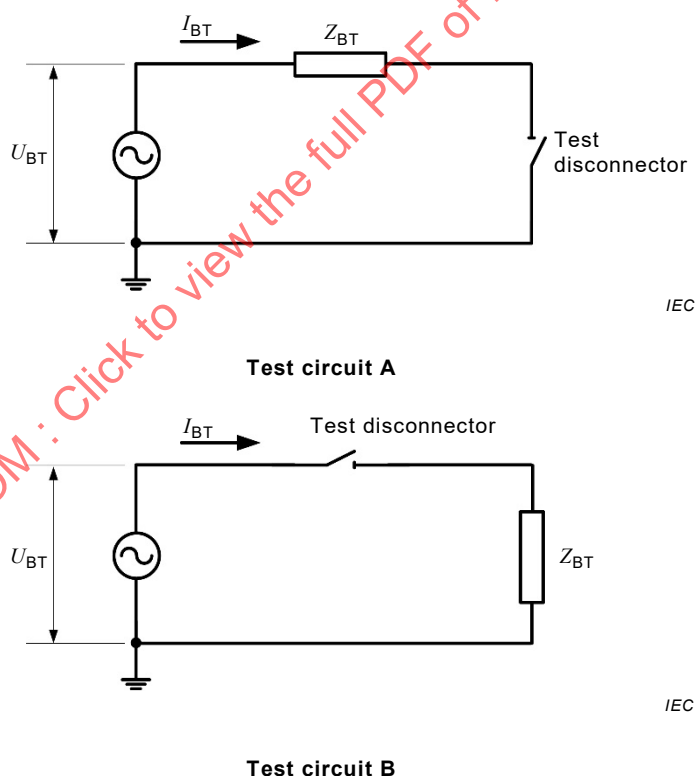


Figure 11 – Example of test circuit for bus-transfer current switching tests

7.106.2.7 Test duty

One hundred make-break operating cycles shall be made.

NOTE These 100 operating cycles are not considered adequate to demonstrate electrical life but they do provide an indication of contact erosion.

The opening operation shall follow the closing operation with a time delay between the two operations at least sufficient for any transient currents to subside. As well, the time between operations shall be sufficient to cool down the disconnecter if specified by the manufacturer instructions.

The tests shall be performed without reconditioning of the disconnecter during the test duty.

7.106.2.8 Behaviour of the disconnecter during tests

The disconnecter shall perform successfully without undue mechanical or electrical distress.

Outward emission of flame or metallic particles from the disconnecter during operation is permitted, if this does not impair its insulation level. Flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.106.2.9 Condition of disconnecter after tests

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the disconnecter shall be essentially in the same condition as before the test.

It is recognized that mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, will impair the switching capability of the disconnecter. However, the current-carrying capability and the isolating properties of the disconnecter shall not be impaired. The quality of the material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level.

The isolating properties of a disconnecter in the open position shall not be reduced below what corresponds to normal wear and ageing, by deterioration of insulating parts.

No-load operation and visual inspection of the disconnecter after tests are usually sufficient for verification of the isolating properties and the current-carrying capability of the disconnecter. In case of doubt, it can be necessary to perform the appropriate tests as mentioned below.

- If the isolating properties are doubted, a voltage test as condition check according to 7.2.12 is to be performed to verify the insulating properties. Alternative test methods given in 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For disconnectors that are sealed-for-life, the voltage test as a condition check is mandatory.
- If the current-carrying capacity is doubted, main circuit resistance measurement may be used where ever it is possible to measure the resistance close to the contacts. The increase in main circuit resistance after test shall not exceed 20 %. If the contact resistance exceeds this value, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the main contacts.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % from the value measured before the test. A visual inspection of the resistor shall be made after the type tests. No evidence of flashover across the resistor or any mechanical damage shall be observed. It can be necessary to disassemble the disconnecter for the visual inspection.

7.106.2.10 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017 the type test report shall contain the following information:

- a) typical oscillographic or similar records of the tests performed (at least one oscillogram for each 10 operations);
- b) test circuit;
- c) test currents;
- d) test voltages;
- e) power frequency recovery voltages;
- f) ~~prospective transient recovery voltages (TRV)~~ void;
- g) arcing times;
- h) number of making and breaking operations;
- i) condition of the contacts after test (see 7.106.2.9).

General information concerning the supporting structure of the disconnecter should be included. The operating time of the disconnecter and the type of operating devices employed during the tests shall be recorded.

7.107 Induced current switching tests on earthing switches

7.107.1 General

Type tests for earthing switches having a rated induced current switching capability shall include:

- tests to prove the electromagnetically induced current making and breaking capability;
- tests to prove the electrostatically induced current making and breaking capability.

7.107.2 Arrangement of the earthing switch for tests

The earthing switch under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be operated in the manner prescribed and, in particular, if it is electrically or pneumatically operated, it shall be operated either at the minimum supply voltage or supply pressure, respectively.

Before commencing making and breaking tests, no-load operations shall be made and details of the operating characteristics of the earthing switch, such as speed of travel, closing time and opening time, shall be recorded (see 7.102.3.2).

For gas-insulated earthing switches, tests shall be performed at the minimum functional gas pressure (density) for switching.

Earthing switches having a manual operating device may be operated by remote control using a power-operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

Only single-phase tests on one pole of a three-pole earthing switch need to be performed provided that it is not in a more favourable condition than the complete three-pole earthing switch with respect to:

- speed of closing;
- speed of opening;
- influence of adjacent poles or proximity of energized phases.

Single-phase tests are adequate to demonstrate the making and breaking performance of an earthing switch provided that it can be demonstrated that the arcing time and arc-reach are such that there is no possibility that involvement of an adjacent energized phase can occur. If, on the basis of a single-phase test, it is determined that the arc may reach an adjacent energized phase, then three-phase tests shall be performed using the specific earthing switch configuration.

7.107.3 Earthing of test circuit and earthing switch

The test circuit shall be earthed through the terminal of the earthing switch which is normally connected to earth.

7.107.4 Test frequency

Earthing switches shall be tested at rated frequency, however earthing switches rated 50 Hz or 60 Hz may be tested with any of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of $\pm 10\%$ according Table C.1.

7.107.5 Test voltage

The test voltages shall be set so as to yield the voltage specified in Table 9 before making and after breaking, and shall be measured across the earthing switch terminals during the test.

As noted in 7.107.2, only single-phase tests are normally required. If three-phase tests are required, then the test voltage of each phase shall not be different from the average test voltage by more than 10 %.

The power frequency test voltage shall be maintained for at least 0,3 s after interruption.

7.107.6 Test currents

The test currents shall be equal to the rated induced currents ($^{+10}_0\%$). The current to be interrupted shall be symmetrical. The contacts of the earthing switch shall not be separated until transient currents due to closing of the circuit have subsided.

If three-pole making and breaking tests are performed, the test current shall be measured as the average of the current in all three poles. The test current for each phase shall not be different from the average test current by more than 10 %.

Before contact separation, the waveform of the test current for electrostatically induced current breaking tests should be, as nearly as possible, sinusoidal (see IEC/TR 62271-305). This condition is considered to be met if the ratio of the RMS value of the total current to the RMS value of the fundamental component does not exceed 1,2. The test current shall not go through zero more than once per half cycle of power frequency before contact separation.

7.107.7 Test circuits

7.107.7.1 General

For type tests, the transmission lines may be replaced by elements consisting of capacitors, inductors and resistors.

If three-phase tests are required, the test circuit shall incorporate the same elements in each phase as for the single-phase test circuit in order to yield the appropriate test voltages and currents. The neutral of the supply circuit shall be earthed.

As an alternative, other test circuits than those specified may be used provided they fulfil the requirements for test currents, voltages and the transient recovery voltage parameters.

7.107.7.2 Test circuit for electromagnetically induced current making and breaking tests

The single-phase test circuit (Figure 12) consists of a supply circuit yielding the appropriate test voltage and test current such that the circuit power factor does not exceed 0,15. The components R and C are selected to yield the appropriate transient recovery voltage parameters. The damping resistance R may be connected in series or in parallel with the capacitance C .

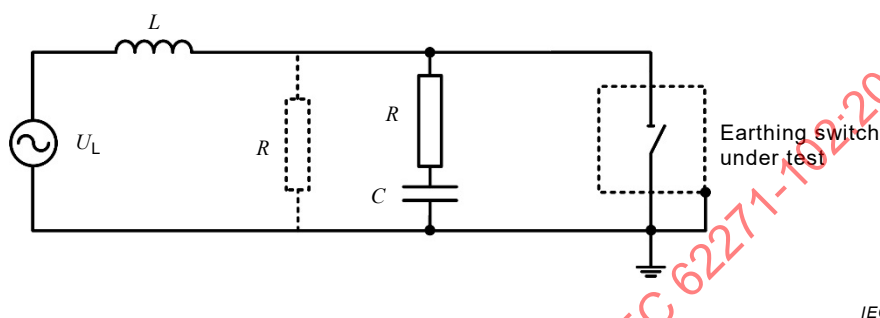


Figure 12 – Test circuit for electromagnetically induced current switching tests

The values of supply voltage (U_L) and inductance (L) can be calculated from the values of voltage and current given in Table 9, so as to produce the proper values of test current and power frequency recovery voltage.

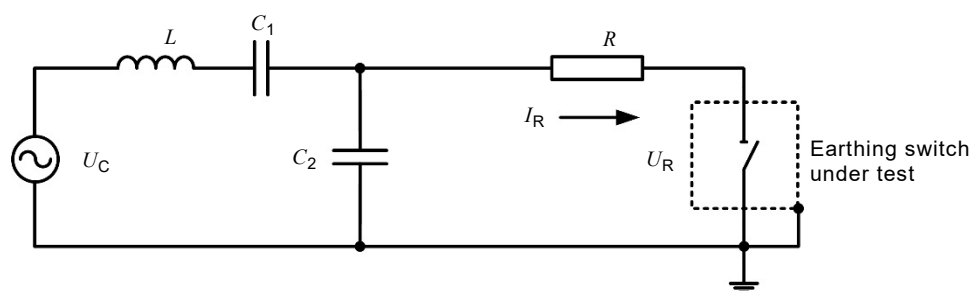
The prospective transient recovery voltage waveforms should have the form of a triangular wave due to the surge impedance of the connected transmission lines. As an alternative, transient recovery voltages having a $(1 - \cos)$ form may be used. Values of R and C may be selected to yield the proper transient recovery voltage parameters specified in Table 17.

Table 17 – Standard values of recovery voltages for electromagnetically induced current breaking tests

Rated voltage U_r kV	Class A			Class B			
	Power frequency recovery voltage	TRV peak	Time to peak	Power frequency recovery voltage	TRV peak	Time to peak	
	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right. \% \right)$ kV RMS	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right. \% \right)$ kV	$\left(\begin{smallmatrix} 0 \\ -10 \end{smallmatrix} \right. \% \right)$ μs	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right. \% \right)$ kV RMS	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right. \% \right)$ kV	$\left(\begin{smallmatrix} 0 \\ -10 \end{smallmatrix} \right. \% \right)$ μs	
72,5	0,5	1,1	100	2	4,5	300	
100							
123							
145	1	2,3	200				
170							
245	1,4	3,2					
300		850					
362	2	4,5	325	10	23	1 000	
420				20		45	2 000
550							
800							
1 100	5	11,3	750	65	145	2 400	
1 200							

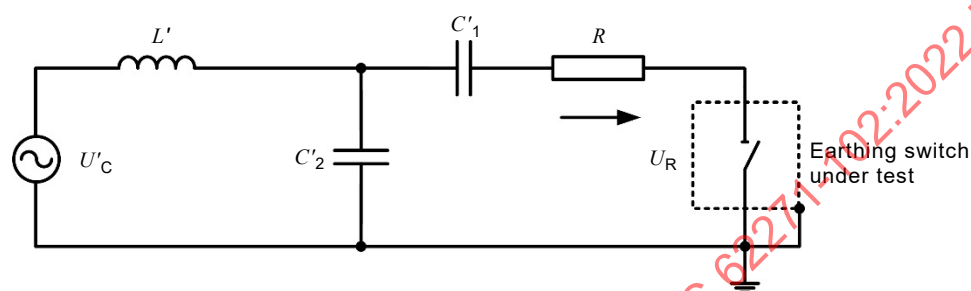
NOTE 1 Recovery voltages are valid for single-phase or three-phase tests.

NOTE 2 The prospective TRV waveform may be of a triangular or (1 – cos) form (see 7.107.7.2). The time to peak is valid for either waveform type.



Test circuit 1

IEC



Test circuit 2

IEC

$$L = Z_0^2 \times C_1$$

$$L' = L \times \left[\frac{C_1}{C_1 + C_2} \right]^2$$

$$u_c = \frac{i_R}{\omega C_1}$$

$$u'_c = \left[\frac{C_1}{C_1 + C_2} \right] \times u_c, \text{ or } u'_c = u_R$$

$$C_2 = C_1 \times \left[\frac{u_c}{u_R} - 1 \right]$$

$$C'_1 = C_1 + C_2 \quad C'_2 = C_2 \left(1 + \frac{C_2}{C_1} \right)$$

where

Z_0 is the surge impedance of the line:

- 425 Ω for 52 kV < $U_r \leq 170$ kV;
- 380 Ω for 245 kV $\leq U_r \leq 300$ kV;
- 325 Ω for 362 kV $\leq U_r \leq 800$ kV;
- 290 Ω for 1 100 kV $\leq U_r \leq 1\,200$ kV.

Key

i_R is the rated induced current from Table 9

u_R is the rated induced voltage from Table 9

C_1 is the test circuit capacitance given in Table 18

Figure 13 – Test circuits for electrostatically induced current-switching tests

7.107.7.3 Test circuits for electrostatically induced current switching tests

Either test circuit 1 or 2 in Figure 13 shall be selected as suitable for the test laboratory, since they are equivalent, as long as the equations within the circuit parameters are satisfied.

The power factor of the test circuit shall not exceed 0,15. The values of supply voltage (U_C), inductance L and capacitance C_2 for test circuit 1 can be calculated from the given values of C_1 in Table 18 and the rated current and voltage values in Table 9, by using the equations noted in Figure 13. This will result in the appropriate values of test current and voltage as well as the proper inrush current frequency and test-circuit surge impedance. Values for test circuit 2 can be calculated from the values derived for test circuit 1.

A resistance (R), not exceeding 10 % of the capacitive impedance [$1 / \omega (C_1 + C_2) = 1 / \omega C_1'$], as seen from the earthing switch, may be inserted in the circuits as shown in Figure 13. The value chosen, however, should not be greater than the surge impedance of the transmission line considered (see Table 18), nor lead to an aperiodic damping of the inrush current when closing the earthing switch.

Table 18 – Test circuit capacitances (C_1 values) for electrostatically induced current switching tests

Rated voltage U_r kV	Test circuit capacitance	
	Class A μF	Class B μF
72,5 – 100 – 123	0,07	0,27
145 – 170	0,13	
245	0,15	
300		0,80
362 – 420	0,29	1,18
550 – 800	0,35	1,47
1 100 – 1 200	0,8	2,63

NOTE Values of C_1 can be calculated from the expression:

$$C_1 = (6D) / (\pi Z_0)$$

where

D is the line length, in km;

Z_0 is the line surge impedance, in Ω .

Surge impedance assumed:

- 72,5 kV $\leq U_r \leq$ 170 kV: 425 Ω ;
- 245 kV $\leq U_r \leq$ 300 kV: 380 Ω ;
- 362 kV $\leq U_r \leq$ 800 kV: 325 Ω .
- 1 100 kV $\leq U_r \leq$ 1 200 kV: 290 Ω .

7.107.7.4 Test duties

Ten make-break operating cycles shall be made for each of the electrostatically and electromagnetically induced current-switching tests.

NOTE Ten operating cycles are not considered adequate to demonstrate electrical life, but will provide an indication of contact erosion.

The opening operation shall follow the closing operation with sufficient time delay between the two operations for any transient currents to subside.

The tests shall be performed without reconditioning of the earthing switch during the test programme.

7.107.7.5 Behaviour of earthing switch during tests

The earthing switch shall perform successfully without undue mechanical or electrical distress.

Outward emission of flame or metallic particles from the earthing switch during operation is permitted, if this does not impair its insulation level. Flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.107.7.6 Condition of earthing switch after tests

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the earthing switch shall be essentially in the same condition as before the test. The earthing switch shall be capable of carrying its rated peak withstand current and its rated short-time withstand current.

Mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, are acceptable.

Visual inspection and no-load operation of the earthing switch after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests as mentioned below.

If the isolating properties are doubted, a voltage test as condition check according to 7.2.12 is to be performed to verify the isolating properties. As an alternative, 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For earthing switches that are sealed for life, the voltage test as a condition check is mandatory.

7.107.7.7 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017, the type test report shall contain the following information:

- a) typical oscillographic or similar records;
- b) test circuits;
- c) test currents;
- d) test voltages;
- e) power frequency recovery voltages;
- f) prospective transient recovery voltages;
- g) arcing times;
- h) number of making and breaking operations;
- i) condition of earthing switch after test.

General information concerning the supporting structure of the earthing switch should be included. The operating time of the earthing switch and the type of operating devices employed during the tests shall be recorded.

7.108 Bus-charging current switching tests on disconnectors

7.108.1 General

These tests shall be performed on disconnectors forming part of gas-insulated switchgear classified for bus-charging current switching.

NOTE The limit of 300 kV is derived from SF₆-insulated switchgear experience. The dielectric performance of disconnectors during bus-charging current switching and the performance against VFTO during the switching depends on the insulating gas used. For more information, refer to CIGRE Technical Brochure No. 260, 2004 [7].

7.108.2 Test duties

Three test duties are defined:

- *test duty 1*: switching of a very short section of busbar duct, this test duty shall be performed on disconnectors of $U_r \geq 300$ kV;
- *test duty 2*: switching of parallel capacitors of circuit-breakers under 180° out-of-phase condition; this test duty is not mandatory;
- *test duty 3*: current-switching capability test; this test duty is not mandatory.

NOTE 1 Test duty 2 is a special type test for disconnectors placed close to circuit-breakers that are equipped with parallel capacitors.

NOTE 2 Test duty 3 is a special type test to be carried out according to this specification by agreement between the manufacturer and the user. It serves to demonstrate the current interruption capability of the disconnector when de-energizing long busbars. Typical current values are given in Table 11.

7.108.3 Arrangement of the disconnector for tests

The operating device of the disconnector under test shall be operated in the manner specified by the manufacturer and, in particular, if it is power operated, it shall be operated at the specified minimum supply voltage and/or minimum supply pressure. The time delay between operations shall be sufficient to cool down the disconnector if specified by the manufacturer instructions.

Before commencing the making and breaking tests, no-load operations shall be made and details of the operating characteristics of the disconnector such as closing time and opening time shall be recorded (see 7.102.3.2).

Tests shall be performed at the minimum functional gas pressure (density) for switching of the disconnector under test. Associated compartments shall be at their minimum functional gas pressure (density) as well.

In most cases the design of the disconnector involves asymmetries (for example asymmetrical shields, or moving contact/fixed contact differences, etc.). For these cases, the test arrangement of the disconnector shall be such as to perform the test under the most severe conditions. For test duty 1, the most severe test arrangement is considered to be that which results in maximum pre-striking distance for the closing operation. For test duty 2 and test duty 3, the test arrangement of the disconnector is considered to be of minor importance.

Only single-phase tests on one pole of a three-pole operated disconnector need to be performed, provided that this does not mean a change of operating speed of more than ± 15 %.

For disconnectors having three poles in one enclosure, a three-phase test arrangement is required. One phase is connected to the testing circuit, and the two remaining poles not involved in the switching process shall be grounded at both terminals.

7.108.4 Test frequency

Disconnectors shall be tested at rated frequency, however disconnectors rated 50 Hz or 60 Hz may be tested with any of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of ± 10 % in accordance with Table C.1.

7.108.5 Test voltages for making and breaking tests

During making and breaking tests, the power frequency voltage shall be applied and maintained for at least 0,3 s before and after the switching operation. In the case of a DC pre-charge voltage at the load side (test duty 1), the DC voltage shall be applied according to the specified level for about 1 min before the close operation. The load side shall not be grounded between the open and close operations. The test circuit should not contain elements that cause a decay of the trapped charge.

With reference to Figures 14, 16 and 17, the test voltages at source side and load side of the test arrangement shall be applied as given in Table 19.

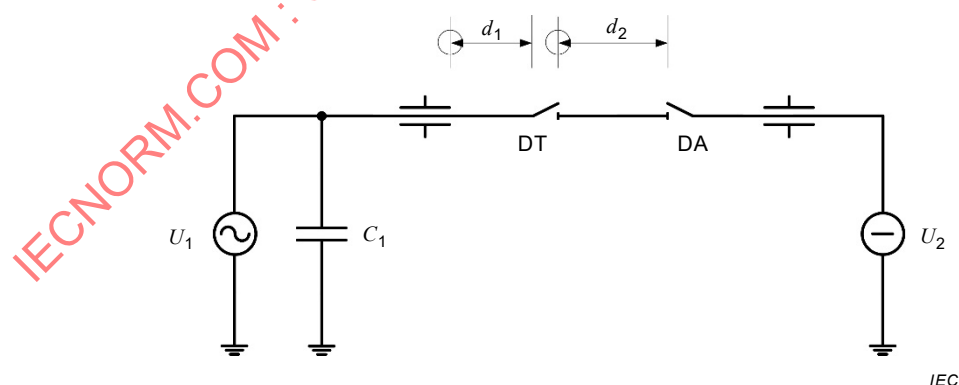
The test voltages in Table 19 are valid for the disconnector in the open position.

NOTE In the case of test duty 3, the test voltage can be considerably higher when the disconnector is in the closed position. This is caused by resonance phenomena, especially if the impedance of the supplying transformer is high, which is normal for transformers used for dielectric AC voltage tests. This voltage will increase severity of the test conditions. It will normally not be more than 10 %.

Table 19 – Test voltages for making and breaking tests

Test duty	Test voltage	
	Source side U_1	Load side U_2
1	$1,1 \times U_r / \sqrt{3}$	Pre-charge with negative DC voltage $-1,1 \times U_r \times \sqrt{2} / \sqrt{3}$
2	$1,1 \times U_r / \sqrt{3}$	AC voltage in phase opposition $1,1 \times U_r / \sqrt{3}$
3	$U_r / \sqrt{3}$	–

NOTE The factor 1,1 has been chosen to take into account statistical effects which are inherent in this kind of switching phenomena, and to restrict the number of test operations to those specified in Table 20. As test duty 3 should only indicate the switching capability of the disconnector, this increase of the test voltage is not necessary.



Key

DT Disconnector under test

DA Auxiliary disconnector

Busbar lengths d_1 and d_2 are understood to be taken as the following distances:

d_1 : open contact of the disconnector under test (DT) to the bushing connection;

d_2 : open contact of the disconnector under test (DT) to the open contact of the auxiliary disconnector (DA).

Figure 14 – Test circuit for test duty 1

7.108.6 Test circuits for making and breaking tests

7.108.6.1 Switching of a very short section of busbar duct, test duty 1

7.108.6.1.1 General

Figure 14 shows the test circuit for test duty 1. The load side shall be represented by a section of busbar, d_2 3 m to 5 m in length. The connection to the supply side shall be realised by another section of busbar, d_1 in length. In order to obtain representative very fast transient (VFT) conditions, the ratio d_2/d_1 , shall be in the range of 0,36 to 0,52. The source-side circuit shall have an added lumped capacitance, C_1 . The value of C_1 shall be chosen so that the peak value of the voltage to earth at the disconnector terminals is met as defined in 7.108.6.1.2.

Before starting a closing operation, the load side shall be charged by DC voltage according to Table 18, and the DC voltage source disconnected by the auxiliary disconnector, DA.

7.108.6.1.2 Transient voltage values

The voltage transients at the disconnector location during a close operation are used to characterize the behaviour of the test circuit and to ensure consistent overvoltage characteristics under test conditions. Two distinct aspects of transient voltages are of importance: these are the very fast transient (VFT) phenomena and the fast transient (FT) phenomena. The VFT phenomena are determined by the circuit arrangement as described in 7.108.6.1.1. The circuit response for the fast transient phenomena shall be verified at least once for the test arrangement by direct measurement (see 7.108.11) under the following conditions:

- source-side test voltage: $U_r/\sqrt{3}$;
- load-side voltage: 0 (no pre-charge).

For these conditions, the maximum peak value of the transient voltage to earth U_{TVE} at the first prestrike during a close operation shall be not less than $1,4 \times U_r \sqrt{2}/\sqrt{3}$ (for practical purposes a variation of 5 % is considered acceptable) and the time to maximum peak shall be less than 500 ns, (Figure 15).

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear the resistor shall be short-circuited or replaced by a solid conductor before the tests in order to verify the test circuit conditions described above.

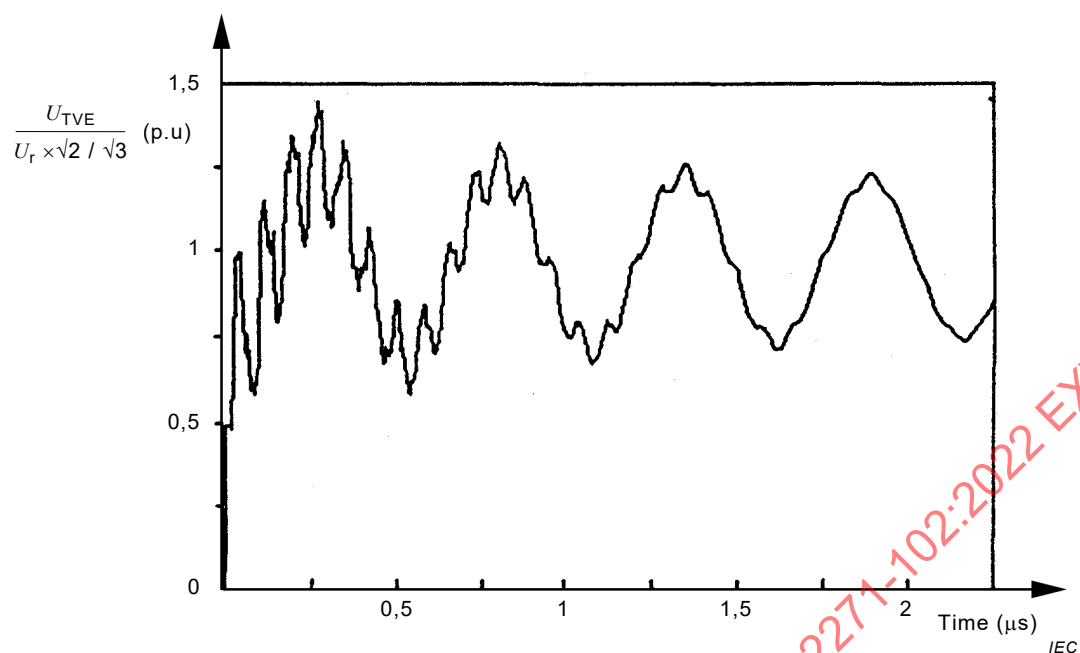


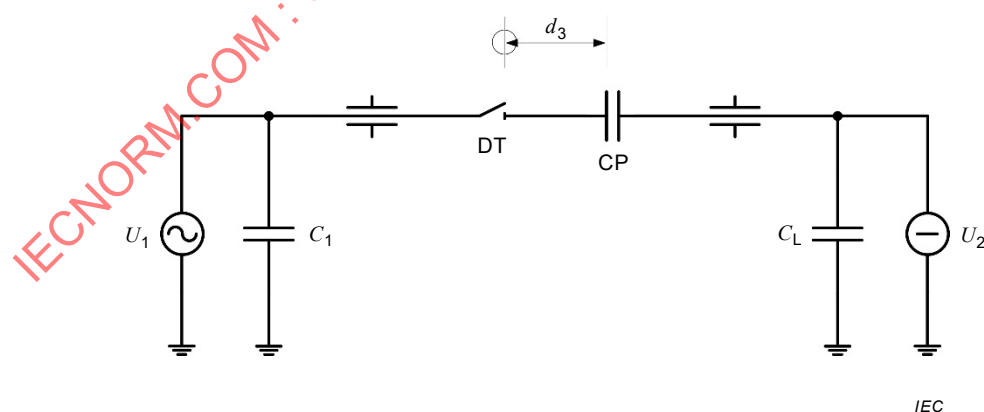
Figure 15 – Typical voltage waveform (Including VFT and FT components)

7.108.6.2 Out-of-phase switching, test duty 2

Figure 16 shows the test circuit for out-of-phase switching. The parallel capacitor CP of a circuit-breaker may be represented by the actual circuit-breaker with its own capacitor or by an adequate capacitance of equal or higher value than the capacitance used in service.

The shortest possible distance d_3 between capacitor CP and disconnector shall be established. The lengths of the other test circuit parts are not specified, but they should be as short as possible in order to minimize their influence on the capacitance of the test circuit.

The lumped capacitance C_L (Figure 16) shall be of a value not less than 400 pF. The ratio C_1/C_L shall be in the range of 4 to 6.



Key

- DT Disconnector under test
- CP Circuit-breaker parallel capacitor or equivalent capacitor

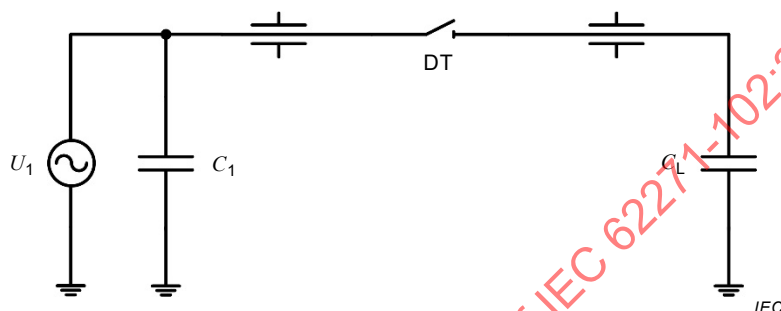
Figure 16 – Test circuit for test duty 2

7.108.6.3 Current switching capability test, test duty 3

The test circuit shown in Figure 17 applies. For this type of switching, the specific lengths of the busbar sections are of no significance. On the load side, a lumped capacitance C_L should be added in order to achieve the bus-charging current as given in Table 11 with a tolerance of $\pm 10\%$.

In order to reduce resonance effects, which can be caused due to a high source impedance, connection of a lumped capacitance C_1 of any value is acceptable to the source side.

Further testing conditions that affect the transient recovery conditions are subject to agreement between the manufacturer and the user.



Key

DT Disconnector under test

Figure 17 – Test circuit for test duty 3

7.108.7 Performance of making and breaking tests

During each test duty, the test series shall be performed without reconditioning the disconnector. The number of tests is given in Table 20.

Table 20 – Number of tests

Test duty	Number of make and break operations	
	Standard disconnector	Fast-acting disconnector ^a
1	50 ^b	200 ^{a, c}
2	50	200
3	50	50
^a Disconnectors having a contact speed in the range of 1 m/s or higher at the moment of contact separation. ^b If the most severe disconnector arrangement cannot be determined clearly (with reference to 7.108.3), test duty 1 shall be repeated with reversed disconnector terminals. ^c Reduction of the number of tests down to 50 is acceptable if the test voltage is increased (to cover statistical effects) to the following values: – source side: $U_r \times 1,2/\sqrt{3}$; – load side: (DC pre-charge): $-U_r \times 1,2 \sqrt{2}/\sqrt{3}$.		

7.108.8 Behaviour of the disconnector during making and breaking tests

The disconnector shall perform successfully without mechanical or electrical damage.

Disruptive discharges from phase to earth or from phase to phase are not permitted. Additionally, for resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear disruptive discharges are not permitted across the resistor.

NOTE It is essential that disruptive discharges to earth or between phases can be detected properly by adequate measuring or detecting equipment.

7.108.9 Condition after test

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the disconnector shall be essentially in the same condition as before the test.

Mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, are acceptable. However, the current-carrying capability and the isolating properties of the disconnector shall not be impaired. The quality of the material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level. There may be deposits on the insulators caused by the decomposition of the arc extinguishing medium.

The isolating properties of a disconnector in the open position shall not be reduced below what corresponds to normal wear and ageing, by deterioration of insulating parts.

No-load operation and visual inspection of the disconnector after tests are usually sufficient for verification of the isolating properties and the current-carrying capability of the disconnector. In case of doubt, it can be necessary to perform the appropriate tests as mentioned below. For disconnectors that are sealed for life, it is mandatory to perform the voltage test as a condition check.

If the isolating properties are doubted, a voltage test as condition check in accordance with 7.2.12 is to be performed to verify the insulating properties. Alternative test methods given in 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable.

In case of doubt of current-carrying capacity, main circuit resistance measurement may be used where ever it is possible to measure the resistance close to the contacts. The increase in main circuit resistance after test shall not exceed 20 %. If the contact resistance exceeds this value, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017 by monitoring the temperature at the points as close as possible to the main contacts.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % of the value measured before the test. A visual inspection of the resistor shall be made after the type tests. No evidence of flashover across the resistor or any mechanical damage shall be observed. It can be necessary to disassemble the disconnector for the visual inspection.

7.108.10 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017, the type test report shall contain the following information:

- a) representative oscillographic record of one make and one break operation;
- b) test circuit(s);
- c) steady-state test current (only for test duty 3);
- d) test voltage(s);
- e) transient voltage characteristics;

- f) record of operating characteristics;
- g) insulating-gas pressure during the tests;
- h) number of make and break switching operations;
- i) condition after test;
- j) type of fault detection system;
- k) supply voltage or pressure of mechanism operated.

7.108.11 Requirements for U_{TVE} measurements

Requirements for the measurements:

- U_{TVE} verification shall be carried out at least once during each performed test-duty. Configurational changes such as different connecting lead length, equipment orientation, etc., are considered as changes to the test circuit and will require additional measurements;
- U_{TVE} measurements shall be made within 1 m of the arcing contacts of the disconnecter. If this is not possible, U_{TVE} verification may be done by computer calculation, provided that other measurements (within the test section but outside the 1 m zone) are performed at least once to check the validity of the calculation technique;
- care shall be taken to ensure that possible stray power frequency interference is taken into account;
- U_{TVE} measurement shall be made with sufficient bandwidth to properly record the VFT component.

8 Routine tests

8.1 General

Clause 8 of IEC 62271-1:2017 is applicable with the following additions.

Addition to the list of routine tests.

- f) mechanical operating tests in accordance with 8.101.
- g) verification of earthing function in accordance with 8.102

Disconnectors and earthing switches integrated in enclosed switchgear shall be tested as part of the switchgear assembly in accordance with IEC 62271-200, IEC 62271-201 or IEC 62271-203.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 is applicable with the following additions and/or deviations.

In case of disconnectors or earthing switches placed

- inside sealed pressure systems, the dielectric test may be performed at rated filling pressure for insulation;
- inside controlled or closed pressure systems, the dielectric test shall be performed at minimum functional pressure for insulation.

If the conditions indicated in the third paragraph of 8.2 of IEC 62271-1:2017 are not fulfilled, the following applies:

- for testing of disconnectors the test conditions shall be in accordance with Table 21. For an explanation of the reference designations for connections, see Figure 2 of IEC 62271-1:2017;

Table 21 – Power frequency voltage tests

Test condition no.	Disconnector position	Voltage applied to	Earth connected to
1 ^a	Closed	Aa	BbCcF
2 ^a	Closed	Bb	AaCcF
3 ^a	Closed	Cc	AaBbF
4	Open	ABC	abcF
5	Open	abc	ABCF
6 ^b	Open	ABC or abc	Earthing switch
^a If the insulation between poles is air at atmospheric pressure and if the dimensions are checked, test conditions nos. 1, 2 and 3 may be combined, the test voltage being applied between all parts of the main circuit connected together and the base.			
^b Earthing switch in the position resulting in the shortest gap between its moving parts and ABC or abc. The test is applicable only to disconnectors with integrated earthing switch.			

- for testing of earthing switches, the test voltage shall be applied with the earthing switch in the open position:
 - 1) between adjacent insulated terminals with the bases earthed (e.g. A to B with F earthed);
 - 2) between all the insulated terminals connected together and the bases earthed (e.g. ABC to F earthed).

8.3 Tests on auxiliary and control circuits

Subclause 8.3 of IEC 62271-1:2017 is applicable.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 is applicable only to disconnectors.

8.5 Tightness test

Subclause 8.5 of IEC 62271-1:2017 is applicable.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 is applicable.

8.101 Mechanical operating tests

Operating tests are made to ensure that the disconnectors or earthing switches show the specified operating behaviour within the specified supply voltage, if any, and supply pressure limits, if any, of their operating mechanisms.

During these tests, which are performed without voltage on, or current flowing through the main circuit, it shall be verified that:

- the disconnectors or earthing switches open and close correctly when their operating mechanisms are energized;
- the interlocks work properly in any interlocked position;

- the position-indicating and -signalling devices indicate correctly the open and closed positions.

The disconnector or earthing switch shall be subjected to the following tests:

- at specified minimum supply voltage and/or pressure (if any): five operating cycles;
- at specified maximum supply voltage and/or pressure (if any): five operating cycles;
- if a disconnector or earthing switch can be operated manually: five manual operating cycles.

During these operating cycles, the operating characteristics such as, if applicable, operating times, power consumption, maximum forces for manual operation, shall be verified. Satisfactory operation of control and auxiliary contacts, and position-indicating devices (if any) shall be verified. The values of each parameter shall be within the tolerances specified by the manufacturer.

During these tests no adjustment shall be made and the operation shall be faultless. The closed and open position shall be reached with the specified indication and signalling during each operating cycle.

After these tests, no parts of the disconnector or earthing switch shall be damaged.

For disconnectors and earthing switches of $U_r > 52$ kV, the mechanical operating routine tests may be performed on sub-assemblies.

Where mechanical routine tests are performed on separate components, they shall be repeated at site on a complete assembled disconnector during the commissioning tests. The same total number of operations as specified in 7.102.3.2 shall be performed.

8.102 Verification of earthing function

The earthing function shall be verified according to the manufacturer's specification. However, test of electrical continuity shall be performed. Some examples of other routine tests that can be specified are as follows:

- contact resistance;
- contact pressure;
- visual inspection;
- dimension check;
- electrical continuity.

9 Guide to the selection of disconnectors and earthing switches (informative)

9.1 General

Clause 9.1 of IEC 62271-1:2017 is applicable with the following additions.

For the selection of disconnectors and earthing switches, the following conditions and requirements at site should be considered:

- continuous current load and overload conditions;
- existing fault conditions;
- static and dynamic terminal loads resulting from the substation design;
- use of rigid or flexible conductors to be connected to the disconnector or earthing switch or to which the separated contact is mounted;
- environmental conditions (climate, pollution, etc.);

- altitude of the substation site;
- required operational performance (mechanical endurance);
- switching requirements (bus-transfer current switching by disconnectors, induced current switching by earthing switches, short-circuit making capacity of earthing switches).

NOTE See Annex B for more information about current-switching capabilities of disconnectors and earthing switches

When selecting a disconnector or earthing switch, due allowance should be made for the likely future development of the system as a whole so that the disconnector or earthing switch is suitable not merely for immediate requirements, but also for those of the future.

9.2 Selection of rated values

Clause 9.2 of IEC 62271-1:2017 is applicable with the following additions:

9.2.101 General

All rated characteristics and classes of a disconnector or earthing switch given in Clause 5 should be considered, as far as applicable, together with subclauses 9.2.102 to 9.2.110.

9.2.102 Selection of rated voltage and rated insulation level

The rated voltage of the disconnector or earthing switch should be chosen so as to be at least equal to the highest voltage of the system at the point where the disconnector or earthing switch is to be installed.

The rated voltage of a disconnector or earthing switch should be selected from the standard values and their related insulation levels given in 5.2 and 5.3 of IEC 62271-1:2017.

For disconnectors and earthing switches installed at high altitudes, refer to 4.2.2 of IEC 62271-1:2017.

9.2.103 Selection of rated continuous current

The rated continuous current of a disconnector should be selected from the standard values given in 5.5 of IEC 62271-1:2017.

It should be noted that disconnectors have no standardized continuous overcurrent capability. When selecting a disconnector, therefore, the rated continuous current should be such as to make it suitable for any load current that may occur in service. Where intermittent overcurrents are expected to be frequent and severe, the manufacturer should be consulted.

9.2.104 Selection of rated contact zone

For proper function of a divided support disconnector or earthing switch, the user should ensure that the fixed contact stays within the limits given in Table 2 by considering the service conditions when specifying the substation design and the cantilever strength of the insulators.

When selecting the rated contact zone, the user should verify that the rated contact zone specified by the manufacturer is not exceeded in its specific application for the following additional constraints, if applicable:

- a longitudinal deflection resulting from wind acting on other connected components that are perpendicular to the bus work and from equipment movement;
- a perpendicular deflection resulting from forces from wind on other connected components that are perpendicular to the bus work and from equipment movement;

- a vertical deflection resulting from other vertical loads hung from the bus and from operating loads imposed by the operation of other equipment connected to the bus.

9.2.105 Selection of rated static mechanical terminal load

The rated static mechanical terminal load should be selected based on the requirements of 5.104 and the definitions of 3.7.119. The most disadvantageous conditions should be considered by the user when specifying the rated static terminal loads.

To calculate the required static terminal loads as well as the required strength of insulators, the forces resulting from the conductors connected to the disconnector or earthing switch, including the forces of wind and ice (if applicable) and minimum specified ambient air temperature on these conductors should be considered.

9.2.106 Selection of a bus-transfer current switching capability for disconnectors of $U_r > 52$ kV

Although disconnectors are, by definition, only capable of opening and closing a circuit when either negligible current is broken or made or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs, disconnectors in some applications are used for load transfer from one bus system to a parallel bus. Even if a bus coupling is closed, the load transfer can be a more or less severe switching operation for the disconnector, depending on the dimensions of the substation and the current to be transferred.

If a bus-transfer current switching capability is required, the values of transfer current and expected recovery voltage should be specified in the enquiry (see Clause 10).

9.2.107 Selection of an induced-current switching capability for earthing switches of $U_r > 52$ kV

An earthing switch is normally used for opening and closing a connection to earth from an isolated section of an electrical installation or line.

In high-voltage networks, tower configurations are sometimes used with more than one system being mounted on the same line tower. In such cases, induced currents have to be switched when earthing or unearthing one of the lines whilst the other line is connected to the system and can be carrying load current. The magnitude of the induced currents to be switched by the earthing switch depends on the capacitive and inductive coupling factors between the lines, and on the voltage, load and length of the parallel system.

Usually, higher voltage networks are characterised by longer loop distances and higher load currents resulting in higher values of induced currents.

If a switching capability is required, the values given in Table 9 can be used for most of the cases to be specified in the enquiry (see Clause 10).

9.2.108 Selection of rated short-time withstand current and of rated duration of short-circuit

Subclauses 5.6 and 5.8 of IEC 62271-1:2017 are applicable.

The test arrangements represented in Figures 3, 4 and 5 are for type test purposes. It cannot be excluded that electrical installation designs exist in which the disconnector or earthing switch undergoes higher stresses.

NOTE For short-time currents it can be considered that the thermal stress is constant when $I^2t = \text{constant}$.

9.2.109 Selection of rated peak withstand current and of rated short-circuit making current for earthing switches

The selected disconnecter or earthing switch should have a rated peak withstand current not less than the highest peak value of the fault current occurring in the actual system (by considering the actual value of the time constant of the network).

Subclause 5.6 should be considered.

This applies also to the rated short-circuit making current of an earthing switch (where applicable).

9.2.110 Selection of short-circuit making capability for earthing switches

The selection should be done according to the classification mentioned in subclause 5.102. The selection of class E1 or E2 depends on operational procedures of the electrical network. Usually, this ability is not requested for earthing switches forming part of air-insulated switchgears of $U_r > 52$ kV.

9.3 Cable-interface considerations

Clause 9.3 of IEC 62271-1:2017 is applicable.

9.4 Continuous or temporary overload due to changed service conditions

Clause 9.4 of IEC 62271-1:2017 is applicable.

9.5 Environmental aspects

Clause 9.5 of IEC 62271-1:2017 is applicable with the following additions:

9.5.101 Local environmental conditions

For the normal and special service conditions for disconnectors and earthing switches, Clause 4 of IEC 62271-1:2017 applies.

For disconnectors and earthing switches, pollution conditions in certain areas both outdoors and indoors are unfavourable on account of smoke, chemical fumes, salt-laden spray, etc. Where such adverse conditions are known to exist, special consideration should be given to the design and materials used with the disconnector or earthing switch. In these conditions, care should be taken when considering the performance of parallel insulation. Pollution tests could be necessary to be performed on the disconnector or the earthing switch.

For insulators normally exposed to the atmosphere, refer to 6.15 of IEC 62271-1:2017. The performance of an insulator in polluted atmospheres also depends on the frequency with which artificial washing or other pollution control methods are carried out or natural cleaning occurs.

NOTE Insulator designs which have been proved by testing to fulfil the requirements of the user, can have a nominal creepage distance smaller than that given by the product of the rated voltage and the minimum specific creepage distance.

For open-terminal, indoor installations in coastal areas where salt deposit is a problem, it is recommended, for $U_r > 52$ kV, to use equipment with outdoor insulation as this is more readily available than special indoor insulation. The use of GIS installations is also possible.

If a disconnector or earthing switch is to be located where the wind speed exceeds 34 m/s, this should be stated in the enquiry.

If a disconnector or earthing switch is to be located in a surrounding where an ice-coating with a thickness exceeding 1 mm is expected, this should be stated in the enquiry, taking 7.103 into consideration.

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

Clause 10 of IEC 62271-1:2017 is applicable with the following additions/modifications.

For disconnectors and earthing switches used in gas-insulated and/or metal-enclosed switchgear, Clause 9 of IEC 62271-200:2011 or IEC 62271-203:2011 is applicable.

10.2 Information with enquiries and orders

Subclause 10.2 of IEC 62271-1:2017 is replaced as follows.

When enquiring for or ordering a disconnector or an earthing switch, the following information, where applicable, should be supplied by the enquirer:

- a) particulars of system, i.e. nominal and highest voltages, frequency, number of phases and details of neutral earthing;
- b) service conditions, including minimum and maximum ambient air temperatures if different from the normal values (refer to Clause 9), altitude if over 1 000 m, ice and any special conditions likely to exist or arise, for example unusual exposure to steam or vapour, moisture, fumes, explosive gases, excessive dust or salt air (see 9.5.101);
- c) characteristics of the disconnector or earthing switch. The following information should be given:
 - 1) indoor or outdoor installation;
 - 2) number of phases;
 - 3) rated voltage;
 - 4) rated frequency;
 - 5) rated insulation level where a choice exists between different insulation levels corresponding to a given rated voltage or, if other than standard, desired insulation level (see Tables 1 to 4 of IEC 62271-1:2017);
 - 6) rated continuous current (for disconnectors only);
 - 7) rated short-time withstand current (I_k);
 - 8) rated duration of short-circuit (if different from 1 s);
 - 9) rated peak withstand current (if different from 2,5 I_k);
 - 10) rated short-circuit making current, if any (for earthing switches only) (see 5.101);
 - 11) rated static mechanical terminal loads, if applicable (see 5.104);
 - 12) use of rigid or flexible conductors to be connected to the disconnector or earthing switch or to which the separated contact is mounted, if applicable (see 5.104);
 - 13) mounting conditions and HV connections, for example hanging arrangement of the fixed contact of the disconnector and earthing switch; support structure to be supplied with the equipment or not, if applicable;
 - 14) requirements for insulators (if applicable) to be used with the disconnector and earthing switch:
 - class of pollution taken from IEC/TS 60815-1 [4];
 - profile of the sheds (if applicable); taken from IEC/TS 60815 (all parts) [3];
 - see item 11);

- 15) required contact zone; if applicable;
 - 16) operation under severe ice conditions, if applicable;
 - 17) rated bus-transfer current switching (disconnectors only), if applicable;
 - 18) rated induced current switching (earthing switches only), if applicable;
 - 19) rated mechanical endurance class, if different from M0;
 - 20) rated short-circuit making capability class, if different from E0 (earthing switches only);
 - 21) bus-charging current switching capability;
 - 22) degree of protection for the enclosure and partitions (if any of both);
 - 23) circuit diagrams;
- d) characteristics of the operating mechanism and associated equipment, in particular:
- 1) method of operation, whether manual and/or power dependent;
 - 2) for independent manual operation of earthing switches: the duration of a time delay;
 - 3) the operating height above servicing level;
 - 4) for power operation, the type of available supply energy (e.g. compressed air, or electrical DC or AC) and its ratings (pressure, voltage, frequency);
 - 5) number and type of auxiliary contacts to be available;
 - 6) degree of protection if higher than that specified in 6.14;
 - 7) interlocking requirements;
 - 8) minimum duration of the operating signal;
 - 9) maximum operating time for power operation;
- e) requirements concerning the use of compressed gas and requirements for design and tests of pressure vessels;
- f) any routine tests or additional checks required to be witnessed by the user;
- g) any other information concerning special conditions not included above that might influence the tender or the order, such as, for example, special mounting or installation conditions, the location of the external high-voltage connections or requirements for cable testing;
- h) request for type test documentation or any specific request about conformity assessment material.

10.3 Information with tenders

Subclause 10.3 of IEC 62271-1:2017 is replaced as follows.

The information given by the manufacturer with tenders should cover the requirements specified in 10.2 as applicable, and should state compliance with and deviations from the enquiry details. The dimensions given in drawings of disconnectors and earthing switches are subject to tolerances as standardized by ISO 2768-1 unless otherwise specified. National requirements enforcing deviation from IEC 62271-1 should be stated in the tender documents.

The information given by the manufacturer with tenders should include, where applicable:

- a) rated values and characteristics as enumerated in item c) of 10.2, and Clause 5;
- b) constructional features, when applicable:
 - 1) mass of complete disconnector or earthing switch;
 - 2) overall dimensions in closed and open position (if different);
 - 3) arrangement of the external connections;
 - 4) facilities necessary for transport and mounting;

- 5) mounting provisions;
 - 6) accessible sides;
 - 7) type of gas-pressure or liquid-pressure system (if any);
 - 8) minimum clearances in air:
 - between poles;
 - to earth;
 - for isolating distance (for disconnectors only);
 - 9) for divided support disconnectors and earthing switches, the rated contact zone;
 - 10) corrosion protection;
 - 11) for disconnectors having a fixed contact requiring reaction forces when closing and opening the contact, these forces and their direction shall be stated by the manufacturer in the documentation;
 - 12) where applicable, the dielectric losses (mW) of the insulation system of the external grounding connection shall be given;
- c) operating mechanism and associated equipment:
- 1) type of operating mechanism;
 - 2) rated supply voltage and/or pressure of operating mechanism;
 - 3) current required at rated supply voltage to operate the disconnector or earthing switch; maximum current and maximum voltage at the terminals of the operating mechanism;
 - 4) quantity of free gas required to operate the disconnector or earthing switch at the rated supply pressure, as applicable;
 - 5) number and type of available auxiliary contacts;
 - 6) design of the device or description of means for securing the position;
 - 7) design of indicating and signalling device;
 - 8) operating times.

11 Transport, storage, installation, operating instructions, and maintenance

11.1 General

Subclause 11.1 of IEC 62271-1:2017 is applicable with the following addition:

For disconnectors and earthing switches used in gas-insulated and/or metal-enclosed switchgear, Clause 10 of IEC 62271-200:2011 or of IEC 62271-203:2011 is applicable.

11.2 Conditions during transport, storage and installation

Subclause 11.2 of IEC 62271-1:2017 is applicable.

11.3 Installation

Subclause 11.3 of IEC 62271-1:2017 is applicable with the following addition:

Disconnectors and earthing switches shall be packed, as far as it is practicable, as one unit.

Packages and crates containing more than one unit or more than one component (insulators, drive rods, operating mechanisms and similar components) should be clearly identified and accompanied by a list of content.

11.4 Operation

Subclause 11.4 of IEC 62271-1:2017 is applicable.

11.5 Maintenance

Subclause 11.5 of IEC 62271-1:2017 is applicable with the following addition:

For disconnectors and earthing switches with any switching capability, the number of operations needs to be taken into account in order to estimate the maintenance intervals.

For maintenance purposes, the disconnector in gas-insulated switchgear shall be considered to have its full isolating properties only if the gas pressure is not lower than its minimum functional pressure (density).

12 Safety

12.1 General

Clause 12 of IEC 62271-1:2017 is applicable with the following additions:

NOTE The terms "skilled person" and "instructed person" are defined in IEV 826-09-01 and IEV 826-09-02, respectively. The requirements for "skilled person" and "instructed person" can deviate depending on local safety rules.

For actuating principles, refer to IEC 60447:2004 [5].

12.2 Precautions by manufacturers

Subclause 12.2 of IEC 62271-1:2017 is applicable.

12.3 Precautions by users

Subclause 12.3 of IEC 62271-1:2017 is applicable.

13 Influence of the product on the environment

Clause 13 of IEC 62271-1:2017 is applicable.

Annex A (informative)

Test voltage for the most disadvantageous dielectric position of an earthing switch during operation (minimum temporary clearance)

For standardization of dielectric strength in the most disadvantageous dielectric position of an earthing switch during operation, it has to be taken into consideration that:

- for $52 \text{ kV} < U_r \leq 170 \text{ kV}$, different types of neutral systems exist;
- for $U_r > 170 \text{ kV}$, the solid earthing of the neutral is the typical one.

Therefore:

- for the lower voltage range ($52 \text{ kV} < U_r \leq 170 \text{ kV}$), even if different neutral systems exist, it is reasonable to standardize only one test voltage, considering the most severe condition, which is the one of unearthed neutral systems;
- for the higher voltage range ($U_r > 170 \text{ kV}$), only the solid earthing of the neutral is considered for standardizing the test voltage.

Furthermore, for $U_r \geq 300 \text{ kV}$ the proportion of the power frequency withstand voltage to the system voltage is reduced compared with the proportion of the test voltage to the system voltage below 300 kV (in the higher range, switching impulse tests are standardized).

Because of the relatively low power-frequency withstand voltage for systems of 300 kV and above, the disconnectors and earthing switches of $U_r = 245 \text{ kV}$ have a singular position. On the one hand, they belong to the range with solidly earthed systems; on the other hand, they belong to the test voltage range below 300 kV . This makes it necessary, therefore, to consider whether to relate the required dielectric strength to the standardized power frequency withstand voltage (line-to-earth) or to the rated voltage.

A fixed relation to the line-to-earth withstand voltage would give too high a value for the lower rated voltages and too low a value for the higher rated voltages.

Since the safety distances in substations are not related to the dielectric test voltages but to the rated voltage, the dielectric strength for the minimum temporary clearance should also be related to the rated voltage and the earthing condition of the network. Also the fact should be considered that the test voltages might be changed once in a while, and this should not result in a change of the test voltage for the minimum temporary clearance.

For standardization, the following values are therefore suggested:

- a) for $52 \text{ kV} < U_r \leq 170 \text{ kV}$: $1,3 \times U_r$;
- b) for $U_r > 170 \text{ kV}$: $2 \times U_r / \sqrt{3}$.

For disconnectors with integrated earthing switches, the suggested test voltages with the earthing switch in the most disadvantageous dielectric position are given in Table 14 after taking into consideration the above-mentioned details. An impulse voltage test is not required because of the very low probability of a lightning or switching impulse during the earthing procedure.

Annex B (informative)

Current-switching capability required of disconnectors and earthing switches

B.1 Bus-transfer current switching capability of disconnectors

For disconnectors used to transfer load currents from one bus system to another, a capability to make and break bus-transfer currents is required. This requirement is applied to disconnectors of $U_r > 52$ kV.

The bus-transfer currents and voltages depend upon the magnitude of the load current and upon the size of the loop between the location(s) of the bus coupling and the location of the disconnector to be operated.

The values of the rated bus-transfer voltages in Table 7 are based on calculations of the bus-transfer current corresponding to the rated continuous current of the disconnector taking into account impedances as shown in Table B.1 and typical loop lengths as follows:

- loop length for gas-insulated installations: 65 m for $52 \text{ kV} < U_r < 245 \text{ kV}$ and 130 m for $U_r \geq 245 \text{ kV}$;
- loop length for air-insulated installations: 200 m for $52 \text{ kV} < U_r < 245 \text{ kV}$ and 400 m for $U_r \geq 245 \text{ kV}$.

Table B.1 – Average impedances

Rated voltage U_r kV	Average impedance $\mu\Omega/\text{m}$	
	Gas-insulated installations	Air-insulated installations
72,5	63	314
100		
123		
145		
170		
245 / 300	67	346
420		
550		361
800	76	355
1 100	80	388

B.2 Bus-charging current switching capability of disconnectors

Energizing or de-energizing unloaded sections of busbar duct or parallel capacitors of circuit-breakers is considered as capacitive switching. Very fast transient overvoltage (VFTO) phenomena occur as an inherent part of capacitive switching with disconnectors in gas-insulated metal-enclosed switchgear. Since the VFTO might cause disruptive discharges to earth, correct design of the disconnector is required to avoid disruptive discharges to earth. This requirement is normally applied to disconnectors of $U_r \geq 300$ kV.

For $U_r < 300$ kV, the VFTO does not become so high compared with the specified lightning impulse withstand voltage (LIWV) because the ratios between the LIWV and rated voltage are

sufficiently high. Simultaneous switching of several disconnectors in the same circuit is not advisable and thus not considered in this document.

As a special case for disconnectors used to de-energize long busbars or other energized parts, for example short lengths of cables, a capability of current-switching is required. This requirement can be applied not only to disconnectors of $U_r \geq 300$ kV but also of $U_r < 300$ kV.

With $U_r \geq 800$ kV the maximum VFTO in GIS systems can reach the insulation level of lightning impulse withstand voltage in certain cases. In such cases, resistor-fitted disconnectors may be used to mitigate the VFTO. Three different types of resistor-fitted disconnectors are given as examples in Figure B.1. The resistor can be positioned in parallel or in series to the switching gap. In the arc-commutation method, the current is switched to the parallel resistor during an opening operation by commutation of the arc from the main contact to the resistor contact.

Typical resistors of values 200Ω to $1\,000 \Omega$ are used. The overvoltage damping factor depends on the ratio of the resistance of the resistor and the system impedance.

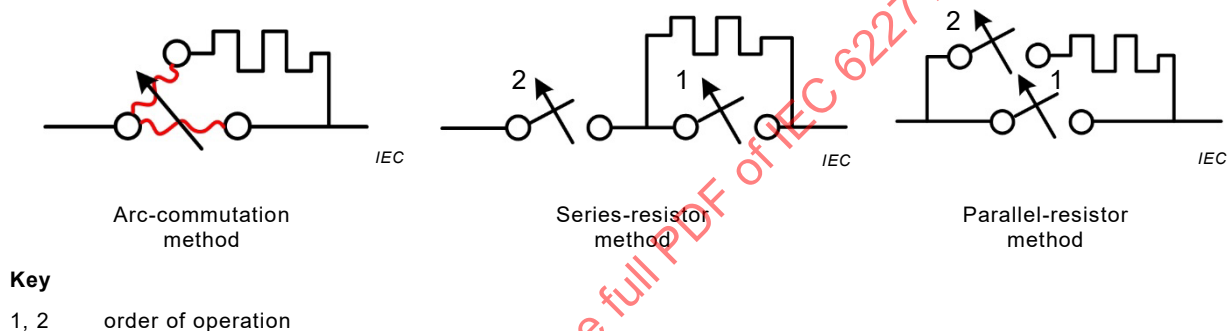


Figure B.1 – Examples of resistor-fitted disconnectors

B.3 Induced current-switching capability of earthing switches

For earthing switches used to earth multiple configurations of overhead transmission lines, a capability to make and break induced currents is required. This requirement is applied to earthing switches of $U_r > 52$ kV.

In the case of multiple configurations of overhead transmission lines, current can circulate in de-energized and earthed lines as a result of capacitive and inductive coupling with adjacent energized lines. Earthing switches applied to earth these lines shall therefore be capable of assuring the following service conditions:

- making and breaking of a capacitive current when the earth connection is open at one termination and earthing switching is performed at the other termination;
- making and breaking of an inductive current when the line is earthed at one termination and earthing switching is performed at the other termination;
- carrying continuously the capacitive and inductive currents.

Annex C (normative)

Tolerances on test quantities for type tests

A tolerance is defined as the range of the test values specified in the document within which the measured test value shall lie for a test to be valid.

Any deviation between the measured test value and the true test value caused by the uncertainty of the measurement are not taken into account in this respect.

Table C.1 states tolerances on test quantities for type tests.

Table C.1 – Tolerances on test quantities for type tests (1 of 2)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference
7.101	Short-circuit making tests of earthing switches	Test frequency	f_r	$\pm 10 \%$	7.101.3
		Test voltage (average phase to phase)	U_r	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4
		Any phase voltage / average (three-phase)	1	$\pm 5 \%$	7.101.4 a)
		Test voltage (average, single phase)	$U_r / \sqrt{3}$	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4 b)
		Test voltage (average, three-phase)	U_r	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4 b)
		Short-circuit current at 200 ms	I_k	$\geq 80 \%$	7.101.5
		Short-circuit making current (peak, prospective)	I_{ma}	$\left(\begin{smallmatrix} +5 \\ 0 \end{smallmatrix} \right) \%$	7.101.5
7.106	Bus-transfer current switching	Test frequency	f_r	$\pm 10 \%$	7.106.2.3
		Test voltage	U_{bt}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.106.2.4
		Test current	I_{bt}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.106.2.5
		Any phase current / average	1	$\pm 10 \%$	7.106.2.5
		Power factor of test circuit		$\leq 0,5$	7.106.2.6

Table C.1 (2 of 2)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference
7.107	Induced current switching	Test frequency	f_r	$\pm 10 \%$	7.107.4
		Test voltage	U_{im}, U_{is}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.5
		Any phase voltage / average	1	$\pm 10 \%$	7.107.5
		Test current	I_{im}, I_{is}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.6
		Any phase current / average	1	$\pm 10 \%$	7.107.6
		Power factor of supply circuit		$\leq 0,15$	7.107.7.2
		TRV peak (electromagnetically induced current)		$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.7.2
		Time to peak (electromagnetically induced current)		$\left(\begin{smallmatrix} 0 \\ -10 \end{smallmatrix} \right) \%$	7.107.7.2
7.108	Bus-charging current switching test	Test frequency	f_r	$\pm 10 \%$	7.108.4
		Test voltage	U_1, U_2	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.108.5
	Current switching capability test duty 3	Bus-charging current		$\pm 10 \%$	7.108.5

Annex D (normative)

Alternative test methods for short-circuit current making tests

D.1 General

In this annex applying to 7.101.5 a), alternative test methods are given to obtain the conditions corresponding to correct making current with correct pre-arcing time.

For the tests using alternative methods in which the required pre-arcing time is obtained, the making angle can be extended to -40 electrical degrees and $+15$ electrical degrees with reference to the voltage peak of the current source.

NOTE At -40 electrical degrees, the pre-arc energy is higher than within the limitation of -30 electrical and $+15$ electrical degrees.

For convenience of testing in a three-phase circuit it is allowed to have the maximum pre-arcing time only in one phase, while at the other two phases the current is applied at reduced voltage.

D.2 Alternative methods

D.2.1 Synthetic test method with both rated voltage and rated short-circuit current

The synthetic test methods as given in Clause 5 of IEC 62271-101:2012 may be applied.

The test circuit and specific requirements shall fulfil the requirement a) of 7.101.5.

D.2.2 Test methods with reduced voltage

D.2.2.1 General

To obtain comparable results between tests with rated voltage and alternative tests with reduced voltages, the pre-arcing time obtained during the making test with reduced voltage shall not be less than the pre-arcing time in the test with the rated voltage.

The test is split up in two parts:

- part 1: a test at rated voltage and reduced current to determine the pre-arcing time of the earthing switch;
- part 2: a test at reduced voltage and rated short-circuit making current, with the required pre-arcing time.

D.2.2.2 Part 1: determination of pre-arcing time

The pre-arcing time shall be determined by performing making tests at rated voltage and reduced current. The arrangement of the earthing switch shall be as described in 7.101.2. The current shall be low enough that the contact surface is not influenced by contact erosion. The pre-arcing time shall be determined at each of these tests.

Ten making tests performed to evaluate the pre-arcing time shall result in a current initiation instant corresponding to an angle of -15 electrical degrees to $+15$ electrical degrees on the peak of the applied AC voltage wave-shape. The average value of these valid pre-arcing times measured and the standard deviation (σ) shall be calculated to be applied in Part 2 (see D.2.2.3).

As an alternative, DC voltage may be used. The DC voltage shall correspond to the peak value of the test voltage. The pre-arcing time can differ depending on the polarity of the voltage at making. Therefore, 10 making tests shall be divided into 5 operations with positive polarity and 5 operations with negative polarity. The longest average pre-arcing time out of the two polarities and its standard deviation (σ) shall be calculated and applied in Part 2.

NOTE A travel transducer or an equivalent device can be used for the measurement of the pre-arcing time. In a three-phase device, one phase can be used for evaluating the pre-arcing time and the other phases can be used to measure the actual contact touch. A no-load operation with contact timing measurement on all three poles can be used to compensate time spread between poles.

D.2.2.3 Part 2: short-circuit current making tests at reduced voltage

During making tests with rated short-circuit current at reduced voltage, the pre-arcing time (see 7.101.5 a) shall be at least equal to the average of the pre-arcing time plus 2σ determined in the tests as described in Part 1 (see D.2.2.2).

The short-circuit current obtained during tests at reduced voltage shall be at least equal to the rated short-circuit current.

In order to obtain the required pre-arcing time, the initiation of the current can be achieved by the three methods listed below.

Method 1: A current source at reduced voltage and a voltage source of any wave form, high enough to initiate the pre-arcing at the correct point on the wave.

Method 2: For gas-insulated earthing switches, both the gas pressure and the applied voltage of the current source can be decreased such that the required pre-arcing time is still obtained.

Instead of just decreasing the gas pressure, the test object may also be filled with an alternative medium, such as air or nitrogen.

The speed at contact touch shall not change by more than 10 % due to the reduction of the gas pressure or replacing the gas by an alternative medium.

NOTE 1 It can be useful to estimate the required voltage at reduced pressure by the same method as described in Part 1 in order to obtain the correct pre-arcing time.

NOTE 2 In case that reduced pressure or alternative gas is used, the behaviour of the rupture disk cannot be verified, since the transient pressure can be lower or higher than expected in service conditions when service gas and rated filling pressure are used.

Method 3: A current source with reduced voltage and pre-arcing initiated by a fuse wire of maximum 0,5 mm diameter. The fuse wire is required in the pole to be tested for the short-circuit making current with the correct pre-arcing time.

NOTE 3 Some extra tests can be necessary to estimate the length of the fuse wire.

Annex E (informative)

Extension of validity of type tests

E.1 General

Annex J, except subclause J.2, of IEC 62271-1:2017 is applicable with the following addition:

Upon agreement between the manufacturer and the user, an individual type test does not need to be repeated for change of construction detail if the manufacturer can demonstrate that this change does not influence the result of that individual type test.

E.2 Dielectric tests

The rated voltage covers every voltage equal or less than the tested one.

E.3 Short-time withstand current tests

Test results obtained on a disconnector or earthing switch placed in a certain position (e.g. horizontal or vertical) are valid for the position of the disconnector or earthing switch during this test. However, in some cases, the position in which it is tested can validate other positions depending on the design and construction of the disconnector or earthing switch.

E.4 Short-circuit making performance of earthing switches

The rated voltage covers every network voltage equal or less than the tested one. The rated short-circuit making current covers every network short-circuit current equal or less than the tested one.

E.5 Operating and mechanical endurance tests

The test carried out on a given disconnector or earthing switch with a specified rated voltage and/or current covers lower rated voltage and/or current.

Interlocking devices of a given design may be used with other disconnectors and earthing switches, without repeating the type test, if the manufacturer can show the evidence that they work in the same way as they worked during the type test.

E.6 Bus-transfer current switching tests on disconnectors

Bus-transfer current switching elements of a given design may also be used within other disconnectors, without repeating the type test, if the manufacturer can show evidence that the bus-transfer current switching elements are operated by the other disconnector in the same way as by the disconnector with which the type test has been performed.

E.7 Induced current switching tests on earthing switches

Making and breaking elements of earthing switches having a rated induced current switching capability of a given design may also be used within other earthing switches without repeating the type test, if the manufacturer can show evidence that the making and breaking elements are operated by the other earthing switch in the same way as by the earthing switch with which the type test has been performed.

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SOMMAIRE

AVANT-PROPOS	115
1 Domaine d'application	118
2 Références normatives	118
3 Termes et définitions	119
3.1 Termes et définitions généraux	119
3.2 Ensembles de l'appareillage	120
3.3 Parties d'ensembles	120
3.4 Appareils de connexion	120
3.5 Parties d'appareils de connexion	122
3.6 Fonctionnement	124
3.7 Grandeurs caractéristiques	126
3.8 Liste des définitions	130
4 Conditions normales et spéciales de service	132
5 Caractéristiques assignées	133
5.1 Généralités	133
5.2 Tension assignée (U_r)	133
5.3 Niveau d'isolement assigné (U_d , U_p , U_s)	133
5.4 Fréquence assignée (f_r)	134
5.5 Courant permanent assigné (I_r)	134
5.6 Courant de courte durée admissible assigné (I_k)	134
5.7 Valeur de crête du courant admissible assignée (I_p)	134
5.8 Durée de court-circuit assignée (t_k)	134
5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)	134
5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande	134
5.11 Pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue	135
5.11.101 Pression d'alimentation assignée en gaz comprimé pour l'isolement et/ou la coupure	135
5.11.102 Pression d'alimentation assignée en gaz comprimé pour la manœuvre	135
5.101 Courant établi assigné en court-circuit (I_{ma})	135
5.102 Classification des sectionneurs de terre pour le pouvoir de fermeture en court-circuit	135
5.103 Zone de contact assignée	135
5.104 Effort mécanique statique assigné sur les bornes	136
5.105 Classification des sectionneurs pour l'endurance mécanique	137
5.106 Classification des sectionneurs de terre pour l'endurance mécanique	138
5.107 Couche de glace assignée	138
5.108 Valeurs assignées des sectionneurs pour l'établissement-coupure de courant de transfert de barres	138
5.108.1 Courant assigné de transfert de barres	138
5.108.2 Tension assignée de transfert de barres	138
5.109 Classification et valeurs assignées des sectionneurs de terre pour la coupure de courant induit	139
5.110 Classification et valeurs assignées des sectionneurs pour l'établissement-coupure de courant de jeux de barres à vide	140
6 Conception et construction	141

6.1	Exigences pour les liquides utilisés dans les sectionneurs et les sectionneurs de terre	141
6.2	Exigences pour les gaz utilisés dans les sectionneurs et les sectionneurs de terre.....	141
6.3	Raccordement à la terre des sectionneurs et sectionneurs de terre	141
6.4	Équipements et circuits auxiliaires et de commande	142
6.5	Manœuvre dépendante à source d'énergie extérieure	142
6.6	Manœuvre à accumulation d'énergie.....	142
6.7	Manœuvre indépendante sans accrochage mécanique (manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure)	142
6.8	Organes de commande à manœuvre manuelle	142
6.9	Fonctionnement des déclencheurs	143
6.10	Indication de la pression / du niveau	143
6.11	Plaques signalétiques	143
6.12	Dispositifs de verrouillage	145
6.13	Indicateur de position.....	145
6.14	Degrés de protection procurés par les enveloppes	145
6.15	Lignes de fuite pour les isolateurs d'extérieur	145
6.16	Étanchéité au gaz et au vide	146
6.17	Étanchéité des systèmes de liquide	146
6.18	Risque de feu (inflammabilité).....	146
6.19	Compatibilité électromagnétique (CEM).....	146
6.20	Émission de rayons X	146
6.21	Corrosion	146
6.22	Niveaux de remplissage pour l'isolement, la coupure et/ou la manœuvre	146
6.101	Exigences spéciales pour les sectionneurs de terre	146
6.102	Exigences relatives à la distance de sectionnement des sectionneurs	146
6.103	Résistance mécanique.....	147
6.104	Manœuvre des sectionneurs et des sectionneurs de terre – Position des contacts mobiles et de leurs dispositifs indicateurs et de signalisation	147
6.104.1	Verrouillage de la position	147
6.104.2	Exigences complémentaires pour les mécanismes à source d'énergie extérieure	147
6.104.3	Indication et signalisation de la position.....	147
6.105	Effort maximal exigé pour la manœuvre (dépendante ou indépendante) manuelle.....	149
6.105.1	Généralités	149
6.105.2	Manœuvre exigeant plus d'un tour	149
6.105.3	Manœuvre exigeant au plus un tour	149
6.106	Tolérances dimensionnelles	149
6.107	Sectionneurs de terre avec pouvoir de fermeture en court-circuit	150
7	Essais de type	150
7.1	Généralités	150
7.1.1	Principes fondamentaux	150
7.1.2	Informations pour l'identification des objets d'essai	152
7.1.3	Informations à inclure dans les rapports d'essai de type	152
7.2	Essais diélectriques	152
7.2.1	Généralités	152
7.2.2	Conditions de l'air ambiant pendant les essais.....	152

7.2.3	Modalités des essais sous pluie.....	153
7.2.4	Disposition de l'appareil.....	153
7.2.5	Conditions de réussite des essais.....	153
7.2.6	Application de la tension d'essai et conditions d'essai	153
7.2.7	Essais des sectionneurs et des sectionneurs de terre de $U_r \leq 245$ kV.....	154
7.2.8	Essais des sectionneurs et des sectionneurs de terre de $U_r > 245$ kV	154
7.2.9	Essais de pollution artificielle pour les isolateurs d'extérieur.....	154
7.2.10	Essais de décharges partielles	154
7.2.11	Essais diélectriques sur les circuits auxiliaires et de commande	154
7.2.12	Essai de tension comme essai de vérification d'état	154
7.3	Essai de tension de perturbation radioélectrique	154
7.4	Mesurage de la résistance	154
7.5	Essais au courant permanent.....	155
7.6	Essais au courant de courte durée admissible et à la valeur de crête du courant admissible.....	155
7.6.1	Généralités.....	155
7.6.2	Disposition des sectionneurs et des sectionneurs de terre et du circuit d'essai.....	155
7.6.3	Valeurs du courant d'essai et de sa durée	161
7.6.4	État des sectionneurs et des sectionneurs de terre après l'essai	161
7.7	Vérification de la protection.....	162
7.8	Essais d'étanchéité.....	162
7.9	Essais de compatibilité électromagnétique (CEM).....	163
7.10	Essais complémentaires sur les circuits auxiliaires et de commande.....	163
7.11	Essai des rayonnements X pour les ampoules à vide	163
7.101	Essai pour vérifier les performances de fermeture en court-circuit des sectionneurs de terre	163
7.101.1	Conditions générales d'essai	163
7.101.2	Disposition du sectionneur de terre pour les essais	163
7.101.3	Fréquence d'essai	164
7.101.4	Tension d'essai	164
7.101.5	Courant établi en court-circuit pour essai.....	164
7.101.6	Circuits d'essai.....	164
7.101.7	Procédures d'essai	165
7.101.8	Comportement des sectionneurs de terre au cours de l'établissement des courants de court-circuit.....	166
7.101.9	Conditions du sectionneur de terre après les essais de fermeture en court-circuit	166
7.101.10	Essais non valables	166
7.101.11	Rapports d'essais de type.....	167
7.102	Essais de fonctionnement et d'endurance mécanique	168
7.102.1	Conditions générales d'essai	168
7.102.2	Essai de la zone de contact.....	168
7.102.3	Essai d'endurance mécanique	170
7.102.4	Fonctionnement au cours de l'application des efforts mécaniques statiques assignés sur les bornes	172
7.102.5	Essais complémentaires d'endurance mécanique	173
7.102.6	Essais des dispositifs de verrouillage mécanique.....	174
7.103	Fonctionnement dans des conditions sévères de formation de glace.....	174
7.103.1	Généralités.....	174

7.103.2	Disposition d'essai.....	175
7.103.3	Procédure d'essai.....	175
7.104	Essais à basse et haute température	177
7.104.1	Généralités	177
7.104.2	Mesurage de la température de l'air ambiant	177
7.104.3	Essai à la température basse.....	178
7.104.4	Essai à la température haute	180
7.105	Essais pour vérifier le bon fonctionnement de l'indicateur de position	181
7.105.1	Généralités	181
7.105.2	Essais sur la chaîne cinématique de puissance et la chaîne cinématique de l'indicateur de position	181
7.106	Essais de coupure de courant de transfert de barres sur les sectionneurs.....	182
7.106.1	Généralités	182
7.106.2	Essais d'établissement et de coupure	182
7.107	Essais de coupure de courant induit sur les sectionneurs de terre.....	186
7.107.1	Généralités	186
7.107.2	Disposition du sectionneur de terre pour les essais	186
7.107.3	Mise à la terre du circuit d'essai et du sectionneur de terre.....	186
7.107.4	Fréquence d'essai	187
7.107.5	Tension d'essai	187
7.107.6	Courants d'essai.....	187
7.107.7	Circuits d'essai.....	187
7.108	Essais de coupure de courant de jeux de barres à vide sur les sectionneurs.....	193
7.108.1	Généralités	193
7.108.2	Séquences d'essai.....	193
7.108.3	Disposition du sectionneur pour les essais	193
7.108.4	Fréquence d'essai	194
7.108.5	Tensions d'essai pour les essais d'établissement et de coupure	194
7.108.6	Circuits d'essai pour les essais d'établissement et de coupure	195
7.108.7	Modalités d'exécution des essais d'établissement et de coupure	197
7.108.8	Comportement du sectionneur pendant les essais d'établissement et de coupure	198
7.108.9	État après essai.....	198
7.108.10	Rapports d'essais de type.....	199
7.108.11	Exigences pour les mesurages de la tension transitoire à la terre U_{TVE}	199
8	Essais individuels de série	200
8.1	Généralités	200
8.2	Essai diélectrique du circuit principal	200
8.3	Essais des circuits auxiliaires et de commande.....	201
8.4	Mesurage de la résistance du circuit principal	201
8.5	Essai d'étanchéité.....	201
8.6	Contrôles visuels et de conception.....	201
8.101	Essais de fonctionnement mécanique	201
8.102	Vérification de la fonction de mise à la terre.....	202
9	Guide pour le choix des sectionneurs et des sectionneurs de terre (informative)	202
9.1	Généralités	202
9.2	Choix des valeurs assignées.....	202
9.2.101	Généralités	202
9.2.102	Choix de la tension assignée et du niveau d'isolement assigné	203

9.2.103	Choix du courant permanent assigné	203
9.2.104	Choix d'une zone de contact assignée	203
9.2.105	Choix des efforts mécaniques statiques assignés sur les bornes	203
9.2.106	Choix du pouvoir d'établissement et de coupure de courant de transfert de barres pour les sectionneurs de $U_f > 52$ kV	204
9.2.107	Choix du pouvoir d'établissement et de coupure de courant induit pour des sectionneurs de terre de $U_f > 52$ kV	204
9.2.108	Choix du courant de courte durée admissible assigné et de la durée du court-circuit assignée	204
9.2.109	Choix de la valeur de crête du courant admissible assignée et du courant établi assigné en court-circuit des sectionneurs de terre	204
9.2.110	Choix du pouvoir de fermeture en court-circuit des sectionneurs de terre	205
9.3	Considérations sur les interfaces avec les câbles	205
9.4	Surcharge continue ou temporaire due à une modification des conditions de service	205
9.5	Aspects d'environnement	205
9.5.101	Conditions environnementales locales	205
10	Renseignements à donner dans les appels d'offres, les soumissions et les commandes (informatif)	206
10.1	Généralités	206
10.2	Renseignements dans les appels d'offres et les commandes	206
10.3	Renseignements pour les soumissions	207
11	Transport, stockage, installation, instructions de fonctionnement et maintenance	208
11.1	Généralités	208
11.2	Conditions à respecter pendant le transport, le stockage et l'installation	209
11.3	Installation	209
11.4	Fonctionnement	209
11.5	Maintenance	209
12	Sécurité	209
12.1	Généralités	209
12.2	Précautions devant être prises par les constructeurs	209
12.3	Précautions devant être prises par les utilisateurs	209
13	Influence du produit sur l'environnement	210
Annexe A (informative) Tension d'essai applicable à la position la plus défavorable d'un point de vue diélectrique du sectionneur de terre pendant sa manœuvre (distance d'isolement minimale temporaire)		211
Annexe B (informative) Pouvoir d'établissement et de coupure de courant exigé des sectionneurs et des sectionneurs de terre		213
B.1	Pouvoir d'établissement et de coupure de courant de transfert de barres des sectionneurs	213
B.2	Pouvoir d'établissement et de coupure de courant de jeux de barres à vide des sectionneurs	213
B.3	Pouvoir d'établissement et de coupure de courant induit des sectionneurs de terre	214
Annexe C (normative) Tolérances sur les grandeurs d'essai pour les essais de type		216
Annexe D (normative) Autres méthodes d'essai pour les essais d'établissement de courant en court-circuit		218
D.1	Généralités	218
D.2	Autres méthodes	218
D.2.1	Méthode d'essai synthétique avec tension assignée et courant de court-circuit assigné	218

D.2.2	Méthodes d'essai à tension réduite	218
Annexe E (informative)	Extension de la validité des essais de type	220
E.1	Généralités	220
E.2	Essais diélectriques	220
E.3	Essais au courant de courte durée admissible	220
E.4	Performances de fermeture en court-circuit des sectionneurs de terre	220
E.5	Essais de fonctionnement et d'endurance mécanique	220
E.6	Essais de coupure de courant de transfert de barres sur les sectionneurs	220
E.7	Essais de coupure de courant induit sur les sectionneurs de terre	221
Bibliographie		222
Figure 1	– Dispositifs indicateurs/de signalisation de position	148
Figure 2	– Disposition d'essai triphasé pour des sectionneurs et des sectionneurs de terre	156
Figure 3	– Disposition d'essai monophasé pour sectionneurs comportant une distance de sectionnement horizontale et pour sectionneurs de terre de $U_T > 52$ kV, destinés à être utilisés avec des conducteurs souples ou rigides	158
Figure 4	– Disposition d'essai monophasé pour sectionneurs à éléments séparés (sectionneurs de terre) de $U_T > 52$ kV à distance de sectionnement verticale, destinés à être utilisés avec des conducteurs souples	159
Figure 5	– Disposition d'essai monophasé pour sectionneurs à éléments séparés (sectionneurs de terre) de $U_T > 52$ kV à distance de sectionnement verticale, destinés à être utilisés avec des conducteurs rigides	160
Figure 6	– Contact fixe parallèle au support	169
Figure 7	– Contact fixe perpendiculaire au support	169
Figure 8	– Exemple d'application des efforts mécaniques statiques assignés sur les bornes d'un sectionneur (ou sectionneur de terre) pantographe (à éléments séparés)	170
Figure 9	– Exemple d'application des efforts mécaniques statiques assignés sur les bornes d'un sectionneur à deux colonnes	171
Figure 10	– Séquences d'essai pour les essais à basse et haute température	178
Figure 11	– Exemple de circuit pour les essais de coupure de courant de transfert de barres	184
Figure 12	– Circuit d'essai pour l'établissement-coupure de courant d'induction électromagnétique	188
Figure 13	– Circuits d'essai pour l'établissement-coupure de courant d'induction électrostatique	190
Figure 14	– Circuit d'essai pour la séquence d'essai 1	195
Figure 15	– Forme d'onde de tension typique (incluant les composantes VFT et FT)	196
Figure 16	– Circuit d'essai pour la séquence d'essai 2	197
Figure 17	– Circuit d'essai pour la séquence d'essai 3	197
Figure B.1	– Exemples de sectionneurs équipés de résistances	214
Tableau 1	– Classification des sectionneurs de terre pour la fermeture en court-circuit	135
Tableau 2	– Zones de contact préférentielles pour les contacts "fixes" supportés par des conducteurs souples	136
Tableau 3	– Zones de contact préférentielles pour les contacts "fixes" supportés par des conducteurs rigides	136
Tableau 4	– Efforts mécaniques statiques préférentiels sur les bornes	137
Tableau 5	– Classification des sectionneurs pour l'endurance mécanique	137

Tableau 6 – Classification des sectionneurs de terre pour l'endurance mécanique.....	138
Tableau 7 – Tensions assignées de transfert de barres des sectionneurs	139
Tableau 8 – Classification des sectionneurs de terre pour la coupure de courant induit	139
Tableau 9 – Valeurs des courants assignés d'induction et des tensions assignées d'induction	140
Tableau 10 – Classification des sectionneurs pour établissement-coupure de jeux de barres à vide.....	141
Tableau 11 – Valeurs normalisées des courants de jeux de barres à vide assignés	141
Tableau 12 – Informations sur le produit	143
Tableau 13 – Liste des essais de type	151
Tableau 14 – Tensions de tenue à fréquence industrielle.....	153
Tableau 15 – Exigences relatives à l'instant de fermeture	165
Tableau 16 – Essais non valables	167
Tableau 17 – Valeurs normalisées des tensions de rétablissement pour les essais de coupure de courant d'induction électromagnétique.....	189
Tableau 18 – Capacités du circuit d'essai (valeurs C_1) pour l'établissement-coupure de courant d'induction électrostatique.....	191
Tableau 19 – Tensions d'essai pour les essais d'établissement et de coupure.....	194
Tableau 20 – Nombre d'essais.....	198
Tableau 21 – Essais de tension à fréquence industrielle	200
Tableau B.1 – Impédances moyennes.....	213
Tableau C.1 – Tolérances sur les grandeurs d'essai pour les essais de type	216

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

APPAREILLAGE À HAUTE TENSION –

Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif

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Cette version consolidée de la Norme IEC officielle et de son amendement a été préparée pour la commodité de l'utilisateur.

L'IEC 62271-102 édition 2.1 contient la deuxième édition (2018-05) [documents 17A/1173/FDIS et 17A/1180/RVD] et son amendement 1 (2022-04) [documents 17A/1322/CDV et 17A/1337/RVC].

Dans cette version Redline, une ligne verticale dans la marge indique où le contenu technique est modifié par l'amendement 1. Les ajouts sont en vert, les suppressions sont en rouge, barrées. Une version Finale avec toutes les modifications acceptées est disponible dans cette publication.

La Norme internationale IEC 62271-102 a été établie par le sous-comité 17A: Appareils de connexion, du comité d'études 17 de l'IEC: Appareillage haute tension.

Cette deuxième édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) adoption d'une nouvelle numérotation conformément à l'IEC 17/1025/RQ pour se conformer aux Directives ISO/IEC, Partie 2, et à l'IEEE C37.100.1;
- b) alignement de la numérotation des articles avec l'IEC 62271-1:2017;
- c) extension du Domaine d'application pour couvrir toutes les installations pour l'intérieur et pour l'extérieur. Prise en compte des appareils de connexion comportant, en plus d'autres fonctions, des fonctionnalités de déconnexion et/ou de mise à la terre couvertes par le présent document;
- d) transfert des caractéristiques assignées des Annexes B, C et E à l'Article 5; l'ordre des paragraphes correspond désormais à l'ordre des paragraphes de l'Article 7;
- e) affectation de nouvelles valeurs assignées au courant de transfert de barres et à la tension de transfert de barres;
- f) ajout d'une nouvelle classe d'endurance mécanique pour les sectionneurs de terre (M1);
- g) le paragraphe "Valeurs assignées d'endurance électrique pour les sectionneurs de terre" s'intitule désormais "Classification des sectionneurs de terre pour le pouvoir de fermeture en court-circuit;
- h) ajout d'un nouveau paragraphe avec des caractéristiques assignées pour la couche de glace;
- i) ajout d'un nouveau paragraphe avec classification du pouvoir d'établissement et de coupure de jeux de barres à vide;
- j) ajout de nouvelles exigences en matière de tenue pour les dispositifs de verrouillage;
- k) modification de la manière de se conformer aux exigences de la distance de sectionnement des sectionneurs;
- l) modification des exigences de conception et de construction des indicateurs de position, en alignant les exigences pour l'indication et la signalisation de position;
- m) modification de la valeur de l'effort de manœuvre;
- n) révision et modification si nécessaire des procédures d'essai et des critères de validation;
- o) modification des exigences relatives à la tension appliquée lors des essais monophasés sur les sectionneurs de terre à fermeture non simultanée;
- p) suppression des exigences non vérifiables;
- q) ajout d'un nouveau paragraphe pour soumettre à l'essai les dispositifs de verrouillage mécanique;
- r) réalisation obligatoire de l'essai aux températures haute et basse si les limites de température pour les conditions de service de l'appareil (définies par le constructeur) sont supérieures à 40 °C ou inférieures à -5 °C, et fourniture d'une procédure d'essai plus détaillée;
- s) réalisation d'essai matériellement possible sur chacune des technologies utilisées, favorisée par la procédure d'essai de vérification du bon fonctionnement de l'indicateur de position;
- t) ajout d'une nouvelle Annexe B intitulée: "Pouvoir d'établissement et de coupure de courant exigé des sectionneurs et des sectionneurs de terre";
- u) ajout d'une nouvelle Annexe C intitulée: "Tolérances sur les grandeurs d'essai pour les essais de type"
- v) ajout d'une nouvelle Annexe E intitulée: "Extension de la validité des essais de type".

Sauf spécification contraire, cette norme doit être lue conjointement à l'IEC 62271-1:2017, à laquelle elle fait référence et qui est applicable. Dans le but de simplifier les indications des exigences correspondantes, la numérotation des articles et des paragraphes, sauf des annexes, est identique à celle utilisée dans l'IEC 62271-1:2017. Les paragraphes complémentaires sont numérotés à partir de 101.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2

Une liste de toutes les parties de la série IEC 62271 publiées sous le titre général, *Appareillage à haute tension*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de la publication de base et de son amendement ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

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APPAREILLAGE À HAUTE TENSION –

Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif

1 Domaine d'application

La présente partie de l'IEC 62271 s'applique aux sectionneurs et aux sectionneurs de terre à courant alternatif, conçus pour être installés à l'intérieur et à l'extérieur, pour des tensions nominales supérieures à 1 000 V et des fréquences de service inférieures ou égales à 60 Hz.

Elle s'applique également aux dispositifs de manœuvre de ces sectionneurs et sectionneurs de terre et à leurs équipements auxiliaires.

Des exigences complémentaires pour les sectionneurs et les sectionneurs de terre intégrés dans l'appareillage sous enveloppe sont données dans l'IEC 62271-200, l'IEC 62271-201 et l'IEC 62271-203.

NOTE Les sectionneurs dont le fusible fait partie intégrante ne sont pas couverts par la présente norme.

Le présent document s'applique également aux appareils de connexion comportant, en plus d'autres fonctions, des fonctionnalités de déconnexion et/ou de mise à la terre, par exemple un sectionneur de terre haute vitesse, un disjoncteur ou un interrupteur-sectionneur.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-151, *Vocabulaire Electrotechnique International – Partie 151: Dispositifs électriques et magnétiques*

IEC 60050-441, *Vocabulaire Electrotechnique International – Chapitre 441: Appareillage et fusibles*

IEC 60050-471, *Vocabulaire Electrotechnique International – Partie 471: Isolateurs*

IEC 60050-614, *Vocabulaire Electrotechnique International – Partie 614: Production, transport et distribution de l'énergie électrique – Exploitation*

IEC 60071-1, *Coordination de l'isolement – Partie 1: Définitions, principes et règles*

~~IEC 60071-2, *Coordination de l'isolement – Partie 2: Guide d'application*~~

IEC 60137, *Traversées isolées pour tensions alternatives supérieures à 1 000 V*

IEC 60270, *Techniques des essais à haute tension – Mesures des décharges partielles*

IEC 60529:1989, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60865-1, *Courants de court-circuit – Calcul des effets – Partie 1: Définitions et méthodes de calcul*

IEC 62262:2002, *Degrés de protection procurés par les enveloppes de matériels électriques contre les impacts mécaniques externes (code IK)*

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-100:2008, *Appareillage à haute tension – Partie 100: Disjoncteurs à courant alternatif*

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-101:2012, *Appareillage à haute tension – Partie 101: Essais synthétiques*
IEC 62271-101:2012/AMD1:2017

IEC 62271-200:2011, *Appareillage à haute tension – Partie 200: Appareillage sous enveloppe métallique pour courant alternatif de tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV*

IEC 62271-201:2014, *Appareillage à haute tension – Partie 201: Appareillage sous enveloppe isolante solide pour courant alternatif de tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV*

IEC 62271-203:2011, *Appareillage à haute tension – Partie 203: Appareillage sous enveloppe métallique à isolation gazeuse de tensions assignées supérieures à 52 kV*

IEC/TR 62271-305, *Appareillage à haute tension – Partie 305: Capacitive current switching capability of air-insulated disconnectors for rated voltages above 52 kV (disponible en anglais seulement)*

ISO 2768-1, *Tolérances générales – Partie 1: Tolérances pour dimensions linéaires et angulaires non affectées de tolérances individuelles*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60050-151, l'IEC 60050-441, l'IEC 60050-471, l'IEC 60050-614, et l'IEC 62271-1, ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

3.1 Termes et définitions généraux

3.1.101

appareillage pour l'intérieur

appareillage qui n'est conçu que pour être installé à l'intérieur d'un bâtiment ou d'un autre abri, dans lequel l'appareillage est protégé contre le vent, la pluie, la neige, les pollutions anormales, la condensation anormale, la glace et le givre

[SOURCE: IEC 60050-441:2000, 441-11-04]

3.1.102

appareillage pour l'extérieur

appareillage convenant pour l'installation en plein air, c'est-à-dire capable de supporter le vent, la pluie, la neige, les pollutions, la condensation, la glace et le givre

[SOURCE: IEC 60050-441:2000, 441-11-05]

3.1.103

utilisateur

personne ou entité légale utilisant des sectionneurs ou des sectionneurs de terre

Note 1 à l'article: Il peut être l'acheteur (par exemple un distributeur d'électricité), mais peut également être la société contractante, le personnel chargé du montage, le personnel chargé de la maintenance ou de l'exploitation ou toute autre personne qui peut être, d'une manière occasionnelle ou permanente, responsable du sectionneur, du sectionneur de terre, de l'installation électrique, voire de la manœuvre de l'appareillage.

3.2 Ensembles de l'appareillage

3.2.1

objet d'essai

matériel nécessaire pour représenter le spécimen pour un essai de type particulier

[SOURCE: IEC 62271-1:2017, 3.2.1, modifié – "appareillage" remplacé par "spécimen"]

3.3 Parties d'ensembles

Les dispositions de 3.3 de l'IEC 62271-1:2017 s'appliquent.

3.4 Appareils de connexion

3.4.101

sectionneur

appareil mécanique de connexion qui assure, en position d'ouverture, une distance de sectionnement satisfaisant à des conditions spécifiées

Note 1 à l'article: Un sectionneur est capable d'ouvrir et de fermer un circuit lorsqu'un courant d'intensité négligeable est interrompu ou établi, ou bien lorsqu'il ne se produit aucun changement notable de la tension aux bornes de chacun des pôles du sectionneur. Il est aussi capable de supporter des courants dans les conditions normales du circuit et de supporter des courants pendant une durée spécifiée dans des conditions anormales telles que celles du court-circuit.

Note 2 à l'article: Le terme "intensité négligeable" est relatif aux courants tels que les courants capacitifs des traversées, des jeux de barres, des connexions, des très courtes longueurs de câbles, aux courants des impédances de répartition des disjoncteurs connectées en permanence et aux courants des transformateurs et des diviseurs de tension (voir également l'IEC/TR 62271-305). Pour $U_r \leq 420$ kV, une intensité ne dépassant pas 0,5 A est considérée comme une intensité négligeable pour l'application de cette définition; pour $U_r > 420$ kV et les intensités supérieures à 0,5 A, il convient de consulter le constructeur. L'expression "pas de variation notable de la tension" vise les applications comme le pontage des régulateurs de tension inductifs ou des disjoncteurs et le transfert de barres.

[SOURCE: IEC 60050-441:2000, 441-14-05, modifié – Ajout d'une Note 2 à l'article]

3.4.102

sectionneur à éléments séparés

sectionneur de terre à éléments séparés

sectionneur (ou sectionneur de terre) dont les contacts fixes et mobiles de chaque pôle ne sont pas supportés par une embase ou un châssis communs

Note 1 à l'article: Un exemple caractéristique est le sectionneur (ou sectionneur de terre) pantographe ou semi-pantographe.

[SOURCE: IEC 60050-441:2000, 441-14-06 et -07, modifié – Le terme "sectionneur de terre" est complété par "à éléments séparés" et le terme "sectionneur" est remplacé par

"sectionneur de terre" dans la Note 1 à l'article, le cas échéant; Suppression de la Note 2 à l'article.]

3.4.103

sectionneur à coupure centrale

sectionneur dans lequel les deux contacts de chaque pôle sont mobiles et se réunissent en un point sensiblement à mi-chemin des colonnes supports

Note 1 à l'article: Ce terme ne concerne que les sectionneurs à haute tension.

[SOURCE: IEC 60050-441:2000, 441-14-08]

3.4.104

sectionneur à double coupure

sectionneur qui ouvre un circuit en deux points

[SOURCE: IEC 60050-441:2000, 441-14-09]

3.4.105

sectionneur équipé de résistances

sectionneur équipé de résistance en série ou en parallèle aux contacts de commutation, afin d'atténuer la surtension transitoire très rapide (VFTO – *very fast transient overvoltage*) pendant les manœuvres d'ouverture et de fermeture dans l'appareillage sous enveloppe métallique, à isolation gazeuse

3.4.106

sectionneur de terre

appareil mécanique de connexion utilisé pour mettre à la terre des parties d'un circuit, capable de supporter pendant une durée spécifiée des courants dans des conditions anormales telles que celles du court-circuit, mais non prévu pour supporter du courant dans les conditions normales du circuit

Note 1 à l'article: Un sectionneur de terre peut avoir un pouvoir de fermeture en court-circuit.

Note 2 à l'article: Un sectionneur de terre de $U_r > 52$ kV peut avoir des caractéristiques assignées pour établir, couper et transiter les courants induits.

Note 3 à l'article: Ces appareils peuvent être quelquefois manœuvrés en court-circuit. Les différentes classes de sectionneurs de terre sont liées au nombre de manœuvres de fermeture en court-circuit.

Note 4 à l'article: Dans certains cas, les sectionneurs de terre sont utilisés comme des appareils qui génèrent des défauts.

[SOURCE: IEC 60050-441:2000, 441-14-11, modifié – Ajout des Notes 2, 3 et 4 à l'article]

3.4.107

sectionneur de terre à fonction combinée

sectionneur de terre avec un système de contact commun pour la mise à la terre et au moins une des fonctions suivantes:

- déconnexion;
- établissement et/ou coupure des courants jusqu'au courant de court-circuit

3.4.108

interrupteur-sectionneur

interrupteur qui, dans sa position d'ouverture, satisfait aux conditions d'isolement spécifiées pour un sectionneur

[SOURCE: IEC 60050-441:2000, 441-14-12]

3.5 Parties d'appareils de connexion

3.5.101

pôle d'un appareil de connexion

élément constituant d'un appareil de connexion associé exclusivement à un chemin conducteur électriquement séparé appartenant à son circuit principal, cet élément ne comprenant pas les éléments constitutifs assurant la fixation et le fonctionnement d'ensemble de tous les pôles

Note 1 à l'article: Un appareil de connexion est appelé unipolaire s'il n'a qu'un pôle. S'il a plus d'un pôle, il peut être appelé multipolaire (bipolaire, tripolaire, etc.) à condition que les pôles soient ou puissent être liés entre eux de façon qu'ils fonctionnent ensemble.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.102

circuit principal

<d'un appareil de connexion> ensemble de pièces conductrices d'un appareil de connexion insérées dans le circuit qu'il a pour fonction de fermer ou d'ouvrir

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.103

contact

<d'un appareil de connexion> pièces conductrices destinées à établir la continuité d'un circuit lorsqu'elles se touchent et qui, par leur mouvement relatif pendant la manœuvre, ouvrent et ferment un circuit ou, dans le cas de contacts pivotants ou glissants, maintiennent la continuité du circuit

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.104

contact principal

contact inséré dans le circuit principal d'un appareil mécanique de connexion, prévu pour supporter, dans la position de fermeture, le courant du circuit principal

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.105

contact de commande

contact inséré dans un circuit de commande d'un appareil mécanique de connexion et manœuvré mécaniquement par cet appareil

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.106

contact à fermeture

contact "a"

contact de commande ou auxiliaire qui est fermé lorsque les contacts principaux de l'appareil mécanique de connexion sont fermés et qui est ouvert lorsque ces contacts sont ouverts

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.107

contact à ouverture

contact "b"

contact de commande ou auxiliaire qui est ouvert lorsque les contacts principaux de l'appareil mécanique de connexion sont fermés et qui est fermé lorsque ces contacts sont ouverts

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.108

indicateur de position

partie d'un appareil mécanique de connexion qui indique les positions de celui-ci, par exemple: position d'ouverture, position de fermeture, ou, le cas échéant, position de mise à la terre

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.109

dispositif de signalisation de position

partie d'un sectionneur ou d'un sectionneur de terre qui utilise une énergie auxiliaire afin d'indiquer si les contacts du circuit principal sont dans la position d'ouverture ou dans la position de fermeture

3.5.110

borne

partie conductrice d'un dispositif, d'un circuit électrique ou d'un réseau électrique, destinée à le connecter à un ou plusieurs conducteurs extérieurs

[SOURCE: IEC 60050-151:2014, 151-12-12, modifié – la note a été supprimée.]

3.5.111

zone de contact

<pour les sectionneurs et les sectionneurs de terre à éléments séparés> région spatiale des différentes positions que le contact fixe peut prendre pour qu'il puisse s'engager correctement avec le contact mobile

3.5.112

chaîne cinématique de puissance

dispositif de liaison mécanique entre le mécanisme de commande et les contacts mobiles, tous deux inclus

Note 1 à l'article: Se reporter à la Figure 1.

3.5.113

chaîne cinématique de l'indicateur de position

dispositif de liaison mécanique entre les contacts mobiles et l'indicateur (ou les indicateurs) de position, tous deux inclus

3.5.114

chaîne cinématique du dispositif de signalisation de position

dispositif de liaison mécanique entre les contacts mobiles et le ou les dispositifs de signalisation de position

3.5.115

point de connexion

point le plus en amont (c'est-à-dire le plus proche de la source d'énergie) des parties communes entre les chaînes cinématiques "indicateur de position" ou "dispositif de signalisation de position"

3.5.116

dispositif limiteur de contrainte

dispositif limitant à une valeur spécifiée le couple ou l'effort transmis coté aval du dispositif, indépendamment du couple ou l'effort appliqué coté amont

3.5.117

contrôleur de couple (d'effort)

système surveillant et contrôlant le couple (l'effort) transmis coté aval du dispositif, par rapport à une valeur spécifiée

3.5.118

traversée

dispositif servant à faire passer un ou plusieurs conducteurs à travers une paroi, telle qu'un mur ou une cuve, en isolant le(s) conducteur(s) de cette paroi

[SOURCE: IEC 60050-471:2007,471-02-01, modifiée – Suppression des Notes 1 et 2 à l'article]

3.5.119

source d'énergie

origine de l'énergie libérée ou de l'effort/du couple appliqué à la chaîne cinématique de puissance d'un appareil de connexion lors d'une manœuvre ou à n'importe quelle position stable de l'appareil de connexion

Note 1 à l'article: L'énergie, l'effort ou le couple peut être d'origine humaine, électrique, hydraulique, pneumatique et mécanique, c'est-à-dire les ressorts, les poids, etc. seuls ou associés.

3.6 Fonctionnement

3.6.101

manœuvre

<d'un appareil mécanique de connexion> passage d'un ou de plusieurs contacts mobiles d'une position à une position adjacente

Note 1 à l'article: Par exemple, pour un disjoncteur ce pourra être une manœuvre de fermeture ou une manœuvre d'ouverture.

Note 2 à l'article: Si une distinction est nécessaire, on emploiera les mots manœuvre électrique (par exemple: établissement ou coupure) et manœuvre mécanique (par exemple: fermeture ou ouverture).

[SOURCE: IEC 60050-441:2000, 441-16-01]

3.6.102

cycle de manœuvres

<d'un appareil mécanique de connexion> suite de manœuvres d'une position à une autre avec retour à la première position en passant par toutes les autres positions, s'il en existe

[SOURCE: IEC 60050-441:2000, 441-16-02]

3.6.103

manœuvre de fermeture

<d'un appareil mécanique de connexion> manœuvre par laquelle on fait passer l'appareil de la position d'ouverture à la position de fermeture

[SOURCE: IEC 60050-441:2000, 441-16-08]

3.6.104

manœuvre d'ouverture

<d'un appareil mécanique de connexion> manœuvre par laquelle on fait passer l'appareil de la position de fermeture à la position d'ouverture

[SOURCE: IEC 60050-441:2000, 441-16-09]

3.6.105

manœuvre dépendante manuelle

<d'un appareil mécanique de connexion> manœuvre effectuée exclusivement au moyen d'une énergie manuelle directement appliquée, de telle sorte que la vitesse et la force de la manœuvre dépendent de l'action de l'opérateur

Note 1 à l'article: La manœuvre dépendante manuelle peut être effectuée par une manivelle ou un levier (horizontal ou vertical).

Note 2 à l'article: Les appareils de connexion à manœuvre dépendante manuelle ne possèdent aucun pouvoir inhérent d'établissement et de coupure.

[SOURCE: IEC 60050-441:2000, 441-16-13, modifiée – Ajout des Notes 1 et 2 à l'article]

3.6.106

manœuvre dépendante à source d'énergie extérieure

<d'un appareil mécanique de connexion> manœuvre effectuée au moyen d'une énergie autre que manuelle et dont l'achèvement dépend de la continuité de l'alimentation en énergie (de solénoïdes, moteurs électriques ou pneumatiques, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.107

manœuvre à accumulation d'énergie

<d'un appareil mécanique de connexion> manœuvre effectuée au moyen d'énergie emmagasinée dans le mécanisme lui-même avant l'achèvement de la manœuvre et suffisante pour achever la manœuvre dans des conditions prédéterminées

Note 1 à l'article: Ce type de manœuvre peut être subdivisé suivant:

- 1) le mode d'accumulation de l'énergie (ressort, poids, etc.)
- 2) la provenance de l'énergie (manuelle, électrique, etc.);
- 3) le mode de libération de l'énergie (manuel, électrique, etc.).

[SOURCE: IEC 60050-441:2000, 441-16-15]

3.6.108

manœuvre indépendante manuelle

<d'un appareil mécanique de connexion> manœuvre à accumulation d'énergie dans laquelle l'énergie provient de l'énergie manuelle accumulée et libérée en une seule manœuvre continue, de telle sorte que la vitesse et la force de la manœuvre sont indépendantes de l'action de l'opérateur

[SOURCE: IEC 60050-441:2000, 441-16-16]

3.6.109

position de fermeture

<d'un appareil mécanique de connexion> position dans laquelle la continuité prédéterminée du circuit principal de l'appareil est assurée

Note 1 à l'article: La continuité prédéterminée signifie que les contacts sont totalement fermés pour supporter les courants continus assignés et les courants de court-circuit assignés, lorsqu'applicable.

[SOURCE: IEC 60050-441:2000, 441-16-22, modifiée – Ajout d'une Note à l'article]

3.6.110

position d'ouverture

<d'un appareil mécanique de connexion> position dans laquelle la distance prédéterminée d'isolement entre contacts ouverts est assurée dans le circuit principal de l'appareil

[SOURCE: IEC 60050-441:2000, 441-16-23]

3.6.111

point de bascule

point au-delà duquel tout mouvement additionnel du mécanisme de charge provoque la libération de l'énergie stockée

3.6.112

endurance mécanique

<d'un sectionneur ou sectionneur de terre> pouvoir d'un sectionneur ou d'un sectionneur de terre à effectuer un nombre défini de manœuvres sans mise sous tension du circuit ou circulation de courant dans le circuit, dans des conditions de fonctionnement spécifiées

3.7 Grandeurs caractéristiques

3.7.101

valeur de crête du courant établi

<d'un sectionneur de terre> valeur de crête de la première grande alternance du courant dans un pôle du sectionneur de terre pendant la période transitoire qui suit l'instant d'établissement du courant lors d'une manœuvre de fermeture

Note 1 à l'article: Pour un circuit triphasé, lorsqu'une seule valeur (de crête) du courant établi est indiquée, sauf spécification contraire, il s'agit de la plus grande valeur dans n'importe quelle phase.

3.7.102

valeur de crête du courant

valeur de crête de la première grande alternance du courant pendant la période transitoire qui suit son établissement

3.7.103

courant de courte durée admissible

courant qu'un circuit ou un appareil de connexion dans la position de fermeture peut supporter pendant un court intervalle de temps spécifié et dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:2000, 441-17-17]

3.7.104

valeur de crête du courant admissible

valeur de crête du courant qu'un circuit ou un appareil de connexion dans la position de fermeture peut supporter dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:2000, 441-17-18]

3.7.105

niveau d'isolement

ensemble des tensions de tenue spécifiées qui caractérisent la tenue diélectrique de l'isolation

[SOURCE: IEC 60050-614:2016, 614-03-23]

3.7.106

tension de tenue à fréquence industrielle

valeur efficace de la tension sinusoïdale à fréquence industrielle que l'isolation du matériel considéré peut supporter lors d'essais faits dans des conditions spécifiées et pendant une durée spécifiée

[SOURCE: IEC 60050-614:2016, 614-03-22]

3.7.107

tension de tenue aux chocs de foudre

valeur de crête de la tension de choc de foudre que l'isolation du sectionneur ou du sectionneur de terre tient dans des conditions spécifiées

3.7.108

tension de tenue aux chocs de manœuvre

valeur de crête de la tension de choc de manœuvre que l'isolation du sectionneur ou du sectionneur de terre tient dans des conditions d'essais spécifiées

3.7.109

isolation externe

distances dans l'air atmosphérique et sur les surfaces des isolations solides d'un matériel en contact avec l'air atmosphérique, qui sont soumises aux contraintes diélectriques et à l'influence des conditions atmosphériques ou d'autres conditions environnementales provenant du site

Note 1 à l'article: Des exemples de conditions environnementales sont la pollution, l'humidité, les animaux, etc.

Note 2 à l'article: L'isolation externe est soit "protégée contre les intempéries" soit "non protégée contre les intempéries". Elle est conçue en vue d'applications à l'intérieur ou à l'extérieur d'abris fermés respectivement.

[SOURCE: IEC 60050-614:2016, 614-14-02, modifiée – Ajout d'une Note 2 à l'article]

3.7.110

isolation interne

distances internes dans l'isolation solide, liquide ou gazeuse des matériels qui sont à l'abri de l'influence des conditions atmosphériques ou d'autres agents externes

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.7.111

isolation autorégénératrice

isolation qui retrouve intégralement ses propriétés isolantes en un intervalle de temps court après une décharge disruptive

[SOURCE: IEC 60050-614:2016, 614-03-04]

3.7.112

isolation non autorégénératrice

isolation qui perd ses propriétés isolantes, ou ne les retrouve pas intégralement, après une décharge disruptive

Note 1 à l'article: Les définitions 3.7.111 et 3.7.112 s'appliquent uniquement lorsque la décharge est provoquée par l'application d'une tension d'essai au cours d'un essai diélectrique. Cependant, des décharges qui se produisent en service peuvent provoquer la perte partielle ou totale des propriétés autorégénératrices de l'isolation originale.

[SOURCE: IEC 60050-614:2016, 614-03-05, modifiée – Ajout d'une Note à l'article]

3.7.113

isolation parallèle

montage d'isolateurs avec deux éléments en parallèle dans laquelle la distance entre les deux isolateurs pourrait influencer la tenue diélectrique

Note 1 à l'article: Avec des sectionneurs et des sectionneurs de terre dont les bornes sont à l'air libre, l'isolation parallèle est utilisée lorsqu'un isolateur d'entraînement est situé à proximité d'un isolateur support.

3.7.114

décharge disruptive

défaillance de l'isolation sous une contrainte électrique, pendant laquelle la décharge court-circuite complètement l'isolation en essai, réduisant la tension appliquée entre les électrodes à une valeur pratiquement nulle

Note 1 à l'article: Des décharges disruptives non entretenues pendant lesquelles l'objet en essai est momentanément court-circuité par une étincelle ou un arc peuvent se produire. Pendant ces événements, la tension aux bornes de l'objet en essai est momentanément réduite à zéro ou à une très faible valeur. Selon les caractéristiques du circuit d'essai et de l'objet en essai, la rigidité diélectrique peut être rétablie et peut même permettre à la tension d'essai d'atteindre une valeur plus élevée. Il convient de considérer un tel événement comme une décharge disruptive sauf spécification contraire du comité d'études concerné.

Note 2 à l'article: Une décharge disruptive dans un diélectrique solide occasionne la perte définitive de la rigidité diélectrique; dans les diélectriques liquides ou gazeux, cette perte peut n'être que momentanée.

[SOURCE: IEC 60060-1:2010, 3.1.1]

3.7.115

distance d'isolement

distance entre deux parties conductrices le long d'un fil tendu suivant le plus court trajet possible entre ces deux parties conductrices

[SOURCE: IEC 60050-441:2000, 441-17-31]

3.7.116

distance d'isolement entre pôles

distance d'isolement entre n'importe quelles parties conductrices de pôles adjacents

[SOURCE: IEC 60050-441:2000, 441-17-32]

3.7.117

distance d'isolement à la terre

distance d'isolement entre n'importe quelle partie conductrice et n'importe quelle partie réunie à la terre ou prévue pour être réunie à la terre

[SOURCE: IEC 60050-441:2000, 441-17-33]

3.7.118

distance d'isolement entre contacts ouverts

distance d'isolement totale entre les contacts, ou n'importe quelles parties conductrices qui leur sont reliées d'un pôle d'un appareil mécanique de connexion dans la position d'ouverture

Note 1 à l'article: La distance d'isolement totale correspond à la somme des distances d'isolement existant entre les contacts.

[SOURCE: IEC 60050-441:2000, 441-17-34, modifiée – Ajout d'une Note à l'article]

3.7.119

efforts mécaniques sur les bornes

effort mécanique externe agissant sur chaque borne

Note 1 à l'article: L'effort externe est la résultante des forces mécaniques combinées qui peuvent être appliquées aux bornes de l'appareil de connexion. Les efforts dus au vent sur l'appareil lui-même ne sont pas compris, car ils ne contribuent pas à l'effort externe agissant sur les bornes.

Note 2 à l'article: Un sectionneur ou un sectionneur de terre peut être soumis à plusieurs efforts mécaniques dont les valeurs, la direction et le point d'application peuvent être différents.

Note 3 à l'article: Les efforts mécaniques sur les bornes tels qu'ils sont définis ici ne s'appliquent généralement pas aux appareillages sous enveloppe.

3.7.119.1

effort mécanique statique sur les bornes

effort mécanique statique sur chaque borne équivalent à la force mécanique à laquelle est soumise cette borne du sectionneur ou du sectionneur de terre du fait du conducteur souple ou rigide connecté à cette borne

Note 1 à l'article: L'effort mécanique statique sur les bornes inclut les efforts dus à la glace, au vent et aux conducteurs connectés.

3.7.119.2

effort mécanique dynamique assigné sur les bornes

combinaison des efforts mécaniques statiques sur chaque borne avec les efforts électromagnétiques en régime de court-circuit

3.7.120

transfert de barres

ouverture et fermeture de sectionneurs en charge quand cette charge n'est pas interrompue, mais qu'elle est transférée d'une barre vers une barre parallèle

3.7.121

courant de transfert de barres

courant qui circule lorsqu'une charge est transférée d'un jeu de barres vers un autre

3.7.122

tension de transfert de barres

tension à fréquence industrielle entre bornes du sectionneur ouvert après interruption, ou avant établissement, du courant de transfert de barres

3.7.123

coupure de courant induit

établissement ou coupure de courants capacitifs ou inductifs par un sectionneur de terre, par lequel les courants sont induits dans un système isolé ou à la terre par des lignes ou câbles adjacents sous tension

Note 1 à l'article: Quand deux lignes de transport ou plus sont montées ensemble, de l'énergie est induite par couplage électrostatique et/ou électromagnétique d'un système sous tension vers un système hors tension en provoquant des courants inductifs ou capacitifs qui circulent dans ce dernier système. La nature de ces courants dépend de la mise à la terre du système, à une extrémité seulement ou aux deux extrémités

3.7.124

courant d'induction électromagnétique

<sur un sectionneur de terre> courant inductif qui circule à travers un sectionneur de terre lorsqu'il connecte et déconnecte de la terre une extrémité d'une ligne de transport hors tension, l'autre extrémité étant reliée à la terre, et une ligne de courant sous tension étant en parallèle et à proximité de la ligne reliée à la terre

Note 1 à l'article: Le courant inductif dans une ligne hors tension reliée à la terre aux deux extrémités dépend du courant de la ligne sous tension et du coefficient de couplage avec la ligne sous tension, tel qu'il est déterminé par la configuration du circuit.

3.7.125

courant d'induction électrostatique

<sur un sectionneur de terre> courant capacitif qui circule à travers un sectionneur de terre lorsqu'il connecte et déconnecte de la terre une extrémité d'une ligne de transport hors tension, l'autre extrémité étant ouverte, et une ligne sous tension étant en parallèle et à proximité de la ligne reliée à la terre

Note 1 à l'article: Le courant capacitif dans une ligne hors tension reliée à la terre à une extrémité dépend de la tension de la ligne sous tension, du coefficient de couplage avec la ligne sous tension, tel qu'il est déterminé par la configuration du circuit, et de la longueur de la ligne reliée à la terre entre l'extrémité reliée à la terre et l'extrémité ouverte.

3.7.126

établissement-coupure de courant de jeux de barres à vide

établissement ou coupure de courant de jeux de barres à vide par un sectionneur

3.7.127

courant de jeux de barres à vide

courant capacitif qui circule lorsqu'une portion isolée d'un jeu de barres est mise sous tension ou hors tension

3.7.128

tension transitoire à la terre

U_{TVE}

tension phase-terre apparaissant au premier préamorçage pendant une manœuvre de fermeture d'un sectionneur

3.7.129

pression de remplissage pour l'isolement et/ou la coupure

masse volumique de remplissage pour l'isolement et/ou la coupure

pression (en Pa), pour l'isolement et/ou la coupure, rapportée aux conditions atmosphériques normales de +20 °C et de 101,3 kPa (ou masse volumique), pouvant être exprimée de façon relative ou absolue, à laquelle le compartiment est rempli avant la mise en service, ou rempli de nouveau automatiquement

[SOURCE: IEC 62271-1:2017, 3.6.5.1]

3.7.130

pression minimale de fonctionnement pour l'isolement et/ou la coupure

masse volumique minimale de fonctionnement pour l'isolement et/ou la coupure

pression (en Pa), pour l'isolement et/ou la coupure, rapportée aux conditions atmosphériques normales de +20 °C et de 101,3 kPa (ou masse volumique), pouvant être exprimée de façon relative ou absolue, à laquelle et au-dessus de laquelle les caractéristiques assignées de l'appareillage sont conservées, et à laquelle un complément de remplissage devient nécessaire

[SOURCE: IEC 62271-1:2017, 3.6.5.5]

3.8 Liste des définitions

A – B

contact à fermeture.....	3.5.106
contact à ouverture.....	3.5.107
Courant de jeux de barres à vide.....	3.7.127
Établissement-coupure de courant de jeux de barres à vide.....	3.7.126
Traversée.....	3.5.118
Courant de transfert de barres.....	3.7.121
Coupure de courant de transfert de barres.....	3.7.120
Tension de transfert de barres.....	3.7.122

C

Sectionneur à coupure centrale.....	3.4.103
Distance d'isolement.....	3.7.115
Distance d'isolement entre contacts ouverts.....	3.7.118
Distance d'isolement entre pôles.....	3.7.116

Distance d'isolement à la terre	3.7.117
Position de fermeture (d'un appareil mécanique de connexion)	3.6.109
Manœuvre de fermeture (d'un appareil mécanique de connexion)	3.6.103
Sectionneur de terre à fonction combinée	3.4.107
Point de connexion	3.5.115
Contact (d'un appareil de connexion)	3.5.103
Zone de contact (pour les sectionneurs et les sectionneurs de terre à éléments séparés)	3.5.111
Contact de commande	3.5.105

D

Manœuvre dépendante manuelle (d'un appareil mécanique de connexion)	3.6.105
Manœuvre dépendante à source d'énergie extérieure (d'un appareil mécanique de connexion)	3.6.106
Sectionneur	3.4.101
Décharge disruptive	3.7.114
Sectionneur à éléments séparés	3.4.102
Sectionneur de terre à éléments séparés	3.4.102
Sectionneur à double coupure	3.4.104
Effort mécanique dynamique assigné sur les bornes	3.7.119.2

E

Sectionneur de terre	3.4.106
Courant d'induction électromagnétique (sur un sectionneur de terre)	3.7.124
Courant d'induction électrostatique (sur un sectionneur de terre)	3.7.125
Isolation externe	3.7.109

I

Manœuvre indépendante manuelle (d'un appareil mécanique de connexion)	3.6.108
Appareillage pour l'intérieur	3.1.101
Coupure de courant induit	3.7.123
Niveau d'isolement	3.7.105
Isolation interne	3.7.110

L – N

Tension de tenue aux chocs de foudre	3.7.107
Circuit principal (d'un appareil de connexion)	3.5.102
Contact principal	3.5.104
Endurance mécanique d'un sectionneur (ou sectionneur de terre)	3.6.112
Efforts mécaniques sur les bornes	3.7.119
Masse volumique minimale de fonctionnement pour l'isolement	3.7.130
Pression minimale de fonctionnement pour l'isolement	3.7.130
Isolation non autorégénératrice	3.7.112

O

Position d'ouverture (d'un appareil mécanique de connexion)	3.6.110
Manœuvre d'ouverture (d'un appareil mécanique de connexion)	3.6.104
Manœuvre (d'un appareil mécanique de connexion)	3.6.101
Cycle de manœuvres (d'un appareil mécanique de connexion).....	3.6.102
Appareillage pour l'extérieur.....	3.1.102

P

Isolation parallèle	3.7.113
Valeur de crête du courant	3.7.102
Valeur de crête du courant établi (d'un sectionneur de terre)	3.7.101
Valeur de crête du courant admissible	3.7.104
Pôle d'un appareil de connexion	3.5.101
Indicateur de position.....	3.5.108
Chaîne cinématique de l'indicateur de position.....	3.5.113
Dispositif de signalisation de position	3.5.109
Chaîne cinématique du dispositif de signalisation de position	3.5.114
Tension de tenue à fréquence industrielle	3.7.106
Chaîne cinématique de puissance	3.5.112

R – U

Masse volumique assignée de remplissage pour l'isolement	3.7.129
Pression assignée de remplissage pour l'isolement	3.7.129
Sectionneur équipé de résistances	3.4.105
Isolation autorégénératrice.....	3.7.111
Courant de courte durée admissible.....	3.7.103
Source d'énergie	3.5.119
Effort mécanique statique sur les bornes	3.7.119.1
Manœuvre à accumulation d'énergie (d'un appareil mécanique de connexion).....	3.6.107
Dispositif limiteur de contrainte	3.5.116
Interrupteur-sectionneur.....	3.4.108
Tension de tenue aux chocs de manœuvre	3.7.108
Borne	3.5.110
Objet d'essai	3.2.1
Point de bascule	3.6.111
Contrôleur de couple (d'effort).....	3.5.117
Tension transitoire à la terre	3.7.128
Utilisateur.....	3.1.103

4 Conditions normales et spéciales de service

L'Article 4 de l'IEC 62271-1:2017 s'applique.

5 Caractéristiques assignées

5.1 Généralités

L'Article 5 de l'IEC 62271-1:2017 s'applique au sectionneur ou au sectionneur de terre, y compris leurs dispositifs de manœuvre et équipements auxiliaires. La liste des caractéristiques assignées est complétée par les points suivants:

- k) courant établi assigné en court-circuit (seulement pour les sectionneurs de terre);
- l) zone de contact assignée;
- m) effort mécanique statique assigné sur les bornes;
- n) couche de glace assignée;
- o) valeurs assignées du pouvoir d'établissement et de coupure de courant de transfert de barres (pour les sectionneurs uniquement);
- p) valeurs assignées du pouvoir de coupure de courant induit (pour les sectionneurs de terre uniquement);
- q) valeurs assignées du pouvoir d'établissement et de coupure de courant de jeux de barres à vide (pour les sectionneurs uniquement).

Les classes suivantes peuvent être assignées en plus des tensions assignées indiquées ci-dessus:

- r) classe de pouvoir de fermeture en court-circuit (pour les sectionneurs de terre uniquement);
- s) classe d'endurance mécanique;
- t) classe de coupure de courant induit (pour les sectionneurs de terre uniquement);
- u) classe d'établissement et de coupure de courant de jeux de barres à vide (pour les sectionneurs uniquement).

Les sectionneurs ou les sectionneurs de terre classés pour plusieurs pouvoirs d'établissement et de coupure peuvent indiquer leur classe réelle par la combinaison de leurs désignations de classe. Par exemple, un sectionneur de terre dont le pouvoir de fermeture en court-circuit est de classe E1 et le pouvoir d'établissement et de coupure de courant induit est de classe B peut être classé dans la classe B+E1.

Les caractéristiques assignées pour les pouvoirs de fermeture et de coupure ne peuvent pas être attribuées aux sectionneurs et sectionneurs de terre à manœuvre dépendante manuelle uniquement.

Dans le cas des sectionneurs et des sectionneurs de terre à manœuvre dépendante à source d'énergie extérieure et à manœuvre dépendante manuelle, aucun pouvoir de fermeture et de coupure n'est valide pour la manœuvre dépendante manuelle.

5.2 Tension assignée (U_r)

Le paragraphe 5.2 de l'IEC 62271-1:2017 s'applique.

5.3 Niveau d'isolement assigné (U_d , U_p , U_s)

Le paragraphe 5.3 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Pour les sectionneurs ayant une tension assignée supérieure à 52 kV et les sectionneurs ayant une distance de sectionnement parallèle à la base du sectionneur, équipés de sectionneurs de terre associés, le niveau d'isolement entre les parties mobiles du sectionneur de terre et les parties actives opposées, pendant la manœuvre du sectionneur de terre, doit

correspondre au moins à la tension de tenue de courte durée à fréquence industrielle (spécifiée en 7.2.6) pour le plus petit intervalle de sectionnement entre elles.

Si des règles de sécurité nationales spécifient des valeurs de tenue plus élevées pour les sectionneurs de terre à commande uniquement manuelle, cela doit faire l'objet d'un accord entre l'utilisateur et le constructeur.

5.4 Fréquence assignée (f_r)

Le paragraphe 5.4 de l'IEC 62271-1:2017 s'applique.

5.5 Courant permanent assigné (I_r)

Le paragraphe 5.5 de l'IEC 62271-1:2017 s'applique. Ce paragraphe ne s'applique qu'aux sectionneurs.

5.6 Courant de courte durée admissible assigné (I_k)

Le paragraphe 5.6 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Il peut être attribué à un sectionneur de terre une valeur assignée différente de la valeur assignée du circuit principal associé (le cas échéant).

Il peut être attribué à un sectionneur de terre formant une partie intégrante d'un sectionneur de terre à fonction combinée une valeur assignée différente de la valeur assignée de son circuit principal.

5.7 Valeur de crête du courant admissible assignée (I_p)

Le paragraphe 5.7 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Il peut être attribué à un sectionneur de terre une valeur assignée différente de la valeur assignée du circuit principal associé (le cas échéant).

Il peut être attribué à un sectionneur de terre formant une partie intégrante d'un sectionneur de terre à fonction combinée une valeur assignée différente de la valeur assignée de son circuit principal.

5.8 Durée de court-circuit assignée (t_k)

Le paragraphe 5.8 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Il peut être attribué à un sectionneur de terre une valeur assignée différente de la valeur assignée du circuit principal associé (le cas échéant).

Il peut être attribué à un sectionneur de terre formant une partie intégrante d'un sectionneur de terre à fonction combinée une valeur assignée différente de la valeur assignée de son circuit principal.

5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)

Le paragraphe 5.9 de l'IEC 62271-1:2017 s'applique.

5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande

Le paragraphe 5.10 de l'IEC 62271-1:2017 s'applique.

5.11 Pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue

Le paragraphe 5.11 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

5.11.101 Pression d'alimentation assignée en gaz comprimé pour l'isolement et/ou la coupure

Les limites de pression doivent être fournies par le constructeur.

5.11.102 Pression d'alimentation assignée en gaz comprimé pour la manœuvre

Alimentation pneumatique ou hydraulique extérieure:

Sauf spécification contraire du constructeur, les limites de la pression de fonctionnement sont 85 % et 110 % de la pression assignée.

5.101 Courant établi assigné en court-circuit (I_{ma})

Le courant établi assigné en court-circuit ne s'applique qu'aux sectionneurs de terre de classes E1 et E2. Il doit être égal à la valeur de crête du courant admissible assignée.

Le paragraphe 5.102 donne une classification des sectionneurs de terre pour leur pouvoir de fermeture en court-circuit.

5.102 Classification des sectionneurs de terre pour le pouvoir de fermeture en court-circuit

Le pouvoir de fermeture en court-circuit des sectionneurs de terre de réaliser un nombre défini de manœuvres de fermeture en court-circuit sans maintenance majeure doit correspondre à l'une des classes données au Tableau 1.

NOTE Le nombre plus important de manœuvres de fermeture de classe E2 est généralement associé à des tensions jusqu'à et y compris 52 kV selon les conditions de manœuvre et les systèmes de protection de ces réseaux.

Tableau 1 – Classification des sectionneurs de terre pour la fermeture en court-circuit

Classe	Type de sectionneur de terre
E0	Sectionneur de terre sans pouvoir de fermeture en court-circuit
E1	Sectionneur de terre avec le pouvoir de réaliser deux manœuvres de fermeture en court-circuit
E2	Sectionneur de terre avec le pouvoir de réaliser cinq manœuvres de fermeture en court-circuit

5.103 Zone de contact assignée

Dans le cas des sectionneurs à éléments séparés et des sectionneurs de terre à éléments séparés, le constructeur doit indiquer les valeurs assignées de la zone de contact (représentées par x_r , y_r et z_r). Les valeurs préférentielles sont données dans le Tableau 2 et le Tableau 3. Les valeurs assignées doivent être spécifiées par le constructeur. Cela s'applique également pour un déplacement angulaire tolérable du contact fixe.

Tableau 2 – Zones de contact préférentielles pour les contacts "fixes" supportés par des conducteurs souples

Tension assignée U_r kV	x mm	y mm	z_1 mm	z_2 mm	
72,5 – 100	100	300	200	300	
123 – 145		350			
170		400			
245	200	500	250	450	
300			300		
362				400	500
420					
550					
800	250	650	450	550	
1 100 – 1 200	300	700	500	600	

x = amplitude totale du mouvement longitudinal du conducteur support (température).

y = déviation horizontale totale (perpendiculaire au conducteur support) (vent).

z = déviation verticale (température et glace).

NOTE z_1 sont des valeurs pour les portées courtes, z_2 sont des valeurs pour les portées longues des conducteurs souples sur lesquels les contacts fixes sont montés.

Tableau 3 – Zones de contact préférentielles pour les contacts "fixes" supportés par des conducteurs rigides

Tension assignée U_r kV	x mm	y mm	z mm
72,5 – 100 – 123 – 145	100	100	100
170 – 245 – 300 – 362 – 420	150	150	150
550	175	175	175
800	200	200	200
1 100 – 1 200	250	250	250
x = amplitude totale du mouvement longitudinal du conducteur support (température). y = déviation horizontale totale (perpendiculaire au conducteur support) (vent). z = déviation verticale (glace).			

5.104 Effort mécanique statique assigné sur les bornes

Lorsque les sectionneurs ou les sectionneurs de terre sont destinés à être raccordés directement aux lignes, c'est-à-dire aux conducteurs souples ou rigides, l'effort mécanique statique assigné sur les bornes doit être assigné à chaque borne, en indiquant les directions d'application.

L'effort mécanique statique maximal auquel une borne d'un sectionneur ou d'un sectionneur de terre est susceptible d'être soumise dans les conditions les plus défavorables correspond à l'effort mécanique statique assigné sur les bornes.

Des valeurs préférentielles d'efforts mécaniques statiques sur les bornes sont données au Tableau 4. Ces valeurs sont destinées à servir de guide.

Tableau 4 – Efforts mécaniques statiques préférentiels sur les bornes

Tension assignée U_r kV	Courant permanent assigné I_r A	Sectionneurs ou sectionneurs de terre à deux et à trois colonnes		Sectionneurs ou sectionneurs de terre à éléments séparés		Force verticale F_c^a N	
		Effort longitudinal F_{a1} et F_{a2}	Effort transversal F_{b1} et F_{b2}	Effort longitudinal F_{a1} et F_{a2}	Effort transversal F_{b1} et F_{b2}		
		Voir Figure 9		Voir Figure 8			
		N	N	N	N		
72,5	$\leq 1\,600$	400	130	800	200	500	
	$> 1\,600$	500	170	800	200		
100 – 123 – 145	$\leq 1\,600$	500	170	800	200	1 000	
	$> 1\,600$	600	200	1 000	300		
170	$\leq 1\,600$	600	200	1 000	300		
	$> 1\,600$	800	250	1 250	400		
245	$\leq 2\,500$	800	270	1 250	400		1 250
	$> 2\,500$	1 000	330	1 600	500		
300 – 362	$\leq 2\,500$	1 000	400	1 600	500	1 500	
	$> 2\,500$	1 500	500	1 800	600		
420	$\leq 3\,150$	1 600	530	2 000	800	1 500	
	$> 3\,150$	2 000	660	4 000	1 600		
550	$\leq 3\,150$	1 600	530	2 000	800	1 500	
	$> 3\,150$	2 000	660	4 000	1 600		
800	$\leq 3\,150$	1 600	530	2 000	800	1 500	
	$> 3\,150$	2 000	660	4 000	1 600		
1 100 – 1 200	$\leq 4\,000$	2 000	660	4 000	1 600	2 000	
	$> 4\,000$	2 500	1 000	5 000	2 000		

^a F_c simule les forces dirigées vers le bas dues au poids des conducteurs de connexion. F_c ne s'applique pas aux conducteurs souples.

NOTE L'effort mécanique statique sur les bornes inclut les efforts dus à la glace, au vent et aux conducteurs connectés.

5.105 Classification des sectionneurs pour l'endurance mécanique

L'endurance mécanique des sectionneurs doit correspondre à l'une des classes données au Tableau 5. Les manœuvres sont exécutées en tenant compte d'un programme de maintenance défini par le constructeur.

Tableau 5 – Classification des sectionneurs pour l'endurance mécanique

Classe	Nombre de cycles de manœuvres	Endurance mécanique
M0	1 000	Normale
M1	2 000	Accrue
M2	10 000	Accrue

5.106 Classification des sectionneurs de terre pour l'endurance mécanique

L'endurance mécanique des sectionneurs de terre doit correspondre à l'une des classes données au Tableau 6. Les manœuvres sont exécutées en tenant compte d'un programme de maintenance défini par le constructeur.

Tableau 6 – Classification des sectionneurs de terre pour l'endurance mécanique

Classe	Nombre de cycles de manœuvres	Endurance mécanique
M0	1 000	Normale
M1	2 000	Accrue

5.107 Couche de glace assignée

Pour les sectionneurs et les sectionneurs de terre capables de fonctionner dans des conditions de glace, une couche de glace assignée doit être attribuée par le constructeur.

Les valeurs assignées préférentielles de la couche de glace sont: 1 mm, 10 mm et 20 mm.

5.108 Valeurs assignées des sectionneurs pour l'établissement-coupure de courant de transfert de barres

5.108.1 Courant assigné de transfert de barres

Le courant assigné de transfert de barres des sectionneurs utilisés dans les installations à isolement dans l'air ou à isolation gazeuse est:

- pour $52 \text{ kV} < U_r < 245 \text{ kV}$, 80 % du courant permanent assigné du sectionneur, mais limité à 1 600 A;
- pour $245 \text{ kV} \leq U_r \leq 550 \text{ kV}$, 60 % du courant permanent assigné du sectionneur, mais limité à 4 000 A;
- pour $U_r > 550 \text{ kV}$, 80 % du courant permanent assigné du sectionneur, mais limité à 4 000 A.

Des valeurs de courant assigné de transfert de barres supérieures à celles spécifiées ci-dessus peuvent être attribuées par le constructeur.

NOTE 1 Les sectionneurs de $U_r \leq 52 \text{ kV}$ peuvent aussi avoir un pouvoir d'établissement et de coupure de transfert de barres. Dans ce cas, la vérification des performances se fait sur la base d'un accord entre l'utilisateur et le constructeur.

NOTE 2 Pour de plus amples informations, se reporter aux éléments suivants: pour les informations concernant 60 % et 80 %, se reporter au CIGRE TB 570 – 2014 [1]¹ et au troisième rapport SC A3 du CIGRE présenté à Paris (FR) en 2016, et pour les informations concernant les courants de 4 000 A, se reporter au colloque SC A3 et B3 du CIGRE organisé à Nagoya (JP), document n°212, 2015.

5.108.2 Tension assignée de transfert de barres

Les tensions assignées de transfert de barres sont données au Tableau 7. Des valeurs de tension de transfert de barres différentes de celles données dans le Tableau 7 ci-dessous peuvent être attribuées par le constructeur.

¹ Les chiffres entre crochets se réfèrent à la Bibliographie.

Tableau 7 – Tensions assignées de transfert de barres des sectionneurs

Courant permanent assigné I_r A	Tension assignée U_r			Tension assignée U_r		
	$52 \text{ kV} < U_r < 245 \text{ kV}$	$245 \text{ kV} \leq U_r \leq 550 \text{ kV}$	$U_r > 550 \text{ kV}$	$52 \text{ kV} < U_r < 245 \text{ kV}$	$245 \text{ kV} \leq U_r \leq 550 \text{ kV}$	$U_r > 550 \text{ kV}$
	Installations à isolation gazeuse V (valeur efficace)			Installations à isolement dans l'air V (valeur efficace)		
2 000	10	15	20	100	175	250
2 500					220	310
3.150		20	30		275	390
4 000		25	42		350	500
5 000					435	625
6.300		35			550	
8.000					580	
NOTE Les valeurs du tableau sont fondées sur des calculs d'un courant de transfert de barres correspondant au courant permanent assigné du sectionneur, prenant en compte les longueurs et impédances caractéristiques des boucles spécifiées à l'Annexe B.						

5.109 Classification et valeurs assignées des sectionneurs de terre pour la coupure de courant induit

Des valeurs de courant assigné d'induction et de tension assignée d'induction doivent être attribuées aux sectionneurs de terre de $U_r > 52 \text{ kV}$ destinés à l'établissement ou à la coupure de courants d'induction capacitifs ou inductifs (voir 3.7.124 et 3.7.125), exigeant par conséquent un pouvoir d'établissement et de coupure de courant induit.

Pour cette application, une classification (pour l'attribution de la classe A ou B) des sectionneurs de terre pour la coupure de courant induit doit être effectuée. Cette classification dépend de la sévérité des conditions d'utilisation du courant induit. Le Tableau 8 fournit une classification des sectionneurs de terre pour la coupure de courant induit.

Tableau 8 – Classification des sectionneurs de terre pour la coupure de courant induit

Classe	Type de sectionneur de terre
A	Sectionneur de terre conçu pour une utilisation sur des portions de lignes relativement courtes ou ayant de faibles coefficients de couplage avec les lignes adjacentes sous tension
B	Sectionneur de terre conçu pour une utilisation sur des portions de lignes relativement longues ou ayant de forts coefficients de couplage avec les lignes adjacentes sous tension

Le Tableau 9 fournit les valeurs de courant assigné d'induction et de tension assignée d'induction pour les deux classes de sectionneurs de terre. Ces valeurs représentent les pouvoirs maximums de coupure pour chaque tension assignée.

**Tableau 9 – Valeurs des courants assignés d'induction
et des tensions assignées d'induction**

Tension assignée U_r kV	Couplage électromagnétique				Couplage électrostatique							
	Courant assigné d'induction A (valeur efficace)		Tension assignée d'induction kV (valeur efficace)		Courant assigné d'induction A (valeur efficace)		Tension assignée d'induction kV (valeur efficace)					
	Classe		Classe		Classe		Classe					
	A	B	A	B	A	B	A	B				
72,5	50	80	0,5	2	0,4	2	3	6				
100												
123												
145			1									
170						9						
245	80	1,4		10	1,25	3	5	12				
300		2				10		15				
362						18		17				
420		20			25			20				
550							8		25			
800							12		32			
1 100	110	440	5	65	7,5	50	20	40				
1 200												

NOTE 1 Dans certains cas (très longues sections de lignes à la terre à proximité d'une ligne sous tension; charge très élevée de la ligne sous tension; ligne sous tension de tension de service plus élevée que la ligne à la terre, etc.), les courants induits et les tensions induites peuvent dépasser les valeurs assignées. Dans ces cas, les valeurs assignées font l'objet d'un accord entre le constructeur et l'utilisateur.

NOTE 2 Les tensions assignées d'induction sont des tensions entre phase et terre, pour des essais unipolaires ou tripolaires (voir 7.107.5).

5.110 Classification et valeurs assignées des sectionneurs pour l'établissement-coupe de courant de jeux de barres à vide

Les sectionneurs faisant partie de l'appareillage à isolation gazeuse de $U_r \geq 300$ kV doivent être classés pour leur pouvoir d'établissement-coupe de courant de jeux de barres à vide. En général les essais pour les sectionneurs de $U_r < 300$ kV ne sont pas nécessaires et font l'objet d'un accord entre le constructeur et l'utilisateur. Dans ce cas, pour $52 \text{ kV} < U_r < 300 \text{ kV}$, l'essai de classification de BCS est facultatif.

NOTE Le pouvoir d'établissement et de coupe de jeux de barres à vide pour les sectionneurs à isolement dans l'air fait l'objet d'un accord entre le constructeur et l'utilisateur (se reporter à l'IEC/TR 62271-305).

Quatre classes sont identifiées en fonction de l'application. Voir le Tableau 10 qui indique également les séquences d'essai associées.

Tableau 10 – Classification des sectionneurs pour établissement-coupure de jeux de barres à vide

Classe	Application	Séquences d'essai associées (voir 7.108.2)
BCS	Mise en et hors circuit de très courts tronçons de jeux de barres de circuits ouverts	TD ₁
BCB	Classe BCS + mise en et hors circuit de condensateurs en parallèle associés à des disjoncteurs, en opposition de phase à 180° des circuits ouverts	TD ₁ & TD ₂
BCL	Classe BCS + mise en et hors circuit de très longs tronçons de jeux de barres de circuits ouverts	TD ₁ & TD ₃
BCT	Classe BCS + classe BCB + classe BCL	TD ₁ , TD ₂ & TD ₃

Le courant de jeux de barres à vide assigné n'est associé qu'aux sectionneurs de classe BCL ou BCT. Aucun courant de jeux de barres à vide assigné ne peut être attribué aux séquences d'essai TD₁ et TD₂, puisqu'elles dépendent de la conception, de la construction physique de l'installation et de la tension assignée. Les valeurs normalisées de cette caractéristique assignée sont données au Tableau 11. Ces valeurs sont seulement associées à la mise hors tension de longs tronçons de jeux de barres conformément à la séquence d'essai 3 indiquée en 7.108.2. Pour de plus amples informations, se reporter à l'Annexe B.

Tableau 11 – Valeurs normalisées des courants de jeux de barres à vide assignés

Tension assignée U_r kV (valeur efficace)	72,5	100	123	145	170	245	300	362	420	550	800	1 100	1 200
Courant de jeux de barres à vide assigné A (valeur efficace)	0,1	0,1	0,1	0,1	0,1	0,25	0,25	0,5	0,5	0,5	0,8	1,0	1,0

NOTE En pratique, ces valeurs ne sont généralement pas dépassées. Elles s'appliquent aussi bien à 50 Hz qu'à 60 Hz. Lorsqu'en pratique les valeurs sont plus élevées, d'autres valeurs d'essai sont pris en considération selon accord entre le constructeur et l'utilisateur.

6 Conception et construction

6.1 Exigences pour les liquides utilisés dans les sectionneurs et les sectionneurs de terre

Le paragraphe 6.1 de l'IEC 62271-1:2017 s'applique.

6.2 Exigences pour les gaz utilisés dans les sectionneurs et les sectionneurs de terre

Le paragraphe 6.2 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

NOTE En général, le terme "gaz" associé à l'isolation et/ou à la manœuvre utilisé dans le présent document renvoie au SF₆ (hexafluorure de soufre). Cependant les principes mentionnés peuvent être aussi utilisés pour d'autres gaz.

6.3 Raccordement à la terre des sectionneurs et sectionneurs de terre

Le paragraphe 6.3 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants.

Pour les sectionneurs et sectionneurs de terre utilisés dans les ensembles d'appareillages sous enveloppe, le paragraphe 5.3 de l'IEC 62271-200:2011, de l'IEC 62271-201:2014 ou de l'IEC 62271-203:2011 s'applique (suivant le cas).

Les enveloppes métalliques et les mécanismes de commande qui ne font pas partie intégrante de la structure métallique du sectionneur ou du sectionneur de terre et qui ne sont pas connectés électriquement à cette structure doivent être équipés d'une borne de mise à la terre marquée du symbole de la terre de protection.

S'il existe, pour des raisons d'essais post-installation (par exemple, les essais des câbles ou le mesurage de la résistance du contact), une connexion amovible pour la mise à la terre du circuit principal à travers le sectionneur de terre, cette connexion doit être capable de supporter la valeur de crête du courant admissible assignée ou le courant de courte durée admissible assigné. Le niveau d'isolement correspondant (en courant continu et en courant alternatif) de cette connexion extérieure – lorsqu'elle est démontée – doit être précisé par le constructeur.

6.4 Équipements et circuits auxiliaires et de commande

Le paragraphe 6.4 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Se reporter également au 6.104 du présent document.

6.5 Manœuvre dépendante à source d'énergie extérieure

Le paragraphe 6.5 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants.

Dans le cas des sectionneurs et des sectionneurs de terre à la fois à manœuvre dépendante à source d'énergie extérieure et à manœuvre dépendante manuelle, l'absence de pouvoir de fermeture et de coupure, lorsqu'ils fonctionnent à manœuvre manuelle, doit être clairement mentionnée dans le manuel d'instructions et près du point de manœuvre manuelle.

Les sectionneurs et les sectionneurs de terre équipés d'un dispositif de manœuvre hydraulique ou pneumatique doivent être capables de se fermer ou de s'ouvrir lorsque la pression d'alimentation est comprise entre la pression minimale et la pression maximale d'alimentation spécifiées (se reporter à 5.11.102).

Voir aussi 6.105 pour les efforts maximums de manœuvre manuelle.

6.6 Manœuvre à accumulation d'énergie

Le paragraphe 6.6 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Voir aussi 6.105 pour les efforts (d'accumulation d'énergie) maximums de manœuvre manuelle.

6.7 Manœuvre indépendante sans accrochage mécanique (manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure)

Le paragraphe 6.7 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Voir aussi 6.105 pour les efforts (d'accumulation d'énergie) maximums de manœuvre manuelle.

6.8 Organes de commande à manœuvre manuelle

Le paragraphe 6.8 de l'IEC 62271-1:2017 s'applique.

6.9 Fonctionnement des déclencheurs

Le paragraphe 6.9 de l'IEC 62271-1:2017 s'applique.

6.10 Indication de la pression / du niveau

Le paragraphe 6.10 de l'IEC 62271-1:2017 s'applique.

6.11 Plaques signalétiques

Le paragraphe 6.11 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

- Les sectionneurs, les sectionneurs de terre et leurs dispositifs de manœuvre, qui sont destinés à être:
 - utilisés de façon autonome ou qui peuvent être intégrés comme composants de l'appareillage, doivent être équipés de plaques signalétiques contenant les renseignements donnés au Tableau 12;
 - intégrés dans une famille particulière d'appareillage doivent porter sur leur(s) plaque(s) signalétique(s) et/ou intégrer dans le manuel d'instructions du constructeur les renseignements donnés au Tableau 12.

Tableau 12 – Informations sur le produit (1 de 2)

Informations à porter sur la plaque signalétique	Abréviation	Unité	Sectionneur	Sectionneur de terre ^a	Dispositif de manœuvre
Constructeur			x	x	x
Désignation de type du constructeur			x	x	x
Classe d'endurance mécanique			x ^b	x ^b	x
Classe de pouvoir de fermeture en court-circuit				x ^b	
Référence du manuel d'instructions			x	x	x
Année de fabrication			x	x	x
Référence de la présente norme			x	x	x
Numéro de série			x	x	x
Tension assignée	U_r	kV	x	x	
Fréquence assignée	f_r	Hz	x	x	
Tension de tenue aux chocs de foudre assignée	U_p	kV	x	x	
Tension de tenue aux chocs de manœuvre assignée pour $U_r \geq 300$ kV	U_s	kV	x	x	
Tension de tenue à fréquence industrielle assignée	U_d	kV	x	x	
Courant permanent assigné	I_r	A	x		
Courant de courte durée admissible assigné	I_k	kA	x	x	
Durée de court-circuit assignée	t_k	s	x ^c	x ^c	
Valeur de crête du courant admissible assignée	I_p	kA	x	x	
Courant établi assigné en court-circuit	I_{ma}	kA		x ^d	
Masse du fluide pour l'isolement	M_f	kg	x ^e	x ^e	
Température minimale et maximale de l'air ambiant		°C	x ^f	x ^f	x ^f

Tableau 12 (2 de 2)

Informations soit à porter sur la plaque signalétique soit à intégrer au manuel d'instructions	Abréviation	Unité	Sectionneur	Sectionneur de terre ^a	Dispositif de manœuvre
Courant de jeux de barres à vide assigné	I_{bc}	A	x^g		
Classe d'établissement-coupure de courant de jeux de barres à vide			x^g		
Courant assigné de transfert de barres	I_{bt}	A	x^h		
Tension assignée de transfert de barres	U_{bt}	V	x^h		
Classe de sectionneur de terre (classe A ou B) ⁱ				x^i	
Courant assigné d'induction (électromagnétique)	I_{im}	A		x^i	
Tension assignée d'induction (électromagnétique)	U_{im}	V		x^i	
Courant assigné d'induction (électrostatique)	I_{is}	A		x^i	
Tension assignée d'induction (électrostatique)	U_{is}	V		x^i	
Valeur de la résistance	R	Ω	x^j		
Pression assignée de remplissage pour la manœuvre	P_{rm}	Pa			x
Pression minimale de fonctionnement pour la manœuvre	p_{mm}	Pa			x
Pression d'alarme pour la manœuvre	P_{am}	Pa			x
Pression assignée de remplissage pour l'isolement	P_{re}	Pa	x	x	
Pression minimale de fonctionnement pour l'isolement	p_{me}	Pa	x	x	
Pression d'alarme pour l'isolement	P_{ae}	Pa	x	x	
Pression minimale de fonctionnement pour la coupure	p_{sw}	Pa	x	x	
Tension d'alimentation assignée des circuits auxiliaires et de commande	U_a	V			x^k
Effort mécanique statique assigné sur les bornes	F	N	x	x	
Masse (y compris le liquide)	M	kg	x	x	x
Couche de glace assignée		mm	x	x	x
Zone de contact assignée	x_r, y_r et z_r	mm	x^l	x^l	
NOTE 1 Le marquage des valeurs indiquées par x est obligatoire (le cas échéant).					
NOTE 2 Il n'est pas nécessaire que le terme "assigné" figure sur la plaque signalétique.					

a	Une seule plaque signalétique peut être utilisée pour un sectionneur et un sectionneur de terre assemblé en un seul appareil.
b	L'indication de marquage de la classe est obligatoire lorsqu'elle est différente de M0 ou E0. Cela peut être inclus dans la désignation de type afin d'éviter de réserver un espace supplémentaire.
c	Obligatoire si t est différent de 1 s.
d	Pour les sectionneurs de terre ayant un pouvoir de fermeture en court-circuit.
e	La formule chimique du gaz ou le nom commercial du liquide (le cas échéant) doit être indiqué(e).
f	Obligatoire si différente de $-5\text{ }^{\circ}\text{C}$ et/ou $+40\text{ }^{\circ}\text{C}$.
g	Pour les sectionneurs faisant partie d'un appareillage à isolation gazeuse de tension assignée $U_r \geq 300\text{ kV}$.
h	Pour les sectionneurs de $U_r > 52\text{ kV}$ ayant un pouvoir d'établissement et de coupure de courant de transfert de barres.
i	Pour les sectionneurs de terre de $U_r > 52\text{ kV}$ ayant un pouvoir d'établissement et de coupure de courant induit.
j	Pour les sectionneurs équipés de résistances.
k	Les tensions d'alimentation assignées des circuits auxiliaires et de commande peuvent avoir des valeurs distinctes qui doivent être indiquées. Le constructeur doit aussi indiquer si l'alimentation est une source en courant continu ou alternatif.
l	Pour les sectionneurs à éléments séparés et/ou les sectionneurs de terre à éléments séparés de tension assignée $U_r > 52\text{ kV}$.

6.12 Dispositifs de verrouillage

Le paragraphe 6.12 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Les sectionneurs et les sectionneurs de terre prévus pour être verrouillés mécaniquement par le blocage de l'arbre de commande ou de la chaîne cinématique de puissance du sectionneur ou du sectionneur de terre, et non intégrés aux ensembles d'appareillages couverts par les normes IEC 62271-200, IEC 62271-201 ou IEC 62271-203, doivent être conçus de manière à supporter:

- pendant la manœuvre à l'aide d'un moteur, la contrainte générée par le couple de démarrage du moteur à la tension d'alimentation maximale du moteur ou, en cas de présence d'un dispositif limiteur de contrainte, à sa valeur limite, et
- pendant la manœuvre manuelle, 3 fois la valeur de l'effort maximal correspondant attribuée à la manœuvre manuelle en 6.105 (sans prise en compte de la valeur de crête) ou, en cas de présence d'un dispositif limiteur de contrainte, 1,5 fois sa valeur limite.

6.13 Indicateur de position

Le paragraphe 6.13 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant. Se reporter également au 6.104 du présent document.

6.14 Degrés de protection procurés par les enveloppes

Le paragraphe 6.14 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant pour les enveloppes des circuits auxiliaires et de commande:

Le degré de protection procuré par les enveloppes pour les installations extérieures doit être au minimum de IP3XDW de l'IEC 60529:1989 + AMD1:1999 + AMD2:2013.

Pour les installations intérieures, le degré de protection ne doit pas être inférieur à IP2X de l'IEC 60529:2013.

6.15 Lignes de fuite pour les isolateurs d'extérieur

Le paragraphe 6.15 de l'IEC 62271-1:2017 s'applique.

6.16 Étanchéité au gaz et au vide

Le paragraphe 6.16 de l'IEC 62271-1:2017 s'applique.

6.17 Étanchéité des systèmes de liquide

Le paragraphe 6.17 de l'IEC 62271-1:2017 s'applique.

6.18 Risque de feu (inflammabilité)

Le paragraphe 6.18 de l'IEC 62271-1:2017 s'applique.

6.19 Compatibilité électromagnétique (CEM)

Le paragraphe 6.19 de l'IEC 62271-1:2017 s'applique.

6.20 Émission de rayons X

Le paragraphe 6.20 de l'IEC 62271-1:2017 s'applique.

6.21 Corrosion

Le paragraphe 6.21 de l'IEC 62271-1:2017 s'applique.

6.22 Niveaux de remplissage pour l'isolement, la coupure et/ou la manœuvre

Le paragraphe 6.22 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

La pression en Pa (ou masse volumique) ou la masse de liquide doit être assignée par le constructeur, rapportée aux conditions atmosphériques de 20 °C auxquelles l'appareillage à remplissage de gaz ou de liquide est rempli avant sa mise en service.

Pour les dispositifs de manœuvre dont le compresseur ou la pompe fait partie intégrante et qui sont équipés de leur propre accumulateur de pression, les limites de la pression de remplissage (fonctionnement) doivent être spécifiées par le constructeur.

6.101 Exigences spéciales pour les sectionneurs de terre

Tout type de matériau et de section sont admis pour les connexions entre les parties mobiles d'un sectionneur de terre et son châssis, à condition que les connexions soient en mesure de supporter les contraintes électriques, mécaniques et environnementales qui se produisent en service.

6.102 Exigences relatives à la distance de sectionnement des sectionneurs

Lorsque l'isolation sur la distance de sectionnement peut être exposée à la pollution en service, des précautions doivent être prises pour rendre la conception de l'isolateur adéquate (par exemple, ligne de fuite, hydrophobicité, orientation de l'isolateur). L'IEC/TS 60815 (toutes les parties) [3] peut être utilisée comme recommandations pour le choix d'une conception appropriée de l'isolateur. Il convient de vérifier les performances satisfaisantes de l'isolation sur la distance de sectionnement dans des conditions polluées par rapport au niveau approprié de tenue à la tension correspondant à la distance de sectionnement à laquelle le sectionneur est destiné.

La conception doit également tenir compte des effets de la pollution causée par l'usure et les sous-produits dus à l'arc. L'efficacité de la conception à résister à ces effets est mesurée par les vérifications d'état spécifiées à l'Article 7 après les essais de type appropriés.

NOTE 1 L'IEC 62271-1:2017 spécifiant des niveaux de tenue à la tension sur la distance de sectionnement plus élevés que ceux de l'isolation phase-terre, la distance de sectionnement d'un sectionneur est habituellement plus

grande que la distance d'isolement phase-terre. Cependant, lorsqu'une ligne de fuite longue est exigée, la distance d'isolement phase-terre peut devenir plus grande que la distance de sectionnement du sectionneur. Dans de tels cas, l'utilisation de dispositifs de protection tels que des parafoudres ou des éclateurs peut être nécessaire.

NOTE 2 La méthode d'essai des isolateurs est disponible dans l'IEC 60507 [2] et l'IEC/TS 60815 (toutes les parties) [3].

6.103 Résistance mécanique

Le sectionneur et le sectionneur de terre, y compris les isolateurs utilisés, installés suivant les instructions du constructeur, doivent être capables:

- d'ouvrir et de fermer correctement les contacts principaux lorsqu'ils sont soumis à leurs efforts mécaniques statiques assignés sur leurs bornes;
- de supporter le courant permanent assigné (le cas échéant) lorsqu'ils sont soumis à leurs efforts mécaniques statiques assignés sur leurs bornes;
- de supporter les forces dynamiques sur leurs bornes dans des conditions de court-circuit.

La résistance en porte à faux exigée d'un isolateur doit être calculée en prenant en compte la hauteur des bornes au-dessus du sommet de l'isolateur et en prenant en compte les forces supplémentaires qui agissent sur l'isolateur (voir 3.7.119 et 9.102.4).

6.104 Manœuvre des sectionneurs et des sectionneurs de terre – Position des contacts mobiles et de leurs dispositifs indicateurs et de signalisation

6.104.1 Verrouillage de la position

Les sectionneurs et les sectionneurs de terre, y compris leurs mécanismes de commande, doivent être conçus de telle façon qu'ils ne puissent pas quitter leurs positions d'ouverture ou de fermeture par gravité, pression du vent, vibration, chocs d'importance raisonnable ou efforts accidentels sur les bielles de liaison à leur commande selon les conditions de service définies à l'Article 4.

À l'exception des sectionneurs et sectionneurs de terre dont les contacts sont directement déplacés à l'aide d'une perche, les sectionneurs et les sectionneurs de terre doivent pouvoir être verrouillés au moins dans leur position d'ouverture (pour les sectionneurs) et leur position de fermeture (pour les sectionneurs de terre).

6.104.2 Exigences complémentaires pour les mécanismes à source d'énergie extérieure

Les mécanismes à source d'énergie extérieure doivent aussi être équipés d'un dispositif de manœuvre manuelle. Le couplage d'un dispositif de manœuvre manuelle (par exemple, une manivelle) au mécanisme de commande à énergie extérieure doit interrompre de façon sûre l'énergie de commande du mécanisme à énergie extérieure.

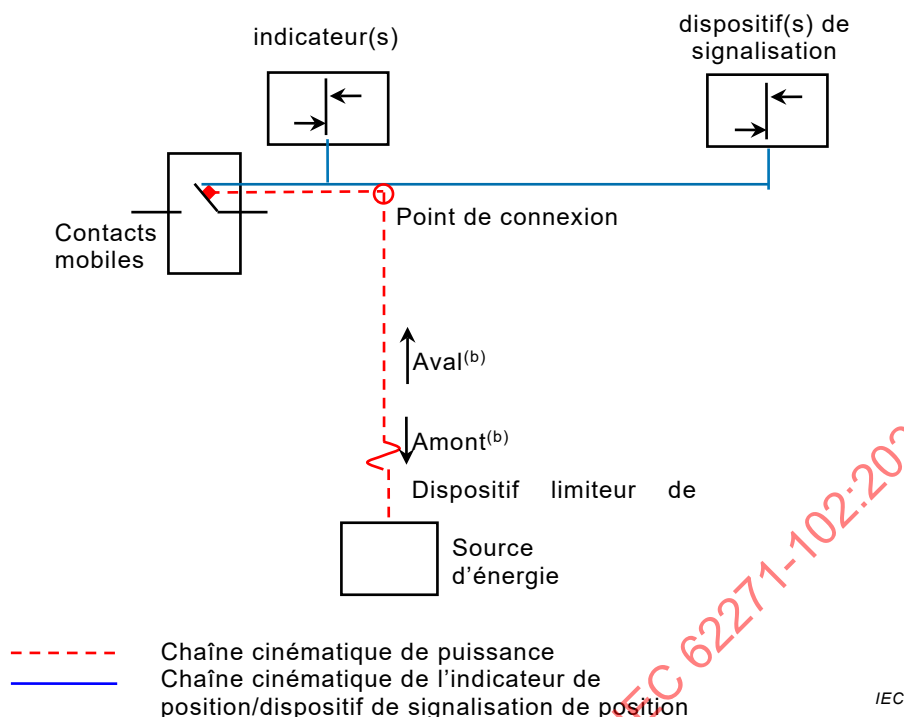
6.104.3 Indication et signalisation de la position

6.104.3.1 Exigences générales

L'indication et la signalisation des positions de fermeture et d'ouverture ne doivent pas être effectives tant que les contacts mobiles n'ont pas atteint respectivement leur position de fermeture ou d'ouverture.

NOTE Pour la définition de "position de fermeture" et de "position d'ouverture", voir 3.6.109 et 3.6.110.

La Figure 1 représente les différents éléments impliqués dans l'indication et la signalisation des positions ainsi que certaines conditions de conception.



- a) Le dispositif limiteur de contrainte (le cas échéant) peut être un dispositif externe ou un dispositif interne faisant partie de la source d'énergie, par exemple, le contrôleur de couple (d'effort).
- b) "Amont" est la direction vers la source d'énergie, "aval" est la direction vers les contacts.

Figure 1 – Dispositifs indicateurs/de signalisation de position

Le dispositif limiteur de contrainte (le cas échéant) peut être placé en tout point le long de la chaîne cinématique de puissance entre la source d'énergie et le point de connexion, mais il ne doit pas être le long de la chaîne cinématique du dispositif indicateur/de signalisation de position. Voir 6.104.3.2 et 6.104.3.3.

L'indicateur ou les indicateurs de position doivent être fixés directement sur une partie mécanique de la chaîne cinématique de puissance ou être mécaniquement connectés à celle-ci par une chaîne cinématique séparée du dispositif indicateur/de signalisation de position. Si l'indicateur de position n'est pas directement fixé sur la partie mécanique de la chaîne cinématique de puissance, la chaîne cinématique de l'indicateur de position à partir du point de connexion doit alors être placée à l'intérieur d'une enveloppe fournissant un degré minimum de protection égal à IP2XC de l'IEC 60529:1989 + AMD1:1999 + AMD2:2013 et un niveau d'impact IK 07 de l'IEC 62262:2002.

La chaîne cinématique du dispositif de signalisation de position doit être placée à l'intérieur d'une enveloppe avec les mêmes niveaux de protection que ceux définis pour la chaîne cinématique de l'indicateur de position.

6.104.3.2 Indication de position

Il doit être possible de connaître la position du sectionneur ou du sectionneur de terre. L'indication de position du sectionneur ou du sectionneur de terre est fournie lorsqu'une des conditions suivantes est remplie:

- au moins la position des contacts mobiles de chaque pôle est visible, en position d'ouverture pour les sectionneurs et en position de fermeture pour les sectionneurs de terre;
- les positions d'ouverture et de fermeture des contacts mobiles de chaque pôle sont indiquées par un indicateur de position fiable. Il est admis d'utiliser un indicateur de

position commun uniquement si tous les pôles du sectionneur ou du sectionneur de terre sont manœuvrés par un mécanisme de commande commun.

NOTE Dans certains pays, la conception du sectionneur est telle que la distance de sectionnement est visible (Canada).

La chaîne cinématique entre les contacts mobiles et l'indicateur de position doit être conçue avec une résistance mécanique suffisante pour satisfaire aux exigences des essais spécifiés (voir 7.105). La chaîne cinématique de l'indicateur de position doit assurer une manœuvre à commande positive. L'indicateur de position peut être marqué directement sur une partie mécanique, par tout moyen convenable, sur une partie mécanique de la chaîne cinématique de puissance. Le dispositif limiteur de contrainte, le cas échéant, ne doit pas constituer un élément de la chaîne cinématique de l'indicateur de position.

6.104.3.3 Signalisation de la position au moyen de contacts auxiliaires

Une indication commune pour tous les pôles d'un sectionneur et d'un sectionneur de terre ne doit être donnée que si tous les pôles du sectionneur ou du sectionneur de terre sont dans une position conforme au 6.104.3.1.

Il est admis d'utiliser un dispositif de signalisation de position commun uniquement si le sectionneur ou le sectionneur de terre à trois pôles est manœuvré par un mécanisme de commande commun.

La chaîne cinématique entre les contacts mobiles et le(s) dispositif(s) de signalisation de position doit être conçue avec une résistance mécanique suffisante pour satisfaire aux exigences des essais d'endurance mécanique. La chaîne cinématique du dispositif de signalisation de position doit assurer une manœuvre à commande positive. Le dispositif limiteur de contrainte, le cas échéant, ne doit pas constituer un élément de la chaîne cinématique du dispositif de signalisation de position.

6.105 Effort maximal exigé pour la manœuvre (dépendante ou indépendante) manuelle

6.105.1 Généralités

Les valeurs données en 6.105.2 et 6.105.3 s'appliquent également pour la manœuvre manuelle lors de la maintenance des sectionneurs et des sectionneurs de terre manœuvrés habituellement à l'aide d'un moteur.

NOTE Ces valeurs incluent le bris de la glace, le cas échéant.

6.105.2 Manœuvre exigeant plus d'un tour

La force maximale nécessaire à la manœuvre ou au stockage d'énergie à l'intérieur d'un sectionneur ou d'un sectionneur de terre, manœuvre exigeant plus d'un tour (manivelle, par exemple), ne doit pas dépasser 80 N durant 90 % du nombre total de tours exigés et ne jamais dépasser 120 N.

6.105.3 Manœuvre exigeant au plus un tour

Il convient que la force nécessaire à la manœuvre ou au stockage d'énergie à l'intérieur d'un sectionneur ou d'un sectionneur de terre, manœuvre exigeant au plus un tour (levier de manœuvre, par exemple), ne dépasse pas 250 N (se reporter à 6.6.4 de l'IEC 62271-1:2017). Une valeur maximale de 450 N est acceptée pendant une rotation d'au maximum 15°.

6.106 Tolérances dimensionnelles

Pour les sectionneurs et les sectionneurs de terre installés et/ou connectés par l'utilisateur, les dimensions correspondantes de montage et les dimensions des connexions haute tension, ainsi que pour les connexions de terre des sectionneurs et sectionneurs de terre, les

tolérances indiquées dans l'ISO 2768-1 doivent s'appliquer pour les dimensions linéaires et angulaires.

6.107 Sectionneurs de terre avec pouvoir de fermeture en court-circuit

Les sectionneurs de terre auxquels un courant établi en court-circuit a été assigné doivent être capables d'établir, à une tension assignée et inférieure, tout courant inférieur ou égal au courant établi assigné en court-circuit. Cette exigence est considérée comme satisfaite si le sectionneur de terre démontre avec succès sa classe d'endurance électrique.

7 Essais de type

7.1 Généralités

7.1.1 Principes fondamentaux

Les dispositions de 7.1.1 de l'IEC 62271-1:2017 s'appliquent avec les ajouts suivants.

Les sectionneurs et sectionneurs de terre doivent être soumis à l'essai pour vérifier leurs caractéristiques assignées dans les conditions particulières d'installation et d'utilisation (par exemple, ils doivent être soumis à l'essai tels qu'ils sont généralement montés dans l'appareillage à isolation gazeuse ou sous enveloppe métallique) avec tous les matériels associés dont la disposition peut avoir une influence sur les performances tels que les connexions, les supports, les dispositifs d'échappement, les résistances, etc.

Les sectionneurs et sectionneurs de terre différents des exemples donnés à l'Article 7 en matière de construction ou de dispositions de montage doivent être soumis à l'essai dans des conditions représentatives de l'installation réelle.

NOTE Les composants associés sont susceptibles d'influencer les performances. Les forces mécaniques dues au courant de court-circuit, à l'échappement des particules produites par l'arc, aux possibilités de décharges disruptives, etc. peuvent caractériser cette influence. Il est admis que l'influence de ces facteurs peut être relativement négligeable dans certains cas.

Le même réglage du dispositif de signalisation de position pour les positions de fermeture ou d'ouverture doit être utilisé pour l'essai diélectrique et les essais au courant de courte durée admissible et à la valeur de crête du courant admissible.

Les essais de type pour le sectionneur et le sectionneur de terre sont énumérés au Tableau 13. Pour les essais de type, les tolérances sur les grandeurs d'essai sont indiquées à l'Annexe C.

Les informations concernant l'extension de la validité des essais de type sont données à l'Annexe E (informative).

Tableau 13 – Liste des essais de type

Essai de type, selon l'application, caractéristique assignée ou conception	Condition	Dispositif associé		Paragraphes
		Sectionneur	Sectionneur de terre	
Essais diélectriques	a	x	x	7.2
Mesurage de la résistance du circuit principal	a	x		7.4.4
Essais au courant permanent	a	x		7.5
Essais au courant de courte durée admissible et à la valeur de crête du courant admissible	a	x	x	7.6
Essais d'endurance mécanique	a	x	x	7.102.3
Vérification du degré de protection	IP assigné – et/ou code- IK	x	x	7.7
Essai de tension de perturbation radioélectrique	$U_r \geq 245$ kV	x	x	7.3
Essais d'étanchéité	Systèmes à pression entretenue, scellée ou autonome	x	x	7.8
Essais de compatibilité électromagnétique (CEM)	Présence de composants électroniques	x	x	7.9
Essais complémentaires sur les circuits auxiliaires et de commande	Présence de circuits auxiliaires et de commande	x	x	7.10
Essai des rayonnements X	Présence d'ampoules à vide	x	x	7.11
Essai pour vérifier les performances de fermeture en court-circuit des sectionneurs de terre	Classe E1 ou E2		x	7.101
Essai de la zone de contact	Support séparé	x	x	7.102.2
Fonctionnement durant l'application des efforts mécaniques statiques assignés sur les bornes	Effort mécanique assigné sur les bornes	x	x	7.102.4
Essais complémentaires d'endurance mécanique	Classe M1 ou M2	x	x	7.102.5
Essais sur les dispositifs de verrouillage mécanique	Présence de verrouillage bloquant l'arbre de commande ou la chaîne cinématique de puissance	x	x	7.102.6
Fonctionnement dans des conditions sévères de formation de glace	10 mm et plus	x	x	7.103
Essais à basse et haute température	Si température ambiante maximale $>+40$ °C ou température ambiante minimale <-5 °C	x	x	7.104
Essais pour vérifier le bon fonctionnement de l'indicateur de position	Présence de l'indicateur de position	x	x	7.105
Essais de coupure de courant de transfert de barres	Pouvoir d'établissement et de coupure de courant de transfert de barres ^b	x		7.106
Essais de coupure de courant induit	Classe A ou B ^c		x	7.107

Essai de type, selon l'application, caractéristique assignée ou conception	Condition	Dispositif associé		Paragraphes
		Sectionneur	Sectionneur de terre	
Essais de coupure de courant de jeux de barres à vide	Pouvoir d'établissement et de coupure de courant de jeux de barres à vide ^{d, e}	x		7.108
^a Obligatoire sans les conditions du dispositif associé. ^b Applicable aux sectionneurs de $U_r > 52$ kV. ^c Applicable aux sectionneurs de terre de $U_r > 52$ kV. ^d Applicable aux sectionneurs de $U_r > 52$ kV faisant partie d'un appareillage à isolation gazeuse. Pour $U_r < 300$ kV, les essais ne sont généralement pas jugés nécessaires et font l'objet d'un accord entre l'utilisateur et le constructeur. ^e Le pouvoir d'établissement et de coupure de jeux de barres à vide pour les sectionneurs à isolement dans l'air fait l'objet d'un accord entre le constructeur et l'utilisateur, se reporter à l'IEC/TR 62271-305.				

7.1.2 Informations pour l'identification des objets d'essai

Le Paragraphe 7.1.2 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Au début des essais de type, les caractéristiques des manœuvres mécaniques et leurs tolérances pour le sectionneur ou le sectionneur de terre pendant l'ouverture et/ou la fermeture doivent être fournies par le constructeur, par exemple l'intervalle de temps entre les événements pendant la manœuvre et les courbes de déplacement à vide.

7.1.3 Informations à inclure dans les rapports d'essai de type

Se reporter à 7.1.3 de l'IEC 62271-1:2017 avec les ajouts suivants (le cas échéant):

Lorsque pour les besoins des essais, les isolateurs ne sont pas fournis par le constructeur du sectionneur ou du sectionneur de terre, les caractéristiques les plus importantes des isolateurs utilisés pendant les essais de type doivent être incluses dans les rapports d'essai applicables pour comparaison avec celles décrites dans la documentation du constructeur:

- résistance assignée en porte-à-faux;
- résistance assignée en torsion des isolateurs-support (et isolateurs de manœuvre, le cas échéant);
- hauteur et nombre d'éléments;
- ligne de fuite et profil des ailettes;
- déviation sous charge.

Dans le cas d'essais diélectriques, l'information doit porter sur la plus petite distance pour laquelle l'indicateur ou le dispositif de signalisation peut signaler la position OUVERT. Pour les dispositifs à isolement dans l'air, la distance minimale de l'espace et la hauteur au-dessus du sol utilisée pour les essais doivent être précisées (voir 7.2.4). De même, la distance de la partie d'isolation la plus basse par rapport au sol doit être donnée.

7.2 Essais diélectriques

7.2.1 Généralités

Le Paragraphe 7.2.1 de l'IEC 62271-1:2017 s'applique.

7.2.2 Conditions de l'air ambiant pendant les essais

Le Paragraphe 7.2.2 de l'IEC 62271-1:2017 s'applique.

7.2.3 Modalités des essais sous pluie

Le Paragraphe 7.2.3 de l'IEC 62271-1:2017 s'applique.

7.2.4 Disposition de l'appareil

Le Paragraphe 7.2.4 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Les essais diélectriques des sectionneurs ou des sectionneurs de terre en position OUVERT doivent être exécutés avec la distance minimale de sectionnement pour les sectionneurs ou la distance pour les sectionneurs de terre pour laquelle l'indicateur ou le dispositif de signalisation peut signaler la position OUVERT, ou encore avec la distance minimale de sectionnement compatible avec les dispositions de verrouillage spécifiées en 6.104.1, la plus petite de ces deux distances étant retenue. Cette exigence ne s'applique pas aux sectionneurs et sectionneurs de terre de type intérieur à manœuvre indépendante.

Si la conception de l'appareil exige un réglage de l'indicateur de position ou du dispositif de signalisation de position, ce réglage doit être réalisé selon le manuel d'instructions. Aucun écart de réglage de ces dispositifs n'est acceptable pour les essais diélectriques.

7.2.5 Conditions de réussite des essais

Le Paragraphe 7.2.5 de l'IEC 62271-1:2017 s'applique.

7.2.6 Application de la tension d'essai et conditions d'essai

Le Paragraphe 7.2.6 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants.

Les sectionneurs de $U_r > 52$ kV ayant une distance de sectionnement parallèle à la base du sectionneur et ayant des sectionneurs de terre associés doivent également être soumis à l'essai en position d'ouverture, dans des conditions sèches uniquement, avec la tension d'essai à fréquence industrielle indiquée au Tableau 14 dans la position diélectrique la plus défavorable du sectionneur de terre. Si la distance d'isolement minimale temporaire dans l'air est plus importante que les distances d'isolement données dans l'IEC 60071-2 IEC 60071-1, aucun essai n'est exigé.

Tableau 14 – Tensions de tenue à fréquence industrielle

Tension assignée U_r kV	Tension d'essai kV
72,5	94
100	130
123	160
145	188
170	221
245	283
300	346
362	418
420	484
550	635
800	924
1 100	1.270
1 200	1 386

NOTE Voir l'Annexe A pour la justification des valeurs données au Tableau 14.

Pour les essais des sectionneurs de terre, la tension d'essai doit être appliquée avec le sectionneur de terre en position d'ouverture (voir Tableau 21):

- entre des bornes isolées adjacentes et les châssis à la terre (par exemple, A et B avec F à la terre);
- entre toutes les bornes isolées connectées ensemble et les châssis à la terre (par exemple, ABC et F à la terre).

7.2.7 Essais des sectionneurs et des sectionneurs de terre de $U_r \leq 245$ kV

Le Paragraphe 7.2.7 de l'IEC 62271-1:2017 s'applique.

7.2.8 Essais des sectionneurs et des sectionneurs de terre de $U_r > 245$ kV

Le Paragraphe 7.2.8 de l'IEC 62271-1:2017 s'applique.

7.2.9 Essais de pollution artificielle pour les isolateurs d'extérieur

Le Paragraphe 7.2.9 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

NOTE Les performances de l'isolement parallèle peuvent être altérées dans des conditions de pollution et de pluie (des essais complémentaires de pollution peuvent être nécessaires).

7.2.10 Essais de décharges partielles

Le Paragraphe 7.2.10 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Aucun essai de décharges partielles n'est exigé sur un sectionneur ou sectionneur de terre complet sauf lorsqu'il est exigé dans les normes d'assemblage, c'est-à-dire l'IEC 62271-200, l'IEC 62271-201 et l'IEC 62271-203. Cependant, dans le cas de sectionneurs et sectionneurs de terre utilisant des matériels pour lesquels il existe une norme IEC correspondante incluant des mesurages de décharges partielles (par exemple, pour les traversées, voir l'IEC 60137), le constructeur doit démontrer que ces matériels ont satisfait aux essais de décharges partielles spécifiés dans la norme IEC correspondante. Pour le mesurage de décharges partielles, voir l'IEC 60270.

NOTE 1 Le mesurage de décharges partielles permet de détecter certaines anomalies de l'équipement en essai et constitue un complément utile aux essais diélectriques. L'expérience montre que, dans des dispositions particulières, les décharges partielles peuvent conduire à une dégradation de la tenue diélectrique de l'équipement, notamment de l'isolation solide.

NOTE 2 Après accord, d'autres méthodes que celle décrite dans l'IEC 60270, par exemple UHF ou acoustiques, peuvent être utilisées pour le mesurage ou la détection de décharges partielles.

7.2.11 Essais diélectriques sur les circuits auxiliaires et de commande

Le Paragraphe 7.2.11 de l'IEC 62271-1:2017 s'applique.

7.2.12 Essai de tension comme essai de vérification d'état

Le Paragraphe 7.2.12 de l'IEC 62271-1:2017 s'applique.

7.3 Essai de tension de perturbation radioélectrique

Le Paragraphe 7.3 de l'IEC 62271-1:2017 s'applique.

7.4 Mesurage de la résistance

Le Paragraphe 7.4 de l'IEC 62271-1:2017 s'applique.

7.5 Essais au courant permanent

Le Paragraphe 7.5 de l'IEC 62271-1:2017 s'applique.

7.6 Essais au courant de courte durée admissible et à la valeur de crête du courant admissible

7.6.1 Généralités

Le Paragraphe 7.6.1 de l'IEC 62271-1:2017 s'applique.

7.6.2 Disposition des sectionneurs et des sectionneurs de terre et du circuit d'essai

Le Paragraphe 7.6.2 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

7.6.2.101 Conditions générales d'essai

Les sectionneurs ou les sectionneurs de terre soumis à l'essai doivent être installés avec leur propre mécanisme de commande, dans la mesure où cela est nécessaire pour que l'essai soit représentatif.

Les sectionneurs comportant des accessoires pour s'adapter au pouvoir – d'établissement et de coupure de courant de transfert de barres et les sectionneurs de terre comportant des accessoires pour s'adapter au pouvoir d'établissement et de coupure de courant induit doivent être soumis à l'essai avec ces dispositifs montés.

Les essais doivent être effectués dans la position la plus défavorable du mécanisme de commande et des contacts principaux. Il convient de tenir compte du 6.104.3 et, le cas échéant, du 7.105.

Si la conception de l'appareil exige un réglage de l'indicateur de position ou du dispositif de signalisation de position, ce réglage doit être réalisé selon le manuel d'instructions. Aucun écart de réglage de ces dispositifs n'est acceptable pour les essais de court-circuit.

Si la conception autorise des tolérances, celles-ci doivent être déclarées par le constructeur avant l'essai. Les essais au courant de courte durée admissible et à la valeur de crête du courant admissible doivent être réalisés avec le dispositif de signalisation réglé au maximum ou au minimum de la tolérance spécifiée donnant la position la plus défavorable des contacts principaux indiquée par le dispositif de signalisation. Cette exigence ne s'applique pas aux sectionneurs et sectionneurs de terre de type intérieur à manœuvre indépendante.

NOTE La position la plus défavorable des contacts principaux est la première position au cours de la manœuvre de fermeture pour laquelle la signalisation "FERMÉ" apparaît.

Les sectionneurs et sectionneurs de terre de type ouvert doivent être soumis à l'essai selon l'une des dispositions d'essais appropriées spécifiées aux Figures 2, 3, 4 ou 5. Au cours des essais avec des conducteurs souples, les bornes des sectionneurs ou des sectionneurs de terre en essai doivent être contraintes en appliquant leurs efforts longitudinaux mécaniques statiques assignés sur leurs bornes dans les directions indiquées par le constructeur.

La disposition d'essai doit également représenter les conditions les plus défavorables telles que les forces électromagnétiques tendant à ouvrir le sectionneur ou le sectionneur de terre. Les essais sur un sectionneur de terre associé à un sectionneur doivent être réalisés avec les mêmes connexions d'essais que celles utilisées pour l'essai du sectionneur.

Les essais monophasés sur les sectionneurs ou les sectionneurs de terre ayant un mécanisme de commande commun aux trois pôles doivent être effectués sur un seul pôle placé à une distance la plus éloignée possible du mécanisme de commande.

Les sectionneurs de terre, ne faisant pas partie intégrante d'un sectionneur, doivent être soumis à l'essai dans une disposition qui remplit les mêmes exigences que celles applicables aux sectionneurs.

Les sectionneurs et les sectionneurs de terre intégrés à un appareillage sous enveloppe doivent être soumis à l'essai comme une partie de l'ensemble d'appareillage conformément à l'IEC 62271-200, l'IEC 62271-201 ou l'IEC 62271-203.

Pour les sectionneurs et les sectionneurs de terre à éléments séparés, la position verticale du contact dans la zone de contact doit être choisie pour représenter la condition la plus défavorable, en tenant compte du montage du contact fixe avec des conducteurs souples ou rigides. En cas de doute sur la condition la plus défavorable, les essais doivent être réalisés dans la position la plus haute et la plus basse du contact à l'intérieur de la zone de contact assignée.

Il convient de réaliser de préférence tous les essais en triphasé. Si un essai monophasé est réalisé, il convient de le réaliser de préférence sur deux pôles adjacents. Si l'essai est réalisé sur un seul pôle, le conducteur de retour doit être à la distance entre phases par rapport au pôle soumis à l'essai. Le conducteur de retour doit être parallèle au trajet principal du courant dans le sectionneur ou le sectionneur de terre et à la même hauteur par rapport à la base ou l'équivalent pour les sectionneurs ou sectionneurs de terre à contact mobile vertical. La longueur du conducteur de retour doit être comme indiquée aux Figures 2 à 5, selon le cas.

7.6.2.102 Sectionneurs et sectionneurs de terre de $U_r \leq 52$ kV

La disposition d'essai donnée à la Figure 2 doit être utilisée pour les sectionneurs et sectionneurs de terre de type ouvert de $U_r \leq 52$ kV. Les distances L_2 et L_3 sont aussi courtes que possible, mais non inférieures à L_1 .

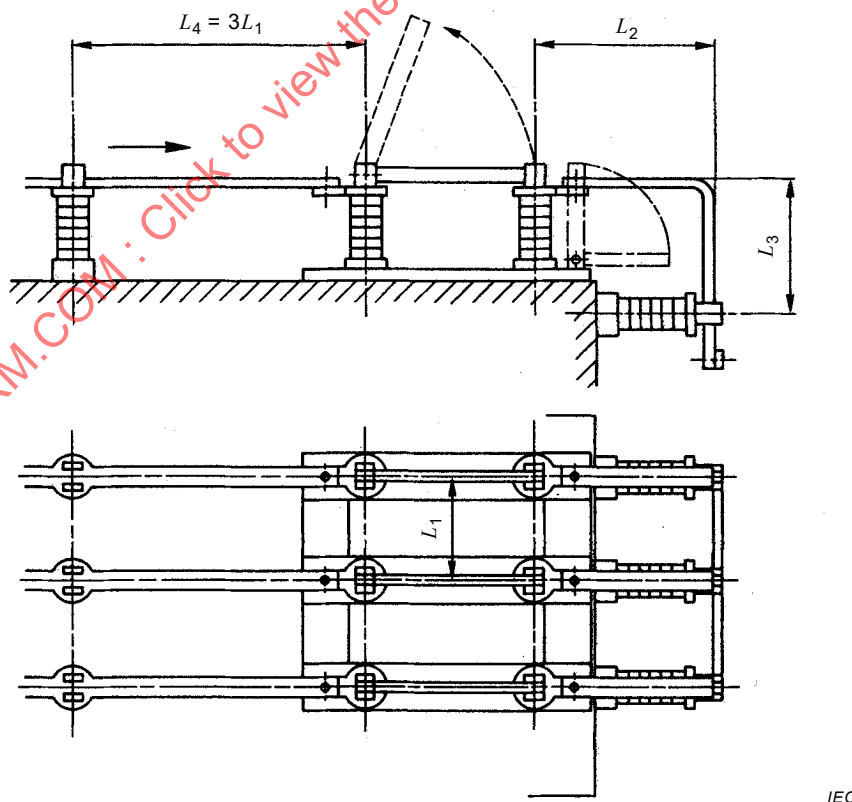


Figure 2 – Disposition d'essai triphasé pour des sectionneurs et des sectionneurs de terre

La disposition représentée couvre:

- les distances non prises en charge inférieures ou égales à L_4 pour les conducteurs rigides;
- la distance entre phases supérieure ou égale à L_1 .

Si L_1 a une plage, la distance entre phases du montage d'essai doit être la plus courte. L_4 doit être la distance la plus longue donnée par le constructeur, mais pas inférieure à trois fois la distance la plus courte L_1 .

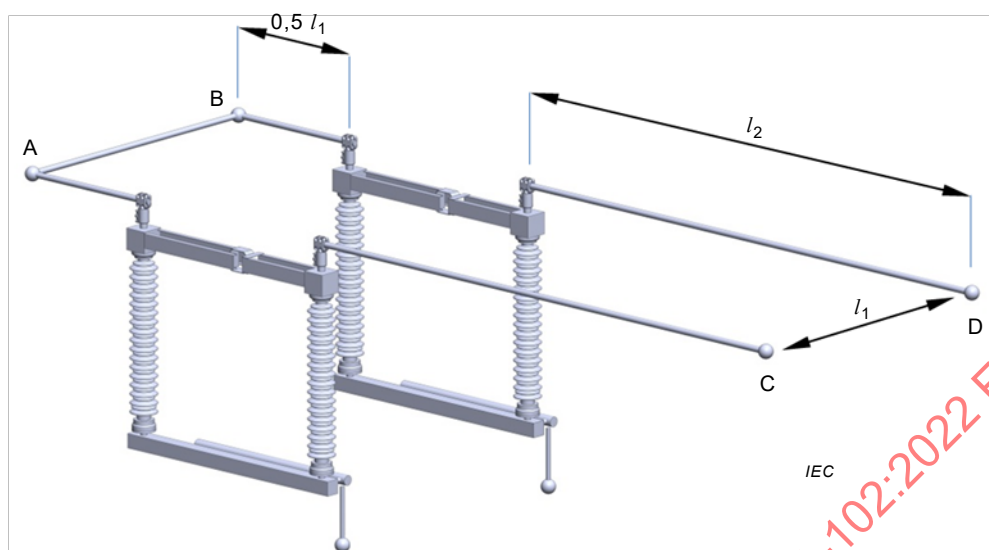
Éviter l'introduction d'efforts non représentatifs des conditions de service par les connexions à la source d'alimentation.

7.6.2.103 Sectionneurs et sectionneurs de terre de $U_r > 52$ kV

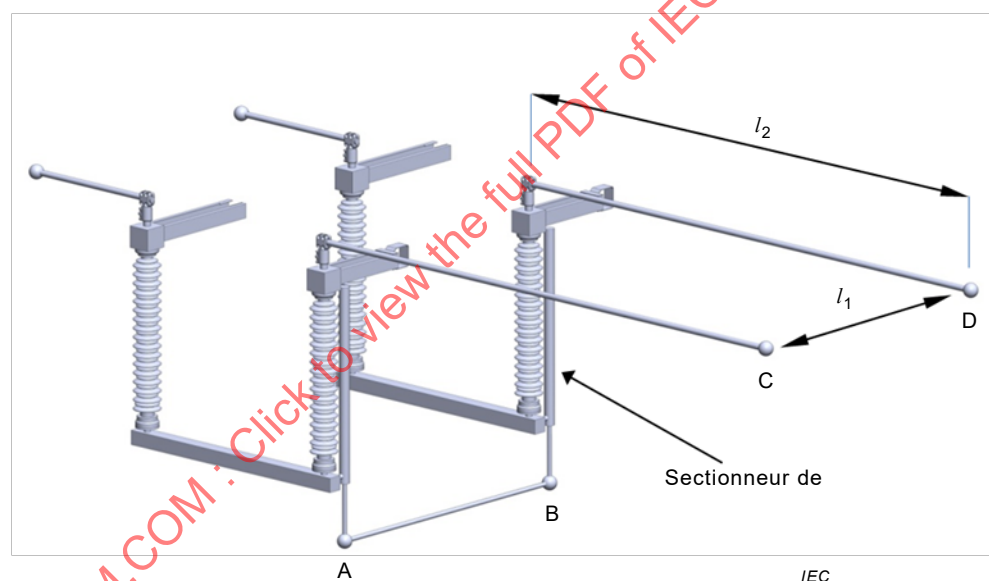
La disposition d'essai monophasé représentée à la Figure 3 doit être utilisée pour les sectionneurs ayant une distance de sectionnement horizontale et les sectionneurs de terre appropriés; les dispositions d'essai représentées à la Figure 4 et à la Figure 5 doivent être utilisées pour les sectionneurs à éléments séparés avec un intervalle de sectionnement vertical et les sectionneurs de terre appropriés. Les résultats d'essai obtenus sur un sectionneur ou un sectionneur de terre monté dans une certaine position (horizontale ou verticale, par exemple) ne sont valables que pour la position du sectionneur ou du sectionneur de terre au cours de cet essai.

Les dispositions d'essais en triphasé doivent suivre le même modèle général que les dispositions d'essais monophasés de la Figure 3 à la Figure 5.

Le trajet du court-circuit entre les pôles du sectionneur de terre représenté schématiquement à la Figure 3 doit reproduire pendant les essais les conditions d'installation indiquées par le constructeur. La position et la méthode de fixation des conducteurs utilisés pour relier les pôles entre eux et à la terre doivent être tout particulièrement prises en considération.



a) Disposition d'essai pour sectionneurs



b) Disposition d'essai pour sectionneurs de terre

Légende

A-B Connexion de court-circuit

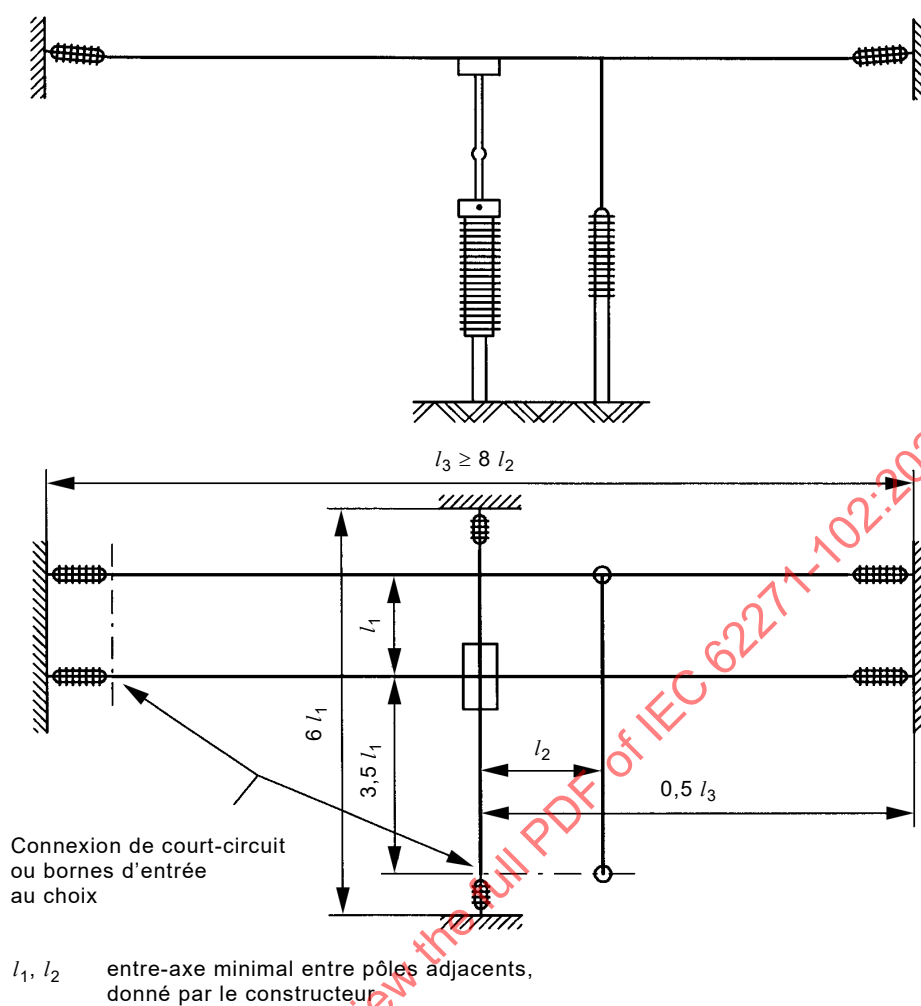
C-D Entrée

l_1 Entre-axe minimal entre pôles adjacents, donné par le constructeur

$l_2 = 2 \times l_1$ Pour $52 \text{ kV} < U_r \leq 550 \text{ kV}$

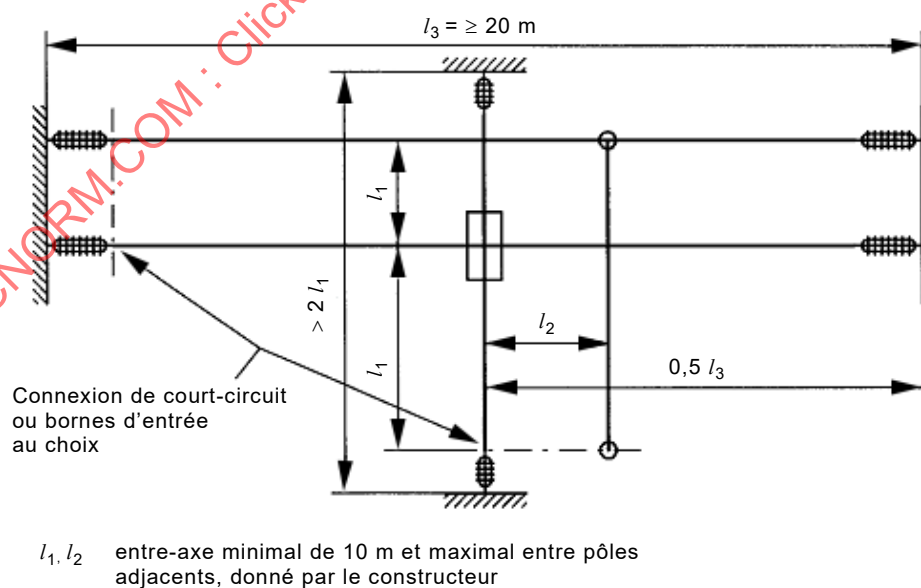
$l_2 = 0,5 \times l_1$ Pour $U_r > 550 \text{ kV}$, avec un minimum de 7 m

Figure 3 – Disposition d'essai monophasé pour sectionneurs comportant une distance de sectionnement horizontale et pour sectionneurs de terre de $U_r > 52 \text{ kV}$, destinés à être utilisés avec des conducteurs souples ou rigides



IEC

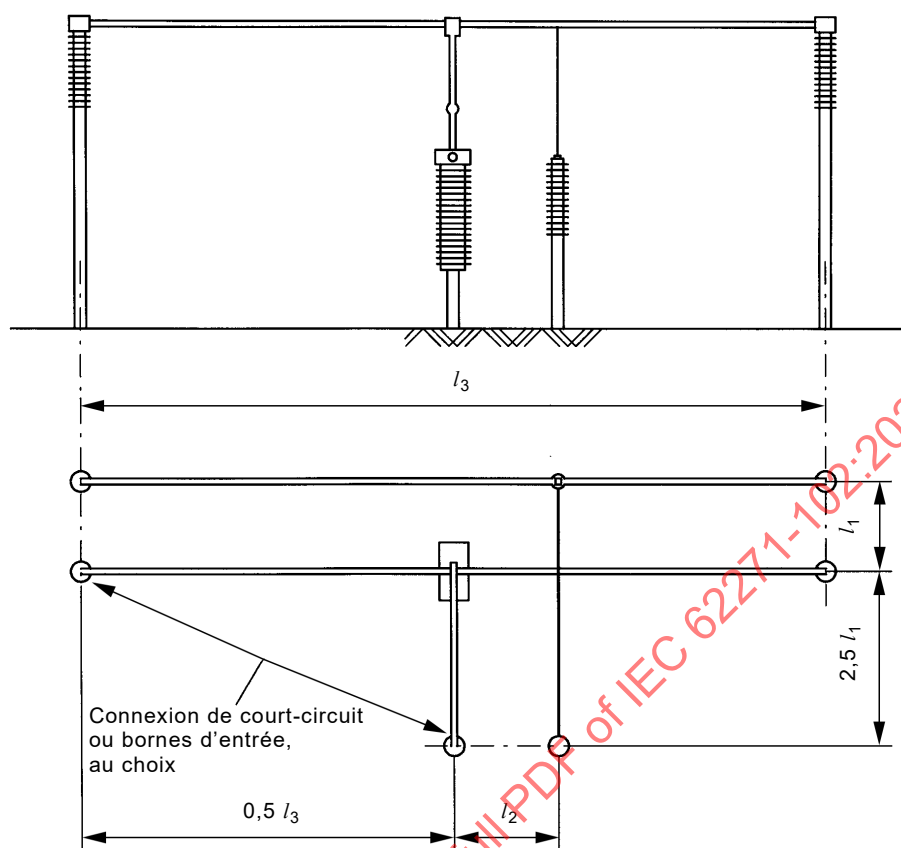
a) Disposition d'essai pour sectionneurs de $52 \text{ kV} < U_r \leq 550 \text{ kV}$



IEC

b) Disposition d'essai pour sectionneurs de $U_r > 550 \text{ kV}$

Figure 4 – Disposition d'essai monophasé pour sectionneurs à éléments séparés (sectionneurs de terre) de $U_r > 52 \text{ kV}$ à distance de sectionnement verticale, destinés à être utilisés avec des conducteurs souples

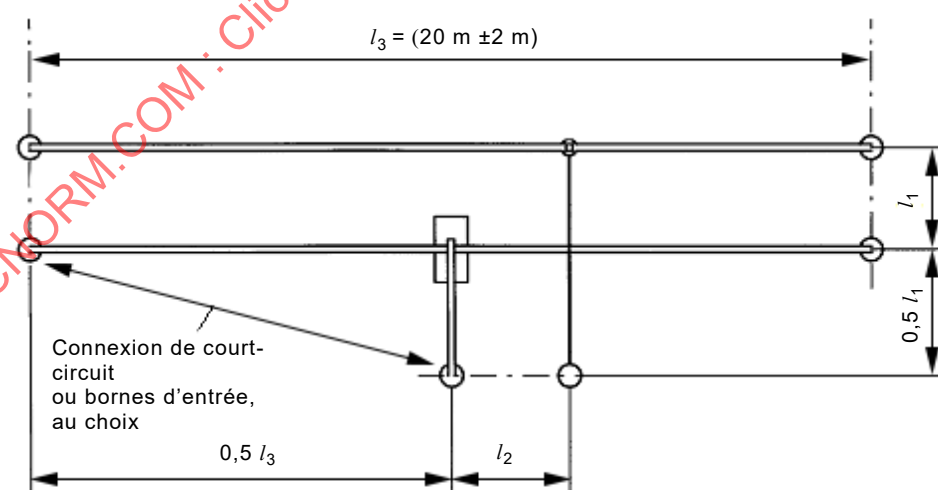


l_1, l_2 entre-axe minimal entre pôles adjacents, donné par le constructeur

IEC

Pour $U_r \leq 145 \text{ kV}$ $l_3 \geq 4l_1$
Pour $U_r \geq 170 \text{ kV}$ $l_3 = (20 \pm 2) \text{ m}$

a) Disposition d'essai pour sectionneurs de $52 \text{ kV} < U_r \leq 550 \text{ kV}$



l_1, l_2 entre-axe minimal entre pôles adjacents, donné par le constructeur

IEC

b) Disposition d'essai pour sectionneurs de $U_r > 550 \text{ kV}$

Figure 5 – Disposition d'essai monophasé pour sectionneurs à éléments séparés (sectionneurs de terre) de $U_r > 52 \text{ kV}$ à distance de sectionnement verticale, destinés à être utilisés avec des conducteurs rigides

Dans un poste, les sectionneurs et les sectionneurs de terre à raccorder à des conducteurs souples ou rigides, conformément à leur documentation, doivent être soumis à l'essai à l'aide de conducteurs souples avec leurs efforts mécaniques statiques assignés sur leurs bornes (par exemple, sens longitudinal F_{a1} ou F_{a2} de la Figure 8 et F_{a1} , et F_{a2} de la Figure 9) dans un montage d'essai aux dimensions respectivement indiquées à la Figure 3 ou à la Figure 4. Conformément à leur documentation, les sectionneurs et sectionneurs de terre à raccorder seulement aux conducteurs rigides doivent être soumis à l'essai avec des conducteurs rigides dans une disposition d'essai de mêmes dimensions et sans effort mécanique statique délibéré assigné sur leurs bornes à l'exception de celui donné par le poids des conducteurs rigides. Les dimensions et le matériau des conducteurs utilisés doivent être indiqués dans le rapport d'essai.

Après l'application de 50 % des efforts longitudinaux statiques assignés sur les bornes, le sectionneur ou le sectionneur de terre peut être réglé avant d'appliquer 100 % des efforts.

Toutes les informations détaillées relatives à la disposition d'essai sont obligatoires, et les informations détaillées du sectionneur et du sectionneur de terre représentés sont données à titre d'exemple.

Pour la normalisation des essais, lorsque ces derniers sont effectués avec des conducteurs souples et que les courants assignés du matériel sont supérieurs au courant permanent de 1 250 A ou au courant de courte durée admissible de 31,5 kA pendant 1 s, deux conducteurs souples doivent être utilisés avec un entre-axe de (70 ± 30) mm sans entretoise. Les sectionneurs et les sectionneurs de terre de $U_r \geq 300$ kV doivent être également soumis à l'essai avec ces deux conducteurs souples.

À moins que le sectionneur ou le sectionneur de terre en essai ne soit solidement fixé sur les fondations, la constante d'élasticité du support doit être prise en considération (IEC 60865-1).

Le rapport d'essai doit fournir des informations détaillées claires sur les dispositions d'essais ou indiquer que le sectionneur était solidement fixé sur les fondations.

Éviter l'introduction d'efforts non représentatifs des conditions de service par les connexions à la source d'alimentation et des efforts statiques sur les bornes plus importants que les efforts mécaniques statiques assignés sur les bornes de l'objet d'essai.

Si, dans le montage d'essai, le côté court du conducteur inférieur ne peut être fixé sur un support, il peut être supporté par le sectionneur. Cela peut conduire à des efforts dynamiques plus importants sur les bornes.

NOTE 1 En principe, la Figure 3 peut s'appliquer à l'essai des sectionneurs de terre, à condition que le conducteur de terre soit disposé de façon adéquate.

NOTE 2 En principe, la Figure 4 peut s'appliquer à l'essai des sectionneurs de terre intégrés, à condition que le conducteur de terre soit disposé de façon adéquate.

7.6.3 Valeurs du courant d'essai et de sa durée

Le Paragraphe 7.6.3 de l'IEC 62271-1:2017 s'applique.

7.6.4 État des sectionneurs et des sectionneurs de terre après l'essai

Le Paragraphe 7.6.4 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

La valeur de crête du courant admissible assignée et le courant de courte durée admissible assigné supportés par un sectionneur ou un sectionneur de terre en position de fermeture pendant la durée de court-circuit assignée ne doivent pas causer:

- de détérioration mécanique sur aucune partie du sectionneur ou sectionneur de terre;

- de séparation des contacts.

Après l'essai, une manœuvre à vide doit être effectuée avec la valeur assignée de l'alimentation pour les dispositifs à manœuvre indépendante à source d'énergie extérieure, avec une valeur minimale de l'alimentation électrique pour les dispositifs à manœuvre dépendante à source d'énergie extérieure, et avec une force ne dépassant pas les valeurs pour les dispositifs à manœuvre manuelle données au 6.105 pour les dispositifs à manœuvre (dépendante ou indépendante) manuelle. Le sectionneur ou le sectionneur de terre doit s'ouvrir lors de la première tentative.

Pour la vérification de la tenue en court-circuit par un essai monophasé sur un seul pôle d'un sectionneur (ou d'un sectionneur de terre) à trois pôles manœuvré par un mécanisme ou un arbre de commande commun, des détails précis sur la procédure d'essai et le couple/effort mesuré à la sortie du mécanisme de commande pendant la manœuvre à vide doivent être consignés afin d'évaluer le résultat de l'essai en fonction de l'aptitude du mécanisme à manœuvrer l'appareil à trois pôles après l'apparition d'un court-circuit triphasé. Cette méthode d'essai peut exiger l'utilisation d'un dispositif de mesure du couple/de l'effort dans la chaîne cinématique de puissance destinée à l'essai. Le couple/l'effort mesuré dans la chaîne cinématique de puissance exercé pour ouvrir le pôle en essai du sectionneur ou du sectionneur de terre ne doit pas dépasser la valeur générée par le mécanisme de commande (lors du blocage de la sortie de ce mécanisme) divisée par le nombre de pôles de l'appareil de connexion en essai.

Après la manœuvre à vide, la solidité de la connexion à la terre et de l'isolement doit être vérifiée pour les sectionneurs de terre comme suit:

- une inspection visuelle doit être effectuée (si possible). Il convient de ne pas observer d'usure ou de soudure significative des contacts. Une soudure légère des contacts est autorisée;
- lorsqu'une usure significative des contacts est suspectée ou une inspection visuelle ne peut être effectuée sans le démontage des contacts, la solidité de la connexion à la terre doit être confirmée par la vérification de la continuité électrique conformément au 7.4.3 de l'IEC 62271-1:2017;
- en cas de doute sur les caractéristiques d'isolement ou si une inspection visuelle ne peut être effectuée sans procéder au démontage, les dispositions du 7.2.12 s'appliquent pour vérifier les conditions diélectriques de la distance de sectionnement et de l'isolement par rapport à la terre.

Concernant les sectionneurs, après la ou les manœuvres à vide:

- pour vérifier le courant admissible, le mesurage de la résistance du circuit principal doit être effectué aussi près que possible des contacts. L'augmentation de la résistance après l'essai ne doit pas dépasser 20 % de la valeur mesurée avant l'essai;
- lorsque la résistance des contacts dépasse cette valeur, un essai au courant permanent assigné (7.5) doit être effectué pour démontrer que l'échauffement des contacts ne dépasse pas les limites indiquées au Tableau 14 de l'IEC 62271-1:2017 en surveillant la température aux points les plus proches possible des contacts;
- une inspection visuelle doit être effectuée (si possible). En cas de doute sur les caractéristiques d'isolement ou si une inspection visuelle ne peut être effectuée sans procéder au démontage, les dispositions du 7.2.12 s'appliquent pour vérifier les conditions diélectriques de la distance de sectionnement et de l'isolement par rapport à la terre.

7.7 Vérification de la protection

Le Paragraphe 7.7 de l'IEC 62271-1:2017 s'applique.

7.8 Essais d'étanchéité

Le Paragraphe 7.8 de l'IEC 62271-1:2017 s'applique.

7.9 Essais de compatibilité électromagnétique (CEM)

Le Paragraphe 7.9 de l'IEC 62271-1:2017 s'applique.

7.10 Essais complémentaires sur les circuits auxiliaires et de commande

Le Paragraphe 7.10 de l'IEC 62271-1:2017 s'applique.

7.11 Essai des rayonnements X pour les ampoules à vide

Le Paragraphe 7.11 de l'IEC 62271-1:2017 s'applique.

7.101 Essai pour vérifier les performances de fermeture en court-circuit des sectionneurs de terre

7.101.1 Conditions générales d'essai

Les sectionneurs de terre ayant un pouvoir de fermeture en court-circuit doivent être soumis respectivement à deux manœuvres de fermeture (classe E1) ou cinq manœuvres de fermeture (classe E2), suivant une séquence d'essai de fermeture conformément aux procédures du 7.101.7.

Les méthodes d'essai suivantes sont applicables aux sectionneurs de terre à fonction combinée dont l'autre fonction comporte un pouvoir de fermeture en court-circuit:

- les essais de fermeture en court-circuit doivent être d'abord effectués sur les autres fonctions, conformément aux normes applicables, et suivis par les essais de fermeture en court-circuit sur la fonction de mise à la terre, sans maintenance préalable;
- en variante, les essais de fermeture en court-circuit sur les sectionneurs de terre à fonction combinée peuvent être effectués sur un nouveau sectionneur de terre à fonction combinée, ces essais étant précédés d'au moins un essai de fermeture en court-circuit sur l'autre fonction, suivi des essais de fermeture en court-circuit sur la fonction de mise à la terre, sans maintenance préalable. Cette méthode d'essai ne vérifie que le pouvoir de fermeture en court-circuit du sectionneur de terre.

7.101.2 Disposition du sectionneur de terre pour les essais

Le sectionneur de terre doit être soumis aux essais dans des conditions représentatives de l'installation et de l'utilisation en ce qui concerne les connexions, le support, l'enveloppe et les dimensions, conformément au 7.6.2.

Son dispositif de manœuvre doit être actionné comme exigé. En particulier, s'il est actionné électriquement, hydrauliquement ou pneumatiquement, il doit être actionné à la tension d'alimentation ou à la pression minimale.

Pour les sectionneurs de terre remplis de gaz, les essais doivent être effectués à la pression minimale de fonctionnement pour l'isolement et/ou la coupure.

Pour faciliter les essais:

- la tension d'alimentation de la bobine pour la manœuvre de fermeture peut être augmentée pour obtenir une durée de fermeture cohérente, à condition que ceci n'augmente pas la vitesse de fermeture des contacts;
- pour obtenir des durées de fermeture exactes, un verrou électrique ou pneumatique peut être introduit au point de bascule.

Les sectionneurs de terre à manœuvre manuelle indépendante peuvent être manœuvrés en utilisant une configuration qui permette la commande à distance.

NOTE Pour les besoins des essais, il peut être nécessaire de mesurer les caractéristiques de déplacement en utilisant par exemple un enregistreur de mouvement.

7.101.3 Fréquence d'essai

Les sectionneurs de terre doivent être soumis à l'essai à la fréquence assignée, avec une tolérance de $\pm 10\%$.

Cependant, les essais à un facteur de crête de 2,6 ou plus et à une fréquence d'alimentation de 50 Hz ou 60 Hz couvrent les exigences des deux fréquences.

7.101.4 Tension d'essai

La tension d'essai doit être la suivante:

- a) pour les essais triphasés, la valeur moyenne de la tension appliquée entre phases ne doit pas être inférieure à la tension assignée U_r et ne doit pas dépasser cette valeur de plus de 10 % sans l'accord du constructeur. Les différences entre la valeur moyenne et les tensions appliquées de chaque pôle ne doivent pas dépasser 5 %;
- b) pour les essais monophasés, la tension appliquée ne doit pas être inférieure à la valeur de la tension phase-terre $U_r/\sqrt{3}$, et ne doit pas dépasser cette valeur de plus de 10 % sans l'accord du constructeur, à l'exception de ce qui suit:

pour les essais monophasés sur les sectionneurs de terre à trois pôles qui présentent un écart entre la première et la seconde entrée en contact pendant la fermeture qui dépasse la moitié d'un cycle de la fréquence assignée, la tension appliquée phase-terre ne doit pas être inférieure à U_r .

7.101.5 Courant établi en court-circuit pour essai

Le courant de court-circuit pendant l'essai de fermeture doit être exprimé en matière de courant de crête et de courant efficace symétrique. La valeur efficace symétrique du courant dans chaque phase à 0,2 s doit valoir au moins 80 % du courant de courte durée admissible assigné. Le courant de crête présumé doit être égal au courant établi assigné en court-circuit (I_{ma}) avec une tolérance de 0 % et +5 %.

La durée du courant de court-circuit doit être au moins de 0,2 s.

Le sectionneur de terre doit être soumis à l'essai dans les deux cas extrêmes spécifiés ci-après:

- a) établissement à la crête de l'onde de tension (avec une tolérance de -30 degrés électriques à $+15$ degrés électriques) conduisant à un courant de court-circuit symétrique et à la plus longue durée de préarc. Pour faciliter l'essai, des méthodes d'essai alternatives peuvent être utilisées. Les méthodes d'essai alternatives sont décrites à l'Annexe D;
- b) établissement à un zéro de l'onde de tension, sans préarc, conduisant à un courant de court-circuit complètement asymétrique. Pour faciliter l'essai, celui-ci peut être effectué à une tension appliquée réduite afin d'obtenir le courant établi assigné en court-circuit (I_{ma}). La manœuvre de fermeture peut ne pas se produire exactement à un zéro de l'onde de tension. Cependant, le cas extrême b) est considéré comme satisfait si le courant établi assigné en court-circuit est obtenu.

7.101.6 Circuits d'essai

Les essais de fermeture doivent être réalisés en utilisant un circuit d'essai triphasé ou un circuit d'essai monophasé.

Les essais en triphasé couvrent:

- l'interaction entre les différentes phases;

- les contraintes sur le mécanisme de commande (dans le cas d'un mécanisme de commande commun).

Les sectionneurs de terre tripolaires doivent être soumis à l'essai dans un circuit triphasé pour couvrir à la fois les applications dans des systèmes à neutre effectivement relié à la terre et à neutre non effectivement relié à la terre. Pour les besoins des essais, la sévérité des essais de fermeture, avec des circuits dont le neutre n'est pas relié à la terre ou avec les circuits dont le neutre est solidement relié à la terre, est considérée comme étant équivalente. Cependant, un essai monophasé des sectionneurs de terre de $U_r > 52$ kV est admis dans les cas suivants:

- a) pour les sectionneurs de terre de type multienveloppes ou de type à l'air libre, l'énergie de fermeture étant stockée séparément pour chaque pôle;
- b) pour les sectionneurs de terre fonctionnant pôle après pôle.

7.101.7 Procédures d'essai

Pour la classe E1, les essais doivent être réalisés selon une séquence de deux manœuvres C avec une seule manœuvre à vide O entre les deux, c'est-à-dire C – O (à vide) – C, à moins que le laboratoire d'essai n'ait besoin de davantage de manœuvres à vide entre les manœuvres de fermeture.

Pour les sectionneurs de terre de la classe E2, la séquence d'essai est $2C - x - 2C - y - 1C$, où x et y représentent le nombre arbitraire de manœuvres à vide. Les manœuvres $2C$ sont constituées de C – O (à vide) – C, à moins que le laboratoire d'essai n'ait besoin de davantage de manœuvres à vide entre les manœuvres de fermeture. Aucune exigence n'est stipulée quant à l'intervalle de temps entre les deux manœuvres de fermeture.

Aucune maintenance n'est autorisée au cours d'une séquence d'essai.

Pour les sectionneurs de terre à fonction combinée, le nombre arbitraire de manœuvres à vide représenté par x et y dans la séquence d'essai pour la classe E2 peut être remplacé par des manœuvres de coupure.

En raison d'une non-simultanéité entre les pôles ou des différents instants de l'amorçage des préarcs dans les différents pôles, un courant établi de crête, qui est supérieur à la valeur assignée, peut se produire dans un pôle. C'est particulièrement le cas si, dans un pôle, le courant commence à circuler quelques millisecondes plus tard que dans les deux autres pôles. Si le sectionneur de terre est défaillant au cours d'un tel événement, ceci est considéré comme étant une défaillance du sectionneur de terre.

Les exigences relatives à l'instant de fermeture spécifiées au Tableau 15 doivent être satisfaites pendant les essais.

Tableau 15 – Exigences relatives à l'instant de fermeture

Classe E1	Classe E2
2 essais	5 essais
Au moins 1 essai répondant aux exigences du 7.101.5 a)	Au moins 2 essais répondant aux exigences du 7.101.5 a)
Au moins 1 essai répondant aux exigences du 7.101.5 b)	Au moins 2 essais répondant aux exigences du 7.101.5 b)
NOTE La vitesse de fermeture des contacts des sectionneurs de terre avec le pouvoir de fermeture en court-circuit est généralement suffisamment élevée pour que le préarc maximal et le courant de crête maximal puissent être atteints au cours d'un même essai, à des phases différentes toutefois.	

7.101.8 Comportement des sectionneurs de terre au cours de l'établissement des courants de court-circuit

Au cours des essais de fermeture, les éléments suivants s'appliquent:

- a) les sectionneurs de terre sous enveloppe ayant un courant établi assigné en court-circuit ne doivent pas, pendant le court-circuit, projeter de flammes, de liquides, de gaz, ni de particules à l'extérieur de l'enveloppe;
- b) pour les sectionneurs de terre de type ouvert, aucune émission de flamme ou de particules métalliques ne doit être projetée au-delà des limites spécifiées par le constructeur dans les instructions de fonctionnement.

7.101.9 Conditions du sectionneur de terre après les essais de fermeture en court-circuit

Après la réalisation des manœuvres spécifiées, les parties mécaniques, les éléments se rapportant à la maîtrise du champ électrique (par exemple, les électrodes de répartition de champ d'un sectionneur de terre pour poste à isolation gazeuse) et les isolateurs du sectionneur de terre doivent être pratiquement dans le même état qu'auparavant. Les propriétés isolantes ne doivent pas être détériorées. Le pouvoir de fermeture en court-circuit et la tenue au courant de courte durée admissible peuvent être compromis.

NOTE La durée de vie utile du sectionneur de terre par rapport au pouvoir de fermeture en court-circuit et à la tenue au courant de courte durée admissible est généralement considérée comme étant terminée à l'issue du nombre spécifié de manœuvres de fermeture nécessitant une maintenance ou un remplacement.

Pour vérifier cette exigence, le sectionneur de terre doit remplir les conditions suivantes d'examen:

- a) conditions mécaniques: Après chaque manœuvre, seule une légère soudure des contacts est autorisée. Toutefois, le sectionneur de terre doit être en mesure de s'ouvrir et se fermer dans les conditions données au 6.5 et au 6.6, avec les valeurs assignées pour les dispositifs à source d'énergie extérieure ou avec 120 % des valeurs données pour les dispositifs à manœuvre manuelle indiquées au 6.105, au moyen de la poignée de manœuvre normale;
- b) continuité électrique: L'inspection visuelle après la manœuvre à vide est habituellement suffisante pour vérifier la continuité électrique du sectionneur de terre. En cas de doute, la continuité électrique doit être mesurée conformément au 7.4.3 de l'IEC 62271-1:2017;
- c) exigences diélectriques: L'inspection visuelle est habituellement suffisante pour vérifier l'exigence ci-dessus. En cas de doute, un essai de tension doit être réalisé en tant que vérification d'état, conformément au 7.2.12. En variante, les dispositions de 6.2.11 de l'IEC 62271-100:2008 + A2:2012 + A2:2017 peuvent être utilisées pour $U_r > 72,5$ kV. La pression minimale de fonctionnement du gaz pour l'isolement doit être utilisée, le cas échéant. Pour les sectionneurs de terre qui sont scellés à vie, l'essai de tension en tant que vérification d'état est obligatoire.

7.101.10 Essais non valables

Dans le cas d'un essai non valable, il peut devenir nécessaire d'effectuer un nombre d'essais de fermeture en court-circuit supérieur à celui qu'exige le présent document. Un essai non valable est un essai au cours duquel au moins un paramètre d'essai spécifié par le document n'est pas atteint. Ceci comprend, par exemple, les courants, les tensions et les temps, ainsi que les exigences sur l'onde (si spécifié) et les particularités complémentaires des essais synthétiques.

L'écart par rapport au document peut rendre l'essai plus ou moins sévère. Quatre cas de figure sont envisagés dans le Tableau 16.

Tableau 16 – Essais non valables

Conditions d'essai par rapport à la norme	Sectionneur de terre ayant réussi	Sectionneur de terre ayant échoué
Plus sévère	Essai valable, résultat accepté	Essai à répéter avec les paramètres corrects Modification de la conception du sectionneur de terre non exigée
Moins sévère	Essai à répéter avec les paramètres corrects Modification de la conception du sectionneur de terre non exigée	Modification de la conception du sectionneur de terre exigée, pour améliorer le pouvoir de fermeture. Tous les essais doivent être répétés sur le sectionneur de terre modifié
NOTE Un essai "Plus sévère" est considéré comme étant effectué à une tension et/ou un courant au-dessus des tolérances et, pour les méthodes d'essai alternatives, avec une durée de préarc plus longue.		

Dans le cas de conditions d'essai moins sévères, la partie non valable d'une séquence d'essai peut être répétée sans remise en état du sectionneur de terre. Dans ces cas, le rapport d'essai doit citer l'essai non valable. Toutefois, en cas de défaillance du sectionneur de terre au cours de ces essais supplémentaires, ou à l'initiative du constructeur, le sectionneur de terre peut être reconditionné et la séquence d'essai complète répétée. Si l'enregistrement d'une manœuvre ne peut pas être réalisé pour des raisons techniques, cette manœuvre est considérée comme valable, dans la mesure où il peut être démontré par un autre biais que le sectionneur de terre n'a pas présenté de défaillance et que les valeurs d'essai exigées étaient conformes.

Dans le cas d'essais directs en triphasé (source d'alimentation unique), même si les exigences en 7.101.5 a) et/ou 7.101.5 b) ne sont toujours pas satisfaites pendant la répétition de la séquence d'essai complète, le sectionneur de terre est considéré comme ayant satisfait à l'essai si les exigences spécifiées en 7.101.8 et 7.101.9 sont satisfaites.

7.101.11 Rapports d'essais de type

Les résultats de l'essai de type doivent être consignés dans des rapports d'essais de type comportant des données suffisantes pour démontrer la conformité aux exigences de fonctionnement en courant établi assigné en court-circuit. Il convient d'inclure des renseignements suffisants pour pouvoir identifier les parties essentielles du sectionneur de terre soumis à l'essai. Se reporter à 7.1.2 de l'IEC 62271-1:2017.

Le rapport d'essai doit contenir les renseignements sur les dispositions d'essais, les circuits d'essai et les procédures d'essai.

Il convient d'inclure des renseignements généraux concernant la structure support du sectionneur de terre. Il convient de consigner, le cas échéant, le type des dispositifs de manœuvre utilisés pendant les essais.

Des enregistrements oscillographiques typiques ou analogues doivent être prévus de manière à pouvoir déterminer ce qui suit:

- le courant établi exprimé en valeur crête et la valeur efficace à 0,2 s;
- les tensions appliquées;
- la valeur instantanée des tensions au moment de la fermeture;
- la durée de préarc.

7.102 Essais de fonctionnement et d'endurance mécanique

7.102.1 Conditions générales d'essai

L'essai doit être réalisé à la température de l'air ambiant du local d'essai. Pendant l'essai, les températures ambiantes doivent être enregistrées et les valeurs maximales et minimales incluses dans le rapport d'essai.

La tension d'alimentation doit être mesurée aux bornes des dispositifs de manœuvre au moment du passage du plein courant. Les appareils auxiliaires faisant partie du dispositif de manœuvre doivent être pris en compte.

Pour les sectionneurs et les sectionneurs de terre triphasés manœuvrés par un mécanisme pour lequel l'application de l'effort sur les bornes est exigée, l'effort doit être appliqué à toutes les bornes simultanément.

7.102.2 Essai de la zone de contact

Cet essai doit être réalisé dans le but de démontrer le bon fonctionnement des sectionneurs à éléments séparés ou des sectionneurs de terre à éléments séparés, dans les différentes positions du contact fixe à l'intérieur des limites de la zone de contact assignée définie selon le 5.103 et les Figures 6 et/ou 7. Avec le dispositif en position d'ouverture, le contact fixe doit être placé dans les positions suivantes:

- a) à une hauteur égale à h suivant l'axe vertical du montage;
- b) à une hauteur égale à $h - z_r$ suivant le même axe;
- c) à une hauteur égale à h et déplacé de l'axe vertical de façon horizontale de $+y_r/2$;
- d) à une hauteur égale à h et déplacé de l'axe vertical de façon horizontale de $-y_r/2$;
- e) positions a) à d) à une distance égale à $+x_r/2$;
- f) positions a) à d) à une distance égale à $-x_r/2$,

où

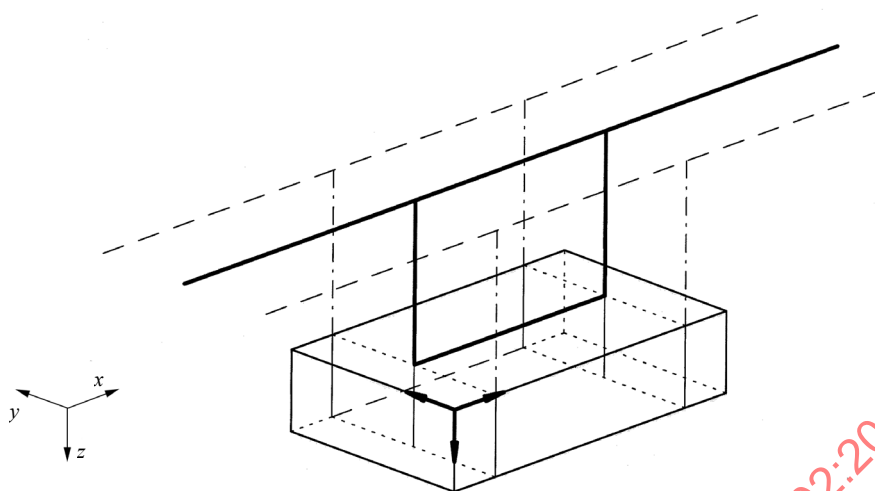
h est la position la plus haute (spécifiée par le constructeur) du contact fixe au-dessus du plan de fixation;

x_r est l'amplitude totale du mouvement du contact fixe dans la direction x ;

y_r est l'amplitude totale du mouvement du contact fixe dans la direction y ;

l'indice r indique la valeur assignée attribuée au sectionneur ou au sectionneur de terre par le constructeur.

Dans chaque position, le dispositif doit fermer et ouvrir correctement.

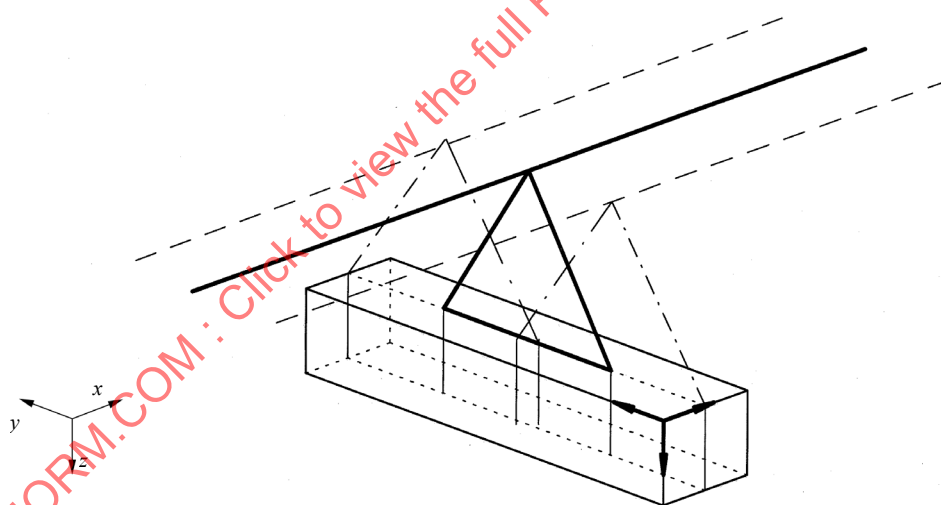


IEC

Légende

- x Longitudinal au support (influence de la température)
- y Perpendiculaire au support (influence du vent)
- z Déviation verticale (température et glace)

Figure 6 – Contact fixe parallèle au support

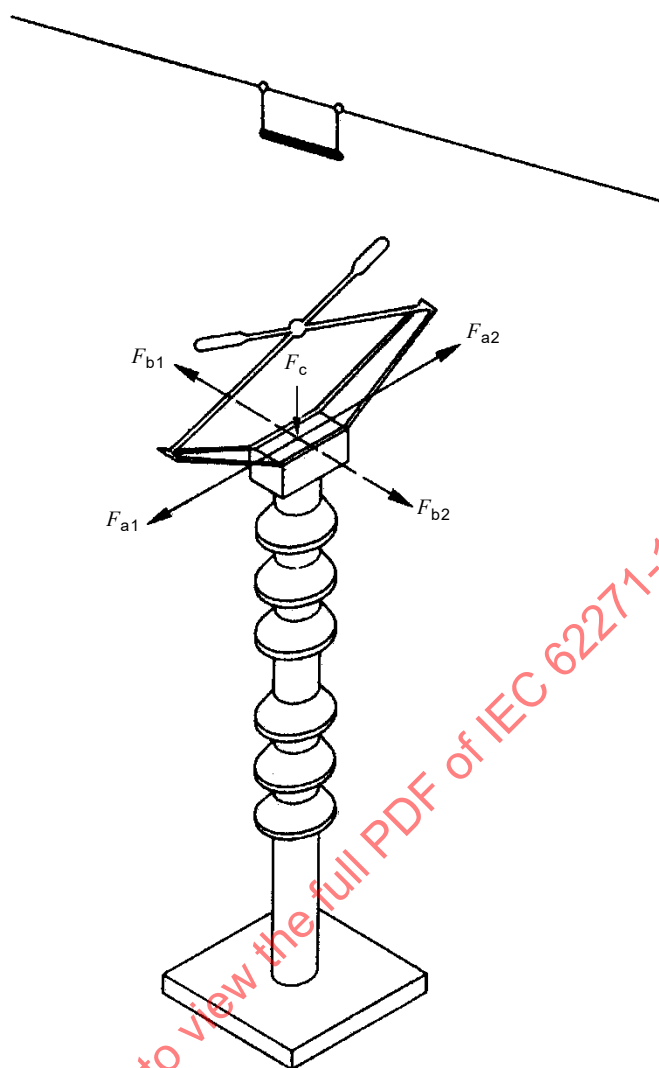


IEC

Légende

- x Longitudinal au support (influence de la température)
- y Perpendiculaire au support (influence du vent)
- z Déviation verticale (température et glace)

Figure 7 – Contact fixe perpendiculaire au support



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NOTE Le contact fixe est représenté au-dessus du pantographe.

Figure 8 – Exemple d'application des efforts mécaniques statiques assignés sur les bornes d'un sectionneur (ou sectionneur de terre) pantographe (à éléments séparés)

7.102.3 Essai d'endurance mécanique

7.102.3.1 Procédure d'essai

Les essais définis dans 7.102.3.1 et dans 7.102.3.2 doivent être réalisés sur les sectionneurs et sectionneurs de terre de classe M0.

L'essai d'endurance mécanique doit comprendre 1 000 cycles de manœuvre. Pour les sectionneurs ou sectionneurs de terre avec un effort assigné sur les bornes, 50 % des efforts statiques assignés sur les bornes doivent être appliqués pendant l'essai selon la direction F_{a1} ou F_{a2} (Figure 8 et Figure 9), sans tension ou courant appliqués sur le circuit principal. Pour les sectionneurs ayant deux ou trois isolateurs et une distance normale de sectionnement horizontale, les 50 % des efforts statiques assignés sur les bornes doivent être appliqués des deux côtés du sectionneur, mais dans des directions opposées. Pour les sectionneurs et les sectionneurs de terre avec un seul isolateur (les isolateurs de manœuvre n'étant pas pris en considération) l'effort sur la borne doit être appliqué uniquement d'un seul côté du sectionneur ou du sectionneur de terre. Après l'application de 50 % des efforts statiques assignés sur les bornes, le sectionneur ou sectionneur de terre peut être réglé avant de réaliser les essais.

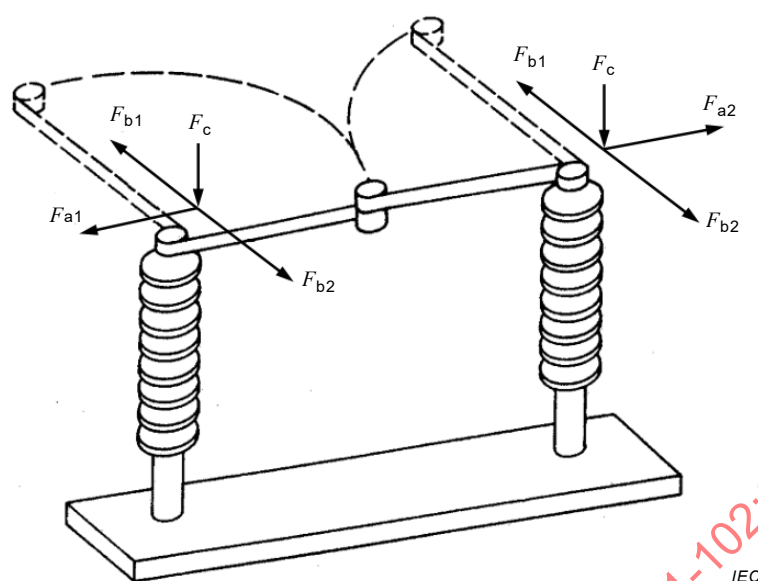


Figure 9 – Exemple d'application des efforts mécaniques statiques assignés sur les bornes d'un sectionneur à deux colonnes

Les positions de fermeture et d'ouverture doivent être atteintes à chaque cycle de manœuvres.

Pendant l'essai, le fonctionnement des contacts auxiliaires et de commande et des dispositifs de signalisation de position (le cas échéant) doit satisfaire aux exigences spécifiées en 6.104 et 6.4 de l'IEC 62271-1:2017. L'essai est considéré comme non satisfait si l'un des contacts auxiliaires et de commande ou des dispositifs de signalisation de position ne fonctionne pas au cours de l'un des cycles de manœuvre de fermeture-ouverture.

L'essai doit être réalisé sur des sectionneurs et des sectionneurs de terre équipés de leurs propres mécanismes de commande. Pendant l'essai, le graissage est permis conformément aux instructions du constructeur, mais pas les réglages mécaniques ou autre maintenance.

Sur un sectionneur ou un sectionneur de terre ayant un mécanisme de commande à énergie extérieure:

- 900 cycles de manœuvres de fermeture-ouverture doivent être réalisés à la tension d'alimentation assignée et/ou à la pression assignée d'alimentation en gaz comprimé;
- 50 cycles de manœuvres de fermeture-ouverture à la tension minimale spécifiée d'alimentation et/ou à la pression minimale spécifiée d'alimentation en gaz comprimé;
- 50 cycles de manœuvres de fermeture-ouverture à la tension maximale spécifiée d'alimentation et/ou à la pression maximale spécifiée d'alimentation en gaz comprimé.

Aucun intervalle de temps spécifique entre les cycles de manœuvre ou entre les manœuvres de fermeture et d'ouverture n'est exigé. Cependant, ces essais doivent être réalisés à une cadence telle que les échauffements des dispositifs de manœuvre électriques sous tension ne dépassent pas les valeurs spécifiées. Pour le même objectif, un système de refroidissement extérieur peut être utilisé au cours de l'essai.

Pour les sectionneurs et sectionneurs de terre manœuvrés manuellement, la poignée de manœuvre peut, pour la commodité de l'essai, être remplacée par un dispositif de manœuvre à source extérieure d'énergie. Dans ce cas, il n'est pas nécessaire de faire varier les paramètres d'alimentation.

7.102.3.2 Vérification de la réussite du fonctionnement

Pour l'évaluation des caractéristiques fonctionnelles, avant et après le programme d'essai d'endurance mécanique, les manœuvres suivantes doivent être effectuées sans l'application des efforts statiques sur les bornes:

- cinq cycles de manœuvres de fermeture-ouverture à la tension d'alimentation assignée et/ou pression d'alimentation assignée (le cas échéant);
- cinq cycles de manœuvres de fermeture-ouverture à la tension minimale d'alimentation et/ou pression minimale d'alimentation (le cas échéant);
- cinq cycles de manœuvres de fermeture-ouverture à la tension maximale d'alimentation et/ou pression maximale d'alimentation (le cas échéant);
- cinq cycles de manœuvres manuelles de fermeture-ouverture si l'appareil de connexion peut être manœuvré manuellement.

Pendant ces cycles de manœuvre, les caractéristiques fonctionnelles telles que, le cas échéant, les durées de manœuvre, la consommation d'énergie ou les forces maximales pour la manœuvre manuelle doivent être enregistrées. Le fonctionnement correct des contacts auxiliaires et de commande et des indicateurs de position (le cas échéant) doit être vérifié. Il n'est pas nécessaire d'inclure tous les oscillogrammes enregistrés dans le rapport d'essai de type.

Les écarts entre les valeurs moyennes de chaque paramètre, mesurées avant et après l'essai d'endurance mécanique, doivent être compris dans les tolérances indiquées par le constructeur.

Après l'essai, tous les éléments, y compris les contacts, doivent être soumis à une inspection visuelle pour vérifier leur bon état et ils ne doivent pas présenter d'usure excessive; voir aussi le point 6 de 7.5.6.2 de l'IEC 62271-1:2017. La résistance du circuit principal, c'est-à-dire des sectionneurs, doit être mesurée avant et après l'essai d'endurance mécanique, à proximité immédiate des contacts. La résistance ne doit pas augmenter de plus de 20 % par rapport à celle mesurée avant l'essai. Si cette limite est dépassée, un essai au courant permanent assigné (7.5) doit être effectué pour démontrer que l'échauffement des contacts ne dépasse pas les limites indiquées au Tableau 14 de l'IEC 62271-1:2017, en surveillant la température aux points les plus proches possible des contacts.

Pour les sectionneurs de terre dont les contacts sont visibles, les positions de fermeture et d'ouverture maximales pendant la manœuvre après l'essai d'endurance mécanique doivent être vérifiées par inspection visuelle.

Pour les sectionneurs de terre dont les contacts ne sont pas visibles, les positions de fermeture et d'ouverture maximales pendant la manœuvre après l'essai d'endurance mécanique doivent être vérifiées à l'aide de l'enregistrement des déplacements ou autres méthodes appropriées.

Pour les sectionneurs et les sectionneurs de terre à isolation gazeuse, un essai d'étanchéité selon 7.8 doit être réalisé avant et après l'essai d'endurance mécanique.

Pour les sectionneurs équipés de résistances dans les appareillages sous enveloppe métallique à isolation gazeuse, la variation maximale de la résistance ohmique de la résistance complète après l'essai ne doit pas dépasser 5 % de la valeur mesurée avant l'essai.

7.102.4 Fonctionnement au cours de l'application des efforts mécaniques statiques assignés sur les bornes

Vingt cycles de manœuvre à la tension d'alimentation assignée doivent être réalisés avec les efforts mécaniques statiques assignés appliqués sur chaque borne dans les directions spécifiées par le constructeur. Lorsque plusieurs configurations d'effort sont spécifiées par le

constructeur, les 20 cycles de manœuvre doivent être répétés pour chaque configuration. Les trois composantes de chaque effort sur les bornes peuvent être appliquées par un conducteur tirant dans la direction résultante et avec la force résultante des trois vecteurs.

NOTE Toute combinaison éventuelle des forces résultantes appliquées aux bornes correspond à une configuration à une charge.

Des exemples d'efforts sur les bornes appliqués aux différents types de sectionneurs sont présentés à la Figure 8 et à la Figure 9.

Un exemple de configurations éventuelles pour un sectionneur à deux colonnes est présenté ci-dessous:

- effort longitudinal appliqué selon la direction F_{a1} à une borne et F_{a2} à la borne opposée;
- effort transversal appliqué selon la direction F_{b1} ou F_{b2} , aux deux bornes dans la même direction;
- effort vertical appliqué selon la direction F_c aux deux bornes (à l'exception des sectionneurs spécifiés pour être raccordés aux conducteurs souples).

Pour les sectionneurs et les sectionneurs de terre à commande uniquement manuelle, le nombre de cycles de manœuvre est réduit à 10.

Les efforts doivent être appliqués sur les deux bornes en même temps.

Le sectionneur ou le sectionneur de terre peut être réglé avant l'essai et après avoir été soumis à 50 % de l'effort mécanique longitudinal ou perpendiculaire assigné sur les bornes.

Pendant chaque manœuvre, le sectionneur ou le sectionneur de terre doit fermer et ouvrir correctement.

Pour vérification, avant et après la séquence complète de cycles de manœuvre, les dispositions du 7.102.3.2 et les critères de comparaison appropriés exigés en 7.102.3.1 pour les essais d'endurance mécanique, s'appliquent (c'est-à-dire sans les efforts mécaniques statiques appliqués sur les bornes).

7.102.5 Essais complémentaires d'endurance mécanique

Les essais définis dans ce paragraphe doivent être réalisés sur des sectionneurs de classes M1 et M2 et des sectionneurs de terre de classe M1.

Dans le cas de sectionneurs et de sectionneurs de terre pour postes à isolation gazeuse, l'enveloppe ne doit pas être ouverte pendant l'essai.

Les essais doivent être effectués comme suit:

- a) Le programme d'essais complémentaires d'endurance mécanique doit comprendre un nombre de manœuvres de fermeture-ouverture selon 7.102.1 et 7.102.3.1.

Selon la classe assignée, un des nombres suivants de cycles de manœuvre doit être exécuté:

- 2 000 (pour la classe M1);
- 10 000 (pour la classe M2).

Après la première série de 1 000 cycles de manœuvre, une maintenance comme le graissage et le réglage mécanique est permise et doit être réalisée en accord avec les instructions du constructeur et sa référence mentionnée dans le rapport d'essai. Une modification des parties dans le circuit principal et dans la chaîne cinématique n'est pas permise.

Après chaque série suivante de 1 000 cycles de manœuvre ou à des intervalles de maintenance (si moins de 1 000 cycles de manœuvre), les caractéristiques fonctionnelles doivent être enregistrées et évaluées (si à manœuvre électrique) à la pression ou tension assignée.

Le programme de maintenance doit être défini par le constructeur avant les essais et consigné dans le rapport d'essai.

- b) Avant et après le programme d'essai complet, la vérification du bon fonctionnement doit être effectuée selon les exigences de 7.102.3.2.
- c) De plus, après le programme d'essai complet, des contrôles et des essais doivent être réalisés comme suit:
 - l'essai de la zone de contact (7.102.2), le cas échéant;
 - la vérification du fonctionnement durant l'application des efforts mécaniques statiques assignés sur les bornes (7.102.4), le cas échéant;
 - la vérification du fonctionnement correct avec la durée d'ordre de manœuvre minimale spécifiée dans la documentation du constructeur;
 - la vérification du fonctionnement des dispositifs limiteurs de contrainte mécanique, le cas échéant.

7.102.6 Essais des dispositifs de verrouillage mécanique

Lorsque des dispositifs de verrouillage mécanique sont prévus pour bloquer l'arbre de commande ou la chaîne cinématique de puissance, les sectionneurs et les sectionneurs de terre qui ne sont pas couverts par les normes d'ensemble d'appareillages (par exemple, l'IEC 62271-200, l'IEC 62271-201 et l'IEC 62271-203) doivent être soumis à l'essai comme ci-dessous.

Tous les dispositifs de verrouillage doivent être soumis à 5 tentatives de manœuvre de fermeture et/ou d'ouverture pour toute position verrouillée du sectionneur et/ou sectionneur de terre, afin de démontrer la conformité aux exigences de 6.12.

Avant chaque tentative, les dispositifs de verrouillage doivent être placés dans la position prévue pour empêcher la manœuvre de l'appareil de connexion, ensuite une tentative doit être faite pour manœuvrer l'appareil de connexion verrouillé. Les efforts de manœuvre donnés en 6.12 doivent être appliqués. Les appareils de connexion ou les dispositifs de verrouillage ne doivent faire l'objet d'aucun réglage.

Les essais sont considérés comme satisfaisants si les appareils de connexion verrouillés et les dispositifs de verrouillage sont en bon état de fonctionnement et si les efforts exigés pour la manœuvre des appareils de connexion sont pratiquement les mêmes avant et après les essais.

Les efforts de manœuvre sont envisagés comme étant les mêmes si la valeur moyenne mesurée après l'essai est comprise dans les valeurs minimale et maximale mesurées avant l'essai. Il convient d'effectuer au moins trois manœuvres de fermeture/ouverture avant l'essai afin de fixer les valeurs minimale et maximale utilisées pour l'acceptation de la manœuvre de fermeture ou d'ouverture après l'essai.

7.103 Fonctionnement dans des conditions sévères de formation de glace

7.103.1 Généralités

Les essais définis dans le présent paragraphe ne doivent être réalisés que si le constructeur garantit un fonctionnement adéquat des sectionneurs et sectionneurs de terre dans des conditions sévères de formation de glace (c'est-à-dire une épaisseur de glace d'au moins 10 mm).

Les sectionneurs et les sectionneurs de terre ayant des dispositifs permettant de s'adapter à un pouvoir d'établissement et de coupure de courant de transfert de barres (sectionneurs uniquement) et à un pouvoir d'établissement et de coupure des courants induits (sectionneurs de terre uniquement) doivent être soumis à l'essai avec ces dispositifs montés.

NOTE La formation de glace peut présenter des difficultés pour la manœuvre des systèmes à fonctionnement électrique. Dans certaines conditions atmosphériques, un dépôt de glace peut se former sur une épaisseur qui parfois rend difficile la manœuvre des équipements de coupure extérieurs.

7.103.2 Disposition d'essai

- a) Tous les éléments du sectionneur ou du sectionneur de terre à soumettre à l'essai doivent être assemblés avec leur mécanisme de commande, dans une salle qui peut être réfrigérée à une température conforme aux exigences données en 7.103.3. L'alimentation des éléments de chauffage du mécanisme de commande est permise pendant les essais. Les supports, les isolateurs de manœuvre et les autres organes de manœuvre peuvent être raccourcis pour réduire la hauteur de l'ensemble afin de s'adapter aux installations d'essais disponibles, à condition que l'angle de rotation des éléments concernés et que la flexion des parties de liaison restent inchangés.

Dans le choix de la capacité de réfrigération exigée, il convient de tenir compte de la chaleur contenue dans l'eau qui est pulvérisée sur l'appareil en essai.

- b) Des éléments unipolaires d'appareil tripolaire peuvent être soumis à l'essai si chaque pôle possède un mécanisme de commande séparé. Dans le cas d'un appareil tripolaire de tension inférieure ou égale à 52 kV ayant un mécanisme de commande commun aux trois pôles, le dispositif tripolaire complet doit être soumis à l'essai. Dans le cas de tensions supérieures à 52 kV et lorsque le laboratoire d'essai ne peut pas installer des appareils tripolaires normalisés complets, il est admis de modifier, dans toute la mesure du possible, les structures de montage, les supports isolants ou l'espacement pour pouvoir réaliser l'essai sur les trois pôles. S'il n'est pas possible d'effectuer les essais même dans cette configuration, il est admis de les effectuer avec un appareil unipolaire entraîné par le mécanisme de commande commun. Dans ce dernier cas, les informations détaillées exactes de la procédure d'essai et le couple mesuré doivent être consignés afin d'évaluer le résultat d'essai par rapport à l'aptitude du mécanisme à manœuvrer l'appareil tripolaire. Dans tous les cas, il n'est pas permis de modifier la distance de sectionnement d'origine pour le sectionneur ou l'intervalle d'isolement pour le sectionneur de terre.
- c) Le sectionneur ou le sectionneur de terre doit être soumis à l'essai de manœuvre séparée à partir de la position d'ouverture et à partir de la position de fermeture.
- d) Avant l'essai, toute trace d'huile ou de graisse sur les parties qui n'ont pas besoin d'être lubrifiées en service doit être enlevée avec un solvant approprié. En effet, un mince film d'huile ou de graisse empêche l'adhérence de la glace et modifie fortement les résultats des essais.
- e) Pour mesurer l'épaisseur de glace, une barre ou un tube en cuivre de 30 mm de diamètre et de 1 m de long doit être monté(e) en position horizontale à un endroit où il (elle) reçoit la même quantité d'eau de pluie que l'appareil en essai.
- f) La disposition d'essai doit permettre l'arrosage de tout l'appareil avec une pluie artificielle tombant selon différents angles compris entre la verticale et 45°. Il convient de refroidir l'eau utilisée pour l'arrosage à une température comprise entre 0 °C et 3 °C. L'eau doit atteindre l'objet d'essai à l'état liquide.

7.103.3 Procédure d'essai

7.103.3.1 Contrôles avant la formation de la couche de glace

Avant l'essai, le sectionneur/sectionneur de terre doit être soumis:

- à 5 cycles de manœuvres de fermeture-ouverture à la tension d'alimentation assignée et/ou pression d'alimentation assignée (le cas échéant);

- à 5 cycles de manœuvres manuelles de fermeture-ouverture si l'appareil de connexion ne peut être manœuvré que manuellement;
- au mesurage de la résistance du circuit principal conformément au 7.4.4.

Pendant les cycles de manœuvre, les caractéristiques fonctionnelles telles que, le cas échéant, les durées de manœuvre, la consommation d'énergie ou les forces maximales pour les manœuvres manuelles doivent être enregistrées. Le bon fonctionnement des contacts auxiliaires et de commande et de l'indicateur de position (le cas échéant) doit être vérifié. Il n'est pas nécessaire d'inclure tous les oscillogrammes enregistrés dans le rapport d'essai de type.

7.103.3.2 Formation de la couche de glace

Les revêtements naturels de glace peuvent être divisés en deux catégories principales:

- a) la glace transparente due généralement à une chute de pluie dans de l'air à une température légèrement en dessous du point de congélation de l'eau, et
- b) le givre, d'un aspect blanc caractéristique, produit par exemple par la condensation de l'humidité sur des surfaces froides.

Pour les essais de type, une couche de glace transparente solide de l'épaisseur exigée, doit être produite selon la procédure décrite ci-dessous.

- a) Abaisser la température de la salle jusqu'à 2 °C et démarrer l'arrosage avec de l'eau préalablement refroidie. Continuer cet arrosage pendant au moins 1 h tout en maintenant la température de la salle entre 0,5 °C et 3 °C.
- b) Abaisser la température de la salle jusqu'à la plage comprise entre –7 °C et –3 °C tout en continuant l'arrosage d'eau. La vitesse de variation de la température n'est pas critique et peut donc être celle qu'autorise l'installation de réfrigération disponible.
- c) Maintenir la température de la salle dans la plage comprise entre –7 °C et –3 °C et continuer à arroser jusqu'à ce que l'épaisseur de glace spécifiée à la surface supérieure de la barre-témoin puisse être mesurée. Il convient de régler la quantité d'eau pour provoquer une accumulation de glace à raison d'environ 6 mm/h.

NOTE 1 Si les capacités calorifiques spécifiques par unité de surface de la barre témoin et de l'appareil en essai diffèrent considérablement, même des conditions identiques d'arrosage peuvent donner lieu à la formation de couches de glace très différentes. Ces différences d'épaisseur peuvent être réduites le plus possible en effectuant de courtes périodes d'arrosage en alternance avec des périodes plus longues de refroidissement.

NOTE 2 À titre indicatif, il a été observé qu'une quantité de 20 l à 80 l d'eau par heure et par m² de surface arrosée est exigée pour obtenir une vitesse de dépôt de glace d'environ 6 mm/h.

- d) Arrêter l'arrosage et maintenir la température de la salle dans la plage comprise entre –7 °C et –3 °C pendant une durée d'au moins 4^{+2}_0 h. Cela assure que tous les éléments du sectionneur/sectionneur de terre et la couche de glace ont atteint une température constante.

7.103.3.3 Contrôles après la formation de la couche de glace

Après la formation de la couche de glace, le fonctionnement correct du sectionneur/sectionneur de terre doit être vérifié:

- si le sectionneur ou le sectionneur de terre est à commande manuelle, le fonctionnement est considéré comme satisfaisant si l'appareil a été manœuvré jusqu'à sa position finale d'ouverture ou de fermeture par l'application d'efforts de manœuvre normaux (capables d'éliminer la couche de glace au point d'insertion de la poignée);
- si le sectionneur ou le sectionneur de terre est à commande électrique, pneumatique ou hydraulique, le fonctionnement est considéré comme satisfaisant si l'appareil a été

manœuvré à la première tentative jusqu'à sa position finale d'ouverture ou de fermeture par son dispositif de manœuvre alimenté à sa tension ou pression assignée.

Immédiatement après la manœuvre de fermeture, la continuité électrique à travers les contacts doit être vérifiée.

Lorsque le sectionneur/sectionneur de terre est sans glace, il doit être soumis aux mêmes contrôles spécifiés en 7.103.3.1, la température de la salle étant rétablie à la température ambiante normale (au-dessus de 10 °C). L'appareil doit être considéré comme ayant satisfait à l'essai si ses performances mécaniques et électriques ne sont pas affectées. Cette condition doit être considérée comme satisfaite si:

- la résistance mesurée avant la formation de la couche de glace n'a pas augmenté de plus de 20 %;
- les écarts entre les valeurs moyennes de chaque paramètre, mesurées avant la formation de la couche de glace, sont compris dans les tolérances indiquées par le constructeur.

La procédure complète liée à la couche de glace et les contrôles associés doivent être effectués pour chaque position (c'est-à-dire de fermeture/d'ouverture) sur le sectionneur et/ou sectionneur de terre. La couche de glace doit s'éliminer naturellement entre les essais, en exposant par exemple l'appareil pendant une période suffisante à une température ambiante adéquate.

7.104 Essais à basse et haute température

7.104.1 Généralités

Si les températures limites pour les conditions de service de l'appareil (définies par le constructeur) sont supérieures à +40 °C ou inférieures à -5 °C, la procédure suivante doit être appliquée:

Des éléments unipolaires d'appareil tripolaire peuvent être individuellement soumis aux essais si chaque pôle possède un mécanisme de commande séparé. Dans le cas d'un appareil tripolaire de $U_r \leq 52$ kV ayant un mécanisme de commande commun aux trois pôles, le dispositif tripolaire complet doit être soumis aux essais.

Dans le cas de $U_r > 52$ kV et lorsque le laboratoire d'essai ne peut pas installer des appareils tripolaires normalisés complets, il est admis de modifier, dans toute la mesure du possible, les structures de montage, les supports isolants ou l'espacement afin de pouvoir réaliser les essais sur les trois pôles. S'il n'est pas possible d'effectuer les essais même dans cette configuration, il est admis de les effectuer avec un appareil unipolaire entraîné par le mécanisme de commande commun. Dans ce dernier cas, les informations détaillées exactes de la procédure d'essai et le couple mesuré doivent être consignés afin d'évaluer le résultat d'essai par rapport à l'aptitude du mécanisme à manœuvrer l'appareil tripolaire. Dans tous les cas, il n'est pas permis de modifier la distance de sectionnement d'origine pour le sectionneur ou l'intervalle d'isolement pour le sectionneur de terre.

Si des sources de chaleur sont exigées, elles doivent fonctionner.

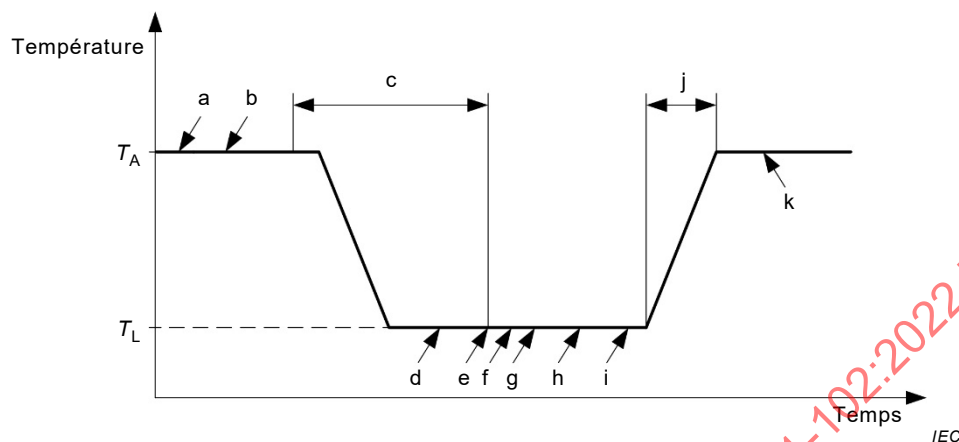
Aucune maintenance, aucun remplacement de pièces, aucun graissage et aucun nouveau réglage de l'appareil ne sont autorisés au cours des essais. Pour les systèmes à pression d'isolement, les essais doivent être effectués à la pression assignée de remplissage pour l'isolement et/ou la coupure. Les caractéristiques enregistrées doivent être conformes aux tolérances spécifiées par le constructeur.

7.104.2 Mesurage de la température de l'air ambiant

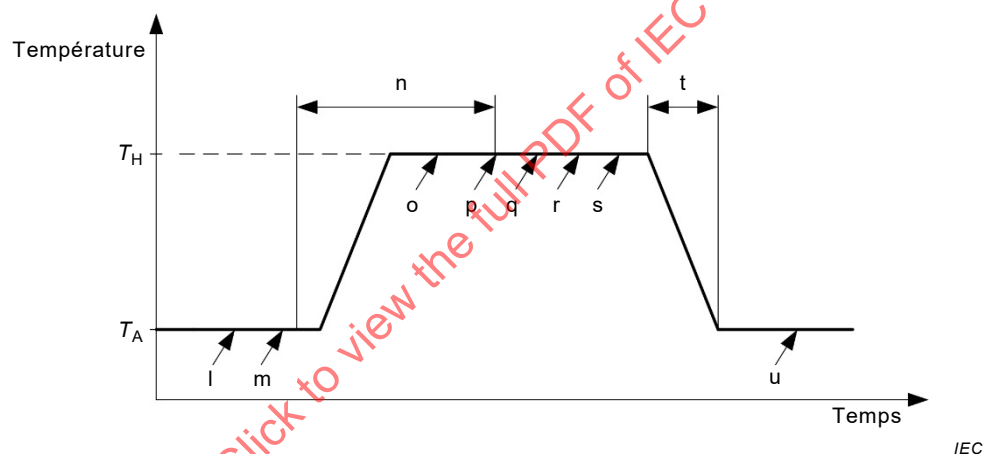
L'écart maximal de température le long de la hauteur de l'appareil ne doit pas dépasser 5 K, la température étant mesurée à une distance de 1 m de l'appareil.

7.104.3 Essai à la température basse

Le diagramme des séquences d'essai et l'identification des points d'application pour les essais spécifiés sont présentés à la Figure 10 a).



a) Essai à la température basse



b) Essai à la température haute

NOTE Les lettres a à u identifient les points d'application des essais spécifiés en 7.104.3 et 7.104.4.

Figure 10 – Séquences d'essai pour les essais à basse et haute température

Si l'essai à la température basse est effectué immédiatement après l'essai à la température haute sur le même échantillon, l'essai à la température basse peut être effectué après l'achèvement du point (t) de l'essai à la température haute. Dans ce cas, les points (a) et (b) ne sont pas pris en considération.

- L'objet d'essai doit être réglé conformément aux instructions du constructeur.
- Les caractéristiques et les réglages de l'objet d'essai doivent être enregistrés conformément au 7.102.3.2 et à une température de l'air ambiant de $(20 \pm 5) ^\circ\text{C}$ (T_A). L'essai d'étanchéité pour les systèmes à pression d'isolement doit être effectué selon 7.8.
- Le sectionneur étant en position de fermeture et/ou le sectionneur de terre en position d'ouverture, la température de l'air doit être réduite à la température minimale de l'air ambiant (T_L) appropriée, selon les conditions de service définies par le constructeur et conformément à l'Article 2, à un taux de variation de 10 K par heure environ. Le sectionneur doit être maintenu en position de fermeture et/ou le sectionneur de terre en position d'ouverture pendant au moins 12 h après stabilisation de la température de l'air ambiant à la température T_L .

- d) Pendant les 12 h pendant lesquelles le sectionneur est resté en position de fermeture et/ou le sectionneur de terre en position d'ouverture à la température T_L , un essai d'étanchéité doit être effectué sur les systèmes à pression d'isolement. Une augmentation du taux de fuite est admissible, à condition que le taux revienne à la valeur d'origine lorsque l'appareil est rétabli à la température de l'air ambiant T_A et est thermiquement stable. Il convient que le taux de fuite accru temporairement ne dépasse pas le taux de fuite temporaire admissible du Tableau 15 de l'IEC 62271-1:2017. Cet essai d'étanchéité doit être un essai intégré et réalisé par la méthode de mesure des fuites par accumulation avec un appareil approprié pour mesurer la concentration de SF_6 à la température basse de l'air dans la salle d'essai. Il est fortement recommandé d'utiliser un mélangeur ou un ventilateur pour une diffusion uniforme du SF_6 en fuite à l'intérieur du volume de contrôle.
- e) Après 12 h à la température T_L , le sectionneur doit être ouvert et fermé et/ou le sectionneur de terre doit être fermé et ouvert trois fois aux valeurs assignées de tension d'alimentation et de pression de fonctionnement, le cas échéant. Les caractéristiques fonctionnelles doivent être enregistrées.
- f) Le comportement à basse température de l'appareil doit être vérifié, le cas échéant, en déconnectant l'alimentation de tous les dispositifs de chauffage, y compris les éléments de chauffage anti-condensation, pendant une durée t_x . À la fin de l'intervalle t_x , un ordre de fonctionnement, aux valeurs assignées de tension d'alimentation et de pression de fonctionnement doit être donné, le cas échéant. Ensuite, le sectionneur doit s'ouvrir et/ou le sectionneur de terre doit se fermer. Les caractéristiques fonctionnelles doivent être enregistrées.
- La valeur de t_x à hauteur de laquelle l'appareil continue à fonctionner sans alimentation auxiliaire des éléments de chauffage est déclarée par le constructeur (pas moins de 2 h). En l'absence d'une telle déclaration, la valeur est égale à 2 h.
- g) Le sectionneur doit être laissé en position d'ouverture et/ou le sectionneur de terre doit être laissé en position de fermeture pendant au moins 4 h.
- h) Pendant les 4 h pendant lesquelles le sectionneur est resté en position d'ouverture et/ou le sectionneur de terre en position de fermeture à la température T_L , un essai d'étanchéité doit être effectué conformément à 7.8 pour les systèmes à pression d'isolement en utilisant la méthode de mesure des fuites par accumulation indiquée au point (d).
- i) Après 4 h à la température T_L , le sectionneur doit être fermé et/ou le sectionneur de terre doit être ouvert trois fois aux valeurs assignées de tension d'alimentation et de pression de fonctionnement, le cas échéant. Les caractéristiques fonctionnelles doivent être enregistrées.
- j) A l'issue des trois manœuvres de fermeture et des trois manœuvres d'ouverture, la température de l'air doit être augmentée à la température de l'air ambiant T_A à un taux de variation de 10 K par heure environ.
- k) Après la stabilisation thermique de l'appareil à la température de l'air ambiant T_A , les réglages de l'appareil doivent être contrôlés à nouveau, les caractéristiques fonctionnelles doivent être enregistrées et vérifiées selon 7.102.3.2. Un essai d'étanchéité doit être effectué comme indiqué au point b) pour comparer le résultat avec les caractéristiques initiales.

Pour les sectionneurs de terre à fonction combinée, y compris une fonction de sectionneur, la manœuvre du sectionneur ainsi que celle du sectionneur de terre comme décrit aux points (e) et (i) doivent être espacées de 4 h ou de $t_x + 4$ h en cas d'extinction des dispositifs de chauffage. Pour les systèmes à pression d'isolement, un essai d'étanchéité doit être effectué au moins une fois lorsqu'à la fois le sectionneur et le sectionneur de terre sont en position d'ouverture.

Après l'essai complet à la température basse, la pression ne doit pas être inférieure à la pression minimale de fonctionnement.

7.104.4 Essai à la température haute

Le diagramme de la séquence d'essai et l'identification des points d'application pour les essais spécifiés sont présentés à la Figure 10 b).

Si l'essai à la température haute est effectué immédiatement après l'essai à la température basse sur le même échantillon, l'essai à la température haute peut être effectué après l'achèvement du point (j) de l'essai à la température basse. Dans ce cas, les points (l) et (m) ci-après ne sont pas pris en considération.

- l) L'objet d'essai doit être réglé conformément aux instructions du constructeur.
- m) Les caractéristiques et les réglages de l'objet d'essai doivent être enregistrés conformément au 7.102.3.2 et à une température de l'air ambiant de $(20 \pm 5) ^\circ\text{C}$ (T_A). L'essai d'étanchéité pour les systèmes à pression d'isolement doit être effectué selon 7.8.
- n) Le sectionneur étant en position de fermeture et/ou le sectionneur de terre en position d'ouverture, la température de l'air doit être augmentée à la température maximale de l'air ambiant (T_H), indiquée par le constructeur, à un taux de variation de 10 K par heure environ. Le sectionneur doit être maintenu en position de fermeture et/ou le sectionneur de terre en position d'ouverture pendant 12 h après stabilisation de la température de l'air ambiant à la température T_H .
- o) Pendant les 12 h pendant lesquelles le sectionneur est resté en position de fermeture et/ou le sectionneur de terre en position d'ouverture à la température T_H , un essai d'étanchéité doit être effectué pour les systèmes à pression d'isolement.
- p) Après 12 h à la température T_H , le sectionneur doit être ouvert et/ou le sectionneur de terre doit être fermé trois fois aux valeurs assignées de tension d'alimentation et de pression de fonctionnement, le cas échéant. Les caractéristiques fonctionnelles doivent être enregistrées.
- q) Le sectionneur doit être laissé en position d'ouverture et/ou le sectionneur de terre doit être laissé en position de fermeture pendant 4 h.
- r) Pendant les 4 h pendant lesquelles le sectionneur est resté en position d'ouverture et/ou le sectionneur de terre en position de fermeture à la température T_H , un essai d'étanchéité doit être effectué pour les systèmes à pression d'isolement en utilisant la méthode de mesure des fuites par accumulation indiquée au point (d) de 7.104.3.
- s) Après 4 h à la température T_H , le sectionneur doit être fermé et/ou le sectionneur de terre doit être ouvert trois fois aux valeurs assignées de tension d'alimentation et de pression de fonctionnement, le cas échéant. Les caractéristiques fonctionnelles doivent être enregistrées.
- t) A l'issue des trois manœuvres de fermeture et des trois manœuvres d'ouverture, la température de l'air doit être augmentée à la température de l'air ambiant T_A à un taux de variation de 10 K par heure environ.
- u) Après la stabilisation thermique de l'appareil à la température de l'air ambiant T_A , les réglages, les caractéristiques fonctionnelles et l'étanchéité de l'appareil doivent être contrôlés à nouveau comme indiqué aux points (l) et (m) afin de les comparer avec les caractéristiques initiales.

Pour les sectionneurs de terre à fonction combinée, y compris une fonction de sectionneur, la manœuvre du sectionneur ainsi que celle du sectionneur de terre comme décrit aux points (p) et (s) doivent être espacées de 4 h. Un essai d'étanchéité doit être effectué au moins une fois lorsqu'à la fois le sectionneur et le sectionneur de terre sont en position d'ouverture.

Après l'essai complet à la température haute, la pression ne doit pas être inférieure à la pression minimale de fonctionnement.

7.105 Essais pour vérifier le bon fonctionnement de l'indicateur de position

7.105.1 Généralités

Ces essais s'appliquent quand un indicateur de position conforme au 6.104.3.2 est utilisé.

L'équipement doit satisfaire à tous les essais définis en 7.105.2, afin de confirmer à la fois la résistance suffisante de la chaîne cinématique de puissance et la fiabilité de la chaîne cinématique de l'indicateur de position.

Un spécimen peut être utilisé pour chaque mode de fonctionnement.

7.105.2 Essais sur la chaîne cinématique de puissance et la chaîne cinématique de l'indicateur de position

Le contact mobile est verrouillé en position de fermeture pour un sectionneur et en position d'ouverture pour un sectionneur de terre.

Dans le cas d'un sectionneur ou sectionneur de terre triphasé entraîné par un dispositif de manœuvre commun, seul le contact mobile du pôle le plus éloigné du point de transport de l'énergie provenant de la source d'alimentation située le long de la chaîne cinématique de puissance est verrouillé.

Les essais consistent en trois tentatives effectuées sur l'appareil de connexion avec son propre dispositif de manœuvre complet équipé d'un dispositif limiteur de contrainte (le cas échéant) et/ou d'un contrôleur de couple (d'effort) (le cas échéant).

- Concernant la manœuvre (dépendante ou indépendante) manuelle, la poignée de commande normale doit être utilisée pour effectuer les tentatives. Au cours des essais, un effort équivalent au double des forces normales doit être appliqué, avec un minimum de 200 N et un maximum de 750 N ou un maximum correspondant à la force de mise en fonctionnement d'un dispositif limiteur de contrainte ou d'un contrôleur de couple (d'effort). Cet effort doit être appliqué à mi-longueur de la partie préhensible de la poignée de commande. Lorsque la poignée de commande ou le dispositif de manœuvre comporte un dispositif permettant de limiter le couple (effort) de manœuvre, l'appareil de connexion doit être manœuvré jusqu'à ce que le dispositif limiteur de contrainte fonctionne, à condition que la poignée de commande avec le dispositif limiteur de contrainte ne soit pas interchangeable avec d'autres poignées.
- Concernant la manœuvre (dépendante ou indépendante) à source d'énergie extérieure, la tension maximale d'alimentation ou la pression maximale d'alimentation pour la manœuvre (si alimentée par une source d'énergie extérieure ou si entraînée par un déclencheur) comme défini en 5.9 et 5.11.102, doit être appliquée respectivement lors des tentatives. En présence d'un dispositif limiteur de contrainte ou d'un contrôleur de couple (d'effort), l'appareil de connexion doit être manœuvré jusqu'à ce que le dispositif limiteur de contrainte ou le contrôleur de couple (d'effort) fonctionne.

Aucun réglage ou remplacement ne doit être effectué entre les tentatives le long de la chaîne de l'indicateur de position. Aucune rupture de la chaîne cinématique mécanique ne doit être produite pendant l'essai, à l'exception des dispositifs limiteurs de contrainte conçus pour se rompre et qui doivent être remplacés après leur rupture. L'essai est considéré comme satisfaisant si après chaque tentative, les trois contacts mobiles restent dans la même position et l'indicateur de position indique correctement la position des contacts mobiles.

Si l'indicateur de position est marqué directement sur une partie mécanique de la chaîne cinématique de puissance, aucun essai supplémentaire n'est exigé.

L'enveloppe assurant la protection de la chaîne cinématique de l'indicateur de position doit être soumise à l'essai pour son IP et IK (conformément à 6.104.3.1). Les coups doivent être

appliqués aux points de l'enveloppe qui sont probablement les plus faibles pour ce qui concerne la protection de la chaîne cinématique de l'indicateur de position.

7.106 Essais de coupure de courant de transfert de barres sur les sectionneurs

7.106.1 Généralités

Ces essais doivent être réalisés uniquement sur les sectionneurs ayant un pouvoir d'établissement et de coupure de courant assigné de transfert de barres.

7.106.2 Essais d'établissement et de coupure

7.106.2.1 Disposition du sectionneur pour les essais

Le sectionneur en essai doit être monté complètement sur son propre support ou sur un support équivalent. Son dispositif de manœuvre doit être actionné dans les conditions spécifiées et en particulier si le dispositif de manœuvre est à commande électrique ou pneumatique, il doit être alimenté, respectivement, sous sa tension minimale ou sa pression minimale d'alimentation pour la manœuvre.

Avant d'entreprendre les essais d'établissement et de coupure, des manœuvres à vide doivent être effectuées pour établir les caractéristiques fonctionnelles mécaniques du sectionneur, telles que la vitesse de déplacement des contacts, les durées de fermeture et d'ouverture.

Les sectionneurs à isolation gazeuse doivent être soumis aux essais à leur pression minimale de fonctionnement pour la coupure.

Les sectionneurs à manœuvre indépendante manuelle peuvent être manœuvrés à distance, au moyen d'une commande à source d'énergie extérieure de manière à obtenir des vitesses de manœuvre équivalentes à celles données par la commande manuelle.

Les effets de l'alimentation du sectionneur par chacune de ses bornes doivent être pris en considération. Quand les dispositions matérielles d'un côté du sectionneur diffèrent de celles de l'autre côté, l'extrémité d'alimentation du circuit d'essai doit être reliée au côté du sectionneur dont le raccordement présente les conditions les plus sévères. En cas de doute, 50 % des essais d'établissement et de coupure doivent être effectués en alimentant le sectionneur d'un côté et 50 % en l'alimentant de l'autre côté.

Seuls des essais monophasés sur un seul pôle d'un sectionneur tripolaire sont nécessaires à condition que le pôle ne soit pas placé dans une condition plus favorable que le sectionneur tripolaire complet en ce qui concerne:

- la vitesse de fermeture;
- la vitesse d'ouverture;
- l'influence des phases adjacentes.

Les essais monophasés conviennent pour établir les performances d'établissement et de coupure d'un sectionneur sous réserve qu'il puisse être démontré que la durée et le développement de l'arc sont tels qu'une phase adjacente ne peut être atteinte. Si un essai monophasé démontre que l'arc peut atteindre une phase adjacente, des essais triphasés doivent alors être réalisés en utilisant la disposition particulière du sectionneur.

7.106.2.2 Mise à la terre du circuit d'essai et du sectionneur

Le châssis du sectionneur et le circuit d'essai doivent être reliés à la terre (voir 7.106.2.6).

7.106.2.3 Fréquence d'essai

Les sectionneurs doivent être soumis aux essais à leur fréquence assignée. Toutefois, les sectionneurs de 50 Hz ou 60 Hz peuvent être soumis aux essais à l'une de ces deux fréquences, les deux étant considérées comme équivalentes pour cet essai. La tolérance sur la fréquence d'essai doit être comprise dans les limites de $\pm 10\%$ selon le Tableau C.1.

7.106.2.4 Tension d'essai

La tension d'essai U_{BT} doit être définie afin d'obtenir la tension assignée de transfert de barres ($^{+10}_0\%$) exigée, et doit être mesurée pendant l'essai aux bornes du sectionneur ouvert.

Comme indiqué en 7.106.2.1, seuls des essais monophasés sont généralement exigés. Si des essais triphasés sont exigés, la tension d'essai dans chaque phase ne doit pas s'écarter de la moyenne des tensions d'essai de plus de 10 %.

La tension de rétablissement à fréquence industrielle doit être maintenue pendant au moins 0,3 s après l'interruption du courant.

7.106.2.5 Courant d'essai

Le courant d'essai doit être égal au courant assigné de transfert de barres ($^{+10}_0\%$) défini en 5.108.1. Le courant à couper doit être symétrique. Les contacts du sectionneur ne doivent pas se séparer avant disparition de la composante transitoire due à la fermeture du circuit.

En cas d'essais triphasés, le courant d'essai est égal à la moyenne des courants dans les trois phases. Le courant d'essai dans chaque phase ne doit pas différer de la moyenne de plus de 10 %.

7.106.2.6 Circuits d'essai

Le circuit d'essai représenté à la Figure 11 doit avoir un facteur de puissance inférieur ou égal à 0,5. La Figure 11 présente deux exemples de circuit d'essai.

Si des essais triphasés sont exigés, le neutre du circuit d'alimentation et le circuit côté charge doivent être reliés à la terre.

L'isolation phase-terre n'est pas vérifiée pendant l'essai en cas d'utilisation du circuit représenté à la Figure 11. Si les performances de l'isolation doivent être vérifiées, il est nécessaire d'utiliser d'autres circuits d'essai qui fournissent la tension assignée phase-terre.

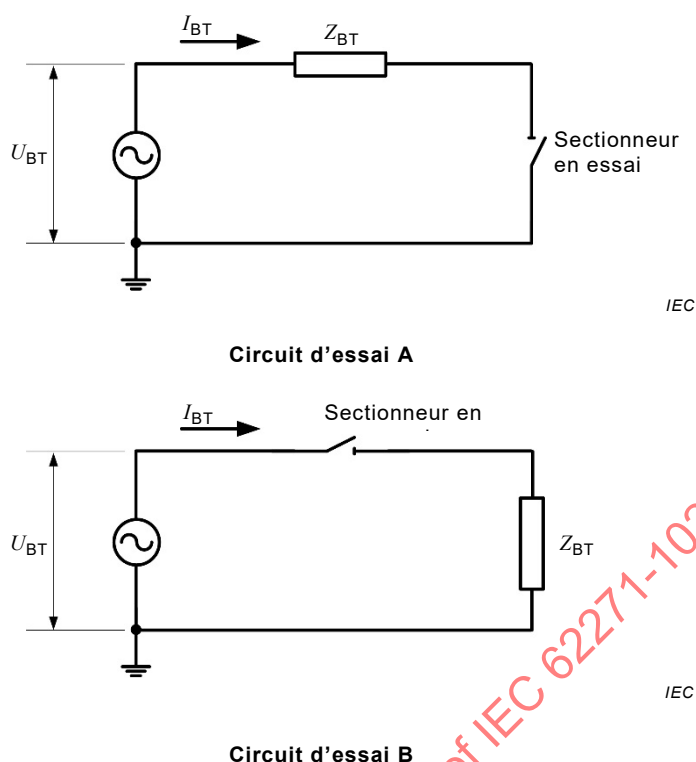


Figure 11 – Exemple de circuit pour les essais de coupure de courant de transfert de barres

7.106.2.7 Séquence d'essai

Cent cycles d'établissement-coupure doivent être effectués.

NOTE Ces 100 cycles ne sont pas considérés comme suffisants pour démontrer une endurance électrique, mais ils donnent des indications sur l'érosion des contacts.

La manœuvre d'ouverture doit suivre la manœuvre de fermeture avec un retard entre les deux manœuvres suffisant pour que tout courant transitoire éventuel ait disparu. L'intervalle de temps entre les manœuvres doit être également suffisant pour le refroidissement du sectionneur, si cela est spécifié dans les instructions du constructeur.

Les essais doivent être effectués sans remise en état du sectionneur pendant la séquence d'essai.

7.106.2.8 Comportement du sectionneur pendant les essais

Le sectionneur doit fonctionner correctement sans présenter de signe exagéré de fatigue mécanique ou électrique.

L'émission de flammes ou de particules métalliques hors du sectionneur est acceptable pendant la manœuvre si cela ne réduit pas son niveau d'isolement. Aucune émission de flamme ou de particules métalliques ne doit être projetée au-delà des limites spécifiées par le constructeur dans les instructions de fonctionnement.

7.106.2.9 État du sectionneur après les essais

Les caractéristiques fonctionnelles mécaniques doivent être comprises dans les tolérances spécifiées par le constructeur et l'isolation du sectionneur doit être pratiquement dans le même état qu'avant les essais.

Il est admis que l'usure mécanique et l'érosion des contacts par l'arc ainsi que des dépôts sur les isolateurs provenant de la décomposition du milieu extincteur de l'arc altèrent le pouvoir d'établissement et de coupure du sectionneur. Cependant, le courant admissible et les caractéristiques d'isolement du sectionneur ne doivent pas être altérés. La qualité du matériau éventuellement utilisé pour la coupure de l'arc peut être altérée et la quantité en être réduite au-dessous de la quantité normale.

Les caractéristiques d'isolement du sectionneur en position d'ouverture ne doivent pas être réduites au-dessous des valeurs correspondant à une usure et un vieillissement normaux, par suite d'une détérioration des parties isolantes.

La manœuvre à vide et l'inspection visuelle du sectionneur après les essais sont habituellement suffisantes pour contrôler les caractéristiques d'isolement du sectionneur et son courant admissible. En cas de doute, il peut être nécessaire de réaliser les essais appropriés comme mentionné ci-dessous.

- En cas de doute sur les caractéristiques d'isolement du sectionneur, un essai de tension en tant que vérification de l'état du sectionneur selon 7.2.12 doit être réalisé pour vérifier les caractéristiques d'isolement. Les méthodes d'essai alternatives spécifiées en 6.2.11 de l'IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 peuvent être utilisées pour $U_r > 72,5$ kV. La pression minimale de fonctionnement du gaz pour l'isolement doit être utilisée, le cas échéant. Pour les sectionneurs qui sont scellés à vie, l'essai de tension en tant que vérification d'état est obligatoire.
- En cas de doute sur le courant admissible du sectionneur, le mesurage de la résistance du circuit principal peut être effectué partout où il est possible de mesurer la résistance près des contacts. L'augmentation de la résistance du circuit principal après l'essai ne doit pas dépasser 20 %. Si la résistance des contacts dépasse cette valeur, un essai au courant permanent assigné (7.5) doit démontrer que l'échauffement des contacts ne dépasse pas les limites indiquées au Tableau 14 de l'IEC 62271-1:2017, en surveillant la température aux points les plus proches possible des contacts principaux.

Pour les sectionneurs équipés de résistances dans les appareillages sous enveloppe métallique à isolation gazeuse, la variation maximale de la résistance ohmique de la résistance complète après l'essai ne doit pas dépasser 5 % de la valeur mesurée avant l'essai. Une inspection visuelle de la résistance doit être effectuée après les essais de type. Il ne doit être observé aucun signe d'amorçage à travers la résistance ni aucun dommage mécanique. Il peut être nécessaire de démonter le sectionneur en vue d'une inspection visuelle.

7.106.2.10 Rapports d'essais de type

Outre les exigences énoncées en 7.1.2 et 7.1.3 de l'IEC 62271-1:2017, le rapport d'essai de type doit comprendre les informations suivantes:

- a) enregistrements oscillographiques ou similaires typiques des essais réalisés (au moins un oscillogramme pour chaque dizaine de manœuvres);
- b) description du circuit d'essai;
- c) valeurs des courants d'essai;
- d) valeurs des tensions d'essai;
- e) valeurs des tensions de rétablissement à fréquence industrielle;
- f) ~~valeurs des tensions transitoires de rétablissement présumées (TRV – transient recovery voltages)~~ vide;
- g) valeurs des durées d'arc;
- h) nombre de manœuvres d'établissement et de coupure;
- i) état des contacts après l'essai (voir 7.106.2.9).

Il convient d'inclure des renseignements généraux concernant la structure support du sectionneur. La durée de manœuvre du sectionneur et le type de dispositifs de manœuvre utilisés pendant les essais doivent être enregistrés.

7.107 Essais de coupure de courant induit sur les sectionneurs de terre

7.107.1 Généralités

Les essais de type des sectionneurs de terre ayant un pouvoir d'établissement et de coupure de courant assigné d'induction doivent comporter:

- des essais pour démontrer le pouvoir d'établissement et de coupure du courant d'induction électromagnétique;
- des essais pour démontrer le pouvoir d'établissement et de coupure du courant d'induction électrostatique.

7.107.2 Disposition du sectionneur de terre pour les essais

Le sectionneur de terre en essai doit être monté complètement sur son propre support ou sur un support équivalent. Son dispositif de manœuvre doit être actionné dans les conditions spécifiées et en particulier si le dispositif de manœuvre est à commande électrique ou pneumatique, il doit être alimenté, respectivement, sous sa tension minimale d'alimentation ou sa pression minimale d'alimentation.

Avant d'entreprendre les essais d'établissement et de coupure, des manœuvres à vide doivent être effectuées et les informations détaillées des caractéristiques fonctionnelles du sectionneur de terre, telles que la vitesse de déplacement des contacts, les durées de fermeture et d'ouverture doivent être enregistrées (voir 7.102.3.2).

Les sectionneurs de terre à isolation gazeuse doivent être soumis aux essais à leur pression (masse volumique) minimale de fonctionnement du gaz pour la coupure.

Les sectionneurs de terre à commande manuelle peuvent être manœuvrés à distance, au moyen d'une commande à source d'énergie extérieure de manière à obtenir des vitesses de manœuvre équivalentes à celles données par la commande manuelle.

Seuls des essais monophasés sur un seul pôle d'un sectionneur de terre tripolaire sont nécessaires à condition que le pôle ne soit pas placé dans une condition plus favorable que le sectionneur de terre tripolaire complet en ce qui concerne:

- la vitesse de fermeture;
- la vitesse d'ouverture;
- l'influence des pôles adjacents ou les effets dus à la proximité des phases sous tension.

Les essais monophasés conviennent pour établir les performances d'établissement et de coupure d'un sectionneur de terre, sous réserve qu'il puisse être démontré que la durée et le développement de l'arc sont tels qu'une phase adjacente sous tension ne peut être atteinte. Si un essai monophasé démontre que l'arc peut atteindre une phase adjacente sous tension, des essais triphasés doivent alors être effectués en utilisant la configuration particulière du sectionneur de terre.

7.107.3 Mise à la terre du circuit d'essai et du sectionneur de terre

Le circuit d'essai doit être mis à la terre par la borne du sectionneur de terre normalement reliée à la terre.

7.107.4 Fréquence d'essai

Les sectionneurs de terre doivent être soumis aux essais à leur fréquence assignée. Toutefois, les sectionneurs de terre de 50 Hz ou 60 Hz peuvent être soumis aux essais à l'une de ces deux fréquences, les deux étant considérées comme équivalentes pour cet essai. La tolérance sur la fréquence d'essai doit être comprise dans les limites de $\pm 10 \%$ selon le Tableau C.1.

7.107.5 Tension d'essai

Les tensions d'essai doivent être définies afin d'obtenir la tension spécifiée au Tableau 9 avant l'établissement et après la coupure du courant, et doivent être mesurées aux bornes du sectionneur de terre pendant l'essai.

Comme indiqué en 7.107.2, seuls des essais monophasés sont généralement exigés. Si des essais triphasés sont exigés, la tension d'essai dans chaque phase ne doit alors pas différer de la moyenne des tensions d'essai de plus de 10 %.

La tension d'essai à fréquence industrielle doit être maintenue pendant au moins 0,3 s après la coupure du courant.

7.107.6 Courants d'essai

Les courants d'essai doivent être égaux aux courants assignés d'induction ($^{+10}_{0} \%$). Le courant à couper doit être symétrique. Les contacts du sectionneur de terre ne doivent pas se séparer avant disparition de la composante transitoire due à la fermeture du circuit.

Si des essais d'établissement et de coupure tripolaires sont effectués, le courant d'essai doit être égal à la moyenne des courants dans les trois pôles. Le courant d'essai dans chaque phase ne doit pas différer de la moyenne des courants d'essai de plus de 10 %.

Avant la séparation des contacts, il convient que la forme d'onde du courant d'essai, pour les essais de coupure de courant d'induction électrostatique, soit autant que possible sinusoïdale (voir l'IEC/TR 62271-305). Cette condition est considérée comme satisfaite si le rapport de la valeur efficace du courant total à la valeur efficace de la composante fondamentale ne dépasse pas 1,2. Le courant d'essai ne doit pas passer par zéro plus d'une fois par demi-période à fréquence industrielle avant séparation des contacts.

7.107.7 Circuits d'essai

7.107.7.1 Généralités

Pour les essais de type, les lignes de transport peuvent être remplacées par des éléments composés de condensateurs, de bobines d'inductance et de résistances.

Si des essais triphasés sont exigés, le circuit d'essai doit comporter dans chaque phase les mêmes éléments que le circuit d'essai monophasé, en vue d'obtenir les tensions et les courants d'essai appropriés. Le neutre du circuit d'alimentation doit être mis à la terre.

En variante, d'autres circuits d'essai peuvent être utilisés à condition qu'ils satisfassent aux exigences relatives aux courants d'essai, aux tensions d'essai et aux paramètres de tension transitoire de rétablissement.

7.107.7.2 Circuit d'essai pour l'établissement et la coupure de courant d'induction électromagnétique

Le circuit d'essai monophasé (Figure 12) comprend un circuit d'alimentation fournissant la tension d'essai et le courant d'essai appropriés avec un facteur de puissance inférieur ou égal à 0,15. Les éléments R et C sont choisis pour donner les paramètres appropriés de tension transitoire de rétablissement. La résistance d'amortissement R peut être connectée en série ou en parallèle avec le condensateur C .

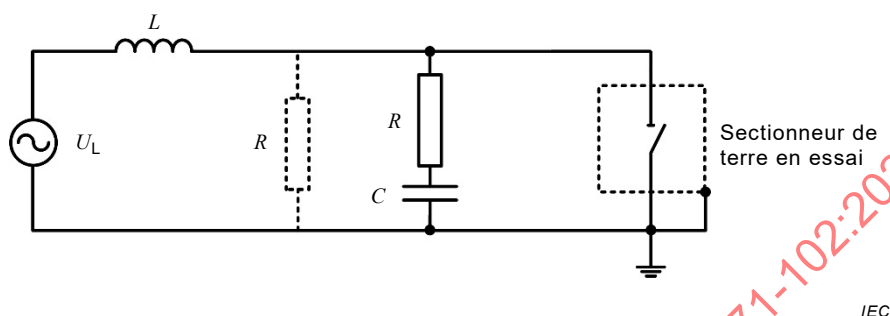


Figure 12 – Circuit d'essai pour l'établissement-coupure de courant d'induction électromagnétique

Les valeurs de la tension d'alimentation (U_L) et de l'inductance (L) peuvent être calculées à partir des valeurs de tension et de courant figurant dans le Tableau 9, pour obtenir les valeurs appropriées du courant d'essai et de la tension de rétablissement à fréquence industrielle.

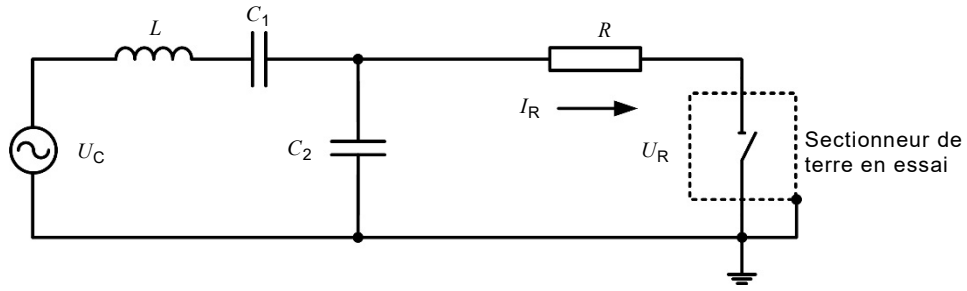
Il convient que la forme d'onde de la tension transitoire de rétablissement présumée soit triangulaire à cause de l'impédance d'onde des lignes de transport connectées. En variante, des tensions transitoires de rétablissement de forme $(1 - \cos)$ peuvent être utilisées. Les valeurs de R et de C peuvent être choisies pour obtenir les paramètres appropriés de la tension transitoire de rétablissement spécifiés au Tableau 17.

Tableau 17 – Valeurs normalisées des tensions de rétablissement pour les essais de coupure de courant d'induction électromagnétique

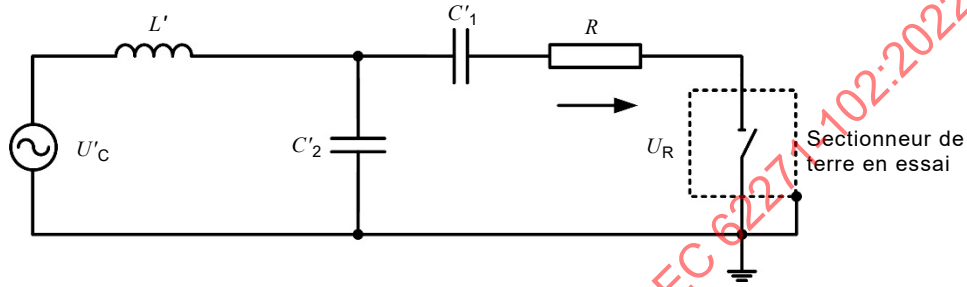
Tension assignée U_r kV	Classe A			Classe B				
	Tension de rétablissement à fréquence industrielle	Valeur de crête de la TTR	Durée de montée de la TTR	Tension de rétablissement à fréquence industrielle	Valeur de crête de la TTR	Durée de montée de la TTR		
	$\begin{pmatrix} +10 \\ 0 \end{pmatrix} \%$ kV (efficace)	$\begin{pmatrix} +10 \\ 0 \end{pmatrix} \%$ kV	$\begin{pmatrix} 0 \\ -10 \end{pmatrix} \%$ μs	$\begin{pmatrix} +10 \\ 0 \end{pmatrix} \%$ kV (efficace)	$\begin{pmatrix} +10 \\ 0 \end{pmatrix} \%$ kV	$\begin{pmatrix} 0 \\ -10 \end{pmatrix} \%$ μs		
72,5	0,5	1,1	100	2	4,5	300		
100								
123								
145	1	2,3	200			330		
170								
245	1,4	3,2				850		
300		10				23	1 000	
362	2	4,5	325			2 000		
420							20	
550						65		145
800			11,3		750	145	2 400	
1 100	5	11,3	750	65	145	2 400		
1 200								

NOTE 1 Les valeurs des tensions de rétablissement sont valables pour des essais monophasés ou triphasés.

NOTE 2 L'onde de la TTR présumée peut être de forme triangulaire ou de forme (1 – cos) (voir 7.107.7.2). Les valeurs des durées de montée de la TTR sont valables pour l'une ou l'autre des formes d'onde.



Circuit d'essai 1



Circuit d'essai 2

$$L = Z_0^2 \times C_1$$

$$L' = L \times \left[\frac{C_1}{C_1 + C_2} \right]^2$$

$$u_C = \frac{i_R}{\omega C_1}$$

$$u'_C = \left[\frac{C_1}{C_1 + C_2} \right] \times u_C, \text{ ou } u'_C = u_R$$

$$C_2 = C_1 \times \left[\frac{u_C}{u_R} - 1 \right] \quad C'_1 = C_1 + C_2 \quad C'_2 = C_2 \left(1 + \frac{C_2}{C_1} \right)$$

où

Z_0 est l'impédance d'onde de la ligne:

- 425 Ω pour 52 kV < $U_r \leq 170$ kV;
- 380 Ω pour 245 kV $\leq U_r \leq 300$ kV;
- 325 Ω pour 362 kV $\leq U_r \leq 800$ kV;
- 290 Ω pour 1 100 kV $\leq U_r \leq 1\,200$ kV.

Légende

i_R est le courant assigné d'induction suivant le Tableau 9

u_R est la tension assignée d'induction suivant le Tableau 9

C_1 est la capacité du circuit d'essai donnée dans le Tableau 18

Figure 13 – Circuits d'essai pour l'établissement-coupure de courant d'induction électrostatique

7.107.7.3 Circuits d'essai pour l'établissement-coupure de courant d'induction électrostatique

Le circuit d'essai 1 ou le circuit d'essai 2 de la Figure 13 doit être appliqué aux essais en laboratoire, les deux étant équivalents, à condition que les relations entre les paramètres de circuit soient satisfaites.

Le facteur de puissance du circuit d'essai ne doit pas dépasser 0,15. Les valeurs de la tension d'alimentation (U_C), de l'inductance L et de la capacité C_2 du circuit d'essai 1 peuvent être calculées à partir des valeurs données de C_1 du Tableau 18 et des valeurs assignées de courant et de tension du Tableau 9, au moyen des équations indiquées à la Figure 13. Il en résulte des valeurs appropriées de courant et de tension d'essai, de fréquence de courant d'appel et d'impédance d'onde du circuit d'essai. Les valeurs pour le circuit d'essai 2 peuvent être calculées à partir des valeurs obtenues pour le circuit d'essai 1.

Une résistance (R), de valeur non supérieure à 10 % de l'impédance capacitive [$1 / \omega (C_1 + C_2) = 1 / \omega C_1$], vue par le sectionneur de terre, peut être insérée dans les circuits comme représenté à la Figure 13. Il convient cependant que la valeur choisie ne dépasse pas l'impédance d'onde de la ligne de transport prise en considération (voir Tableau 18) et ne produise pas un amortissement apériodique du courant d'appel à la fermeture du sectionneur de terre.

Tableau 18 – Capacités du circuit d'essai (valeurs C_1) pour l'établissement-coupure de courant d'induction électrostatique

Tension assignée U_r kV	Capacité du circuit d'essai	
	Classe A μF	Classe B μF
72,5 – 100 – 123	0,07	0,27
145 – 170	0,13	
245	0,15	
300		0,80
362 – 420	0,29	1,18
550 – 800	0,35	1,47
1 100 – 1 200	0,8	2,63

NOTE Les valeurs de C_1 peuvent être calculées d'après la relation:

$$C_1 = (6D) / (\pi Z_0)$$

ou

D est la longueur de la ligne, en km;

Z_0 est l'impédance d'onde de la ligne, en Ω .

Impédance d'onde retenue par hypothèse:

- 72,5 kV $\leq U_r \leq$ 170 kV: 425 Ω ;
- 245 kV $\leq U_r \leq$ 300 kV: 380 Ω ;
- 362 kV $\leq U_r \leq$ 800 kV: 325 Ω .
- 1 100 kV $\leq U_r \leq$ 1 200 kV: 290 Ω .

7.107.7.4 Séquences d'essai

Dix cycles d'établissement-coupure de courant d'induction électromagnétique et dix cycles d'établissement-coupure de courant d'induction électrostatique doivent être effectués.

NOTE Ces 10 cycles ne sont pas considérés comme suffisants pour démontrer une endurance électrique; toutefois ils donnent des indications sur l'érosion des contacts.

La manœuvre d'ouverture doit suivre la manœuvre de fermeture avec un retard suffisant entre les deux manœuvres pour que tout courant transitoire éventuel ait disparu.

Les essais doivent être effectués sans remise en état du sectionneur de terre pendant le programme d'essai.

7.107.7.5 Comportement du sectionneur de terre pendant les essais

Le sectionneur de terre doit fonctionner correctement sans présenter de signe exagéré de fatigue mécanique ou électrique.

L'émission de flammes ou de particules métalliques hors du sectionneur de terre est acceptable pendant la manœuvre si cela ne réduit pas son niveau d'isolement. Aucune émission de flamme ou de particules métalliques ne doit être projetée au-delà des limites spécifiées par le constructeur dans les instructions de fonctionnement.

7.107.7.6 État du sectionneur de terre après les essais

Les caractéristiques fonctionnelles mécaniques doivent être comprises dans les tolérances spécifiées par le constructeur et l'isolation du sectionneur de terre doit être pratiquement dans le même état qu'avant les essais. Le sectionneur de terre doit être capable de supporter la valeur de crête du courant admissible assignée et le courant de courte durée admissible assigné.

Une usure mécanique et une érosion des contacts par l'arc ainsi que des dépôts sur les isolateurs provenant de la décomposition du milieu extincteur de l'arc sont acceptables.

L'inspection visuelle et la manœuvre à vide du sectionneur de terre après les essais sont habituellement suffisantes pour contrôler les exigences ci-dessus. En cas de doute, il peut être nécessaire de réaliser les essais appropriés comme mentionné ci-dessous.

En cas de doute sur les caractéristiques d'isolement du sectionneur de terre, un essai de tension en tant que vérification de l'état du sectionneur selon 7.2.12 doit être réalisé pour vérifier les caractéristiques d'isolement. En variante, les dispositions de 6.2.11 de l'IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 peuvent être utilisées pour $U_r > 72,5$ kV. La pression minimale de fonctionnement du gaz pour l'isolement doit être utilisée, le cas échéant. Pour les sectionneurs de terre qui sont scellés à vie, l'essai de tension en tant que vérification d'état est obligatoire.

7.107.7.7 Rapports d'essais de type

Outre les exigences énoncées en 7.1.2 et 7.1.3 de l'IEC 62271-1:2017, le rapport d'essai de type doit comprendre les informations suivantes:

- a) enregistrements oscillographiques ou similaires typiques;
- b) description des circuits d'essai;
- c) valeurs des courants d'essai;
- d) valeurs des tensions d'essai;
- e) valeurs des tensions de rétablissement à fréquence industrielle;
- f) valeurs des tensions transitoires de rétablissement présumées;
- g) valeurs des durées d'arc;
- h) nombre de manœuvres d'établissement et de coupure;
- i) état du sectionneur de terre après l'essai.

Il convient d'inclure des renseignements généraux concernant la structure support du sectionneur de terre. La durée de manœuvre du sectionneur de terre et le type de dispositifs de manœuvre utilisés pendant les essais doivent être enregistrés.

7.108 Essais de coupure de courant de jeux de barres à vide sur les sectionneurs

7.108.1 Généralités

Ces essais doivent être réalisés sur des sectionneurs qui font partie intégrante d'un appareillage à isolation gazeuse, classés pour la coupure de courant de jeux de barres à vide.

NOTE La limite de 300 kV est dérivée de l'expérience avec l'appareillage à isolation de gaz SF₆. Les performances diélectriques des sectionneurs lors de la coupure de courant de jeux de barres à vide et les performances par rapport à l'atténuation de la surtension transitoire très rapide (VFTO) lors de la coupure dépendent de l'isolant gazeux utilisé. Pour plus d'informations, voir la brochure technique CIGRÉ n° 260, 2004 [7].

7.108.2 Séquences d'essai

Trois séquences d'essai sont définies:

- *séquence d'essai 1:* mise en et hors circuit d'un très court tronçon de jeu de barres. Cette séquence d'essai doit être effectuée sur les sectionneurs de $U_r \geq 300$ kV;
- *séquence d'essai 2:* mise en et hors circuit de condensateurs en parallèle de disjoncteurs en opposition de phase à 180°. Cette séquence d'essai n'est pas obligatoire;
- *séquence d'essai 3:* vérification du pouvoir d'établissement et de coupure. Cette séquence d'essai n'est pas obligatoire.

NOTE 1 La séquence d'essai 2 est un essai de type spécial à réaliser pour les sectionneurs placés près des disjoncteurs équipés de condensateurs en parallèle.

NOTE 2 La séquence d'essai 3 est un essai de type spécial à effectuer selon cette spécification et selon accord entre le constructeur et l'utilisateur. Cet essai permet de démontrer le pouvoir de coupure du sectionneur lors de la mise hors tension de jeux de barres de grande longueur. Des valeurs typiques de courants sont données au Tableau 11.

7.108.3 Disposition du sectionneur pour les essais

Le dispositif de manœuvre du sectionneur en essai doit être utilisé selon les spécifications du constructeur et, en particulier, s'il est alimenté par une source d'énergie extérieure, il doit être manœuvré à la tension minimale d'alimentation et/ou la pression minimale d'alimentation spécifiées. L'intervalle de temps entre les manœuvres doit être suffisant pour le refroidissement du sectionneur, si cela spécifié dans les instructions du constructeur.

Avant de commencer les essais d'établissement et de coupure, le sectionneur doit être manœuvré à vide et les informations détaillées des caractéristiques fonctionnelles du sectionneur telles que les durées de fermeture et d'ouverture doivent être enregistrées (voir 7.102.3.2).

Les essais doivent être réalisés à la pression (ou masse volumique) minimale de fonctionnement du gaz pour la coupure du sectionneur en essai. Les compartiments adjacents doivent également être remplis à leur pression (masse volumique) minimale de fonctionnement du gaz.

Dans la plupart des cas, la conception du sectionneur comporte des asymétries (par exemple, capots asymétriques, différences entre contact mobile/contact fixe, etc.). Dans ces cas, la disposition d'essai du sectionneur doit être celle qui correspond aux conditions d'essai les plus défavorables. Pour la séquence d'essai 1, la disposition d'essai du sectionneur est celle pour laquelle à la distance de préamorçage est maximale au cours d'une manœuvre de

fermeture. Pour les séquences d'essai 2 et 3, la disposition d'essai du sectionneur n'a pas d'influence notable.

Seuls des essais monophasés sur un seul des pôles d'un sectionneur tripolaire sont nécessaires, à condition que la vitesse de manœuvre ne soit pas modifiée de plus de $\pm 15\%$.

Pour les sectionneurs ayant les trois pôles dans une même enveloppe, une disposition d'essai en triphasé est exigée. Une phase est reliée au circuit d'essai, et les deux pôles non utilisés dans le processus de coupure doivent être reliés à la terre, à leurs deux extrémités.

7.108.4 Fréquence d'essai

Les sectionneurs doivent être soumis aux essais à leur fréquence assignée. Toutefois, les sectionneurs de 50 Hz ou 60 Hz peuvent être soumis aux essais à l'une de ces deux fréquences, les deux étant considérées comme équivalentes pour cet essai. La tolérance sur la fréquence d'essai doit être comprise dans les limites de $\pm 10\%$ selon le Tableau C.1.

7.108.5 Tensions d'essai pour les essais d'établissement et de coupure

Pendant les essais d'établissement et de coupure, la tension à fréquence industrielle doit être appliquée et maintenue pendant au moins 0,3 s avant et après la manœuvre. Dans le cas où le jeu de barres du côté charge est préchargé sous tension continue (séquence d'essai 1), la tension continue doit être appliquée à sa valeur spécifiée pendant environ 1 min avant la manœuvre de fermeture. Le jeu de barres côté charge ne doit pas être mis à la terre entre les manœuvres d'ouverture et de fermeture. Il convient que le circuit d'essai ne comporte pas d'éléments susceptibles de provoquer une diminution du niveau de charge piégée.

En référence aux Figures 14, 16 et 17, les tensions d'essai qui doivent être appliquées du côté source et du côté charge du dispositif d'essai sont indiquées au Tableau 19.

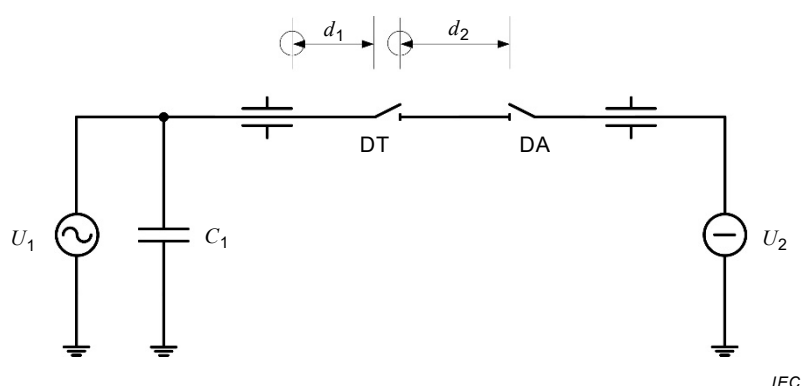
Les tensions d'essai du Tableau 19 sont valables pour le sectionneur en position d'ouverture.

NOTE Dans la séquence d'essai 3, la tension d'essai peut être considérablement plus élevée lorsque le sectionneur est en position de fermeture. Cela est dû à des phénomènes de résonance, qui apparaissent notamment en cas de forte impédance du transformateur d'alimentation, ce qui est une caractéristique normale des transformateurs utilisés pour les essais diélectriques en tension alternative. Cette tension dont l'augmentation ne dépasse pas en principe 10 % renforce la sévérité des conditions d'essai.

Tableau 19 – Tensions d'essai pour les essais d'établissement et de coupure

Séquence d'essai	Tension d'essai	
	Côté source U_1	Côté charge U_2
1	$1,1 \times U_r / \sqrt{3}$	Précharge à tension continue négative $-1,1 \times U_r \times \sqrt{2} / \sqrt{3}$
2	$1,1 \times U_r / \sqrt{3}$	Tension alternative en opposition de phase $1,1 \times U_r / \sqrt{3}$
3	$U_r / \sqrt{3}$	–

NOTE Le coefficient 1,1 a été choisi pour tenir compte des effets statistiques inhérents à ce type de phénomènes de mise en et hors circuit, et pour réduire le nombre d'essais à ceux indiqués au Tableau 20. Comme il convient que la séquence d'essai 3 indique seulement le pouvoir d'établissement-coupure du sectionneur, cette augmentation de la tension d'essai n'est pas nécessaire.



Légende

DT Sectionneur en essai

DA Sectionneur auxiliaire

Les longueurs de jeux de barres d_1 et d_2 correspondent aux distances suivantes:

d_1 : distance entre le contact ouvert du sectionneur en essai (DT – *disconnecter under test*) et la traversée;

d_2 : distance entre le contact ouvert du sectionneur en essai (DT) et le contact ouvert du sectionneur auxiliaire (DA).

Figure 14 – Circuit d'essai pour la séquence d'essai 1

7.108.6 Circuits d'essai pour les essais d'établissement et de coupure

7.108.6.1 Coupure d'un tronçon très court de jeu de barres, séquence d'essai 1

7.108.6.1.1 Généralités

La Figure 14 représente le circuit d'essai correspondant à la séquence d'essai 1. Le côté charge doit être représenté par un tronçon de jeu de barres de longueur d_2 comprise entre 3 m et 5 m. Le raccordement côté alimentation doit être réalisé par un autre tronçon de jeu de barres de longueur, d_1 . Pour engendrer des transitoires très rapides (VFT) représentatifs, le rapport d_2/d_1 , doit être compris entre 0,36 et 0,52. Une capacité additionnelle localisée C_1 doit être connectée au circuit côté source. La valeur de C_1 doit être choisie de telle sorte que la valeur de crête de la tension par rapport à la terre, au niveau des bornes du sectionneur soit conforme à celle spécifiée en 7.108.6.1.2.

Avant de réaliser une manœuvre de fermeture, l'élément de jeu de barres côté charge doit être chargé sous une tension continue conformément aux valeurs indiquées au Tableau 18 et la source de tension continue séparée par le sectionneur auxiliaire DA.

7.108.6.1.2 Valeurs des tensions transitoires

Les tensions transitoires mesurées à l'endroit du sectionneur pendant une manœuvre de fermeture sont utilisées pour caractériser le comportement du circuit d'essai et assurer la conformité des caractéristiques homogènes de surtensions dans les conditions d'essai. Deux aspects distincts des tensions transitoires sont importants: les phénomènes transitoires très rapides (VFT) et les phénomènes transitoires rapides (FT). Les VFT sont déterminés par la configuration du circuit comme décrit en 7.108.6.1.1. Les caractéristiques du circuit relatives aux phénomènes transitoires rapides doivent être vérifiées au moins une fois pour la disposition d'essai par un mesurage direct (voir 7.108.11) dans les conditions suivantes:

- tension d'essai côté source: $U_r/\sqrt{3}$;
- tension côté charge: 0 (pas de précharge).

Pour ces conditions, la valeur de crête maximale de la tension transitoire à la terre U_{TVE} au premier préamorçage lors d'une manœuvre de fermeture ne doit pas être inférieure à $1,4 \times U_r$

$\sqrt{2}/\sqrt{3}$ (pour des raisons pratiques, une variation de 5 % est considérée comme acceptable) et la durée avant la crête maximale doit être inférieure à 500 ns, (Figure 15).

Pour les sectionneurs équipés de résistances dans les appareillages sous enveloppe métallique à isolation gazeuse, la résistance doit être court-circuitée ou remplacée par un conducteur à âme massive avant les essais afin de vérifier les conditions du circuit d'essai décrites ci-dessus.

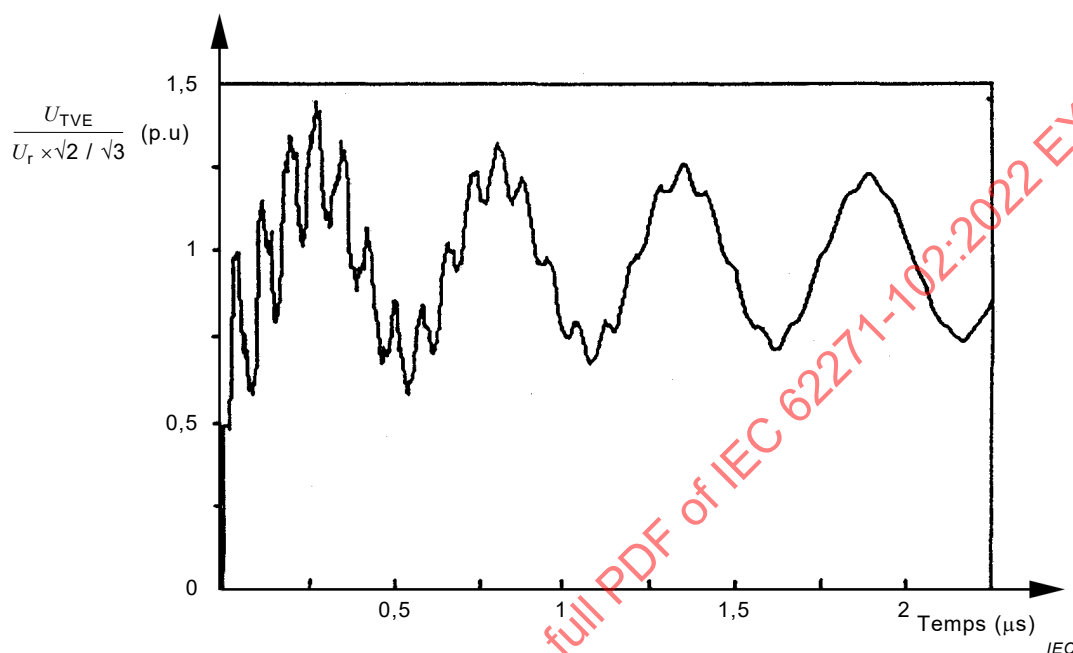


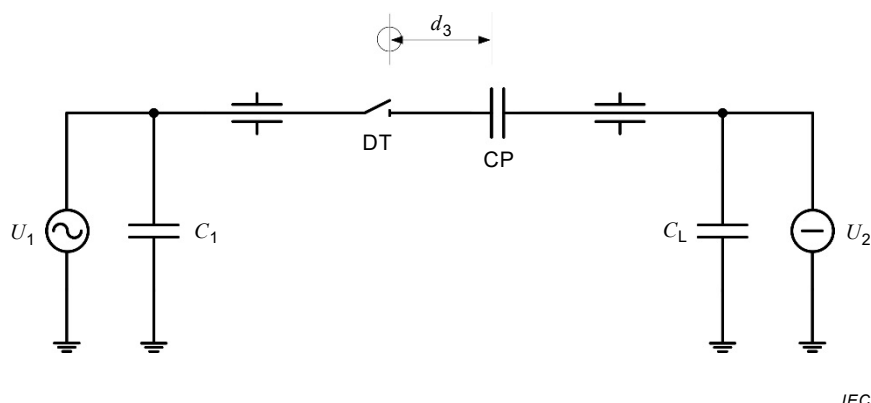
Figure 15 – Forme d'onde de tension typique (incluant les composantes VFT et FT)

7.108.6.2 Établissement-coupure en discordance de phases, séquence d'essai 2

La Figure 16 représente le circuit d'essai utilisé pour l'établissement-coupure en discordance de phases. Le condensateur en parallèle CP d'un disjoncteur peut être représenté par un disjoncteur réel avec son propre condensateur ou par une capacité adéquate de valeur égale ou supérieure à celle utilisée en service.

La distance d_3 entre le condensateur CP et le sectionneur doit être la plus courte possible. Les longueurs des autres parties du circuit d'essai ne sont pas spécifiées, mais il convient qu'elles soient aussi courtes que possible en vue de réduire le plus possible leur influence sur la capacité du circuit d'essai.

La capacité localisée C_L (Figure 16) ne doit pas avoir une valeur inférieure à 400 pF. Le rapport C_1/C_L doit être compris entre 4 et 6.



Légende

DT Sectionneur en essai

CP Condensateur en parallèle du disjoncteur ou condensateur équivalent

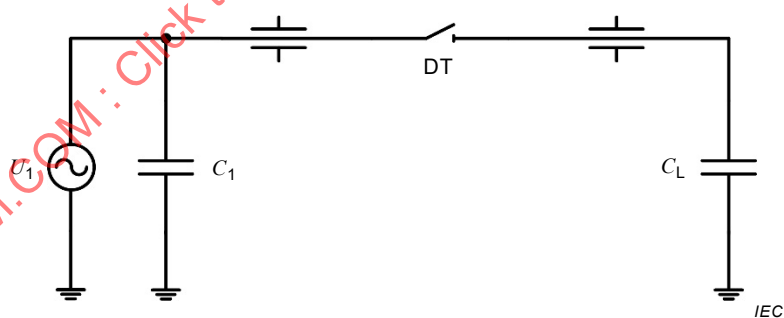
Figure 16 – Circuit d'essai pour la séquence d'essai 2

7.108.6.3 Vérification du pouvoir d'établissement et de coupure, séquence d'essai 3

Le circuit d'essai représenté à la Figure 17 s'applique. Pour ce type d'établissement-coupure, les longueurs spécifiques des tronçons de jeux de barres n'ont pas d'importance. Du côté charge, il convient d'ajouter une capacité localisée C_L de manière à obtenir le courant de jeux de barres à vide indiqué au Tableau 11 avec une tolérance de $\pm 10\%$.

Dans le but de réduire les effets de résonance qui peuvent être occasionnés par une impédance de source élevée, une capacité localisée C_1 d'une valeur quelconque peut être connectée du côté source.

D'autres conditions d'essai qui affectent le régime transitoire de rétablissement sont soumises à accord entre le constructeur et l'utilisateur.



Légende

DT Sectionneur en essai

Figure 17 – Circuit d'essai pour la séquence d'essai 3

7.108.7 Modalités d'exécution des essais d'établissement et de coupure

Dans chaque séquence d'essai, la série d'essais doit être réalisée sans remise en état du sectionneur. Le nombre d'essais est donné au Tableau 20.

Tableau 20 – Nombre d'essais

Séquence d'essai	Nombre d'établissements et de coupures	
	Sectionneur conventionnel	Sectionneur à ouverture rapide ^a
1	50 ^b	200 ^{a, c}
2	50	200
3	50	50
^a Sectionneurs ayant une vitesse de contact, à l'instant de la séparation des contacts, supérieure ou égale à 1 m/s. ^b Dans le cas où la disposition la plus défavorable du sectionneur ne peut pas être déterminée clairement (selon 7.108.3), la séquence d'essai 1 doit être répétée en permutant les bornes du sectionneur. ^c La réduction du nombre d'essais à 50 est acceptable si (pour prendre en compte les données statistiques) la tension d'essai est portée aux valeurs suivantes: – côté source: $U_r \times 1,2/\sqrt{3}$; – côté charge: (précharge en courant continu): $-U_r \times 1,2 \sqrt{2}/\sqrt{3}$.		

7.108.8 Comportement du sectionneur pendant les essais d'établissement et de coupure

Le sectionneur doit subir avec succès les essais sans défaillance mécanique ou électrique.

Les décharges disruptives phase/terre ou entre phases ne sont pas admises. Elles ne sont pas non plus admises aux bornes des résistances des sectionneurs équipés de résistances dans les appareillages sous enveloppe métallique à isolation gazeuse.

NOTE Il est essentiel que les décharges disruptives à la terre ou entre phases puissent être détectées clairement par des mesurages adéquats ou par des appareils de détection appropriés.

7.108.9 État après essai

Les caractéristiques fonctionnelles mécaniques doivent être comprises dans les tolérances spécifiées par le constructeur et l'isolation du sectionneur doit être pratiquement dans le même état qu'avant les essais.

Une usure mécanique et une érosion des contacts par l'arc ainsi que des dépôts sur les isolateurs provenant de la décomposition du milieu extincteur de l'arc sont acceptables. Cependant le courant admissible et les caractéristiques d'isolement du sectionneur ne doivent pas être altérés. La qualité du matériau éventuellement utilisé pour la coupure de l'arc peut être altérée et la quantité en être réduite au-dessous de la quantité normale. Il peut y avoir des dépôts sur les isolateurs provenant de la décomposition du milieu extincteur de l'arc.

Les caractéristiques d'isolement du sectionneur en position d'ouverture ne doivent pas être réduites au-dessous des valeurs correspondant à une usure et un vieillissement normaux, par suite d'une détérioration des parties isolantes.

La manœuvre à vide et l'inspection visuelle du sectionneur après les essais sont habituellement suffisantes pour contrôler les caractéristiques d'isolement du sectionneur et son courant admissible. En cas de doute, il peut être nécessaire de réaliser les essais appropriés comme mentionné ci-dessous. Pour les sectionneurs qui sont scellés à vie, l'essai de tension en tant que vérification d'état est obligatoire.

En cas de doute sur les caractéristiques d'isolement du sectionneur, un essai de tension en tant que vérification de l'état du sectionneur selon 7.2.12 doit être réalisé pour vérifier les caractéristiques d'isolement. Les méthodes d'essai alternatives spécifiées en 6.2.11 de

l'IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 peuvent être utilisées pour $U_r > 72,5$ kV. La pression minimale de fonctionnement du gaz pour l'isolement doit être utilisée, le cas échéant.

En cas de doute sur le courant admissible du sectionneur, le mesurage de la résistance du circuit principal peut être effectué partout où il est possible de mesurer la résistance près des contacts. L'augmentation de la résistance du circuit principal après l'essai ne doit pas dépasser 20 %. Si la résistance des contacts dépasse cette valeur, un essai au courant permanent assigné (7.5) doit démontrer que l'échauffement des contacts ne dépasse pas les limites indiquées au Tableau 14 de l'IEC 62271-1:2017, en surveillant la température aux points les plus proches possible des contacts principaux.

Pour les sectionneurs équipés de résistances dans les appareillages sous enveloppe métallique à isolation gazeuse, la variation maximale de la résistance ohmique de la résistance complète après l'essai ne doit pas dépasser 5 % de la valeur mesurée avant l'essai. Une inspection visuelle de la résistance doit être effectuée après les essais de type. Il ne doit être observé aucun signe d'amorçage à travers la résistance ni aucun dommage mécanique. Il peut être nécessaire de démonter le sectionneur en vue d'une inspection visuelle.

7.108.10 Rapports d'essais de type

Outre les exigences énoncées en 7.1.2 et 7.1.3 de l'IEC 62271-1:2017, le rapport d'essai de type doit comprendre les informations suivantes:

- a) l'enregistrement oscillographique représentatif d'une manœuvre d'établissement et d'une manœuvre de coupure;
- b) le ou les circuits d'essai;
- c) le courant d'essai en régime établi (seulement pour la séquence d'essai 3);
- d) la ou les tensions d'essai;
- e) les caractéristiques des tensions transitoires;
- f) l'enregistrement des caractéristiques fonctionnelles;
- g) la pression de l'isolant gazeux pendant les essais;
- h) le nombre d'établissements et de coupures;
- i) l'état après essai;
- j) le type du dispositif de détection de défaut;
- k) la tension ou pression d'alimentation du mécanisme de commande.

7.108.11 Exigences pour les mesurages de la tension transitoire à la terre U_{TVE}

Exigences relatives aux mesurages:

- La vérification de l' U_{TVE} doit être effectuée au moins une fois pendant chaque séquence d'essai exécutée. Les modifications de configuration telles que les différences de longueur des connexions, l'orientation de l'équipement, etc. sont considérées comme des modifications du circuit d'essai et exigent des mesurages supplémentaires;
- les mesurages de l' U_{TVE} doivent être effectués à moins d'un mètre des contacts d'arc du sectionneur. Si cela n'est pas possible, la vérification de l' U_{TVE} peut être effectuée par calcul, à condition que d'autres mesurages (dans le tronçon en essai, mais à une distance supérieure à 1 m des contacts) soient réalisés au moins une fois pour valider le calcul;
- des précautions doivent être prises pour prendre en compte les interférences possibles dues aux tensions parasites à fréquence industrielle;
- le mesurage de l' U_{TVE} doit être effectué avec une bande passante suffisante pour enregistrer correctement la composante VFT.

8 Essais individuels de série

8.1 Généralités

L'Article 8 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

Ajout à la liste des essais individuels de série:

- f) essais de fonctionnement mécanique conformément à 8.101.
- g) vérification de la fonction de mise à la terre conformément à 8.102.

Les sectionneurs et les sectionneurs de terre intégrés à un appareillage sous enveloppe doivent être soumis à l'essai comme une partie de l'ensemble d'appareillages conformément à l'IEC 62271-200, l'IEC 62271-201 ou l'IEC 62271-203.

8.2 Essai diélectrique du circuit principal

Le Paragraphe 8.2 de l'IEC 62271-1:2017 s'applique avec les ajouts et/ou écarts suivants:

Dans le cas de sectionneurs ou sectionneurs de terre placés

- à l'intérieur des systèmes à pression scellés, l'essai diélectrique peut être effectué à la pression assignée de remplissage pour l'isolement;
- à l'intérieur des systèmes à pression entretenue ou autonome, l'essai diélectrique doit être effectué à la pression minimale de fonctionnement pour l'isolement;

Si les conditions indiquées au troisième alinéa de 8.2 de l'IEC 62271-1:2017 ne sont pas remplies, le point ci-dessous s'applique:

- pour les essais des sectionneurs, les conditions d'essai doivent être conformes aux spécifications du Tableau 21. Pour une explication des désignations de référence de connexion, voir la Figure 2 de l'IEC 62271-1:2017;

Tableau 21 – Essais de tension à fréquence industrielle

Condition d'essai n°	Position du sectionneur	Tension appliquée sur	Terre connectée à
1 ^a	Fermé	Aa	BbCcF
2 ^a	Fermé	Bb	AaCcF
3 ^a	Fermé	Cc	AaBbF
4	Ouvert	ABC	abcF
5	Ouvert	abc	ABCF
6 ^b	Ouvert	ABC ou abc	Sectionneur de terre
^a Si l'isolement entre pôles est de l'air à la pression atmosphérique et si les dimensions sont vérifiées, les conditions d'essai n° 1, 2 et 3 peuvent être combinées, la tension d'essai étant appliquée entre tous les éléments du circuit principal reliés ensemble et le châssis.			
^b Sectionneur de terre dans la position donnant le plus petit intervalle entre ses parties mobiles et ABC ou abc. L'essai s'applique uniquement aux sectionneurs équipés d'un sectionneur de terre intégré.			

- pour les essais des sectionneurs de terre, la tension d'essai doit être appliquée avec le sectionneur de terre en position d'ouverture:
 - 1) entre des bornes isolées adjacentes et les châssis à la terre (par exemple, A et B avec F à la terre);
 - 2) entre toutes les bornes isolées connectées ensemble et les châssis à la terre (par exemple, ABC et F à la terre).

8.3 Essais des circuits auxiliaires et de commande

Le Paragraphe 8.3 de l'IEC 62271-1:2017 s'applique.

8.4 Mesurage de la résistance du circuit principal

Le Paragraphe 8.4 de l'IEC 62271-1:2017 s'applique seulement pour les sectionneurs.

8.5 Essai d'étanchéité

Le Paragraphe 8.5 de l'IEC 62271-1:2017 s'applique.

8.6 Contrôles visuels et de conception

Le Paragraphe 8.6 de l'IEC 62271-1:2017 s'applique.

8.101 Essais de fonctionnement mécanique

Les essais de fonctionnement mécanique sont effectués pour s'assurer que les sectionneurs et les sectionneurs de terre fonctionnent, dans les conditions spécifiées, dans les limites spécifiées de tension et de pression d'alimentation, le cas échéant, de leurs mécanismes de commande.

Durant ces essais, qui sont effectués sans tension ni courant dans le circuit principal, il doit être vérifié que:

- les sectionneurs ou les sectionneurs de terre s'ouvrent et se ferment correctement lorsque leurs mécanismes de commande sont mis sous tension;
- les dispositifs de verrouillage fonctionnent correctement dans n'importe quelle position de verrouillage;
- les indicateurs de position et les dispositifs de signalisation de position indiquent correctement les positions d'ouverture et de fermeture.

Le sectionneur ou le sectionneur de terre doit être soumis aux essais suivants:

- cinq cycles de manœuvres à la tension minimale d'alimentation et/ou pression minimale d'alimentation spécifiées (le cas échéant);
- cinq cycles de manœuvres à la tension maximale d'alimentation et/ou pression maximale d'alimentation spécifiées (le cas échéant);
- cinq cycles de manœuvres manuelles si le sectionneur ou le sectionneur de terre peut être manœuvré manuellement.

Pendant ces cycles de manœuvre, les caractéristiques fonctionnelles telles que, le cas échéant, les durées de manœuvre, la consommation d'énergie ou les forces maximales pour la manœuvre manuelle doivent être vérifiées. Le fonctionnement correct des contacts auxiliaires et de commande et des indicateurs de position (le cas échéant) doit être vérifié. Les valeurs de chaque paramètre doivent être comprises dans les tolérances spécifiées par le constructeur.

Pendant les essais, aucun réglage ne doit être réalisé et le fonctionnement doit être sans faille. Les positions de fermeture et d'ouverture doivent être atteintes avec les indications et les signalisations spécifiées au cours de chaque cycle de manœuvre.

Après ces essais, aucun élément du sectionneur ou du sectionneur de terre ne doit être endommagé.

Pour les sectionneurs et les sectionneurs de terre de $U_r > 52$ kV, les essais de manœuvres mécaniques des essais individuels de série peuvent être effectués sur des sous-ensembles.

Dans le cas où les essais individuels de série sont effectués sur des composants séparés, ils doivent être répétés sur le terrain avec un sectionneur complètement assemblé lors des essais de réception. Le même nombre total de manœuvres, comme spécifié en 7.102.3.2, doit être effectué.

8.102 Vérification de la fonction de mise à la terre

La fonction de mise à la terre doit être vérifiée conformément aux spécifications du constructeur. Toutefois, l'essai de continuité électrique doit être effectué. Des exemples d'autres essais individuels de série, qui peuvent être spécifiés, sont les suivants:

- résistance des contacts;
- pression des contacts;
- inspection visuelle;
- vérification dimensionnelle;
- continuité électrique.

9 Guide pour le choix des sectionneurs et des sectionneurs de terre (informative)

9.1 Généralités

Les dispositions de 9.1 de l'IEC 62271-1:2017 s'appliquent avec les ajouts suivants:

Pour le choix des sectionneurs et des sectionneurs de terre, il convient de prendre en compte les conditions suivantes et les exigences sur site:

- les conditions de courant en régime permanent et en surcharge;
- les conditions de défaut existantes;
- les efforts statiques et dynamiques résultants de la conception de la station;
- l'utilisation de conducteurs rigides ou souples à raccorder au sectionneur ou au sectionneur de terre ou le type de conducteur sur lequel est monté le contact séparé;
- les conditions d'environnement (climat, pollution, etc.);
- l'altitude du site du poste;
- le type de performance exigée en manœuvre (endurance mécanique);
- les exigences pour la coupure (coupure de courant de transfert de barres par les sectionneurs, coupure de courant induit par les sectionneurs de terre, pouvoir de fermeture en court-circuit des sectionneurs de terre).

NOTE Voir l'Annexe B pour de plus amples informations sur les pouvoirs de coupure de courant des sectionneurs et des sectionneurs de terre.

Lors du choix d'un sectionneur ou d'un sectionneur de terre, il convient de tenir compte du développement futur probable d'un réseau dans son ensemble, de telle sorte que le sectionneur ou le sectionneur de terre puisse convenir non seulement pour les besoins immédiats, mais aussi pour les exigences futures.

9.2 Choix des valeurs assignées

Les dispositions de 9.2 de l'IEC 62271-1:2017 s'appliquent avec les ajouts suivants:

9.2.101 Généralités

Il convient, le cas échéant, de prendre en considération toutes les caractéristiques et classes assignées d'un sectionneur ou d'un sectionneur de terre indiquées à l'Article 5, ainsi que les paragraphes 9.102.2 à 9.102.13.

9.2.102 Choix de la tension assignée et du niveau d'isolement assigné

Il convient de choisir la tension assignée d'un sectionneur ou d'un sectionneur de terre au moins égale à la tension la plus élevée du réseau à l'endroit où le sectionneur ou le sectionneur de terre doit être installé.

Il convient de choisir la tension assignée d'un sectionneur ou d'un sectionneur de terre parmi les valeurs normales et leurs niveaux d'isolement correspondants indiqués en 5.2 et 5.3 de l'IEC 62271-1:2017.

Se reporter au 4.2.2 de l'IEC 62271-1:2017 pour les sectionneurs et sectionneurs de terre installés à haute altitude.

9.2.103 Choix du courant permanent assigné

Il convient de choisir la valeur du courant permanent assigné d'un sectionneur parmi les valeurs normales indiquées en 5.5 de l'IEC 62271-1:2017.

Il convient de noter que les sectionneurs n'ont aucune capacité normalisée de surintensité continue. Par conséquent, lors du choix d'un sectionneur, il convient que son courant permanent assigné convienne pour tous les courants de charge qui peuvent se produire en service. Il convient de consulter le constructeur lorsque des surintensités intermittentes, fréquentes et importantes sont prévisibles.

9.2.104 Choix d'une zone de contact assignée

Pour un fonctionnement correct d'un sectionneur ou sectionneur de terre à éléments séparés, il convient que l'utilisateur s'assure que le contact fixe reste dans les limites indiquées au Tableau 2, en prenant en compte les conditions de service lors de la spécification de la conception du poste et de la résistance en porte-à-faux des isolateurs.

Lors du choix de la zone de contact assignée, il convient que l'utilisateur vérifie que la zone de contact assignée spécifiée par le constructeur n'est pas dépassée dans sa propre application avec les contraintes additionnelles suivantes, le cas échéant:

- une déviation longitudinale qui résulte de l'effort dû au vent sur d'autres éléments qui sont connectés perpendiculairement au mouvement du conducteur et de l'appareil;
- une déviation perpendiculaire qui résulte de l'effort dû au vent sur d'autres éléments qui sont connectés perpendiculairement au mouvement du conducteur et de l'appareil;
- une déviation verticale qui résulte d'autres charges verticales suspendues au conducteur et des efforts de manœuvre générés par la manœuvre d'autres appareils connectés au conducteur.

9.2.105 Choix des efforts mécaniques statiques assignés sur les bornes

Il convient de choisir les efforts mécaniques statiques assignés sur les bornes en fonction des exigences de 5.104 et des définitions de 3.7.119. Il convient que l'utilisateur prenne en considération les conditions les plus défavorables au moment de la spécification des efforts statiques assignés sur les bornes.

Pour le calcul des efforts statiques exigés sur les bornes et le calcul de la résistance exigée des isolateurs, il convient de prendre en compte la résultante des efforts des conducteurs raccordés au sectionneur ou sectionneur de terre, y compris les efforts dus au vent et à la glace (le cas échéant) et la température minimale spécifiée de l'air ambiant sur ces conducteurs.

9.2.106 Choix du pouvoir d'établissement et de coupure de courant de transfert de barres pour les sectionneurs de $U_r > 52$ kV

Bien que, par définition, les sectionneurs ne soient capables d'ouvrir et de fermer un circuit que lorsque le courant établi ou coupé est négligeable, ou qu'aucune différence de potentiel significative n'apparaisse aux bornes de chaque pôle, les sectionneurs sont dans certains cas utilisés pour le transfert de charge d'un jeu de barres sur une barre parallèle. Même si une barre de couplage est fermée, le transfert de charge peut être une manœuvre plus ou moins sévère pour le sectionneur, en fonction des dimensions du poste et du courant à transférer.

Si un pouvoir d'établissement et de coupure de courant de transfert de barres est exigé, il convient de spécifier dans l'appel d'offres les valeurs de courant de transfert et la tension de rétablissement présumée (voir Article 10).

9.2.107 Choix du pouvoir d'établissement et de coupure de courant induit pour des sectionneurs de terre de $U_r > 52$ kV

Un sectionneur de terre est généralement utilisé pour ouvrir et établir une connexion à la terre à partir d'un élément isolé d'une installation ou ligne électrique.

Dans les réseaux haute tension, les configurations des pylônes sont parfois utilisées avec plusieurs lignes montées sur un même support. Dans ce cas, des courants induits doivent être coupés ou établis lors de la mise à la terre ou non d'une de ces lignes lorsque l'autre est connectée au réseau et peut transporter un courant de charge. L'amplitude des courants induits à couper ou établir par le sectionneur de terre dépend des facteurs de couplage capacitif et inductif entre les lignes, de la tension, de la charge et de la longueur des lignes en parallèle.

Les réseaux de tension plus élevée sont habituellement caractérisés par des étendues de boucle plus longues et des courants de charge plus élevés qui génèrent des valeurs supérieures des courants induits.

Si un pouvoir d'établissement et de coupure est exigé, les valeurs données au Tableau 9 peuvent être utilisées pour la plupart des cas à spécifier dans l'appel d'offres (voir Article 10).

9.2.108 Choix du courant de courte durée admissible assigné et de la durée du court-circuit assignée

Les paragraphes 5.6 et 5.8 de l'IEC 62271-1:2017 s'appliquent.

Les montages d'essai représentés aux Figures 3, 4 et 5 sont applicables pour les essais de type. Il n'est pas exclu qu'il existe des conceptions d'installations électriques pour lesquelles les sectionneurs ou sectionneurs de terre subissent des contraintes supérieures.

NOTE Pour les courants de courte durée, la contrainte thermique peut être considérée comme constante lorsque $I^2t = \text{constante}$.

9.2.109 Choix de la valeur de crête du courant admissible assignée et du courant établi assigné en court-circuit des sectionneurs de terre

Il convient que le sectionneur ou le sectionneur de terre choisi ait une valeur de crête de courant admissible assignée au moins égale à la plus grande valeur de crête du courant de défaut se produisant dans le réseau réel (en prenant en considération la valeur réelle de la constante de temps du réseau).

Il convient de tenir compte du paragraphe 5.6.

Cela s'applique également au courant établi assigné en court-circuit d'un sectionneur de terre (le cas échéant).

9.2.110 Choix du pouvoir de fermeture en court-circuit des sectionneurs de terre

Il convient d'effectuer le choix selon la classification indiquée en 5.102. Le choix de la classe E1 ou E2 dépend des procédures opérationnelles du réseau électrique. Généralement, cette capacité n'est pas requise pour les sectionneurs de terre faisant partie des appareillages à isolement dans l'air de $U_r > 52$ kV.

9.3 Considérations sur les interfaces avec les câbles

Les dispositions de 9.3 de l'IEC 62271-1:2017 s'appliquent.

9.4 Surcharge continue ou temporaire due à une modification des conditions de service

Les dispositions de 9.4 de l'IEC 62271-1:2017 s'appliquent.

9.5 Aspects d'environnement

Les dispositions de 9.5 de l'IEC 62271-1:2017 s'appliquent avec les ajouts suivants:

9.5.101 Conditions environnementales locales

Pour les conditions normales et spéciales de service des sectionneurs et des sectionneurs de terre, l'Article 4 de l'IEC 62271-1:2017 s'applique.

Pour les sectionneurs et les sectionneurs de terre, les conditions de pollution de certaines zones extérieures et intérieures sont défavorables du fait de la fumée, des vapeurs chimiques, des brouillards salins, etc. Lorsque l'existence de telles conditions défavorables est connue, il convient d'accorder une attention particulière à la conception et aux matériaux utilisés pour le sectionneur et le sectionneur de terre. Dans ces conditions, il convient d'analyser avec attention les performances d'un isolement parallèle. Il peut être nécessaire de réaliser des essais de pollution sur le sectionneur ou le sectionneur de terre.

Pour les isolateurs normalement exposés à l'air, se reporter au 6.15 de l'IEC 62271-1:2017. Le comportement d'un isolateur en atmosphères polluées dépend également de la fréquence à laquelle un lavage artificiel ou autres méthodes de réduction de la pollution sont effectués, ou de la fréquence à laquelle le nettoyage naturel se produit.

NOTE Les conceptions d'isolateurs dont la conformité aux exigences de l'utilisateur a été démontrée par essais peuvent avoir une ligne de fuite nominale plus petite que celle obtenue par le produit de la tension assignée par la ligne de fuite spécifique minimale.

Pour les installations intérieures de matériel de type ouvert, dans des zones côtières où le dépôt salin pose des problèmes, et pour $U_r > 52$ kV, il est recommandé d'utiliser des matériels avec une isolation de type extérieur, parce que ceux-ci sont plus facilement disponibles que les matériels avec des isolations intérieures spéciales. L'utilisation d'installations sous enveloppe (GIS) est également possible.

Si un sectionneur ou un sectionneur de terre doit être placé dans un endroit où la vitesse du vent dépasse 34 m/s, il convient de le spécifier dans l'appel d'offres.

Si un sectionneur ou un sectionneur de terre doit être installé dans un endroit où une couche de glace d'une épaisseur supérieure à 1 mm est prévisible, il convient de le spécifier dans l'appel d'offres en tenant compte de 7.103.

10 Renseignements à donner dans les appels d'offres, les soumissions et les commandes (informatif)

10.1 Généralités

L'Article 10 de l'IEC 62271-1:2017 s'applique avec les ajouts/modifications suivantes:

Pour les sectionneurs et sectionneurs de terre utilisés dans les appareillages à isolation gazeuse et/ou sous enveloppe métallique, l'Article 9 de l'IEC 62271-200:2011 ou l'IEC 62271-203:2011 s'applique.

10.2 Renseignements dans les appels d'offres et les commandes

Le paragraphe 10.2 de l'IEC 62271-1:2017 est remplacé par ce qui suit.

Pour lancer un appel d'offres ou passer une commande d'un sectionneur ou d'un sectionneur de terre, il convient que le demandeur fournisse, le cas échéant, les renseignements suivants:

- a) caractéristiques propres au réseau, c'est-à-dire tension nominale et tension la plus élevée, fréquence, nombre de phases et caractéristiques de mise à la terre du neutre;
- b) conditions en service, y compris les températures minimales et maximales de l'air ambiant, si différentes des valeurs normales (voir l'Article 9); l'altitude si elle est supérieure à 1 000 m; la glace et toutes conditions spéciales susceptibles d'exister ou de se produire, par exemple l'exposition inhabituelle aux vapeurs, à l'humidité, aux fumées, aux gaz explosifs, à une poussière excessive ou à l'air salin (voir de 9.5.101);
- c) caractéristiques du sectionneur ou du sectionneur de terre. Il convient de donner les renseignements suivants:
 - 1) installation pour l'intérieur ou pour l'extérieur;
 - 2) nombre de phases;
 - 3) tension assignée;
 - 4) fréquence assignée;
 - 5) niveau d'isolement assigné s'il existe un choix entre différents niveaux d'isolement correspondant à une tension assignée donnée ou, s'il est différent du niveau normal, niveau d'isolement demandé (voir Tableaux 1 à 4 de l'IEC 62271-1:2017);
 - 6) courant permanent assigné (seulement pour les sectionneurs);
 - 7) courant de courte durée admissible assigné (I_k);
 - 8) durée de court-circuit assignée (si elle est différente de 1 s);
 - 9) valeur de crête du courant admissible assignée (si elle est différente de $2,5 I_k$);
 - 10) courant établi assigné en court-circuit, le cas échéant (seulement pour les sectionneurs de terre), (voir 5.101);
 - 11) efforts mécaniques statiques assignés sur les bornes, le cas échéant (voir 5.104);
 - 12) types de conducteurs souples ou rigides utilisés pour raccorder le sectionneur ou le sectionneur de terre ou type de conducteur sur lequel est monté le contact séparé, le cas échéant (voir 5.104);
 - 13) conditions de montage et connexions haute tension, par exemple type d'accrochage du contact fixe du sectionneur ou sectionneur de terre, structure support à fournir, ou non, avec l'équipement, le cas échéant;
 - 14) exigences pour les isolateurs (le cas échéant) à utiliser avec le sectionneur ou le sectionneur de terre:
 - classe de pollution suivant l'IEC/TS 60815-1 [4];
 - profil des ailettes (le cas échéant) suivant l'IEC/TS 60815-1 (toutes les parties) [3];

- voir le point 11);
- 15) zone de contact exigée, le cas échéant;
- 16) fonctionnement dans des conditions sévères de formation de glace, le cas échéant;
- 17) pouvoir de coupure de courant de transfert de barres assigné (seulement pour les sectionneurs), le cas échéant;
- 18) pouvoir de coupure de courant induit assigné (seulement pour les sectionneurs de terre), le cas échéant;
- 19) classe d'endurance mécanique assignée, si différente de M0;
- 20) classe de pouvoir de fermeture assigné en court-circuit, si différente de E0 (seulement pour les sectionneurs de terre);
- 21) pouvoir d'établissement et de coupure de courant de jeux de barres à vide;
- 22) degré de protection procuré par les enveloppes et les cloisons (le cas échéant);
- 23) schémas de circuits;
- d) caractéristiques du mécanisme de commande et de l'équipement associé, en particulier:
 - 1) type de commande, manuelle et/ou par une source d'énergie extérieure;
 - 2) pour les manœuvres indépendantes manuelles des sectionneurs de terre: la durée de temporisation;
 - 3) la hauteur de manœuvre au-dessus du niveau de service;
 - 4) pour les modes de commande à source d'énergie extérieure, le type d'énergie d'alimentation disponible (par exemple air comprimé, courant continu ou courant alternatif) et ses caractéristiques assignées (pression, tension, fréquence);
 - 5) nombre et type de contacts auxiliaires disponibles;
 - 6) degré de protection s'il est supérieur à celui spécifié en 6.14;
 - 7) exigences de verrouillage;
 - 8) durée minimale d'ordre de manœuvre;
 - 9) temps maximum de manœuvre pour la commande à source d'énergie extérieure;
- e) exigences relatives à l'utilisation de gaz comprimé et exigences relatives à la conception et aux essais des réservoirs sous pression;
- f) tout essai individuel de série ou tout contrôle supplémentaire devant être réalisé en présence de l'utilisateur;
- g) toutes autres informations relatives aux conditions spéciales qui ne figurent pas ci-dessus et qui peuvent influencer la soumission ou la commande, telles que, par exemple, les conditions particulières de montage ou d'installation, l'emplacement des connexions externes à haute tension ou les exigences pour les essais des câbles;
- h) demande de documentation sur les essais de type ou toute demande spécifique relative aux documents d'évaluation de la conformité.

10.3 Renseignements pour les soumissions

Le paragraphe 10.3 de l'IEC 62271-1:2017 est remplacé par ce qui suit.

Il convient que les renseignements fournis par le constructeur pour les soumissions couvrent les exigences spécifiées en 10.2, le cas échéant, et mentionnent la conformité et les écarts par rapport aux spécifications de l'appel d'offres. Les dimensions indiquées sur les plans des sectionneurs et des sectionneurs de terre sont soumises aux tolérances telles que normalisées par l'ISO 2768-1, sauf spécification contraire. Il convient de notifier dans les documents de soumission les exigences nationales qui conduisent à des écarts par rapport à l'IEC 62271-1.

Il convient que les renseignements fournis par le constructeur pour les soumissions comprennent, le cas échéant:

- a) valeurs et caractéristiques assignées telles qu'énumérées au point c) de 10.2, et à l'Article 5;
- b) informations détaillées de construction, le cas échéant:
 - 1) masse du sectionneur ou du sectionneur de terre complet;
 - 2) dimensions hors tout en position de fermeture et d'ouverture (si elles sont différentes);
 - 3) disposition des connexions externes;
 - 4) dispositifs nécessaires pour le transport et le montage;
 - 5) mesures à prévoir pour le montage;
 - 6) faces accessibles;
 - 7) type du système de pression à remplissage de gaz ou de liquide (le cas échéant);
 - 8) distances d'isolement minimales dans l'air:
 - entre pôles;
 - par rapport à la terre;
 - pour la distance de sectionnement (seulement pour les sectionneurs);
 - 9) pour les sectionneurs et sectionneurs de terre à éléments séparés, la zone de contact assignée;
 - 10) protection anticorrosion;
 - 11) pour les sectionneurs ayant un contact fixe exigeant des efforts de réaction lors de l'ouverture et de la fermeture du contact, ces forces et leur direction doivent être spécifiées par le constructeur dans la documentation;
 - 12) le cas échéant, les pertes diélectriques (en mW) du dispositif d'isolement de la connexion de terre extérieure doivent être indiquées.
- c) le mécanisme de commande et son équipement associé:
 - 1) type du mécanisme de commande;
 - 2) tension et/ou pression d'alimentation assignée du mécanisme de commande;
 - 3) courant exigé à la tension d'alimentation assignée pour manœuvrer le sectionneur ou le sectionneur de terre; courant maximal et tension maximale aux bornes du mécanisme de commande;
 - 4) quantité de gaz ramenée à la pression atmosphérique exigée pour manœuvrer le sectionneur ou le sectionneur de terre à la pression d'alimentation assignée, le cas échéant;
 - 5) nombre et type de contacts auxiliaires disponibles;
 - 6) conception ou description du dispositif de verrouillage en position;
 - 7) conception du dispositif indicateur et de signalisation;
 - 8) temps de manœuvre.

11 Transport, stockage, installation, instructions de fonctionnement et maintenance

11.1 Généralités

Le Paragraphe 11.1 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Pour les sectionneurs et sectionneurs de terre utilisés dans les appareillages à isolation gazeuse et/ou sous enveloppe métallique, l'Article 10 de l'IEC 62271-200:2011 ou de l'IEC 62271-203:2011 s'applique.

11.2 Conditions à respecter pendant le transport, le stockage et l'installation

Le Paragraphe 11.2 de l'IEC 62271-1:2017 s'applique.

11.3 Installation

Le Paragraphe 11.3 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Les sectionneurs et sectionneurs de terre doivent être emballés – dans toute la mesure du possible – en une seule unité.

Il convient que les colis et les caisses contenant plusieurs unités ou composants (isolateurs, bielles, mécanismes de commande et composants similaires) soient clairement repérés et accompagnés d'une liste de matériel.

11.4 Fonctionnement

Le Paragraphe 11.4 de l'IEC 62271-1:2017 s'applique.

11.5 Maintenance

Le Paragraphe 11.5 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Pour les sectionneurs et les sectionneurs de terre ayant n'importe quel pouvoir d'établissement et de coupure, il est nécessaire de prendre en compte le nombre de manœuvres pour déterminer les périodes de maintenance.

Pour les opérations de maintenance, le sectionneur de l'appareillage à isolation gazeuse doit être considéré comme ayant ses pleines propriétés d'isolation seulement si la pression du gaz n'est pas inférieure à sa pression (masse volumique) minimale de fonctionnement.

12 Sécurité

12.1 Généralités

L'Article 12 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

NOTE Les termes "personne qualifiée" et "personne avertie" sont respectivement définis dans l'IEV 826-09-01 et dans l'IEV 826-09-02. Les exigences pour "personne qualifiée" et "personne avertie" peuvent varier en fonction des règles locales de sécurité.

Pour les principes de manœuvre, se reporter à l'IEC 60447:2004 [5].

12.2 Précautions devant être prises par les constructeurs

Le Paragraphe 12.2 de l'IEC 62271-1:2017 s'applique.

12.3 Précautions devant être prises par les utilisateurs

Le Paragraphe 12.3 de l'IEC 62271-1:2017 s'applique.

13 Influence du produit sur l'environnement

L'article 13 de l'IEC 62271-1:2017 s'applique.

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Annexe A (informative)

Tension d'essai applicable à la position la plus défavorable d'un point de vue diélectrique du sectionneur de terre pendant sa manœuvre (distance d'isolement minimale temporaire)

Pour la normalisation de la tenue diélectrique à la position la plus défavorable d'un point de vue diélectrique du sectionneur de terre pendant sa manœuvre, les remarques suivantes doivent être prises en compte:

- pour $52 \text{ kV} < U_r \leq 170 \text{ kV}$, il existe différents types de mises à la terre du neutre sur les réseaux;
- pour $U_r > 170 \text{ kV}$, le neutre directement à la terre est la configuration type des réseaux.

Par conséquent:

- pour la plage de tensions inférieures ($52 \text{ kV} < U_r \leq 170 \text{ kV}$), même s'il existe différents types de mises à la terre du neutre sur les réseaux, il est judicieux de normaliser une seule tension d'essai, en prenant en compte la condition la plus sévère qui caractérise les réseaux à neutre non reliés à la terre;
- pour la plage de tensions supérieures ($U_r > 170 \text{ kV}$), seul est pris en compte le neutre directement à la terre pour normaliser la tension d'essai.

Par ailleurs, pour $U \geq 300 \text{ kV}$, le rapport entre tension de tenue à fréquence industrielle et tension du réseau est réduit, comparé au rapport entre tension d'essai et tension du réseau en dessous de 300 kV (dans la plage de tensions supérieures, des essais aux chocs de manœuvre sont normalisés).

Compte tenu du niveau relativement faible de la tension de tenue à fréquence industrielle pour les réseaux de tension à 300 kV et au-dessus, les sectionneurs et sectionneurs de terre de $U_r = 245 \text{ kV}$ occupent une position particulière. D'un côté, ils appartiennent à la plage des réseaux à neutre directement reliés à la terre, et de l'autre ils appartiennent à la plage des tensions d'essai pour réseaux de tension inférieure à 300 kV . Il y a donc lieu de se demander si la tenue diélectrique exigée correspond à la tension de tenue à fréquence industrielle normalisée (phase-terre) ou à la tension assignée.

Un rapport fixe de la tension de tenue phase-terre donnerait des valeurs trop importantes pour les tensions assignées les plus basses et trop réduites pour les tensions assignées les plus élevées.

Les distances de sécurité dans les postes n'étant pas liées aux tensions d'essai diélectrique, mais à la tension assignée, il convient que la tenue diélectrique pour la distance d'isolement minimale temporaire corresponde également à la tension assignée et aux conditions de mise à la terre du réseau. De même, il convient de prendre en considération le fait que les tensions d'essai peuvent évoluer à terme, et il convient que cela ne se traduise pas par une variation de la tension d'essai pour la distance d'isolement minimale temporaire.

Pour la normalisation, il est donc suggéré d'utiliser les valeurs suivantes:

- a) pour $52 \text{ kV} < U_r \leq 170 \text{ kV}$: $1,3 \times U_r$;
- b) pour $U_r > 170 \text{ kV}$: $2 \times U_r / \sqrt{3}$.

Pour les sectionneurs ayant des sectionneurs de terre intégrés, les valeurs de tension d'essai suggérées pour le sectionneur de terre dans la position la plus défavorable d'un point de vue diélectrique sont données au Tableau 14 après prise en compte des remarques ci-dessus. Un essai de tension de tenue aux ondes de choc n'est pas exigé du fait de la très faible probabilité d'apparition d'un choc de foudre ou de manœuvre pendant la procédure de mise à la terre.

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Annexe B (informative)

Pouvoir d'établissement et de coupure de courant exigé des sectionneurs et des sectionneurs de terre

B.1 Pouvoir d'établissement et de coupure de courant de transfert de barres des sectionneurs

Pour les sectionneurs servant à transférer des courants de charge d'un jeu de barres à un autre, un pouvoir d'établissement et de coupure des courants de transfert de barres est exigé. Cette exigence s'applique aux sectionneurs de $U_r > 52$ kV.

Les tensions et les courants de transfert de barres dépendent de l'amplitude du courant de charge, de l'étendue de la boucle entre la travée de couplage des jeux de barres et la travée du sectionneur à manœuvrer.

Les valeurs de tensions assignées de transfert de barres indiquées au Tableau 7 sont fondées sur des calculs du courant de transfert de barres correspondant au courant permanent assigné du sectionneur, prenant en compte les impédances indiquées au Tableau B.1 et les longueurs typiques de boucles comme suit:

- longueur de boucle pour les installations à isolation gazeuse: 65 m pour $52 \text{ kV} < U_r < 245 \text{ kV}$ et 130 m pour $U_r \geq 245 \text{ kV}$;
- longueur de boucle pour les installations à isolement dans l'air: 200 m pour $52 \text{ kV} < U_r < 245 \text{ kV}$ et 400 m pour $U_r \geq 245 \text{ kV}$.

Tableau B.1 – Impédances moyennes

Tension assignée U_r kV	Impédance moyenne $\mu\Omega/\text{m}$	
	Installations à isolation gazeuse	Installations à isolement dans l'air
72,5	63	314
100		
123		
145		
170		
245 / 300	67	346
420		
550		361
800	76	355
1 100	80	388

B.2 Pouvoir d'établissement et de coupure de courant de jeux de barres à vide des sectionneurs

La mise sous tension ou hors tension de tronçons de jeux de barres à vide ou de condensateurs en parallèle de disjoncteurs est considérée comme une manœuvre d'établissement-coupure de courants capacitifs. Les phénomènes de surtensions transitoires très rapides (VFTO – *very fast transient overvoltage*) sont inhérents à l'établissement-coupure de courants capacitifs par les sectionneurs d'appareillage sous enveloppe métallique à

isolation gazeuse. Étant donné que les VFTO peuvent provoquer des décharges disruptives à la terre, une conception adaptée du sectionneur est exigée pour éviter ces décharges. Cette exigence s'applique généralement aux sectionneurs de $U_r \geq 300$ kV.

Pour $U_r < 300$ kV, les VFTO ne deviennent pas si élevées par rapport aux niveaux de tenue aux chocs de foudre (LIWV – *lightning impulse withstand voltage*) spécifiés car les rapports entre le LIWV et la tension assignée sont suffisamment élevés. La coupure simultanée de plusieurs sectionneurs dans le même circuit n'est pas recommandée et n'est pas prise en considération dans le présent document.

Dans le cas particulier des sectionneurs servant à mettre hors tension des jeux de barres de grande longueur ou d'autres parties sous tension (par exemple, de courtes longueurs de câbles), un pouvoir d'établissement et de coupure du sectionneur est exigé. Cette exigence peut s'appliquer non seulement aux sectionneurs de $U_r \geq 300$ kV, mais aussi de $U_r < 300$ kV.

Avec $U_r \geq 800$ kV, les VFTO maximales dans les postes à isolation gazeuse peuvent atteindre dans certains cas le niveau d'isolement de la tension de tenue aux chocs de foudre. Dans de tels cas, des sectionneurs équipés de résistances peuvent être utilisés pour atténuer les VFTO. Trois types de sectionneurs différents équipés de résistances sont proposés à titre d'exemple à la Figure B.1. La résistance peut être placée en parallèle ou en série par rapport à l'intervalle de coupure. Dans la méthode de commutation d'arc, le courant est coupé ou établi pour la résistance parallèle au cours d'une manœuvre d'ouverture par commutation de l'arc allant du contact principal au contact de la résistance.

Généralement, les résistances de valeurs comprises entre 200 Ω et 1 000 Ω sont utilisées. Le facteur d'amortissement de la surtension dépend du rapport de la résistance de la résistance à l'impédance du réseau.

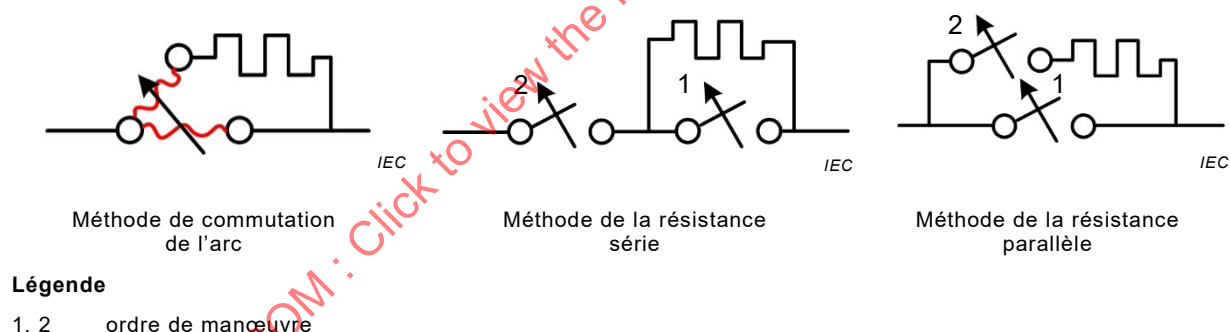


Figure B.1 – Exemples de sectionneurs équipés de résistances

B.3 Pouvoir d'établissement et de coupure de courant induit des sectionneurs de terre

Un pouvoir d'établissement et de coupure des courants induits est exigé pour les sectionneurs de terre destinés à la mise à la terre de lignes aériennes à plusieurs circuits. Cette exigence s'applique aux sectionneurs de terre de $U_r > 52$ kV.

Dans le cas de lignes aériennes à plusieurs circuits, des courants induits peuvent circuler dans les circuits hors tension par suite de couplage capacitif et inductif avec les circuits adjacents sous tension. Les sectionneurs de terre utilisés sur ces lignes doivent donc être aptes à supporter les conditions de service suivantes:

- établir et couper un courant capacitif quand le sectionneur de terre est manœuvré à l'extrémité d'un circuit dont l'autre extrémité est ouverte;
- établir et couper un courant inductif quand le sectionneur de terre est manœuvré à l'extrémité d'un circuit dont l'autre extrémité est à la terre;

- supporter en permanence ces courants capacitifs et inductifs.

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Annexe C (normative)

Tolérances sur les grandeurs d'essai pour les essais de type

Une tolérance est définie comme la plage de valeurs d'essai spécifiée par le document dans laquelle la valeur d'essai mesurée doit figurer pour qu'un essai soit valable.

Tout écart entre la valeur d'essai mesurée et la valeur d'essai réelle causé par l'incertitude de mesure n'est pas pris en compte ici.

Le Tableau C.1 indique les tolérances sur les grandeurs d'essai pour les essais de type.

Tableau C.1 – Tolérances sur les grandeurs d'essai pour les essais de type (1 de 2)

Paragraphe	Description de l'essai	Grandeur d'essai	Valeur d'essai spécifiée	Tolérance d'essai	Référence
7.101	Essais de fermeture en court-circuit des sectionneurs de terre	Fréquence d'essai	f_r	$\pm 10 \%$	7.101.3
		Tension d'essai (moyenne entre phases)	U_r	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4
		Toute tension de phase / moyenne (triphasé)	1	$\pm 5 \%$	7.101.4 a)
		Tension d'essai (moyenne, monophasé)	$U_r / \sqrt{3}$	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4 b)
		Tension d'essai (moyenne, triphasé)	U_r	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.101.4 b)
		Courant de court-circuit à 200 ms	I_k	$\geq 80 \%$	7.101.5
		Courant établi en court-circuit (de crête, présumé)	I_{ma}	$\left(\begin{smallmatrix} +5 \\ 0 \end{smallmatrix} \right) \%$	7.101.5
7.106	Coupure de courant de transfert de barres	Fréquence d'essai	f_r	$\pm 10 \%$	7.106.2.3
		Tension d'essai	U_{bt}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.106.2.4
		Courant d'essai	I_{bt}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.106.2.5
		Tout courant de phase / moyenne	1	$\pm 10 \%$	7.106.2.5
		Facteur de puissance du circuit d'essai		$\leq 0,5$	7.106.2.6

Tableau C.1 (2 de 2)

Paragraphe	Description de l'essai	Grandeur d'essai	Valeur d'essai spécifiée	Tolérance d'essai	Référence
7.107	Coupure de courant induit	Fréquence d'essai	f_r	$\pm 10 \%$	7.107.4
		Tension d'essai	U_{im}, U_{is}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.5
		Toute tension de phase / moyenne	1	$\pm 10 \%$	7.107.5
		Courant d'essai	I_{im}, I_{is}	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.6
		Tout courant de phase / moyenne	1	$\pm 10 \%$	7.107.6
		Facteur de puissance du circuit d'alimentation		$\leq 0,15$	7.107.7.2
		Valeur de la crête de la TTR (courant d'induction électromagnétique)		$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.107.7.2
		Durée de montée de la TTR (courant d'induction électromagnétique)		$\left(\begin{smallmatrix} 0 \\ -10 \end{smallmatrix} \right) \%$	7.107.7.2
7.108	Essai de coupure de courant de jeux de barres à vide	Fréquence d'essai	f_r	$\pm 10 \%$	7.108.4
		Tension d'essai	U_1, U_2	$\left(\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \right) \%$	7.108.5
	Pouvoir d'établissement-coupure de courant, séquence d'essai 3	Courant de jeux de barres à vide		$\pm 10 \%$	7.108.5

Annexe D (normative)

Autres méthodes d'essai pour les essais d'établissement de courant en court-circuit

D.1 Généralités

Dans la présente annexe qui s'applique au 7.101.5 a), d'autres méthodes d'essai sont fournies pour obtenir les conditions correspondant au courant établi correct avec la durée correcte de préarc.

Pour les essais utilisant d'autres méthodes dans lesquelles la durée de préarc exigée est obtenue, l'angle d'établissement peut être étendu entre -40 degrés électriques et $+15$ degrés électriques avec référence à la valeur crête de tension de la source de courant.

NOTE À -40 degrés électriques, l'énergie de préarc est supérieure à celle située dans la limite comprise entre -30 degrés électriques et $+15$ degrés électriques.

Pour faciliter les essais dans un circuit triphasé, il est admis d'appliquer la durée maximale de préarc seulement dans une phase, tandis que le courant est appliqué à tension réduite aux deux autres phases.

D.2 Autres méthodes

D.2.1 Méthode d'essai synthétique avec tension assignée et courant de court-circuit assigné

Les méthodes d'essais synthétiques fournies à l'Article 5 de l'IEC 62271-101:2012 peuvent être appliquées.

Le circuit d'essai et les exigences spécifiques doivent répondre à l'exigence a) du 7.101.5.

D.2.2 Méthodes d'essai à tension réduite

D.2.2.1 Généralités

Pour obtenir des résultats comparables entre les essais à tension assignée et les essais en variante à tensions réduites, la durée de préarc pendant l'essai de fermeture à tension réduite ne doit pas être inférieure à la durée de préarc de l'essai à la tension assignée.

L'essai est divisé en deux parties:

- partie 1: un essai à tension assignée et courant réduit pour déterminer la durée de préarc du sectionneur de terre;
- partie 2: un essai à tension réduite et au courant établi assigné en court-circuit, avec la durée de préarc exigée.

D.2.2.2 Partie 1: détermination de la durée de préarc

La durée de préarc doit être déterminée en réalisant des essais d'établissement à la tension assignée et au courant réduit. La disposition du sectionneur de terre doit être telle que décrite en 7.101.2. Le courant doit être suffisamment faible pour que la surface de contact ne subisse pas l'influence de l'érosion de contact. La durée de préarc doit être déterminée à chacun de ces essais.

La réalisation de dix essais d'établissement pour évaluer la durée de préarc doit donner lieu à un instant d'établissement du courant correspondant à un angle de -15 degrés électriques à $+15$ degrés électriques sur la crête de la forme d'onde de tension alternative appliquée. La valeur moyenne de ces durées de préarc valables mesurées et l'écart-type (σ) doivent être calculés en vue d'être appliqués à la Partie 2 (voir D.2.2.3).

En variante, une tension continue peut être utilisée. La tension continue doit correspondre à la valeur de crête de la tension d'essai. La durée de préarc peut différer en fonction de la polarité de la tension à l'établissement. De ce fait, les 10 essais d'établissement doivent être divisés en 5 manœuvres avec polarité positive et 5 manœuvres avec polarité négative. La durée moyenne la plus longue de préarc des deux polarités et son écart-type (σ) doivent être calculés et appliqués dans la Partie 2.

NOTE Un transducteur de déplacement ou un dispositif équivalent peut être utilisé pour mesurer la durée de préarc. Dans un dispositif triphasé, une phase peut être utilisée pour évaluer la durée de préarc et les autres phases peuvent être utilisées pour mesurer l'entrée en contact réelle. Une manœuvre à vide avec mesurage des instants d'entrée en contact de chacun des trois pôles peut être utilisée pour compenser les écarts d'entrée en contact entre pôles.

D.2.2.3 Partie 2: essais d'établissement de courant en court-circuit à tension réduite

Au cours des essais d'établissement au courant assigné en court-circuit à tension réduite, la durée de préarc (voir 7.101.5 a) doit être au moins égale à la moyenne de la durée de préarc plus 2σ déterminée dans les essais décrits dans la Partie 1 (voir D.2.2.2).

Le courant de court-circuit obtenu pendant les essais à tension réduite doit être au moins égal au courant assigné en court-circuit.

Afin d'obtenir la durée de préarc exigée, l'établissement du courant peut être obtenu par les trois méthodes ci-après:

Méthode 1: Une source de courant à tension réduite et une source de tension de toute forme d'onde, suffisamment élevées pour amorcer le préarc au point correct de l'onde.

Méthode 2: Pour les sectionneurs de terre à isolation gazeuse, tant la pression de gaz que la tension appliquée de la source de courant peuvent être diminuées de manière à obtenir encore la durée de préarc exigée.

Au lieu de simplement diminuer la pression de gaz, l'objet d'essai peut également être rempli d'un autre milieu, tel que l'air ou l'azote.

La vitesse à l'entrée en contact ne doit pas varier de plus de 10 % du fait de la réduction de la pression de gaz ou du remplacement du gaz par un autre milieu.

NOTE 1 Il peut être utile d'estimer la tension exigée à pression réduite par la même méthode que celle décrite dans la Partie 1, afin d'obtenir la durée correcte de préarc.

NOTE 2 En cas d'utilisation d'une pression réduite ou d'un gaz de remplacement, le comportement du disque de rupture ne peut pas être vérifié, étant donné que la pression transitoire peut être plus faible ou plus forte que prévu dans les conditions de service lorsque le gaz de service et la pression de remplissage assignée sont utilisés.

Méthode 3: Une source de courant à tension réduite et préarc amorcé par un fil fusible d'un diamètre maximal de 0,5 mm. Le fil fusible est exigé dans le pôle à soumettre à l'essai au courant établi en court-circuit avec la durée correcte de préarc;

NOTE 3 Certains essais supplémentaires peuvent être nécessaires pour estimer la longueur du fil fusible.

Annexe E (informative)

Extension de la validité des essais de type

E.1 Généralités

L'Annexe J, à l'exception de J.2 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Sur accord entre le constructeur et l'utilisateur, il n'est pas nécessaire de répéter un essai de type individuel par suite de la modification d'un détail de construction si le constructeur peut démontrer que cette modification n'a pas d'incidence sur les résultats de cet essai de type individuel.

E.2 Essais diélectriques

La tension assignée couvre toutes les tensions inférieures ou égales à celle soumise à l'essai.

E.3 Essais au courant de courte durée admissible

Les résultats d'essai produits par un sectionneur ou un sectionneur de terre placé dans une certaine position (horizontale ou verticale, par exemple) sont valables pour la position du sectionneur ou du sectionneur de terre au cours de cet essai. Cependant, dans certains cas, la position particulière dans laquelle le sectionneur ou le sectionneur de terre subit l'essai peut valider d'autres positions en fonction de la conception et de la construction du sectionneur ou du sectionneur de terre.

E.4 Performances de fermeture en court-circuit des sectionneurs de terre

La tension assignée couvre toutes les tensions de réseau inférieures ou égales à celle soumise à l'essai. Le courant établi assigné en court-circuit couvre tout courant de court-circuit du réseau inférieur ou égal à celui soumis à l'essai.

E.5 Essais de fonctionnement et d'endurance mécanique

L'essai effectué sur un sectionneur ou sectionneur de terre donné avec une tension assignée et/ou un courant assigné spécifiés couvre les valeurs inférieures de tension assignée et/ou de courant assigné.

Les dispositifs de verrouillage d'une conception donnée peuvent être utilisés avec d'autres sectionneurs et sectionneurs de terre sans avoir à répéter l'essai de type si le constructeur peut démontrer qu'ils fonctionnent de la même manière que pendant l'essai de type effectué.

E.6 Essais de coupure de courant de transfert de barres sur les sectionneurs

Les éléments de coupure de courant de transfert de barres d'une conception donnée peuvent également être utilisés dans d'autres sectionneurs sans avoir à répéter l'essai de type si le constructeur peut démontrer que les éléments de coupure de courant de transfert de barres sont manœuvrés par l'autre sectionneur de la même façon qu'avec le sectionneur utilisé pour réaliser l'essai de type.

E.7 Essais de coupure de courant induit sur les sectionneurs de terre

Les éléments d'établissement et de coupure des sectionneurs de terre ayant un pouvoir d'établissement et de coupure de courant d'induction assigné peuvent également être utilisés dans d'autres sectionneurs de terre sans avoir à répéter l'essai de type, si le constructeur peut démontrer que les éléments d'établissement et de coupure sont manœuvrés par l'autre sectionneur de terre de la même façon qu'avec le sectionneur de terre utilisé pour réaliser l'essai de type.

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FINAL VERSION**VERSION FINALE**

**High-voltage switchgear and controlgear –
Part 102: Alternating current disconnectors and earthing switches**

**Appareillage à haute tension –
Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif**

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6.4	Auxiliary and control equipment and circuits	35
6.5	Dependent power operation	35
6.6	Stored energy operation.....	35
6.7	Independent unlatched operation (independent manual or power operation)	35
6.8	Manually operated actuators	35
6.9	Operation of releases.....	35
6.10	Pressure/level indication	35
6.11	Nameplates.....	35
6.12	Locking devices	38
6.13	Position indication.....	38
6.14	Degree of protection provided by enclosures	38
6.15	Creepage distances for outdoor insulators	38
6.16	Gas and vacuum tightness.....	38
6.17	Tightness for liquid systems.....	38
6.18	Fire hazard (flammability)	38
6.19	Electromagnetic compatibility (EMC).....	38
6.20	X-ray emission	38
6.21	Corrosion	38
6.22	Filling levels for insulation, switching and/or operation.....	39
6.101	Particular requirements for earthing switches.....	39
6.102	Requirements in respect of the isolating distance of disconnectors	39
6.103	Mechanical strength.....	39
6.104	Operation of disconnectors and earthing switches – Position of the movable contact system and its indicating and signalling devices	40
6.104.1	Securing of position	40
6.104.2	Additional requirements for power-operated mechanisms	40
6.104.3	Indication and signalling of position	40
6.105	Maximum force required for manual (dependent or independent) operation.....	41
6.105.1	General	41
6.105.2	Operation requiring more than one revolution	42
6.105.3	Operation requiring up to one revolution	42
6.106	Dimensional tolerances.....	42
6.107	Earthing switches with short-circuit making current capability	42
7	Type tests	42
7.1	General.....	42
7.1.1	Basics	42
7.1.2	Information for identification of test objects.....	44
7.1.3	Information to be included in type test reports	44
7.2	Dielectric tests	44
7.2.1	General	44
7.2.2	Ambient air conditions during tests	44
7.2.3	Wet test procedure	44
7.2.4	Arrangement of the equipment.....	44
7.2.5	Criteria to pass the test	45
7.2.6	Application of the test voltage and test conditions.....	45
7.2.7	Tests of disconnectors and earthing switches of $U_T \leq 245$ kV.....	45
7.2.8	Test of disconnectors and earthing switches of $U_T > 245$ kV	45
7.2.9	Artificial pollution tests for outdoor insulators.....	45
7.2.10	Partial discharge tests	46

7.2.11	Dielectric tests on auxiliary and control circuits	46
7.2.12	Voltage test as condition check	46
7.3	Radio interference voltage (RIV) test	46
7.4	Resistance measurement	46
7.5	Continuous current tests	46
7.6	Short-time withstand current and peak withstand current tests	46
7.6.1	General	46
7.6.2	Arrangement of the disconnectors and earthing switches and of the test circuit	46
7.6.3	Test current and duration	52
7.6.4	Conditions of disconnectors and earthing switches after test	52
7.7	Verification of the protection	53
7.8	Tightness tests	53
7.9	Electromagnetic compatibility tests (EMC)	53
7.10	Additional tests on auxiliary and control circuits	53
7.11	X-ray radiation test for vacuum interrupters	53
7.101	Test to prove the short-circuit making performance of earthing switches	54
7.101.1	General test conditions	54
7.101.2	Arrangement of the earthing switch for tests	54
7.101.3	Test frequency	54
7.101.4	Test voltage	54
7.101.5	Test short-circuit making current	55
7.101.6	Test circuits	55
7.101.7	Test procedures	55
7.101.8	Behaviour of earthing switches when making short-circuit currents	56
7.101.9	Condition of earthing switch after short-circuit making tests	56
7.101.10	Invalid tests	57
7.101.11	Type test reports	57
7.102	Operating and mechanical endurance tests	58
7.102.1	General test conditions	58
7.102.2	Contact zone test	58
7.102.3	Mechanical endurance test	61
7.102.4	Operation during the application of rated static mechanical terminal loads	63
7.102.5	Extended mechanical endurance tests	64
7.102.6	Testing of mechanical interlocking devices	65
7.103	Operation under severe ice conditions	65
7.103.1	General	65
7.103.2	Test arrangement	65
7.103.3	Test procedure	66
7.104	Low- and high-temperature tests	67
7.104.1	General	67
7.104.2	Measurement of ambient air temperature	68
7.104.3	Low-temperature test	68
7.104.4	High-temperature test	70
7.105	Tests to verify the proper functioning of the position-indicating device	70
7.105.1	General	70
7.105.2	Tests on the power kinematic chain and the position-indicating kinematic chain	71
7.106	Bus-transfer current switching tests on disconnectors	71

7.106.1	General	71
7.106.2	Making and breaking tests	71
7.107	Induced current switching tests on earthing switches	75
7.107.1	General	75
7.107.2	Arrangement of the earthing switch for tests	75
7.107.3	Earthing of test circuit and earthing switch	76
7.107.4	Test frequency	76
7.107.5	Test voltage	76
7.107.6	Test currents	76
7.107.7	Test circuits	76
7.108	Bus-charging current switching tests on disconnectors	81
7.108.1	General	81
7.108.2	Test duties	82
7.108.3	Arrangement of the disconnector for tests	82
7.108.4	Test frequency	82
7.108.5	Test voltages for making and breaking tests	83
7.108.6	Test circuits for making and breaking tests	84
7.108.7	Performance of making and breaking tests	86
7.108.8	Behaviour of the disconnector during making and breaking tests	86
7.108.9	Condition after test	87
7.108.10	Type test reports	87
7.108.11	Requirements for U_{TVE} measurements	88
8	Routine tests	88
8.1	General	88
8.2	Dielectric test on the main circuit	88
8.3	Tests on auxiliary and control circuits	89
8.4	Measurement of the resistance of the main circuit	89
8.5	Tightness test	89
8.6	Design and visual checks	89
8.101	Mechanical operating tests	89
8.102	Verification of earthing function	90
9	Guide to the selection of disconnectors and earthing switches (informative)	90
9.1	General	90
9.2	Selection of rated values	91
9.2.101	General	91
9.2.102	Selection of rated voltage and rated insulation level	91
9.2.103	Selection of rated continuous current	91
9.2.104	Selection of rated contact zone	91
9.2.105	Selection of rated static mechanical terminal load	92
9.2.106	Selection of a bus-transfer current switching capability for disconnectors of $U_r > 52$ kV	92
9.2.107	Selection of an induced-current switching capability for earthing switches of $U_r > 52$ kV	92
9.2.108	Selection of rated short-time withstand current and of rated duration of short-circuit	92
9.2.109	Selection of rated peak withstand current and of rated short-circuit making current for earthing switches	93
9.2.110	Selection of short-circuit making capability for earthing switches	93
9.3	Cable-interface considerations	93

9.4	Continuous or temporary overload due to changed service conditions.....	93
9.5	Environmental aspects.....	93
9.5.101	Local environmental conditions.....	93
10	Information to be given with enquiries, tenders and orders (informative).....	94
10.1	General.....	94
10.2	Information with enquiries and orders	94
10.3	Information with tenders.....	95
11	Transport, storage, installation, operating instructions, and maintenance	96
11.1	General.....	96
11.2	Conditions during transport, storage and installation	96
11.3	Installation	96
11.4	Operation.....	97
11.5	Maintenance	97
12	Safety.....	97
12.1	General.....	97
12.2	Precautions by manufacturers.....	97
12.3	Precautions by users	97
13	Influence of the product on the environment	97
Annex A (informative)	Test voltage for the most disadvantageous dielectric position of an earthing switch during operation (minimum temporary clearance)	98
Annex B (informative)	Current-switching capability required of disconnectors and earthing switches.....	99
B.1	Bus-transfer current switching capability of disconnectors.....	99
B.2	Bus-charging current switching capability of disconnectors	99
B.3	Induced current-switching capability of earthing switches.....	100
Annex C (normative)	Tolerances on test quantities for type tests	101
Annex D (normative)	Alternative test methods for short-circuit current making tests.....	103
D.1	General.....	103
D.2	Alternative methods	103
D.2.1	Synthetic test method with both rated voltage and rated short-circuit current.....	103
D.2.2	Test methods with reduced voltage.....	103
Annex E (informative)	Extension of validity of type tests	105
E.1	General.....	105
E.2	Dielectric tests	105
E.3	Short-time withstand current tests.....	105
E.4	Short-circuit making performance of earthing switches.....	105
E.5	Operating and mechanical endurance tests.....	105
E.6	Bus-transfer current switching tests on disconnectors	105
E.7	Induced current switching tests on earthing switches	106
Bibliography		107
Figure 1	– Position indicating/signalling device(s).....	40
Figure 2	– Three-phase test arrangement for disconnectors and earthing switches	48
Figure 3	– Single-phase test arrangement for disconnectors with a horizontal isolating distance and for earthing switches of $U_T > 52$ kV, to be used with flexible or with rigid conductors	49

Figure 4 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_T > 52$ kV with a vertical isolating distance, to be used with flexible conductors	50
Figure 5 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_T > 52$ kV with a vertical isolating distance, to be used with rigid conductors	51
Figure 6 – Fixed contact parallel to support	59
Figure 7 – Fixed contact perpendicular to support	60
Figure 8 – Example of the application of rated static mechanical terminal loads to a (divided support) pantograph disconnector (or earthing switch)	61
Figure 9 – Example of the application of rated static mechanical terminal loads to a two-column disconnector	62
Figure 10 – Test sequences for low and high temperature tests	68
Figure 11 – Example of test circuit for bus-transfer current switching tests	73
Figure 12 – Test circuit for electromagnetically induced current switching tests	77
Figure 13 – Test circuits for electrostatically induced current-switching tests	79
Figure 14 – Test circuit for test duty 1	83
Figure 15 – Typical voltage waveform (Including VFT and FT components)	85
Figure 16 – Test circuit for test duty 2	85
Figure 17 – Test circuit for test duty 3	86
Figure B.1 – Examples of resistor-fitted disconnectors	100
Table 1 – Classification of earthing switches for short-circuit making	28
Table 2 – Preferred contact zones for "fixed" contacts supported by flexible conductors	29
Table 3 – Preferred contact zones for "fixed" contacts supported by rigid conductors	29
Table 4 – Preferred static mechanical terminal loads	30
Table 5 – Classification of disconnectors for mechanical endurance	31
Table 6 – Classification of earthing switches for mechanical endurance	31
Table 7 – Rated bus-transfer voltages of disconnectors	32
Table 8 – Classification of earthing switches for induced-current switching	32
Table 9 – Rated induced currents and voltages	33
Table 10 – Classification of disconnectors for bus-charging switching	34
Table 11 – Standard rated bus-charging currents	34
Table 12 – Product information	36
Table 13 – List of type tests	43
Table 14 – Power frequency withstand voltages	45
Table 15 – Requirements on the instant of making	56
Table 16 – Invalid tests	57
Table 17 – Standard values of recovery voltages for electromagnetically induced current breaking tests	78
Table 18 – Test circuit capacitances (C_1 values) for electrostatically induced current switching tests	80
Table 19 – Test voltages for making and breaking tests	83
Table 20 – Number of tests	86

Table 21 – Power frequency voltage tests	89
Table B.1 – Average impedances	99
Table C.1 – Tolerances on test quantities for type tests	101

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 102: Alternating current disconnectors and earthing switches

FOREWORD

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 62271-102 edition 2.1 contains the second edition (2018-05) [documents 17A/1173/FDIS and 17A/1180/RVD] and its amendment 1 (2022-04) [documents 17A/1322/CDV and 17A/1337/RVC].

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

International Standard IEC 62271-102 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

This second edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) new numbering according to IEC 17/1025/RQ to harmonize with ISO/IEC Directives, Part 2, and IEEE Std. C37.100.1;
- b) clause numbering has been aligned with IEC 62271-1:2017;
- c) the Scope has been extended to cover all indoor and outdoor installations. Consideration of switching devices having disconnecting and/or earthing switch functionalities, apart from other functions, are also covered by this document;
- d) ratings have been moved from Annexes B, C and E to Clause 5; the order of the subclauses now corresponds to the order of subclauses in Clause 7;
- e) new rating values for bus-transfer current and bus-transfer voltage have been assigned;
- f) new class of mechanical endurance for earthing switches has been added (M1);
- g) subclause "Rated values of electrical endurance for earthing switches" is now called "Classification of earthing switches for short-circuit making capability";
- h) new subclause with ratings for ice-coating has been added;
- i) new subclause with classification of bus-charging switching capability has been added;
- j) new withstand requirements for interlocking devices have been added;
- k) the way to comply with the requirements of the isolating distance of disconnectors has been modified;
- l) design and construction requirements for position-indicating devices have been modified, aligning the requirements for position indication and signalling;
- m) the value of the operating force has been changed;
- n) the test procedures and validation criteria have been revised and modified where necessary;
- o) requirements for applied voltage during single-phase test on non-simultaneous closing earthing switches have been changed;
- p) non-verifiable requirements have been deleted;
- q) a new subclause has been added for testing mechanical interlocking devices;
- r) the high- and low-temperature test is mandatory if the temperature limits for the service conditions of the apparatus (defined by the manufacturer) are above +40 °C or below –5 °C, and a more detailed testing procedure is given;
- s) the testing procedure to verify the proper functioning of the position-indicating device allows a more practicable testing for every technology used;
- t) a new Annex B has been added with title: "Current-switching capability required of disconnectors and earthing switches";
- u) a new Annex C has been added with title: "Tolerances on test quantities for type tests";
- v) a new Annex E has been added with title: "Extension of validity of type tests".

This standard is to be read in conjunction with IEC 62271-1:2017, to which it refers and which is applicable, unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses, except annexes, is used as in IEC 62271-1:2017. Additional subclauses are numbered from 101.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62271 series, published under the general title *High-voltage switchgear and controlgear*, can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 102: Alternating current disconnectors and earthing switches

1 Scope

This part of IEC 62271 applies to alternating current disconnectors and earthing switches, designed for indoor and outdoor installations for nominal voltages above 1 000 V and for service frequencies up to and including 60 Hz.

It also applies to the operating devices of these disconnectors and earthing switches and their auxiliary equipment.

Additional requirements for disconnectors and earthing switches in enclosed switchgear and controlgear are given in IEC 62271-200, IEC 62271-201 and IEC 62271-203.

NOTE Disconnectors in which the fuse forms an integral part are not covered by this standard.

This document is also applicable to switching devices having disconnecting and/or earthing functionalities apart from other functions, such as high-speed earthing switch, circuit-breaker and switch-disconnector.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-151, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-441, *International Electrotechnical Vocabulary – Chapter 441: Switchgear controlgear and fuses*

IEC 60050-471, *International Electrotechnical Vocabulary – Part 471: Insulators*

IEC 60050-614, *International Electrotechnical Vocabulary – Part 614: Generation, transmission and distribution of electricity – Operation*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60137, *Insulating bushings for alternating voltages above 1 000 V*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60865-1, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

IEC 62262:2002, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

IEC 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-101:2012, *High-voltage switchgear and controlgear – Part 101: Synthetic testing*
IEC 62271-101:2012/AMD1:2017

IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-201:2014, *High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC/TR 62271-305, *High-voltage switchgear and controlgear – Part 305: Capacitive current switching capability of air-insulated disconnectors for rated voltages above 52 kV*

ISO 2768-1, *General tolerances – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-151, IEC 60050-441, IEC 60050-471, IEC 60050-614, and IEC 62271-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 General terms and definitions

3.1.101

indoor switchgear and controlgear

switchgear and controlgear designed solely for installation within a building or other housing, where the switchgear and controlgear is protected against wind, rain, snow, abnormal dirt deposits, abnormal condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-04]

3.1.102

outdoor switchgear and controlgear

switchgear and controlgear suitable for installation in the open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-05]

3.1.103

user

person or legal entity using the disconnectors or earthing switches

Note 1 to entry: This can include the purchaser (for example an electricity supplier), but it can also include the contracting company, the staff responsible for erection of installation, the maintenance or operating staff or anybody else temporarily or permanently responsible for the disconnector, earthing switch or electrical installation, or even the operation of the switchgear.

3.2 Assemblies of switchgear and controlgear

3.2.1

test object

equipment needed to represent the specimen for a particular type test

[SOURCE: IEC 62271-1:2017, 3.2.1, modified – "switchgear and controlgear" replaced by "specimen"]

3.3 Parts of assemblies

Subclause 3.3 of IEC 62271-1:2017 is applicable.

3.4 Switching devices

3.4.101

disconnector

mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

Note 1 to entry: A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time currents under abnormal conditions such as those of short-circuit.

Note 2 to entry: "Negligible current" implies currents such as the capacitive currents of bushings, busbars, connections, very short lengths of cable, currents of permanently connected grading impedances of circuit-breakers and currents of voltage transformers and dividers (see also IEC/TR 62271-305). For $U_r \leq 420$ kV, a current not exceeding 0,5 A is a negligible current for the purpose of this definition; for $U_r > 420$ kV and currents exceeding 0,5 A, the manufacturer should be consulted. "No significant change in voltage" refers to such applications as the by-passing of induction voltage regulators or circuit-breakers and bus transfer.

[SOURCE: IEC 60050-441:2000, 441-14-05, modified – Note 2 to entry has been added]

3.4.102

divided support disconnector

divided support earthing switch

disconnector (or earthing switch) in which the fixed and moving contacts of each pole are not supported by a common base or frame

Note 1 to entry: A typical example is the pantograph or semi-pantograph disconnector (or earthing switch).

[SOURCE: IEC 60050-441:2000, 441-14-06 and -07, modified – The term "earthing switch" is completed with "divided support" and the term "disconnector" substituted by "earthing switch" in Note 1 to entry when appropriate; Note 2 to entry deleted.]

3.4.103

centre-break disconnector

disconnector in which both contacts of each pole are movable and engage at a point substantially midway between their supports

Note 1 to entry: This term applies to high-voltage disconnectors only.

[SOURCE: IEC 60050-441:2000, 441-14-08]

3.4.104

double-break disconnecter

disconnecter that opens a circuit at two points

[SOURCE: IEC 60050-441:2000, 441-14-09]

3.4.105

resistor-fitted disconnecter

disconnecter fitted with resistor in series or in parallel to the switching contacts in order to mitigate the very fast transient overvoltage (VFTO) during both the opening and closing operation in metal-enclosed gas-insulated switchgear

3.4.106

earthing switch

mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time currents under abnormal conditions such as those of short-circuit, but not required to carry current under normal conditions of the circuit

Note 1 to entry: An earthing switch may have a short-circuit making capacity.

Note 2 to entry: An earthing switch of $U_r > 52$ kV may have a rating for switching and carrying induced currents.

Note 3 to entry: These devices may sometimes be operated against short-circuit. The different classes of earthing switches are related to the number of short-circuit making operations.

Note 4 to entry: In some cases, earthing switches are used as fault-initiating devices.

[SOURCE: IEC 60050-441:2000, 441-14-11, modified – the Notes 2, 3 and 4 to entry have been added]

3.4.107

combined function earthing switch

earthing switch having a common contact system for earthing and at least one of the following functions:

- disconnecting;
- making and/or breaking of currents up to the short-circuit current.

3.4.108

switch-disconnector

switch which, in the open position, satisfies the isolating requirements specified for a disconnecter

[SOURCE: IEC 60050-441:2000, 441-14-12]

3.5 Parts of switching devices

3.5.101

pole of a switching device

portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.102**main circuit**

<of a switching device> all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.103**contact**

<of a mechanical switching device> conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.104**main contact**

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.105**control contact**

contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.106**"a" contact****make contact**

control or auxiliary contact that is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.107**"b" contact****break contact**

control or auxiliary contact that is open when the main contacts of a mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.108**position-indicating device**

part of a mechanical switching device that indicates whether it is in the open, closed, or where appropriate, earthed position

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.109**position-signalling device**

part of a disconnector or earthing switch which uses auxiliary energy to indicate whether the contacts of the main circuit are in the open or closed position

3.5.110

terminal

conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

[SOURCE: IEC 60050-151:2014, 151-12-12, modified – the note has been deleted.]

3.5.111

contact zone

<for divided support disconnectors and earthing switches> spatial region of positions the fixed contact may take up for correct engagement with the moving contact

3.5.112

power kinematic chain

mechanical connecting system between the operating mechanism and the moving contacts, both included

Note 1 to entry: Refer to Figure 1.

3.5.113

position-indicating kinematic chain

mechanical connecting system between the moving contacts and the position-indicating device(s), both included

3.5.114

position-signalling kinematic chain

mechanical connecting system between the moving contacts and the position of the signalling device(s)

3.5.115

connecting point

most upstream point (i.e. the closest to the source of energy) of the common part of the power and position-indicating/signalling kinematic chains

3.5.116

strain limiting device

device that limits to a defined value the torque or force transmitted to the downstream side of the device irrespective of the torque or force applied to the upstream side

3.5.117

torque (force) controlling system

system that monitors and controls the torque (force) transmitted to the downstream side of the device in comparison with defined value

3.5.118

bushing

device that enables one or several conductors to pass through a partition such as a wall or a tank, and insulate the conductors from it

[SOURCE: IEC 60050-471:2007, 471-02-01, modified – Notes 1 and 2 to entry deleted]

3.5.119

source of energy

origin of the energy released or of the force/torque applied to the power kinematic chain of a switching device during an operation or at any stable position of it

Note 1 to entry: The origin of the energy or force/torque can be human, electrical, hydraulics, pneumatics and mechanics i.e. springs, weights, etc. alone or in combination.

3.6 Operation

3.6.101

operation

<of a mechanical switching device> transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this may be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:2000, 441-16-01]

3.6.102

operating cycle

<of a mechanical switching device> succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:2000, 441-16-02]

3.6.103

closing operation

<of a mechanical switching device> operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:2000, 441-16-08]

3.6.104

opening operation

<of a mechanical switching device> operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:2000, 441-16-09]

3.6.105

dependent manual operation

<of a mechanical switching device> operation solely by means of directly applied manual energy, such that the speed and force of the operation are dependent upon the action of the operator

Note 1 to entry: Dependent manual operation may be performed by a crank or by a swing lever (horizontal or vertical).

Note 2 to entry: Switching devices with dependent manual operation have not any inherent switching capability.

[SOURCE: IEC 60050-441:2000, 441-16-13, modified – Notes 1 and 2 to entry have been added]

3.6.106

dependent power operation

<of a mechanical switching device> operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.107

stored energy operation

<of a mechanical switching device> operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

Note 1 to entry: This kind of operation may be subdivided according to:

- 1) the manner of storing the energy (spring, weight, etc.);
- 2) the origin of the energy (manual, electric, etc.);
- 3) the manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:2000, 441-16-15]

3.6.108

independent manual operation

<of a mechanical switching device> stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

[SOURCE: IEC 60050-441:2000, 441-16-16]

3.6.109

closed position

<of a mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

Note 1 to entry: Predetermined continuity means that the contacts are fully closed to carry the rated continuous and the rated short-circuit currents, as applicable.

[SOURCE: IEC 60050-441:2000, 441-16-22, modified – Note to entry has been added]

3.6.110

open position

<of a mechanical switching device> position in which the predetermined clearance between open contacts in the main circuit of the device is secured

[SOURCE: IEC 60050-441:2000, 441-16-23]

3.6.111

toggle point

point beyond which any further movement of the charging mechanism causes the stored energy to be released

3.6.112

mechanical endurance

<of a disconnector or earthing switch> capability of a disconnector or earthing switch to perform a defined number of operations without voltage on or current through the circuit under specified operation conditions

3.7 Characteristic quantities

3.7.101

peak making current

<of an earthing switch> peak value of the first major loop of the current in a pole of the earthing switch during the transient period following the initiation of current during a making operation

Note 1 to entry: Where, for a three-phase circuit, a single value of (peak) making current is referred to, this is, unless otherwise stated, the highest value in any phase.

3.7.102

peak current

peak value of the first major loop of current during the transient period following initiation

3.7.103

short-time withstand current

current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-17]

3.7.104

peak withstand current

value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-18]

3.7.105

insulation level

set of withstand voltages specified which characterize the dielectric strength of the insulation

[SOURCE: IEC 60050-614:2016, 614-03-23]

3.7.106

power frequency withstand voltage

RMS value of sinusoidal power frequency voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

[SOURCE: IEC 60050-614:2016, 614-03-22]

3.7.107

lightning impulse withstand voltage

peak value of the lightning impulse voltage which the insulation of the disconnector or earthing switch withstands under specified test conditions

3.7.108

switching impulse withstand voltage

peak value of the switching impulse voltage which the insulation of the disconnector or earthing switch withstands under specified test conditions

3.7.109

external insulation

distances in atmospheric air, and along the surfaces in contact with atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin, etc.

Note 2 to entry: External insulation is either weather-protected or non-weather-protected, designed to operate inside or outside closed shelters, respectively.

[SOURCE: IEC 60050-614:2016, 614-03-02, modified – Note 2 to entry has been added]

3.7.110

internal insulation

internal distances of the solid, liquid or gaseous insulation of equipment which are protected from the effects of atmospheric and other external conditions

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.7.111

self-restoring insulation

insulation which completely recovers its insulating properties within a short time after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-04]

3.7.112

non-self-restoring insulation

insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge

Note 1 to entry: Definitions 3.7.111 and 3.7.112 apply only when the discharge is caused by the application of a test voltage during a dielectric test. However, discharges occurring in service can cause a self-restoring insulation to lose partially or completely its original insulating properties.

[SOURCE: IEC 60050-614:2016, 614-03-05, modified – Note to entry has been added]

3.7.113

parallel insulation

insulator arrangement with two insulators in parallel where the distance between the two insulators might influence the dielectric strength

Note 1 to entry: With open terminal disconnectors and earthing switches, parallel insulation is used when a drive insulator is situated next to a support insulator.

3.7.114

disruptive discharge

failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between electrodes to practically zero

Note 1 to entry: Non-sustained disruptive discharge in which the test object is momentarily bridged by a spark or arc may occur. During these events the voltage across the test object is momentarily reduced to zero or to a very small value. Depending on the characteristics of the test circuit and the test object, a recovery of dielectric strength may occur and may even allow the test voltage to reach a higher value. Such an event should be interpreted as a disruptive discharge unless otherwise specified by the relevant technical committee.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric the loss may be only temporary.

[SOURCE: IEC 60060-1:2010, 3.1.1]

3.7.115

clearance

distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:2000, 441-17-31]

3.7.116

clearance between poles

clearance between any conductive parts of adjacent poles

[SOURCE: IEC 60050-441:2000, 441-17-32]

3.7.117

clearance to earth

clearance between any conductive parts and any parts which are earthed or intended to be earthed

[SOURCE: IEC 60050-441:2000, 441-17-33]

3.7.118

clearance between open contacts

total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position

Note 1 to entry: The total clearance is the sum of the clearances existing between the contacts

[SOURCE: IEC 60050-441:2000, 441-17-34, modified – Note to entry has been added]

3.7.119

mechanical terminal load

external load acting on each terminal

Note 1 to entry: The external load is the result of the combined mechanical forces which may be applied to the terminals of the switching device. Wind forces acting on the equipment itself are not included as they do not contribute to the external load acting on terminals.

Note 2 to entry: A disconnector or earthing switch can be subjected to several mechanical forces different in value, direction and point of action.

Note 3 to entry: The terminal loads as defined here do not usually apply to enclosed switchgear.

3.7.119.1

static mechanical terminal load

static mechanical terminal load at each terminal equivalent to the mechanical force to which this terminal of the disconnector or earthing switch is subjected by the flexible or rigid conductor connected to this terminal

Note 1 to entry: The static mechanical terminal load includes forces resulting from ice, wind and connected conductors.

3.7.119.2

dynamic mechanical terminal load

combination of the static mechanical load and the electromagnetic forces under short-circuit conditions

3.7.120

bus-transfer current switching

opening and closing of disconnectors under load when this load is not interrupted, but transferred from one bus to a parallel bus

3.7.121

bus-transfer current

current that flows when a load is transferred from one bus system to another

3.7.122

bus-transfer voltage

power frequency voltage across the open disconnector after breaking or before making the bus-transfer current

3.7.123

induced current switching

making or breaking of inductive or capacitive currents by an earthing switch, whereupon the currents are induced in an earthed or unearthed system by adjacent energized lines or cables

Note 1 to entry: When two or more transmission lines are mounted together, energy will be induced electrostatically and/or electromagnetically from a live system into a de-energized system resulting in capacitive or inductive currents flowing in this system, depending whether it is earthed at one or at both ends.

3.7.124

electromagnetically induced current

<on an earthing switch> inductive current that flows through an earthing switch when it connects to and disconnects from earth one termination of a de-energized transmission line, with the other termination earthed, and with an energized line carrying current in parallel with, and in proximity to, the earthed line

Note 1 to entry: The inductive current in a de-energized line earthed at both terminations is dependent upon the current in the energized line and the coupling factor to the energized line, as determined by the circuit configuration.

3.7.125

electrostatically induced current

<on an earthing switch> capacitive current that flows through an earthing switch when it connects to and disconnects from earth one termination of a de-energized transmission line, with the other termination open, and with an energized line in parallel with, and in proximity to, the earthed line

Note 1 to entry: The capacitive current in a de-energized line earthed at one termination is dependent upon the voltage of the energized line, the coupling factor to the energized line as determined by the circuit configuration, and the length of the earthed line between the earthed termination and the open termination.

3.7.126

bus-charging current switching

making or breaking of bus-charging currents by disconnectors

3.7.127

bus-charging current

capacitive current that flows when an isolated part of a busbar system is energised or de-energised

3.7.128

transient voltage to earth

U_{TVE}

voltage to earth which appears at the first prestrike during a closing operation of a disconnector

3.7.129

filling pressure for insulation and/or switching

filling density for insulation and/or switching

pressure in Pascal (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

[SOURCE: IEC 62271-1:2017, 3.6.5.1]

3.7.130

minimum functional pressure for insulation and/or switching

minimum functional density for insulation and/or switching

pressure (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or

absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment becomes necessary

[SOURCE: IEC 62271-1:2017, 3.6.5.5]

3.8 Index of definitions

A – B

"a" contact.....	3.5.106
"b" contact.....	3.5.107
Bus-charging current.....	3.7.127
Bus-charging current switching.....	3.7.126
Bushing.....	3.5.118
Bus-transfer current.....	3.7.121
Bus-transfer current switching.....	3.7.120
Bus-transfer voltage.....	3.7.122

C

Centre-break disconnector.....	3.4.103
Clearance.....	3.7.115
Clearance between open contacts.....	3.7.118
Clearance between poles.....	3.7.116
Clearance to earth.....	3.7.117
Closed position (of a mechanical switching device).....	3.6.109
Closing operation (of a mechanical switching device).....	3.6.103
Combined function earthing switch.....	3.4.107
Connecting point.....	3.5.115
Contact (of a mechanical switching device).....	3.5.103
Contact zone (for divided support disconnectors and earthing switches).....	3.5.111
Control contact.....	3.5.105

D

Dependent manual operation (of a mechanical switching device).....	3.6.105
Dependent power operation (of a mechanical switching device).....	3.6.106
Disconnector.....	3.4.101
Disruptive discharge.....	3.7.114
Divided support disconnector.....	3.4.102
Divided support earthing switch.....	3.4.102
Double-break disconnector.....	3.4.104
Dynamic mechanical terminal load.....	3.7.119.2

E

Earthing switch.....	3.4.106
Electromagnetically induced current (on an earthing switch).....	3.7.124
Electrostatically induced current (on an earthing switch).....	3.7.125

External insulation	3.7.109

I

Independent manual operation (of a mechanical switching device)	3.6.108
Indoor switchgear and controlgear	3.1.101
Induced current switching	3.7.123
Insulation level	3.7.105
Internal insulation	3.7.110

L – N

Lightning impulse withstand voltage	3.7.107
Main circuit (of a switching device)	3.5.102
Main contact	3.5.104
Mechanical endurance of a disconnecter or earthing switch	3.6.112
Mechanical terminal load	3.7.119
Minimum functional density for insulation	3.7.130
Minimum functional pressure for insulation	3.7.130
Non-self-restoring insulation	3.7.112

O

Open position (of a mechanical switching device)	3.6.110
Opening operation (of a mechanical switching device)	3.6.104
Operation (of a mechanical switching device)	3.6.101
Operating cycle (of a mechanical switching device)	3.6.102
Outdoor switchgear and controlgear	3.1.102

P

Parallel insulation	3.7.113
Peak current	3.7.102
Peak making current (of an earthing switch)	3.7.101
Peak withstand current	3.7.104
Pole of a switching device	3.5.101
Position-indicating device	3.5.108
Position-indicating kinematic chain	3.5.113
Position-signalling device	3.5.109
Position-signalling kinematic chain	3.5.114
Power frequency withstand voltage	3.7.106
Power kinematic chain	3.5.112

R – U

Rated filling density for insulation	3.7.129
Rated filling pressure for insulation	3.7.129
Resistor-fitted disconnecter	3.4.105
Self-restoring insulation	3.7.111
Short-time withstand current	3.7.103
Source of energy	3.5.119
Static mechanical terminal load	3.7.119.1
Stored energy operation (of a mechanical switching device)	3.6.107
Strain limiting device	3.5.116
Switch-disconnector	3.4.108
Switching impulse withstand voltage	3.7.108
Terminal	3.5.110
Test object	3.2.1
Toggle point	3.6.111
Torque (force) controlling system	3.5.117
Transient voltage to earth	3.7.128
User	3.1.103

4 Normal and special service conditions

Clause 4 of IEC 62271-1:2017 is applicable.

5 Ratings

5.1 General

Clause 5 of IEC 62271-1:2017 is applicable for a disconnector or earthing switch, including their operating devices and auxiliary equipment. The list of ratings is complemented with the following items:

- k) rated short-circuit making current (for earthing switches only);
- l) rated contact zone;
- m) rated static mechanical terminal load;
- n) rated ice-coating;
- o) rated values of the bus-transfer current switching capability (for disconnectors only);
- p) rated values of the induced current switching capability (for earthing switches only);
- q) rated values of the bus-charging current switching capability (for disconnectors only).

In addition to the rated values given above, the following classifications may be assigned:

- r) short-circuit making class (for earthing switches only);
- s) mechanical endurance class;
- t) induced current switching class (for earthing switches only);
- u) bus-charging current switching class (for disconnectors only).

Disconnectors or earthing switches being classified for more than one switching capability may indicate their classification by combined class designations. For example, an earthing

switch having short-circuit making capability class E1 and an induced current switching capability class B may be classified as class B+E1.

Ratings for making and breaking capabilities cannot be assigned to disconnectors and earthing switches with only manual dependent operation.

In the case of disconnectors and earthing switches with both dependent power and dependent manual operation, any making and breaking capability is not valid for dependent manual operation.

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:2017 is applicable.

5.3 Rated insulation level (U_d , U_p , U_s)

Subclause 5.3 of IEC 62271-1:2017 is applicable with the following addition:

For disconnectors rated above 52 kV and disconnectors having an isolating distance in parallel to the base of the disconnector and having integrated earthing switches, the insulation level between moving parts of the earthing switch and the opposite live parts, during operation of the earthing switch, shall be at least the short-duration power frequency withstand voltage for the smallest gap between them specified in 7.2.6.

If national safety regulations specify higher withstand values for earthing switches that have manual operating mechanisms only, this has to be agreed upon between the user and the manufacturer.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 is applicable.

5.5 Rated continuous current (I_r)

Subclause 5.5 of IEC 62271-1:2017 is applicable. This subclause applies only to disconnectors.

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 is applicable with the following addition.

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 is applicable with the following addition.

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 is applicable with the following addition:

An earthing switch may be assigned a rating different from the rating of the related main circuit (if applicable).

An earthing switch forming an integral part of a combined function earthing switch may be assigned a rating different from the rating of its main circuit.

5.9 Rated supply voltage of auxiliary and control circuits (U_a)

Subclause 5.9 of IEC 62271-1:2017 is applicable.

5.10 Rated supply frequency of auxiliary circuits and control circuits

Subclause 5.10 of IEC 62271-1:2017 is applicable.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is applicable with the following addition:

5.11.101 Rated pressure of compressed gas supply for insulation and/or switching

The limits of pressure shall be given by the manufacturer.

5.11.102 Rated pressure of compressed gas supply for operation

External pneumatic or hydraulic supply:

Unless otherwise specified by the manufacturer, the limits of the operating pressure are 85 % and 110 % of the rated pressure.

5.101 Rated short-circuit making current (I_{ma})

The rated short-circuit making current is applicable only to the earthing switches class E1 and E2. This shall be equal to the rated peak withstand current.

Subclause 5.102 provides a classification of earthing switches for short-circuit making capability.

5.102 Classification of earthing switches for short-circuit making

The short-circuit making capability of earthing switches to perform a defined number of short-circuit making operations, without major maintenance, shall correspond to one of the classes given in Table 1.

NOTE The increased number of making operations of Class E2 is typically related to voltages up to and including 52 kV depending on the operating conditions and the protection systems of such networks.

Table 1 – Classification of earthing switches for short-circuit making

Class	Type of earthing switch
E0	Earthing switch with no short-circuit making capability
E1	Earthing switch with capability to perform two short-circuit making operations
E2	Earthing switch with capability to perform five short-circuit making operations

5.103 Rated contact zone

In case of divided support disconnectors and divided support earthing switches the manufacturer shall state the rated values of the contact zone (indicated by x_r , y_r and z_r). Preferred values are given in Table 2 and Table 3. The rated values shall be specified by the manufacturer. This refers also to a tolerable angular displacement of the fixed contact.

Table 2 – Preferred contact zones for "fixed" contacts supported by flexible conductors

Rated voltage U_r kV	x mm	y mm	z_1 mm	z_2 mm	
72,5 – 100	100	300	200	300	
123 – 145		350			
170	200	400	250	450	
245		500			
300					300
362					
420		600	400	500	
550					
800	250	650	450	550	
1 100 – 1 200	300	700	500	600	

x = total amplitude of longitudinal movement of the supporting conductor (temperature).

y = total horizontal deflection (perpendicular to supporting conductor) (wind).

z = vertical deflection (temperature and ice).

NOTE z_1 are values for short-span, z_2 are values for long-span of the flexible conductors to which the fixed contacts are mounted.

Table 3 – Preferred contact zones for "fixed" contacts supported by rigid conductors

Rated voltage U_r kV	x mm	y mm	z mm
72,5 – 100 – 123 – 145	100	100	100
170 – 245 – 300 – 362 – 420	150	150	150
550	175	175	175
800	200	200	200
1 100 – 1 200	250	250	250
x = total amplitude of longitudinal movement of the supporting conductor (temperature). y = total horizontal deflection (perpendicular to supporting conductor) (wind). z = vertical deflection (ice).			

5.104 Rated static mechanical terminal load

When disconnectors or earthing switches are intended to be directly connected to lines, i.e. flexible or rigid conductors, the rated static mechanical terminal load of each terminal shall be assigned, indicating the directions of application.

The maximum static mechanical terminal load to which a terminal of a disconnector or earthing switch is allowed to be subjected under the most disadvantageous conditions is the rated static mechanical terminal load.

Preferred values of static mechanical terminal loads are given in Table 4 and are intended to be used as a guide.

Table 4 – Preferred static mechanical terminal loads

Rated voltage U_r kV	Rated continuous current I_r A	Two- and three-column disconnectors or earthing switches		Divided support disconnectors or earthing switches		Vertical Force F_c^a N
		Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	
		In Figure 9		In Figure 8		
		N	N	N	N	
72,5	$\leq 1\,600$	400	130	800	200	500
	$> 1\,600$	500	170	800	200	
100 – 123 – 145	$\leq 1\,600$	500	170	800	200	1 000
	$> 1\,600$	600	200	1 000	300	
170	$\leq 1\,600$	600	200	1 000	300	
	$> 1\,600$	800	250	1 250	400	
245	$\leq 2\,500$	800	270	1 250	400	1 250
	$> 2\,500$	1 000	330	1 600	500	
300 – 362	$\leq 2\,500$	1 000	400	1 600	500	1 500
	$> 2\,500$	1 500	500	1 800	600	
420	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
550	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
800	$\leq 3\,150$	1 600	530	2 000	800	1 500
	$> 3\,150$	2 000	660	4 000	1 600	
1 100 – 1 200	$\leq 4\,000$	2 000	660	4 000	1 600	2 000
	$> 4\,000$	2 500	1 000	5 000	2 000	
^a F_c simulates the downward forces caused by the weight of the connecting conductors. F_c does not apply to flexible conductors.						
NOTE The static mechanical terminal load includes forces resulting from ice, wind and connected conductors.						

5.105 Classification of disconnectors for mechanical endurance

The mechanical endurance of disconnectors shall correspond to one of the classes given in Table 5. The performance is associated to a programme of maintenance defined by the manufacturer.

Table 5 – Classification of disconnectors for mechanical endurance

Class	Number of operating cycles	Mechanical endurance
M0	1 000	Normal
M1	2 000	Extended
M2	10 000	Extended

5.106 Classification of earthing switches for mechanical endurance

The mechanical endurance of earthing switches shall correspond to one of the classes given in Table 6. The performance is associated to a programme of maintenance defined by the manufacturer.

Table 6 – Classification of earthing switches for mechanical endurance

Class	Number of operating cycles	Mechanical endurance
M0	1 000	Normal
M1	2 000	Extended

5.107 Rated ice-coating

For disconnectors and earthing switches able to operate under ice-conditions a rated ice-coating shall be assigned by the manufacturer.

Preferred ratings of ice-coating are: 1 mm, 10 mm and 20 mm.

5.108 Rated values of disconnectors for bus-transfer current switching

5.108.1 Rated bus-transfer current

The rated bus-transfer current of disconnectors used in both air-insulated and gas-insulated installations is:

- for $52 \text{ kV} < U_r < 245 \text{ kV}$ 80 % of the rated continuous current of the disconnector, but limited to 1 600 A;
- for $245 \text{ kV} \leq U_r \leq 550 \text{ kV}$ 60 % of the rated continuous current of the disconnector, but limited to 4 000 A;
- for $U_r > 550 \text{ kV}$ 80 % of the rated continuous current of the disconnector, but limited to 4 000 A.

Rated bus-transfer currents greater than the values given above may be assigned by the manufacturer.

NOTE 1 It is recognised that disconnectors of $U_r \leq 52 \text{ kV}$ can also have bus-transfer switching capability. In this case, checking of the performance is subjected to an agreement between the user and the manufacturer.

NOTE 2 For more information refer to the following: for information about 60 % and 80 %, refer to CIGRE TB 570 – 2014 [1]¹ and CIGRE SC A3 third report, presented in Paris (FR), 2016, and about 4 000 A refer to CIGRE SC A3 and B3 colloquium in Nagoya (JP), paper no. 212, 2015.

¹ Numbers in square brackets refer to the Bibliography.

5.108.2 Rated bus-transfer voltage

Rated bus-transfer voltages are given in Table 7. Different bus-transfer voltages than the values given in Table 7 below may be assigned by the manufacturer.

Table 7 – Rated bus-transfer voltages of disconnectors

Rated continuous current I_r A	Rated voltage U_r			Rated voltage U_r		
	$52\text{ kV} < U_r < 245\text{ kV}$	$245\text{ kV} \leq U_r \leq 550\text{ kV}$	$U_r > 550\text{ kV}$	$52\text{ kV} < U_r < 245\text{ kV}$	$245\text{ kV} \leq U_r \leq 550\text{ kV}$	$U_r > 550\text{ kV}$
	Gas-insulated installations V (RMS value)			Air-insulated installations V (RMS value)		
2 000	10	15	20	100	175	250
2 500					220	310
3 150		20	30		275	390
4 000		25	42		350	500
5 000					435	625
6 300		35			550	
8 000					580	
NOTE The values in the table are based on calculations of a bus-transfer current corresponding to the rated continuous current of the disconnector taking into account typical loop lengths and impedances given in Annex B.						

5.109 Classification and rated values of earthing switches for induced current switching

Rated induced current and voltage shall be assigned to earthing switches of $U_r > 52 \text{ kV}$ and designed for making or breaking of inductive or capacitive induced currents (see 3.7.124 and 3.7.125), hence requiring an induced current switching capability.

For this application, a classification for induced current switching (class A or B) shall be assigned to the earthing switch. This class depends upon the severity of the induced current switching duty. The classification of earthing switches for induced current switching is given in Table 8.

Table 8 – Classification of earthing switches for induced-current switching

Class	Type of earthing switch
A	Earthing switch designed to be used in circuits having relatively short sections of line or low coupling to adjacent energized circuits
B	Earthing switch designed to be used in circuits having relatively long sections of lines or high coupling to adjacent energized circuits

The values of rated induced current and voltage for the two classes of earthing switches are given in Table 9. These values represent the maximum switching capabilities for each rated voltage.

Table 9 – Rated induced currents and voltages

Rated voltage U_r kV	Electromagnetic coupling				Electrostatic coupling																				
	Rated induced current A (RMS value)		Rated induced voltage kV (RMS value)		Rated induced current A (RMS value)		Rated induced voltage kV (RMS value)																		
	Class		Class		Class		Class																		
	A	B	A	B	A	B	A	B																	
72,5	50	80	0,5	2	0,4	2	3	6																	
100									3	9															
123			5			12																			
145								10		15															
170									18		20														
245	80	160		1,4	10		1,25			25		8	25												
300						2		20	2		3			12	32										
362			2													20	2	3	12	32					
420				2																	20	2	3	12	32
550																									
800	2	20	2	3	12	32																			
1 100							110	440	5	65	7,5	50	20	40											
1 200	110	440													5	65	7,5	50	20	40					

NOTE 1 In some situations (very long sections of the earthed line in proximity to an energized line; very high loading on the energized line; energized line having a service voltage higher than the earthed line, etc.), the induced current and voltage can be higher than the given values. For these situations, the rated values are subject to agreement between manufacturer and user.

NOTE 2 The rated induced voltages correspond to line-to-earth values for both single-phase and three-phase tests (see 7.107.5).

5.110 Classification and rated values of disconnectors for bus-charging current switching

Disconnectors forming part of the gas-insulated switchgear and controlgear of $U_r \geq 300$ kV shall be classified for bus-charging current switching performance. Tests for disconnectors of $U_r < 300$ kV are generally not necessary and are subject to agreement between the manufacturer and the user. In any case, for $52 \text{ kV} < U_r < 300 \text{ kV}$, the test for classification of BCS is not mandatory.

NOTE Bus-charging switching capability for air-insulated disconnectors is subject to agreement between the manufacturer and the user, refer to IEC/TR 62271-305.

Four classes are distinguished depending upon application. See Table 10, where the associated test duties are also indicated.

Table 10 – Classification of disconnectors for bus-charging switching

Class	Application	Associated test duties (see 7.108.2)
BCS	Switching of very short sections of busbar ducts of open circuits	TD ₁
BCB	BCS class + switching of parallel capacitors associated to circuit-breakers, under 180° out-of-phase condition of open circuits	TD ₁ & TD ₂
BCL	BCS class + switching of long sections of busbar ducts of open circuits	TD ₁ & TD ₃
BCT	BCS class + BCB class + BCL class	TD ₁ , TD ₂ & TD ₃

The rated bus-charging current is associated only to disconnectors classified as BCL or BCT. No rated bus-charging current can be assigned to TD₁ and TD₂, as they depend on the design, the physical construction of the installation, and rated voltage. The standard values for this rating are given in Table 11. These values are only associated to the de-energizing of long sections of busbar ducts in accordance with test duty 3 in 7.108.2. For more information, refer to Annex B.

Table 11 – Standard rated bus-charging currents

Rated voltage U_r kV (RMS value)	72,5	100	123	145	170	245	300	362	420	550	800	1 100	1 200
Rated bus-charging current A (RMS value)	0,1	0,1	0,1	0,1	0,1	0,25	0,25	0,5	0,5	0,5	0,8	1,0	1,0
NOTE The values are normally not exceeded in practice. They apply to 50 Hz as well as to 60 Hz. In the case of higher values in practice, other test values are considered by agreement between the manufacturer and the user.													

6 Design and construction

6.1 Requirements for liquids in disconnectors and earthing switches

Subclause 6.1 of IEC 62271-1:2017 is applicable.

6.2 Requirements for gases in disconnectors and earthing switches

Subclause 6.2 of IEC 62271-1:2017 is applicable with the following addition.

NOTE In general, the term "gas" for insulation and/or switching in this document refers to SF₆. However, the principles expressed could be also used for other gases.

6.3 Earthing of disconnectors and earthing switches

Subclause 6.3 of IEC 62271-1:2017 is applicable with the following additions.

For disconnectors and earthing switches used in enclosed switchgear and controlgear assemblies, 5.3 of IEC 62271-200:2011, IEC 62271-201:2014 or IEC 62271-203:2011 is applicable (as it corresponds).

Metallic enclosures and operating mechanisms not mounted together with and not electrically connected to the metallic frame of the disconnector or earthing switch, shall be provided with an earthing terminal marked with the protective earth symbol.

If, for testing purposes after installation (e.g. cable testing, contact resistance measurement), a removable connection for earthing the main circuit through the earthing switch exists, it shall be able to withstand the rated peak and short-time withstand current. The relevant insulation level (DC and AC) of this external connection – when removed – shall be stated by the manufacturer.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:2017 is applicable with the following addition.

Refer also to 6.104 of this document.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 is applicable with the following additions.

In case of disconnectors and earthing switches with both dependent power and dependent manual operation, the noncapability of making and breaking, when manually operated, shall be clearly stated in the instruction manual and close to the point of manual operation.

Disconnectors and earthing switches having a pneumatic or hydraulic operating device shall be capable of closing and opening when the supply pressure is between the minimum and the maximum supply pressure specified (refer to 5.11.102).

See also 6.105 for maximum manual operating forces.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is applicable with the following addition.

See also subclause 6.105 for maximum manual operating (storing energy) forces.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 is applicable with the following addition.

See also subclause 6.105 for maximum manual operating (storing energy) forces.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is applicable.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 is applicable.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is applicable with the following additions:

- Disconnectors, earthing switches and their operating devices that are designed to be:
 - used as stand alone or may be integrated as components for switchgear, shall be provided with nameplates that contain information in accordance with Table 12;

- integrated in a particular family of switchgear and controlgear shall integrate the information on the nameplate(s) and/or in the manufacturer instruction manual of the switchgear and controlgear, as indicated in Table 12.

Table 12 – Product information (1 of 2)

Information to be put on the nameplate	Abbreviation	Unit	Disconnecter	Earthing switch ^a	Operating device
Manufacturer			x	x	x
Manufacturer's type designation			x	x	x
Mechanical endurance class			x ^b	x ^b	x
Short-circuit making capability class				x ^b	
Instruction book reference			x	x	x
Year of manufacture			x	x	x
Reference of this standard			x	x	x
Serial number			x	x	x
Rated voltage	U_r	kV	x	x	
Rated frequency	f_r	Hz	x	x	
Rated lightning impulse withstand voltage	U_p	kV	x	x	
Rated switching impulse withstand voltage for $U_r \geq 300$ kV	U_s	kV	x	x	
Rated power-frequency withstand voltage	U_d	kV	x	x	
Rated continuous current	I_r	A	x		
Rated short-time withstand current	I_k	kA	x	x	
Rated duration of short-circuit	t_k	s	x ^c	x ^c	
Rated peak withstand current	I_p	kA	x	x	
Rated short-circuit making current	I_{ma}	kA		x ^d	
Insulating fluid and mass	M_f	kg	x ^e	x ^e	
Minimum and maximum ambient air temperature		°C	x ^f	x ^f	x ^f

Table 12 (2 of 2)

Information to be put either on the nameplate or in the instruction manual	Abbreviation	Unit	Disconnecter	Earthing switch ^a	Operating device
Rated bus-charging current	I_{bc}	A	x ^g		
Class of bus-charging current switching			x ^g		
Rated bus-transfer current	I_{bt}	A	x ^h		
Rated bus-transfer voltage	U_{bt}	V	x ^h		
Class of earthing switch (class A or B) ⁱ				x ⁱ	
Rated induced current (electromagnetic)	I_{im}	A		x ⁱ	
Rated induced voltage (electromagnetic)	U_{im}	V		x ⁱ	
Rated induced current (electrostatic)	I_{is}	A		x ⁱ	
Rated induced voltage (electrostatic)	U_{is}	V		x ⁱ	
Value of the resistor	R	Ω	x ^j		
Rated filling pressure for operation	P_{rm}	Pa			x
Minimum functional pressure for operation	p_{mm}	Pa			x
Alarm pressure for operation	P_{am}	Pa			x
Rated filling pressure for insulation	P_{re}	Pa	x	x	
Minimum functional pressure for insulation	p_{me}	Pa	x	x	
Alarm pressure for insulation	P_{ae}	Pa	x	x	
Minimum functional pressure for switching	p_{sw}	Pa	x	x	
Rated supply voltage of auxiliary and control circuits	U_a	V			x ^k
Rated static mechanical terminal load	F	N	x	x	
Mass (including liquid)	M	kg	x	x	x
Rated ice-coating		mm	x	x	x
Rated contact zone	x_r, y_r and z_r	mm	x ^l	x ^l	
NOTE 1 The marking of values indicated by x is mandatory (if applicable).					
NOTE 2 The word "rated" does not need to appear on the nameplate.					
^a One nameplate may be used for an earthing switch and disconnector assembled as a single unit. ^b The class marking is mandatory if different from M0 or E0. It may be included into the type designation to avoid additional space requirement. ^c Mandatory if t different from 1 s. ^d For earthing switches having short-circuit making capability. ^e Chemical formula for gas or commercial name for liquid (if any of both) shall be indicated. ^f Mandatory if different from –5 °C and/or +40 °C. ^g For disconnectors forming a part of gas-insulated switchgear and controlgear of $U_r \geq 300$ kV. ^h For disconnectors of $U_r > 52$ kV having bus-transfer current switching capability. ⁱ For earthing switches of $U_r > 52$ kV having induced current switching capability. ^j For resistor-fitted disconnectors. ^k Rated supply voltages of auxiliary and control circuits may have separate values which have to be indicated. Manufacturer shall also indicate if the supply is dc or ac source. ^l For divided support disconnectors and/or divided support earthing switches of $U_r > 52$ kV.					

6.12 Locking devices

Subclause 6.12 of IEC 62271-1:2017 is applicable with the following addition:

Disconnectors and earthing switches to be mechanically interlocked by blocking the operating shaft or power kinematic chain of the disconnector or earthing switch, and not integrated in switchgear and controlgear assemblies covered by the standards IEC 62271-200, IEC 62271-201 or IEC 62271-203, shall be designed to withstand:

- during motor-operation, the strain produced by the motor starting torque at the maximum motor supply voltage, or, if a strain limiting device is present, to its limiting value, and
- during manual-operation, 3 times the value of the corresponding maximum force given for manual operation in 6.105 (without considering peak value) or, if a strain limiting device is present, to 1,5 times its limiting value.

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 is applicable with the following addition. Refer also to 6.104 of this document.

6.14 Degree of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 is applicable with the following addition for enclosures containing auxiliary and control circuits:

The degree of protection provided by enclosures for outdoor installation shall be a minimum of IP3XDW of IEC 60529:1989 + AMD1:1999 + AMD2:2013.

For indoor installations the degree of protection shall be not less than IP2X of IEC 60529:2013.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 is applicable.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC 62271-1:2017 is applicable.

6.17 Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 is applicable.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 is applicable.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 is applicable.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 is applicable.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 is applicable.

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 is applicable with the following addition:

The pressure in Pa (or density) or liquid mass shall be assigned by the manufacturer referred to atmospheric air conditions of 20 °C at which the gas- or liquid-filled switchgear is filled before being put into service.

For operating devices having their own compressor or pump integral to them and with their own supplying pressure tank, the limits of filling (operating) pressure shall be stated by the manufacturer.

6.101 Particular requirements for earthing switches

Any material and any cross-section is allowed for connections between movable parts of an earthing switch and its frame, provided that the connections are able to withstand the electrical, mechanical and environmental stresses that occur in service.

6.102 Requirements in respect of the isolating distance of disconnectors

When the insulation across the isolating distance may be subjected to pollution in service, care shall be taken to ensure the suitability of insulator design (e.g. creepage distance, hydrophobicity, orientation of insulator). IEC/TS 60815 (all parts) [3] can be used for guidance selecting the appropriate insulator design. The satisfactory performance of the insulation across the isolating distance under polluted conditions should be verified with the appropriate voltage withstand level corresponding to the isolating distance for which the disconnector is intended.

The design has also to take into account the effects of contamination caused by wear and arcing by-products. The effectiveness of the design to withstand these effects is verified by the condition checks specified in Clause 7 after the relevant type tests.

NOTE 1 It is usual that the isolating gap of a disconnector is longer than the phase-to-ground insulating distance, since IEC 62271-1:2017 specifies higher voltage withstand levels across the isolating distance than for the phase-to-ground insulation. However, where a long creepage distance is required, the phase-to-ground insulation distance can become longer than the isolating gap of the disconnector. For such cases the use of protective devices such as surge arresters or rod gaps can be necessary.

NOTE 2 Test method for insulators can be found in IEC 60507 [2] and IEC/TS 60815 (all parts) [3]

6.103 Mechanical strength

The disconnector and earthing switch, including the insulators used, installed according to the manufacturer's instructions shall be able to:

- open and close correctly the main contacts under its rated static mechanical terminal loads;
- carry the rated continuous current (when applicable) under its rated static mechanical terminal loads;
- withstand the dynamic forces on its terminals under short-circuit conditions.

The required cantilever strength of an insulator shall be calculated taking into consideration the height of the terminal above the top of the insulator as well as additional forces acting on the insulator (see 3.7.119 and 9.102.4).

6.104 Operation of disconnectors and earthing switches – Position of the movable contact system and its indicating and signalling devices

6.104.1 Securing of position

Disconnectors and earthing switches, including their operating mechanisms, shall be designed in such a way that they cannot come out of their open or closed position by gravity, wind pressure, vibrations, reasonable shocks or accidental touching of the connecting rods of their operating system according to their service conditions as defined in Clause 4.

Disconnectors and earthing switches shall permit temporary mechanical locking in at least the open position (for disconnectors) and closed position (for earthing switches) except for disconnectors or earthing switches whose contacts are directly moved by a hook-stick.

6.104.2 Additional requirements for power-operated mechanisms

Power operated mechanisms shall also provide a manual operating facility. Connecting a hand-operating device (for instance a hand crank) to the power-operated mechanism shall ensure safe interruption of the control energy to the power-operated mechanism.

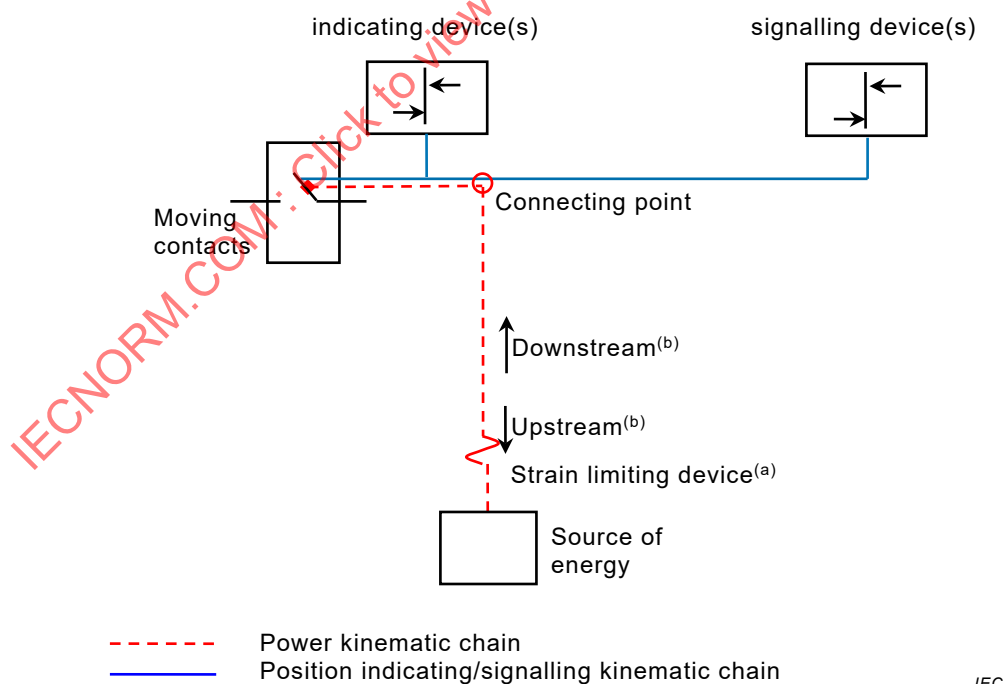
6.104.3 Indication and signalling of position

6.104.3.1 General requirements

Indication and signalling of the closed and open position shall not take place unless the moving contacts have reached their closed or open position, respectively.

NOTE For the definition of "closed" and "open" see 3.6.109 and 3.6.110.

Figure 1 represents the different elements involved in indication and signalling of positions, and some design conditions.



a) The strain limiting device (if any) can be an external device or an internal as part of the source of energy, e.g. torque (force) controlling system.

b) Upstream is the direction towards the source of energy, downstream is the direction towards the contacts.

Figure 1 – Position indicating/signalling device(s)

The strain limiting device (if any) may be placed at any point along the power kinematic chain between the source of energy and the connecting point, but it shall not be along the position indicating/signalling kinematic chain. See 6.104.3.2 and 6.104.3.3.

The position-indicating device(s) shall be fixed directly on a mechanical part of the power kinematic chain or mechanically connected to it through a separate position indicating/signalling kinematic chain. If the position indicator is not directly fixed on the mechanical part of the power kinematic chain, then the position-indicating kinematic chain from the connecting point shall be placed inside an enclosure providing a minimum degree of protection equivalent to IP2XC of IEC 60529:1989 + AMD1:1999 + AMD2:2013, and with an impact level IK 07 of IEC 62262:2002.

The position-signalling kinematic chain shall be placed inside an enclosure with the same levels of protection as defined for the position-indicating kinematic chain.

6.104.3.2 Indication of position

It shall be possible to know the position of the disconnector or earthing switch. The indication of the position of the disconnector or earthing switch is given if one of the following conditions is fulfilled:

- at least the position of the moving contacts of each pole is visible for disconnectors in open position and for earthing switches in closed position;
- both the open and closed positions of the moving contacts of each pole are indicated by a reliable position-indicating device. A common position-indicating device may be used only if all the poles of the disconnector or earthing switch are operated by a common operating mechanism.

NOTE In some countries the design of the disconnector is such that the isolating distance is visible (Canada).

The kinematic chain between the moving contacts and the position-indicating device shall be designed with sufficient mechanical strength to meet the requirements of the specified tests (7.105). The operation of the position-indicating kinematic chain shall be positively driven. The position-indicating device may be marked directly on a mechanical part of the power kinematic chain by suitable means. The strain-limiting device, if any, shall not form part of the position-indicating kinematic chain.

6.104.3.3 Signalling of position by auxiliary contacts

A common signal for all poles of a disconnector or earthing switch shall be given only if all poles of the disconnector or earthing switch are in a position in accordance with 6.104.3.1.

A common position-signalling device is permitted to be used only if the disconnector or earthing switch is three-pole operated by a common operating mechanism.

The kinematic chain between the moving contacts and the position-signalling device(s) shall be designed with sufficient mechanical strength to meet the requirements of the mechanical endurance tests. The position-signalling kinematic chain operation shall be positively driven. The strain-limiting device, if any, shall not form part of the position-signalling kinematic chain.

6.105 Maximum force required for manual (dependent or independent) operation

6.105.1 General

The values given in 6.105.2 and 6.105.3 also apply to maintenance manual operation of normally motor-operated disconnectors and earthing switches.

NOTE These values include ice-breaking, if applicable.

6.105.2 Operation requiring more than one revolution

The maximum force needed to operate or store energy in a disconnector or earthing switch with more than one revolution (hand crank for example) shall not exceed 80 N during 90 % of the total required revolutions and never exceed 120 N.

6.105.3 Operation requiring up to one revolution

The force needed to operate or store energy in a disconnector or earthing switch requiring up to one revolution (swing lever for example) should not exceed 250 N (refer to 6.6.4 of IEC 62271-1:2017). A maximum value of 450 N is accepted during a rotation of 15° maximum.

6.106 Dimensional tolerances

For disconnectors and earthing switches installed and/or connected by the user, the relevant mounting dimensions and the dimensions of high-voltage connections as well as the earthing connections of disconnectors and earthing switches, the tolerances given in ISO 2768-1 shall apply for linear and angular dimensions.

6.107 Earthing switches with short-circuit making current capability

Earthing switches assigned for short-circuit making current shall be capable of making at rated and lower voltage, any current up to and including the rated short-circuit making current. This requirement is considered to be satisfied if the earthing switch successfully demonstrates its electrical endurance class.

7 Type tests

7.1 General

7.1.1 Basics

Subclause 7.1.1 of IEC 62271-1:2017 is applicable with the following additions.

Disconnectors and earthing switches shall be tested to verify their rated characteristics, under the proper conditions of installation and use (e. g. they shall be tested as normally installed in the gas-insulated or metal-enclosed switchgear and controlgear) with all associated components, the arrangement of which may influence the performance, such as connections, supports, provisions for venting, resistors etc.

Disconnector and earthing switches that are different in construction or mounting arrangements as compared to the given examples in Clause 7 shall be tested in conditions that are representative of the actual installation.

NOTE Associated components are likely to influence the performance. Mechanical forces due to the short-circuit current, venting of arc-products, the possibility of disruptive discharges, etc., could characterise this influence. It is recognized that, in some cases, such influences may be quite negligible.

The same setting of the position-signalling device for closed and open positions shall be used for the dielectric test and the short-time withstand current and peak withstand current tests.

The type tests for disconnector and earthing switch are listed in Table 13. For the type tests, the tolerances on test quantities are given in Annex C.

Information regarding the extension of validity of type tests is given in Annex E (informative).

Table 13 – List of type tests

Type test, dependent upon application, rating or design	Condition	Related device		Subclauses
		Disconnector	Earthing switch	
Dielectric tests	a	x	x	7.2
Measurement of the resistance of the main circuit	a	x		7.4.4
Continuous current tests	a	x		7.5
Short-time withstand current and peak withstand current tests	a	x	x	7.6
Mechanical endurance tests	a	x	x	7.102.3
Verification of the degree of protection	Assigned IP- and/or IK-code	x	x	7.7
Radio interference voltage (RIV) test	$U_r \geq 245$ kV	x	x	7.3
Tightness tests	Controlled, sealed or closed pressure systems	x	x	7.8
EMC tests	Presence of electronic components	x	x	7.9
Additional tests on auxiliary and control circuits	Presence of auxiliary and control circuits	x	x	7.10
X- ray radiation test	Presence of vacuum interrupters	x	x	7.11
Test to prove the short-circuit making performance of earthing switches	Class E1 or E2		x	7.101
Contact zone test	Divided support	x	x	7.102.2
Operation during application of rated static mechanical terminal load	Assigned mechanical terminal load	x	x	7.102.4
Extended mechanical endurance tests	Class M1 or M2	x	x	7.102.5
Testing on mechanical interlocking devices	Presence of interlock blocking the operating shaft or power kinematic chain	x	x	7.102.6
Operation under severe ice conditions	10 mm and above	x	x	7.103
Low and high temperature tests	If maximum ambient temperature $> +40^\circ\text{C}$ or minimum ambient temperature $< -5^\circ\text{C}$	x	x	7.104
Tests to verify the proper functioning of the position-indicating device	Presence of position-indicating device	x	x	7.105
Bus-transfer current switching tests	Bus-transfer current switching capability ^b	x		7.106
Induced current switching tests	Class A or B ^c		x	7.107
Bus-charging current switching tests	Bus-charging current switching capability ^{d, e}	x		7.108
^a Mandatory without condition for the related device. ^b Applicable to disconnectors of $U_r > 52$ kV. ^c Applicable to earthing switches of $U_r > 52$ kV. ^d Applicable to disconnectors of $U_r > 52$ kV forming part of gas-insulated switchgear. For $U_r < 300$ kV, tests are generally considered not necessary and are subject to agreement between user and manufacturer. ^e Bus-charging switching capability for air-insulated disconnectors is subject to agreement between the manufacturer and the user, refer to IEC/TR 62271-305.				

7.1.2 Information for identification of test objects

Subclause 7.1.2 of IEC 62271-1:2017 is applicable with the following addition:

At the beginning of the type tests, the mechanical operating characteristics and their tolerances for the disconnector or earthing switch during opening and/or closing shall be given by the manufacturer, e.g. time between events during operation and no-load travel curves.

7.1.3 Information to be included in type test reports

Refer to 7.1.3 of IEC 62271-1:2017 with the following additions (where applicable):

When for testing purposes, the insulators are not provided by the manufacturer of the disconnector or earthing switch, the most important features of insulators used during type tests shall be included in the relevant test reports for comparison with those described in the manufacturer's documentation:

- rated cantilever strength;
- rated torsional strength of support insulators (and operating insulators, where applicable);
- height and number of elements;
- creepage length and shed-profile;
- deflection under load.

In the case of dielectric tests, information shall be included regarding the smallest gap at which the indicating or signalling device can signal the position OPEN. For air-insulated devices, the minimum size of the gap and the height above ground used for the test shall be stated (see 7.2.4). Also the distance of the lowest part of insulation to ground shall be given.

7.2 Dielectric tests

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 is applicable.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC 62271-1:2017 is applicable.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 is applicable.

7.2.4 Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is applicable with the following addition:

Dielectric tests on disconnectors or earthing switches when in the OPEN position shall be carried out with the minimum isolating distance for the disconnector or gap for the earthing switch at which the indicating or signalling device can signal the position OPEN or the minimum isolating distance compatible with the locking arrangements specified in 6.104.1, whichever is the smallest. This requirement does not apply to independent operated indoor disconnectors and earthing switches.

Where the design requires an adjustment of the position indicator or the position-signalling device, this shall be performed according to the instruction manual. No deviation of these devices is acceptable for dielectric tests.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable.

7.2.6 Application of the test voltage and test conditions

Subclause 7.2.6 of IEC 62271-1:2017 is applicable with the following additions.

Disconnectors of $U_r > 52$ kV having an isolating distance in parallel to the base of the disconnector and having integrated earthing switches, shall also be tested in open position, in dry conditions only, with the power frequency test voltage given in Table 14 in the most disadvantageous dielectric position of the earthing switch. If the minimum temporary clearance is larger than the clearances given in IEC 60071-1, no test is required.

Table 14 – Power frequency withstand voltages

Rated voltage U_r kV	Test voltage kV
72,5	94
100	130
123	160
145	188
170	221
245	283
300	346
362	418
420	484
550	635
800	924
1 100	1 270
1 200	1 386

NOTE See Annex A for rationale of the values given in Table 14.

For testing of earthing switches, the test voltage shall be applied with the earthing switch in the open position (see Table 21):

- between adjacent insulated terminals with the bases earthed (e.g. A to B with F earthed);
- between all the insulated terminals connected together and the bases earthed (e.g. ABC to F earthed).

7.2.7 Tests of disconnectors and earthing switches of $U_r \leq 245$ kV

Subclause 7.2.7 of IEC 62271-1:2017 is applicable.

7.2.8 Test of disconnectors and earthing switches of $U_r > 245$ kV

Subclause 7.2.8 of IEC 62271-1:2017 is applicable.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is applicable with the following addition.

NOTE The performance of parallel insulation can be affected under pollution and rain (additional pollution tests could be necessary).

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-1:2017 is applicable with the following addition:

Partial discharge tests are not required to be performed on the complete disconnector or earthing switch except when required by the assembly standards i.e. IEC 62271-200, IEC 62271-201 and IEC 62271-203. However, in the case of disconnectors and earthing switches using components for which a relevant IEC standard exists, including partial discharge measurements (for example, bushings, see IEC 60137), evidence shall be provided by the manufacturer showing that those components have passed the partial discharge tests as laid down in the relevant IEC standard. For partial discharge measurement, see IEC 60270.

NOTE 1 The measurement of partial discharge test is a suitable means of detecting certain defects in the equipment under test and is a useful complement to the dielectric tests. Experience shows that partial discharges can lead in particular arrangements to a degradation in the dielectric strength of the equipment, especially of solid insulation.

NOTE 2 Other methods, for example UHF or acoustic methods, for measuring or detecting the partial discharge other than the one considered in IEC 60270, can be employed by agreement.

7.2.11 Dielectric tests on auxiliary and control circuits

Subclause 7.2.11 of IEC 62271-1:2017 is applicable.

7.2.12 Voltage test as condition check

Subclause 7.2.12 of IEC 62271-1:2017 is applicable.

7.3 Radio interference voltage (RIV) test

Subclause 7.3 of IEC 62271-1:2017 is applicable.

7.4 Resistance measurement

Subclause 7.4 of IEC 62271-1:2017 is applicable.

7.5 Continuous current tests

Subclause 7.5 of IEC 62271-1:2017 is applicable.

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

Subclause 7.6.1 of IEC 62271-1:2017 is applicable.

7.6.2 Arrangement of the disconnectors and earthing switches and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is applicable with the following additions:

7.6.2.101 General test conditions

The disconnectors or earthing switches under test shall be installed with their own operating mechanism as far as necessary to make the test representative.

Disconnectors having accessories to accommodate a bus-transfer current switching capability, and earthing switches having accessories to accommodate induced current switching capability, shall be tested with these devices mounted.

Tests shall be carried out employing the least favourable position of the operating mechanism and the main contacts. Consideration should be given to 6.104.3 and, where applicable, to 7.105.

Where the design requires an adjustment of the position indicator or the position-signalling device, this shall be performed according to the instruction manual. No deviation of these devices is acceptable for short-circuit tests.

If the design allows tolerances, these shall be declared by the manufacturer prior to the test. The short-time withstand current and peak withstand current tests shall be performed with the signalling device set at the maximum or minimum specified tolerance giving the least favourable status of the main contacts indicated by the signalling device. This requirement does not apply to independently operated indoor disconnectors and earthing switches.

NOTE The least favourable status of the main contacts is the first position at which during closing operation the "CLOSED" signal appears.

Open type disconnectors and earthing switches shall be tested with one of the appropriate test arrangements as specified in Figures 2, 3, 4 or 5. Where flexible conductors are used in the test setup, the terminals of the disconnectors or earthing switches under test shall be loaded with their longitudinal rated static mechanical terminal loads applied in the directions indicated by the manufacturer.

The test arrangement shall also be representative of the least favourable conditions of electromagnetic forces tending to open the disconnector or earthing switch. The tests on an earthing switch integral to a disconnector shall be made with the same test connections as for the disconnector test.

Single phase tests on disconnector or earthing switches having one common operating mechanism for three poles shall be performed on a single pole farthest from the operating mechanism.

Earthing switches not forming an integral part of a disconnector shall be tested in an arrangement that fulfils the same requirements as for disconnectors.

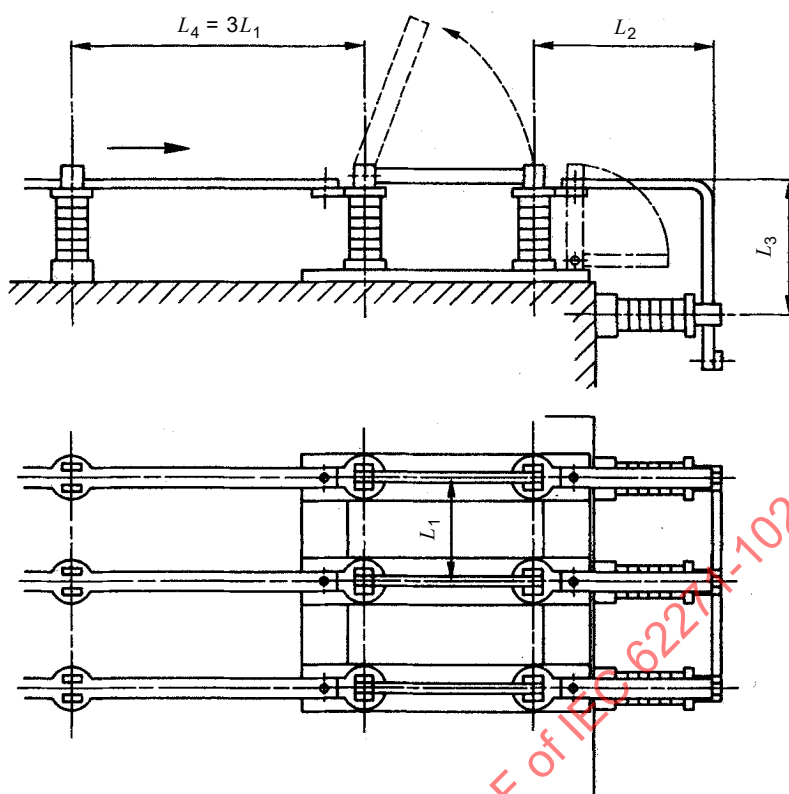
Disconnectors and earthing switches integrated in enclosed switchgear shall be tested as part of the switchgear assembly in accordance with IEC 62271-200, IEC 62271-201 or IEC 62271-203.

For divided support disconnectors and earthing switches, the vertical position of the contact in the contact zone shall be chosen to represent the most unfavourable condition with respect to the mounting of the fixed contact to flexible conductors or a rigid conductor. In case of doubt of the most unfavourable condition, the tests shall be performed in the highest and the lowest position of the contact within the rated contact zone.

All tests should preferably be performed three-phase. If a single-phase test is performed, the test should preferably be performed on two adjacent poles. If the test is performed on one pole, the return conductor shall be at phase distance from the tested pole. The return conductor shall be parallel to the main current path of the disconnector or earthing switch and at the same elevation above the base, or the equivalent, for disconnectors and earthing switches with vertical moving contact. The length of the return conductor shall be as given in Figures 2 to 5, as appropriate.

7.6.2.102 Disconnectors and earthing switches of $U_r \leq 52$ kV

The test arrangement given in Figure 2 shall be used for open type disconnectors and earthing switches of $U_r \leq 52$ kV. Hereby the distances L_2 and L_3 are as small as possible, but not smaller than L_1 .



IEC

Figure 2 – Three-phase test arrangement for disconnectors and earthing switches

The represented disposition covers:

- unsupported distances equal or smaller than L_4 for rigid conductors;
- phase-distance equal or larger than L_1 .

If L_1 has a range the phase distance of the test setup shall be the shortest. L_4 shall be the longest distance given by the manufacturer but not less than three times the shortest L_1 .

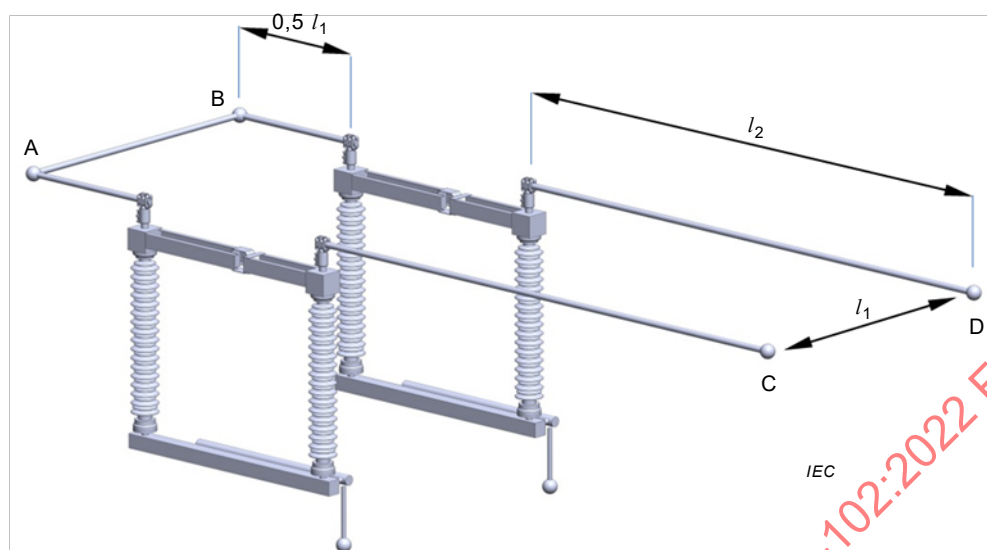
Avoid introduction of forces not representative of service conditions by the connections to the supply.

7.6.2.103 Disconnectors and earthing switches of $U_r > 52$ kV

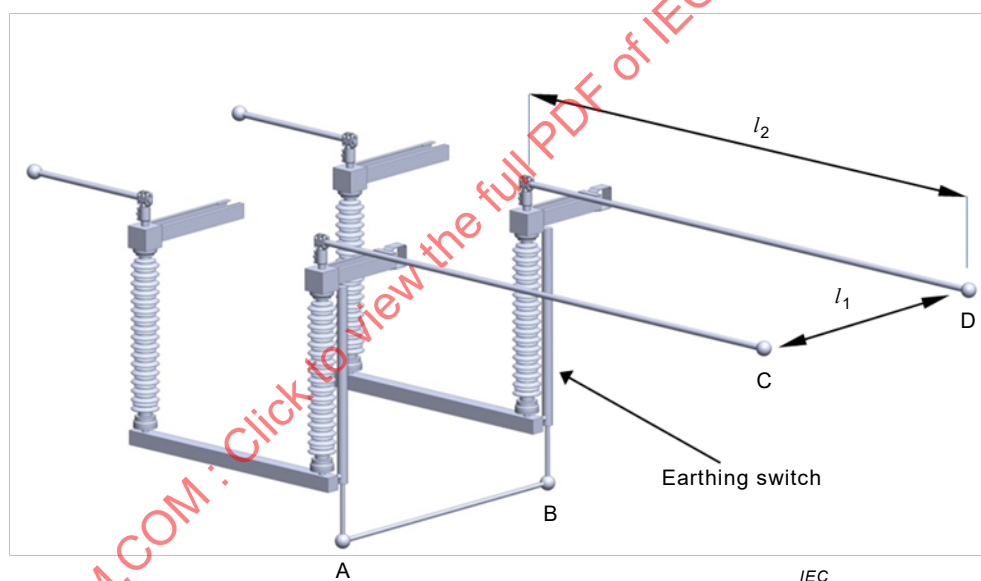
The single-phase test arrangement given in Figure 3 shall be used for disconnectors with a horizontal isolating distance and the relevant earthing switches; the test arrangement given in Figure 4 and Figure 5 shall be used for divided support disconnectors with a vertical isolating gap and the relevant earthing switches. Test results obtained on a disconnector or earthing switch placed in a certain position (e.g. horizontal or vertical) are valid only for the position of the disconnector or earthing switch during this test.

Three-phase test arrangements shall follow the same general pattern as the single-phase test arrangements of Figure 3 to Figure 5.

The short-circuit path between poles of the earthing switch schematically represented in Figure 3 shall reproduce during tests the installation conditions stated by the manufacturer. In particular, the position and fixing method of the conductors used to connect the poles between them and to the earth shall be considered.



a) Test arrangement for disconnectors



b) Test arrangement for earthing switches

Key

A–B Short-circuit connection

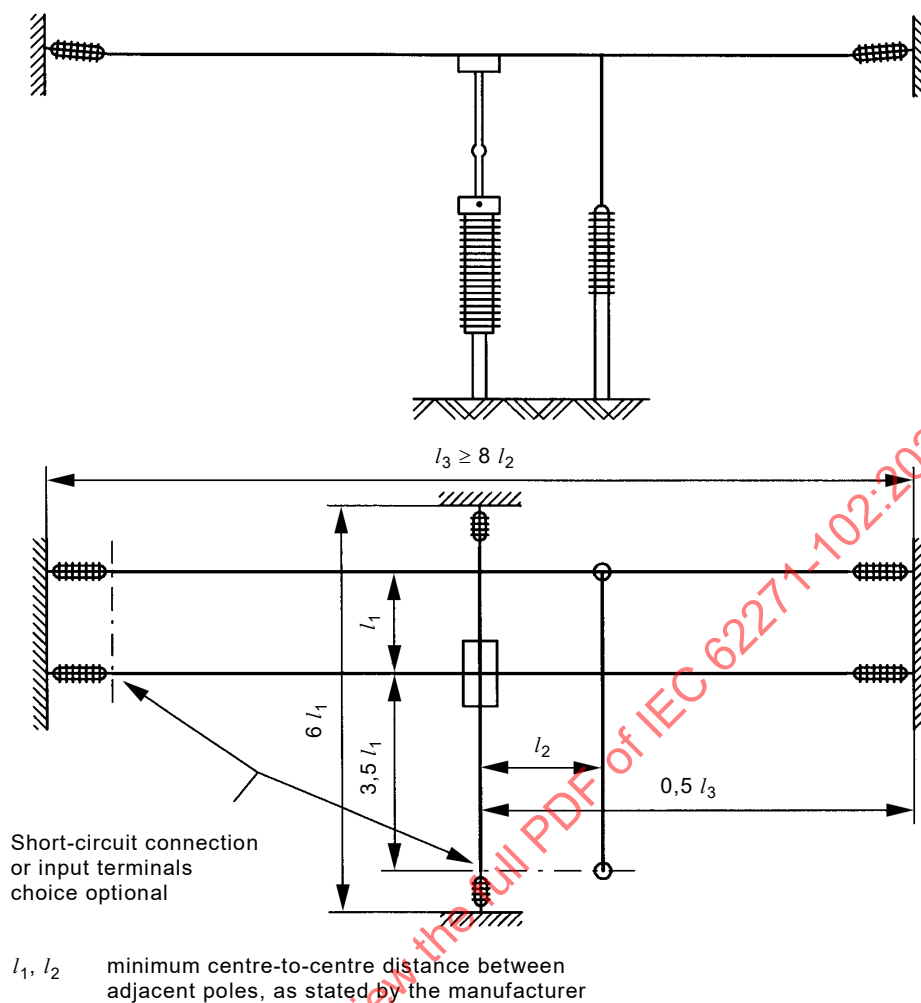
C–D Input

l_1 Minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

$l_2 = 2 \times l_1$ For $52 \text{ kV} < U_r \leq 550 \text{ kV}$

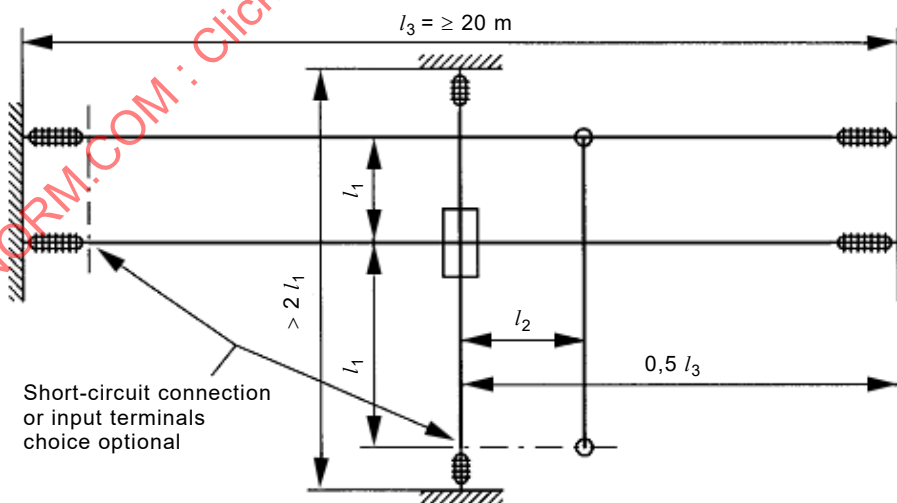
$l_2 = 0,5 \times l_1$ For $U_r > 550 \text{ kV}$, with a minimum of 7 m

Figure 3 – Single-phase test arrangement for disconnectors with a horizontal isolating distance and for earthing switches of $U_r > 52 \text{ kV}$, to be used with flexible or with rigid conductors



IEC

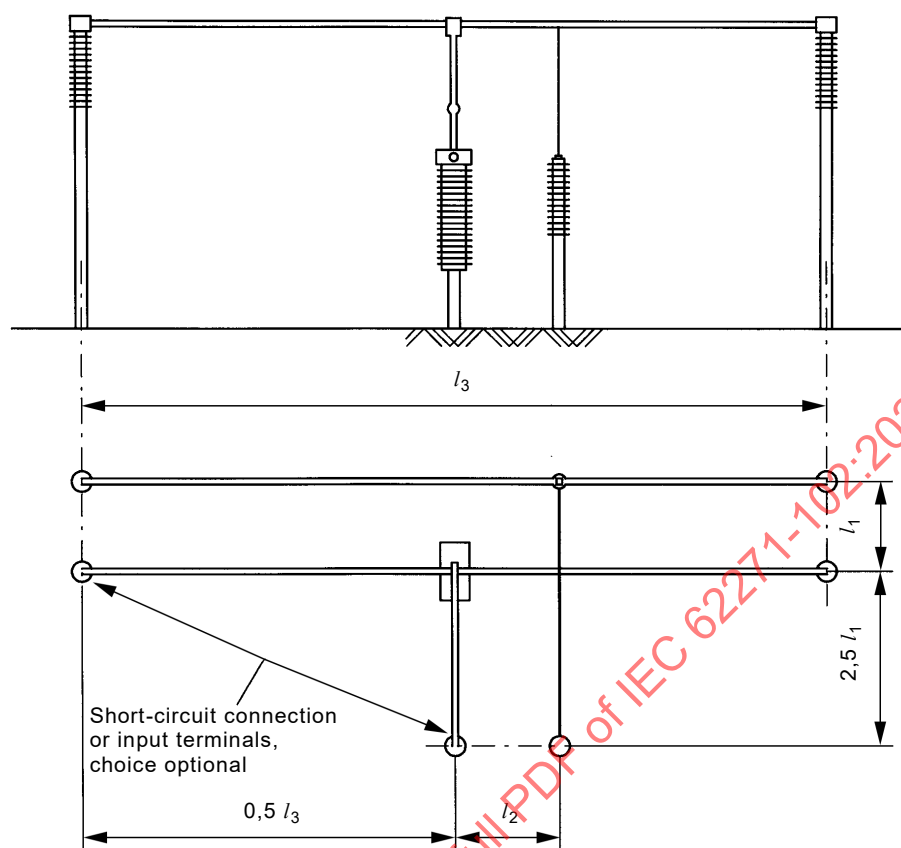
a) Test arrangement for disconnectors of $52 \text{ kV} < U_r \leq 550 \text{ kV}$



IEC

b) Test arrangement for disconnectors of $U_r > 550 \text{ kV}$

Figure 4 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52 \text{ kV}$ with a vertical isolating distance, to be used with flexible conductors

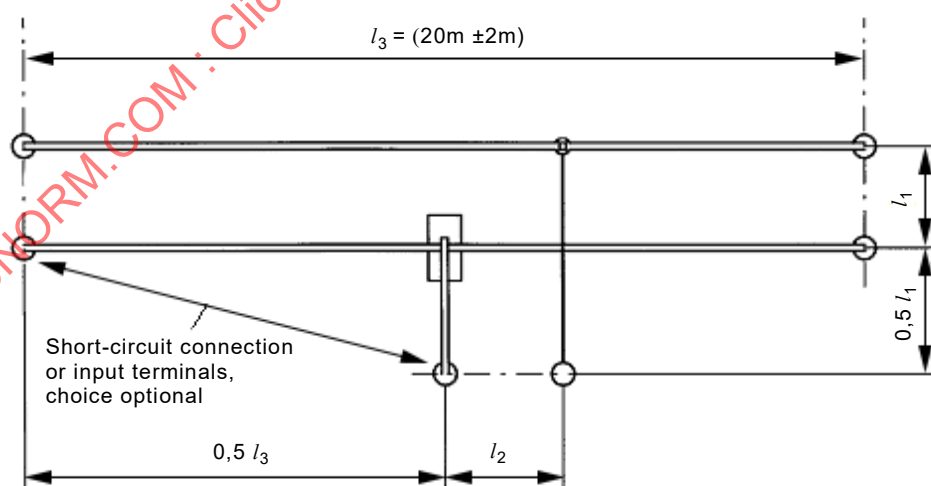


l_1, l_2 minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

IEC

For $U_r \leq 145$ kV $l_3 \geq 4l_1$
For $U_r \geq 170$ kV $l_3 = (20 \pm 2)$ m

a) Test arrangement for disconnectors of $52 \text{ kV} < U_r \leq 550 \text{ kV}$



l_1, l_2 minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

IEC

b) Test arrangement for disconnectors of $U_r > 550 \text{ kV}$

Figure 5 – Single-phase test arrangement for divided support disconnectors (earthing switches) of $U_r > 52 \text{ kV}$ with a vertical isolating distance, to be used with rigid conductors

Disconnectors and earthing switches to be connected in the substation to flexible or rigid conductors, according to their documentation, shall be tested using flexible conductors with their rated static mechanical terminal load (e.g. longitudinal direction F_{a1} or F_{a2} in Figure 8 and F_{a1} , and F_{a2} in Figure 9) in a test setup with the dimensions given in Figure 3 or Figure 4 respectively. Disconnectors and earthing switches, according to their documentation, to be connected only to rigid conductors shall be tested with rigid conductors in a test arrangement with the same dimensions and without intentional static mechanical terminal load except the one given by the weight of rigid conductors. The dimensions and material of the conductors used shall be stated in the test report.

After applying 50 % of the longitudinal rated static terminal load, the disconnector or earthing switch may be adjusted, before the 100 % load is applied

All details referring to the test arrangement are mandatory, the details of the disconnector and earthing switch shown are given as an example.

For standardization of tests when they are performed with flexible conductors, where the rated currents of the equipment are larger than 1 250 A continuous current or 31,5 kA short-time withstand current for a duration of 1 s, two flexible conductors shall be used having a centre line distance of (70 ± 30) mm without spacers. Disconnectors and earthing switches of $U_r \geq 300$ kV shall also be tested with these two flexible conductors.

Unless the tested disconnector or earthing switch is solidly fixed to the foundation, the spring constant of the support structure has to be taken into consideration (IEC 60865-1).

The test report shall provide clear details of the mounting arrangements used for the tests or record that the disconnector was solidly fixed to the foundations.

Avoid introduction of forces not representative of service conditions by the connections to the supply, and static terminal loads larger than the rated static mechanical terminal loads of the test object.

If, in the test setup, the short side of the low-level conductor cannot be supported, it may be supported by the disconnector. This may result in a higher dynamic mechanical terminal load.

NOTE 1 In principle, Figure 3 can be used for testing earthing switches with an appropriate arrangement of the earth conductor.

NOTE 2 In principle, Figure 4 can be used for testing integrated earthing switches with an appropriate arrangement of the earth conductor.

7.6.3 Test current and duration

Subclause 7.6.3 of IEC 62271-1:2017 is applicable.

7.6.4 Conditions of disconnectors and earthing switches after test

Subclause 7.6.4 of IEC 62271-1:2017 is applicable with the following addition.

The rated peak withstand current and the rated short-time withstand current, carried by a disconnector or earthing switch in the closed position during the rated duration of short-circuit, shall not cause:

- mechanical damage to any part of the disconnector or earthing switch;
- separation of the contacts.

After the test, a no-load operation shall be made with the rated value of power supply for independent power-operated devices, with minimum value of power supply for dependent power-operated devices, and for manually (dependent or independent) operated devices with

a force no higher than the values given for manually operated devices in 6.105. The disconnector or earthing switch shall open at the first attempt.

In the case of performing the short-circuit withstand test with a single-phase test on one pole of a three-pole disconnector or earthing switch operated by a common driving mechanism or shaft, exact details of the test procedure and the measured torque/force at the exit of the driving mechanism during the no-load operation shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus after a three phase short circuit occur. This test method may require the insertion of a torque/force measurement device in the power kinematic chain for testing. The measured torque/force in the power kinematic chain to open the pole under test of the disconnector or earthing switch tested shall be not more than the value given by the driving mechanism when blocking the exit of the driving mechanism divided by the number of poles of the switching device under test.

After the no-load operation, for earthing switches, sound earth connection and sound insulation shall be verified by the following:

- visual inspection shall be made (if possible). Significant contact erosion or significant contact welding should not be observed. Light welding of contacts is permitted;
- when significant contact erosion is suspected or if visual inspection is not possible without dismantling the contacts, sound earth connection shall be verified by checking the electrical continuity according to 7.4.3 of IEC 62271-1:2017;
- in case of doubt of insulating properties or if visual inspection is not possible without dismantling, 7.2.12 is applicable to verify the dielectric conditions across the isolating gap and to earth.

After the no-load operation(s), for disconnectors:

- to verify the current carrying capacity main circuit resistance measurement shall be made as close as possible to the contacts. The increase of resistance after the test shall not exceed 20 % of the value measured before the test;
- when the contact resistance exceeds this value a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the contacts;
- visual inspection shall be made (if possible). In case of doubt of insulating properties or if visual inspection is not possible without dismantling, 7.2.12 is applicable to verify the dielectric conditions across the isolating gap and to earth.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1:2017 is applicable.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 is applicable.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 is applicable.

7.10 Additional tests on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:2017 is applicable.

7.11 X-ray radiation test for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 is applicable.

7.101 Test to prove the short-circuit making performance of earthing switches

7.101.1 General test conditions

Earthing switches, having a short-circuit making current capability, shall be subjected to two (class E1) or five (class E2) making operations respectively, in a making test series in accordance with the procedures of 7.101.7.

The following test methods are applicable for combined function earthing switches that have short-circuit making capability in the other function:

- the short-circuit making tests shall first be performed on the other functions, in accordance with the relevant standards, followed by the short-circuit making tests on the earthing function, without intermediate maintenance;
- alternatively, the short-circuit making tests on the combined function earthing switch may be performed on a new combined function earthing switch preceded by at least one short-circuit making test on the other function followed by the short-circuit making tests on the earthing function without intermediate maintenance. This test method verifies only the short-circuit making capability of the earthing switch.

7.101.2 Arrangement of the earthing switch for tests

The earthing switch shall be tested under the representative conditions of installation and use, concerning the connections, support, enclosure and dimensions, in accordance with 7.6.2.

Its operating device shall be operated in the manner prescribed and in particular, if it is electrically, hydraulically or pneumatically operated, it shall be operated at the minimum supply voltage or pressure.

For gas-filled earthing switches, the tests shall be performed at the minimum functional pressure for insulation and/or switching.

For convenience of testing:

- the supply voltage to the coil for the closing operation may be increased to obtain a consistent closing time, provided it does not increase the closing speed of the contacts;
- in order to obtain accurate closing times an electrically or pneumatically released latch may be introduced at the toggle point.

Earthing switches with independent manual operation may be operated by an arrangement provided for the purpose of making remote control possible.

NOTE For testing purposes, it can be necessary to measure the travel characteristics, for example by using a travel recorder.

7.101.3 Test frequency

Earthing switches shall be tested at rated frequency, with a tolerance of $\pm 10\%$.

However, tests with a peak factor of 2,6 or above, at a supply frequency of 50 Hz or 60 Hz cover the requirements of both frequencies.

7.101.4 Test voltage

The test voltage shall be as follows:

- a) for three-phase tests, the average value of the applied voltage phase-to-phase shall not be less than the rated voltage U_r and shall not exceed this value by more than 10 % without the consent of the manufacturer. The differences between the average value and the applied voltages of each pole shall not exceed 5 %;

- b) for single-phase tests, the applied voltage shall not be less than the phase-to-earth value $U_r/\sqrt{3}$, and shall not exceed this value by more than 10 % without the consent of the manufacturer, with the exceptions given below:

for single-phase tests on three-pole operated earthing switches which have a spread between the first and second contact touch during closing exceeding half a cycle of the rated frequency, the applied voltage phase-to-earth shall not be less than U_r .

7.101.5 Test short-circuit making current

The short-circuit current during making test shall be expressed in terms of the peak current and the symmetrical RMS current. The symmetrical RMS value of current in each phase at 0,2 s shall be at least 80 % of the rated short-time withstand current. The prospective peak current shall be equal to the rated short-circuit making current (I_{ma}) with the tolerance of 0 % and +5 %.

The duration of the short-circuit current shall be at least 0,2 s.

The earthing switch shall be tested under the two extreme cases specified as follows:

- a) making at the peak of the voltage wave, (with a tolerance of -30° electrical degrees to $+15^\circ$ electrical degrees) leading to a symmetrical short-circuit current and the longest pre-arcing time. For convenience of testing, alternative test methods may be followed. The alternative test methods are given in Annex D;
- b) making at the zero of the voltage wave, without pre-arcing, leading to a fully asymmetrical short-circuit current. For convenience of testing, the test may be carried out at reduced applied voltage to obtain the rated short-circuit making current (I_{ma}). It may happen that the making operation does not occur exactly at the zero of the voltage wave. However, the extreme case b) is considered met if the rated short-circuit making current has been obtained.

7.101.6 Test circuits

Making tests shall be performed using the three-phase test circuit or the single-phase test circuit.

Three-phase tests cover:

- the interaction between the different phases;
- the stresses on the operating mechanism (in the case of a common operating mechanism).

Three-pole earthing switches shall be tested in a three-phase circuit in order to cover applications in both effectively and non-effectively earthed neutral systems. For testing purposes, the severity of making tests in circuits with unearthed neutral or solidly earthed neutral are considered to be equivalent. However, single-phase testing of earthing switches of $U_r > 52$ kV is allowed in the following cases:

- a) multi-enclosure type or open-air type earthing switches with separately stored closing energy for each pole;
- b) earthing switches operated pole-after-pole.

7.101.7 Test procedures

For class E1, the tests shall be performed with a sequence of two C operations with one single no-load O in between, i.e. C – O (no-load) – C, unless the test laboratory needs more no-load operations between the closing operations.

For class E2 earthing switches, the test sequence is $2C - x - 2C - y - 1C$, where x and y represent arbitrary number of no-load operations. The 2C operations consists of

C – O (no-load) – C, unless the test laboratory needs more no-load operations between the closing operations. There is no requirement on the time interval between the two closing operations.

No maintenance is allowed during a test sequence.

For combined function earthing switches, the arbitrary number of no-load operations represented by x and y in the test sequence for class E2 may be replaced by switching operations.

Due to non-simultaneity of poles or different instants of initiation of pre-arcs in the different poles, a peak making current, which is higher than the rated value, may occur in one pole. This is particularly the case if, in one pole, the current begins to flow a few milliseconds later than in the other two poles. If the earthing switch fails during such an event, this is considered to be a failure of the earthing switch.

The requirements with regard to the instant of making as specified in Table 15 shall be achieved during the tests.

Table 15 – Requirements on the instant of making

Class E1	Class E2
2 tests	5 tests
At least 1 test fulfilling the requirements of 7.101.5 a)	At least 2 tests fulfilling the requirements of 7.101.5 a)
At least 1 test fulfilling the requirements of 7.101.5 b)	At least 2 tests fulfilling the requirements of 7.101.5 b)
NOTE Normally the speed of closing of the contacts of the earthing switches with short-circuit making capability is high enough that both maximum pre-arcing and maximum peak current can be reached within a same test, however at different phases.	

7.101.8 Behaviour of earthing switches when making short-circuit currents

The following applies during the making tests:

- enclosed earthing switches having a rated short-circuit making current shall, when making the short-circuit, not project flames, liquids, gases nor particles outside the enclosure;
- from open type earthing switches, flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.101.9 Condition of earthing switch after short-circuit making tests

After performing the specified operations, mechanical parts, parts related to the electrical field control (for example field electrodes of a GIS earthing switch) and insulators of the earthing switch shall be practically in the same condition as before. The insulating properties shall not be degraded. The short-circuit making performance and short-time current withstand performance may be impaired.

NOTE The useful life of the earthing switch with regard to short-circuit making and short-time current withstand capability is normally considered to be at the end, after the specified number of making operations necessitating maintenance or replacement.

To verify this requirement, the earthing switch shall meet the following inspection conditions:

- mechanical conditions: After each operation only light welding of contacts is permitted. However, the earthing switch shall be able to open and close under the conditions given in 6.5 and 6.6, with the rated values for power operated devices or with 120 % of the values given for manually operated devices in 6.105 using the normal operating handle;

- b) electrical continuity: Visual inspection after the no-load operation is usually sufficient for checking the electrical continuity of the earthing switch. In case of doubt the electrical continuity shall be measured according to 7.4.3 of IEC 62271-1:2017;
- c) dielectric requirements: Visual inspection is usually sufficient for checking the above requirement. In case of doubt, a voltage test as a condition check according to 7.2.12 is to be performed. As an alternative, 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For earthing switches that are sealed for life, the voltage test as a condition check is mandatory.

7.101.10 Invalid tests

In the case of an invalid test, it may become necessary to perform a greater number of short-circuit making tests than required by this document. An invalid test is one where one or more test parameters demanded by the document are not met. This includes, for example, current, voltage and time factors as well as point-on-wave requirements (if specified) and the additional features in synthetic testing.

The deviation from the document could make the test less or more severe. Four different cases are considered in Table 16.

Table 16 – Invalid tests

Test conditions related to standard	Earthing switch passed	Earthing switch failed
More severe	Test valid, result accepted	Test to be repeated with correct parameters Modification of the design of the earthing switch not required
Less severe	Test to be repeated with correct parameters Modification of the design of the earthing switch not required	Modification of the design of the earthing switch required, aiming for improvement of the making capability All tests to be repeated on the modified earthing switch
NOTE "More severe" is considered to be a test performed with voltage and/or current above the tolerances and additionally for the alternative test methods a test with longer prearcing time.		

In the case of less severe test conditions, the invalid part of the test-duty may be repeated without reconditioning of the earthing switch. In those cases, the test report shall include reference to the invalid test. However, in the case of a failure of the earthing switch during such additional tests, or at the discretion of the manufacturer, the earthing switch may be reconditioned and the complete test-duty repeated. If any record of an individual operation cannot be produced for technical reasons, individual operations are not considered invalid, provided that evidence can be given in another manner that the earthing switch did not fail and the required testing values were fulfilled.

In the case of three-phase direct testing (single power source), even if the requirements in 7.101.5 a) and/or 7.101.5 b) are still not met during the repetition of the complete test duty, the earthing switch is considered to have passed the test if the requirements specified in 7.101.8 and 7.101.9 are fulfilled.

7.101.11 Type test reports

The results of the type test shall be recorded in type-test reports containing sufficient data to prove compliance with the rated short-circuit making current performance requirements. Sufficient information should be included so that the essential parts of the earthing switch tested can be identified. Refer to 7.1.2 of IEC 62271-1:2017.

The test report shall contain the information about the test arrangements, test circuits and test procedures.

General information concerning the supporting structure of the earthing switch should be included. Information regarding the operating devices employed during the tests should, where applicable, be recorded.

Typical oscillographic or similar records shall be provided so that the following can be determined:

- the making current expressed as a peak value and the RMS value at 0,2 s;
- the applied voltages;
- instantaneous value of voltages at the moment of the making;
- pre-arcing time.

7.102 Operating and mechanical endurance tests

7.102.1 General test conditions

The test shall be made at the ambient air temperature of the test location. During the test, the ambient temperatures shall be recorded and maximum and minimum values included in the test report.

The supply voltage shall be measured at the terminals of the operating devices with full current flowing. Auxiliary equipment forming part of the operating device shall be included.

For three-phase disconnectors and earthing switches operated by one mechanism, where the application of terminal load is required, it shall be applied to all terminals simultaneously.

7.102.2 Contact zone test

This test shall be made in order to prove satisfactory operation of divided support disconnectors or divided support earthing switches, in the various positions of the fixed contact within the limits of the rated contact zone defined according to 5.103 and Figures 6 and/or 7. With the device in the open position, the fixed contact shall be placed in the following positions:

- a) at a height of h on the vertical axis of the assembly;
- b) at a height of $h - z_r$ on the same axis;
- c) at a height equal to h and displaced from the vertical axis horizontally by $+y_r/2$;
- d) at a height equal to h and displaced from the vertical axis horizontally by $-y_r/2$;
- e) positions a) to d) at a distance equal to $+x_r/2$;
- f) positions a) to d) at a distance equal to $-x_r/2$,

where

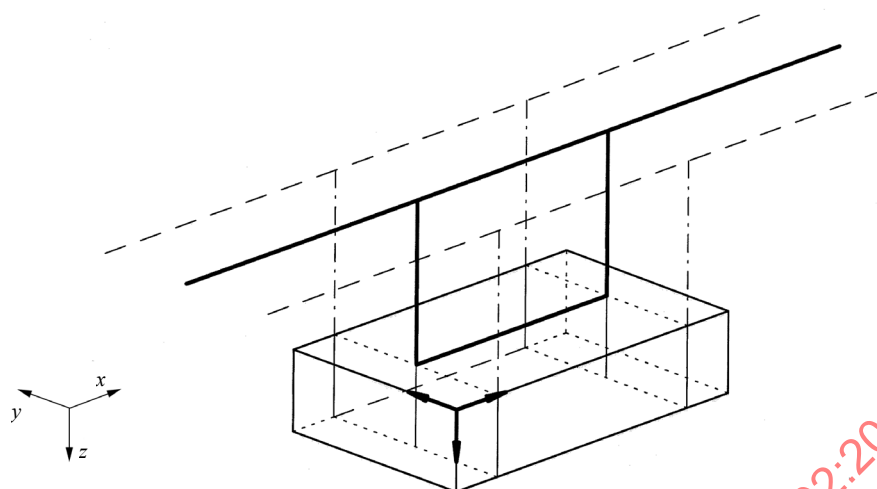
h is the highest position (stated by the manufacturer) of the fixed contact above the mounting plane;

x_r is the total amplitude of movement of the fixed contact in the x -direction;

y_r is the total amplitude of movement of the fixed contact in the y -direction;

the subscript, r , indicates the rated value assigned to the disconnector or earthing switch by the manufacturer.

In each position, the device shall close and open correctly.



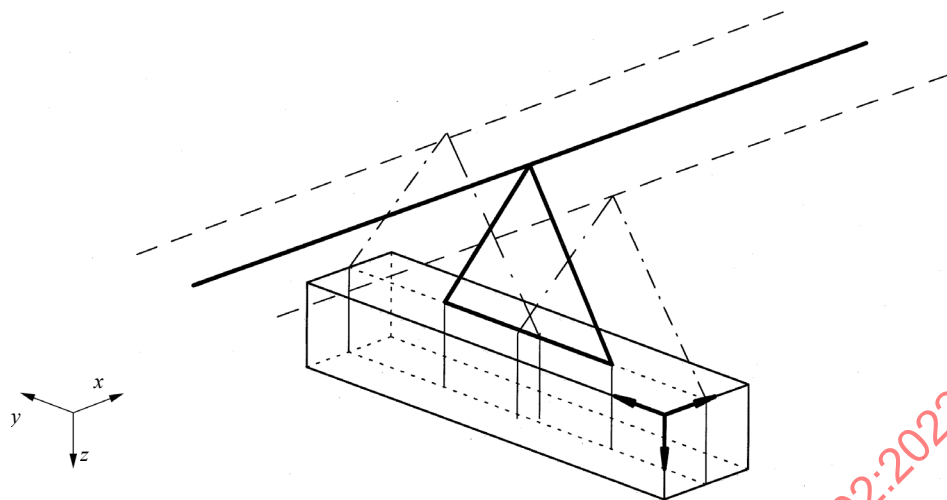
Key

- x Longitudinal to support (influence of temperature)
- y Perpendicular to support (influence of wind)
- z Vertical deflection (temperature and ice)

Figure 6 – Fixed contact parallel to support

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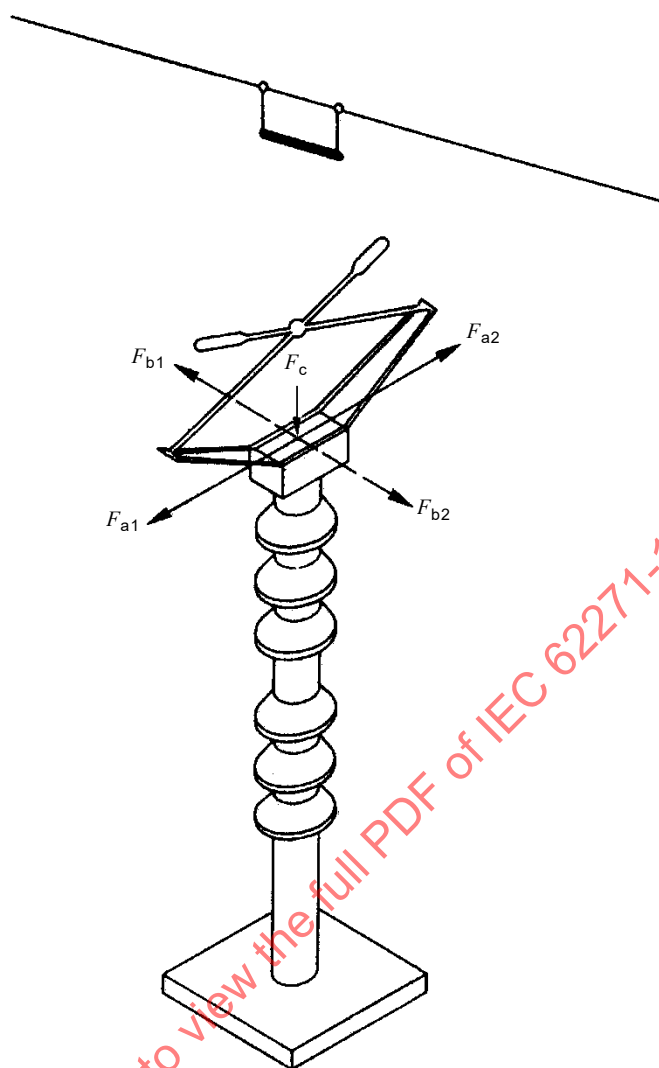
IEC

Key

- x Longitudinal to support (influence of temperature)
- y Perpendicular to support (influence of wind)
- z Vertical deflection (temperature and ice)

Figure 7 – Fixed contact perpendicular to support

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NOTE Above the pantograph, the fixed contact is shown.

Figure 8 – Example of the application of rated static mechanical terminal loads to a (divided support) pantograph disconnector (or earthing switch)

7.102.3 Mechanical endurance test

7.102.3.1 Test procedure

The tests defined in 7.102.3.1 and in 7.102.3.2 shall be performed on disconnectors and earthing switches of class M0.

The mechanical endurance test shall consist of 1 000 operating cycles. For disconnectors or earthing switches having a rated terminal load, 50 % of the rated static terminal load shall be applied during the test in direction F_{a1} or F_{a2} (Figure 8 and Figure 9), without voltage on, or current through, the main circuit. For disconnectors having two or three insulators and a normally horizontal isolating gap, the 50 % rated static terminal load shall be applied at both sides of the disconnector, but in opposite directions. For disconnectors and earthing switches with one insulator (operating insulators not being taken into consideration), the terminal load shall be applied to only one side of the disconnector or earthing switch. After applying 50 % of the rated static terminal load, the disconnector or earthing switch may be adjusted before performing the tests.

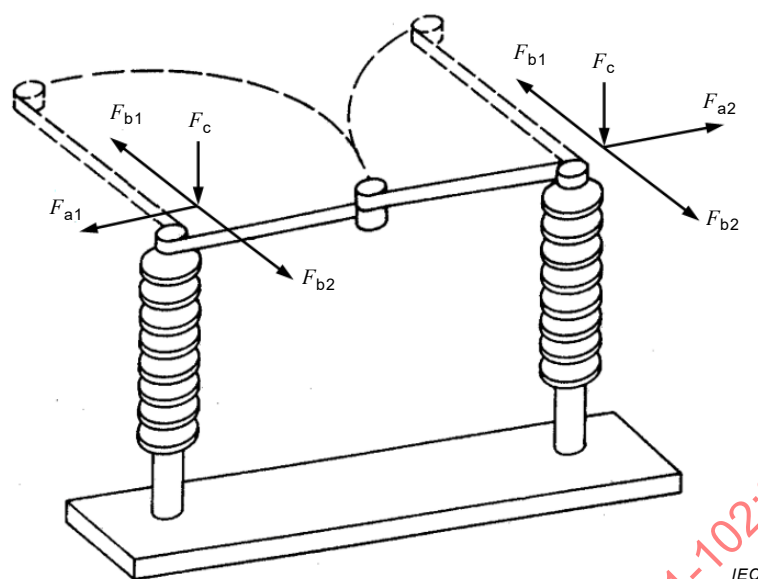


Figure 9 – Example of the application of rated static mechanical terminal loads to a two-column disconnector

The closed and open positions shall be attained during each operating cycle.

During the test, the operation of the control and auxiliary contacts and position-signalling devices (if any) shall meet the requirements expressed in 6.104 and 6.4 of IEC 62271-1:2017. The test is considered failed if any of the control and auxiliary contacts and position-signalling devices do not operate at one of the close-open operating cycles.

The test shall be made on disconnectors and earthing switches equipped with their own operating mechanisms. During the test, lubrication in accordance with the manufacturer's instructions is permitted, but no mechanical adjustment or other maintenance is allowed.

On a disconnector or earthing switch having a power-operated mechanism:

- 900 close-open operating cycles shall be made at the rated supply voltage and/or rated pressure of compressed gas supply;
- 50 close-open operating cycles at the specified minimum supply voltage and/or minimum pressure of compressed gas supply;
- 50 close-open operating cycles at the specified maximum supply voltage and/or maximum pressure of compressed gas supply.

No specific time intervals between operating cycles or between closing and opening operations are required. These tests shall be made, however, at a rate such that the temperature rises of the energised electrical control components do not exceed the specified values. For the same purpose, external cooling may be applied during the test.

For manually operated disconnectors and earthing switches, the handle may, for convenience of testing, be replaced by an external power-operated device. In this case, it is not necessary to vary the power parameters.

7.102.3.2 Verification of successful operation

For the evaluation of the operating characteristics, before and after the mechanical endurance test programme, the following operations shall be performed without the static terminal load applied:

- five close-open operating cycles at the rated supply voltage and/or pressure (if any);
- five close-open operating cycles at the minimum supply voltage and/or pressure (if any);
- five close-open operating cycles at the maximum supply voltage and/or pressure (if any);
- five close-open manual operations if the switching device can be operated manually.

During these operating cycles, the operating characteristics, such as, if applicable, operating times, power consumption, maximum forces for manual operation, shall be recorded. Satisfactory operation of control and auxiliary contacts and position-indicating devices (if any) shall be verified. It is not necessary to include all the oscillograms recorded in the type test report.

The variation between the average values of each parameter, measured before and after the mechanical endurance test, shall be within the tolerances specified by the manufacturer.

After the test, all parts, including contacts, shall be visually inspected to check their good condition and they shall not show undue wear; see also 7.5.6.2, point 6, of IEC 62271-1:2017. The main circuit resistance, i.e. on disconnectors, shall be measured before and after the mechanical endurance test, as close as possible to the contacts. The resistance shall not increase by more than 20 % from the value measured before the test. If this limit is exceeded, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the contacts.

For earthing switches where contacts are visible, the fully closed and open positions during operation after the mechanical endurance test shall be verified by visual inspection.

For earthing switches where contacts are not visible, the fully closed and open positions during operation after the mechanical endurance test shall be verified by using the travel records or other appropriate methods.

For gas-insulated disconnectors and earthing switches, a tightness test according to 7.8 shall be performed before and after the mechanical endurance test.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % from the value measured before the test.

7.102.4 Operation during the application of rated static mechanical terminal loads

Twenty operating cycles with the rated power supply shall be made with the rated mechanical static terminal loads applied at each terminal in the directions specified by the manufacturer. When more than one load configuration is specified by the manufacturer, the 20 operating cycles shall be repeated for each configuration. The three components of each terminal load may be applied by a conductor pulling in the resultant direction and with the resultant force of the three vectors.

NOTE Any possible combination of the resultant forces applied at the terminals corresponds to one load configuration.

Examples of terminal loads applied at different types of disconnectors are shown in Figure 8 and Figure 9.

One example of possible configurations for a two columns disconnector is given here below:

- longitudinal (straight) load applied in direction F_{a1} at one terminal and F_{a2} at the opposite terminal;
- transversal (cross) load applied in direction F_{b1} or F_{b2} , at both terminals in the same direction;

- vertical load applied in direction F_c at both terminals (except for disconnectors specified to be connected to flexible conductors).

For only manually operated disconnectors and earthing switches the number of operating cycles is reduced to 10.

The loads shall be applied on both terminals at the same time.

The disconnector or earthing switch may be adjusted before the test and after having been loaded with 50 % of the rated longitudinal or perpendicular mechanical terminal force.

During each operation, the disconnector or earthing switch shall close and open correctly.

For verification, before and after the complete sequence of operating cycles, 7.102.3.2 and the appropriate comparators as required in 7.102.3.1 for mechanical endurance tests, are applicable (i.e. without static mechanical terminal loads applied).

7.102.5 Extended mechanical endurance tests

The tests defined in this subclause shall be performed on disconnectors class M1 and M2 and on earthing switches class M1.

In the case of disconnectors and earthing switches in GIS, the enclosure shall not be opened during the test.

Tests shall be carried out as follows:

- a) The extended mechanical endurance tests programme shall consist of a number of close-open operations carried out in accordance with 7.102.1 and 7.102.3.1.

According to the class assigned, one of the following number of operating cycles shall be performed:

- 2 000 (for class M1);
- 10 000 (for class M2).

After the first series of 1 000 operating cycles, some maintenance such as lubrication and mechanical adjustment is allowed and shall be performed in accordance with the manufacturer's instructions, and its reference included in the test report. Change of parts in the main circuit and in the kinematic chain is not permitted.

After each next series of 1 000 operating cycles, or at maintenance intervals (if of less than 1 000 operating cycles), the operating characteristics shall be recorded and evaluated (if power operated) at the rated pressure or voltage.

The programme of maintenance shall be defined by the manufacturer before the tests and recorded in the test report.

- b) Before and after the total test programme, verification of successful operation shall be performed as required in 7.102.3.2.
- c) In addition, after the total test programme, checks and tests shall be performed as follows:
- contact zone test (7.102.2), if applicable;
 - verification of operation during application of rated static mechanical terminal loads (7.102.4), if applicable;
 - verification of satisfactory operation with the minimum duration of the operating signal specified in the manufacturer's documentation;
 - verification of operation of the mechanical strain-limiting devices, if any.

7.102.6 Testing of mechanical interlocking devices.

Disconnectors and earthing switches which are not covered by switchgear and controlgear assembly standards (e.g. IEC 62271-200, IEC 62271-201 and IEC 62271-203) shall be tested as follows, if mechanical interlocking devices are provided blocking the operating shaft or power kinematic chain.

All interlocking devices shall be submitted to 5 attempts to perform close and/or open operation for any interlocked position of disconnector and/or earthing switch, in order to prove compliance with requirements in 6.12.

Before each attempt, the interlocking devices shall be set in the position intended to prevent the operation of the switching device and then one attempt shall be made to operate the interlocked switching device. Operating forces given in 6.12 shall be employed and no adjustment shall be made to the switching devices or interlocking devices.

The tests are considered satisfactory if the interlocked switching devices and the interlocking devices are in proper working order and if the forces required to operate the switching devices are practically the same before and after the tests.

The operating forces are considered the same if the average value measured after the test is within the maximum and minimum values measured before the test. At least three close/open operations should be performed before the test to fix the minimum and maximum values for acceptance of the close or open operation after the test.

7.103 Operation under severe ice conditions

7.103.1 General

The tests defined in this subclause shall be made only if the manufacturer claims the suitability of disconnectors and earthing switches for operation under severe ice conditions (i. e. 10 mm ice coating and above).

Disconnectors and earthing switches having accessories to accommodate a bus-transfer current switching capability (disconnectors only) and a switching capability of induced currents (earthing switches only) shall be tested with these devices mounted.

NOTE Formation of ice may produce difficulties in the operation of electric power systems. Under certain atmospheric conditions, a deposit of ice can build up to a thickness that sometimes makes the operation of outdoor switching equipment difficult.

7.103.2 Test arrangement

- a) All parts of the disconnector or earthing switch to be tested shall be assembled, together with their operating mechanism, in a room which can be cooled to a temperature according to the requirements given in 7.103.3. The energizing of heating elements of the control mechanism is permitted during the test. Supports, operating insulators and other operating members may be shortened to reduce the height of the assembly to suit the test facilities available, provided the angle of rotation of the parts affected and the bending of thrust linkages remain unchanged.

In choosing the refrigeration capacity required, the heat content of the water with which the apparatus under test is sprayed should be taken into account.

- b) A single-pole of a three-pole apparatus may be tested if each pole has a separate operating mechanism. In the case of a three-pole apparatus up to and including 52 kV having one common operating mechanism for the three poles, the complete three-pole device shall be tested. In the case of voltages above 52 kV and if the testing laboratory cannot accommodate complete standard three-pole apparatus, modifications of mounting structures, post insulators or spacing, wherever possible, in order to enable the three-pole

test to be made are permitted. If the tests are not possible even in this configuration, tests with a single-pole apparatus operated by the common mechanism are permitted. In this last case, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus. In all cases, it is not allowed to change the original isolating distance for the disconnecter or the gap for the earthing switch.

- c) The disconnecter or earthing switch shall be tested for operation from the open position and the closed position separately.
- d) Prior to the test, any trace of oil or grease on parts that do not need to be lubricated in service shall be removed with an appropriate solvent. This is because thin films of oil or grease prevent ice from adhering and greatly change the results of tests.
- e) For measurement of ice thickness, a copper bar or tube 30 mm in diameter and 1 m in length shall be mounted in a horizontal position in a place where it will receive the same general rainfall as the apparatus under test.
- f) The arrangement shall allow the entire apparatus to be sprayed with artificial rain falling from above at various angles, from the vertical to 45°. The water used in the spray should be cooled to a temperature between 0 °C and 3 °C and shall reach the test object in the liquid state.

7.103.3 Test procedure

7.103.3.1 Checks before the formation of ice coating

Before testing, the disconnecter/earthing switch shall be subjected to:

- 5 close-open operating cycles at the rated supply and/or pressure (if any);
- 5 close-open manual operations if the switching device can only be operated manually;
- the measurement of the resistance of the main circuit in accordance with 7.4.4.

During the operating cycles, operating characteristics such as, if applicable, operating times, power consumption, maximum forces for manual operations, shall be recorded. Satisfactory operation of control and auxiliary contacts, and position-indicating device (if any) shall be verified. It is not necessary to include all the oscillograms recorded in the type test report.

7.103.3.2 Formation of ice coating

Nature produces ice coatings which may be divided into two general categories:

- a) clear ice, generally resulting from rain falling through air somewhat below the freezing point of water;
- b) rime ice, characterized by a white appearance, formed for example from atmospheric moisture condensing on cold surfaces.

For type tests a coating of solid clear ice of the required thickness shall be produced according to the procedure described below.

- a) Lower the room temperature down to 2 °C and start the spray of pre-cooled water. Continue this spray for a minimum of 1 h while holding the room temperature between 0,5 °C and 3 °C.
- b) Lower the room temperature down to the range between –7 °C and –3 °C while continuing the water spray. The rate of temperature change is not critical and may be whatever is obtainable with available refrigeration apparatus.
- c) Hold the room temperature within –7 °C and –3 °C and continue to spray until the specified thickness of ice can be measured on the top surface of the test bar. The amount of water should be controlled to cause ice to build up at the rate of approximately 6 mm/h.

NOTE 1 If the specific thermal capacities per unit surface area of test bar and apparatus under test differ considerably, even identical spraying conditions may produce very different ice coatings. These differences in thickness may be minimized by short periods of spraying alternating with longer periods of cooling.

NOTE 2 As a guide, it has been observed that between 20 l and 80 l per hour per m² of area sprayed is required to cause ice to be deposited at a rate of approximately 6 mm/h.

- d) Discontinue the spray and maintain the room temperature within $-7\text{ }^{\circ}\text{C}$ and $-3\text{ }^{\circ}\text{C}$ for a period of at least 4^{+2}_0 h. This ensures that all parts of the disconnector/earthing switch and the ice coating have reached a constant temperature.

7.103.3.3 Checks after the formation of ice coating

After the formation of ice coating, the satisfactory operation of the disconnector/earthing switch shall be checked:

- if the disconnector or earthing switch is manually operated, the operation will be considered as satisfactorily completed if the apparatus has been operated to its final closed or open position applying normal operating forces (being permissible to remove the ice from the insertion point of the handle);
- if the disconnector or earthing switch is electrically, pneumatically or hydraulically operated, the operation will be considered as satisfactorily completed if the apparatus has been operated on the first attempt up to its final closed or open position by the operating device supplied at its rated voltage or pressure.

Immediately after the closing operation, the electrical continuity across the contacts shall be checked.

When the disconnector/earthing switch is ice-free, it shall be subjected to the same checks of 7.103.3.1, with the room temperature restored to normal ambient temperature (above $10\text{ }^{\circ}\text{C}$). The apparatus shall be considered to have passed the test if its mechanical and electrical performance is not affected; this condition shall be considered as met if:

- the resistance measured before the formation of ice coating has not increased by more than 20 %;
- the variation between the average values of each parameter, measured before the formation of ice coating, is within the tolerances given by the manufacturer.

The complete ice coating procedure and subsequent checks shall be performed for each position (i.e. closed/open) on each disconnector and/or earthing switch. Ice coating shall be naturally removed between tests, for example by leaving the apparatus enough time at adequate room temperature.

7.104 Low- and high-temperature tests

7.104.1 General

If the temperature limits for the service conditions of the apparatus (defined by the manufacturer) are above $+40\text{ }^{\circ}\text{C}$ or below $-5\text{ }^{\circ}\text{C}$, the following procedure shall be applied:

Single poles of three-pole apparatus may be tested individually if each pole has a separate operating mechanism. In the case of three-pole apparatus of $U_r \leq 52\text{ kV}$ having one common operating mechanism for the three poles, the complete three-pole device shall be tested.

In the case of $U_r > 52\text{ kV}$ and if the testing laboratory cannot accommodate complete standard three-pole apparatus, modifications of mounting structures, post insulators or spacing, wherever possible, are permitted to enable tests on all three poles. If the tests are not possible even in this configuration, tests with a single-pole apparatus operated by the common mechanism are permitted. In this last case, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus. In all cases, changing the original isolating distance for the disconnector or the gap for the earthing switch is not allowed.

If heat sources are required, they shall be in operation.

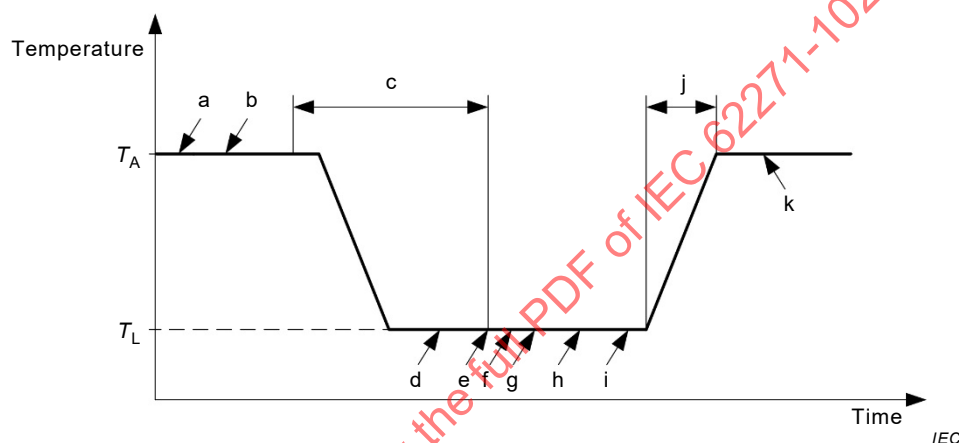
No maintenance, replacement of parts, lubrication or readjustment of the apparatus is permissible during the tests. For insulation pressure systems the tests shall be performed at rated filling pressure for insulation and/or switching. The characteristics recorded shall be within the tolerances specified by the manufacturer.

7.104.2 Measurement of ambient air temperature

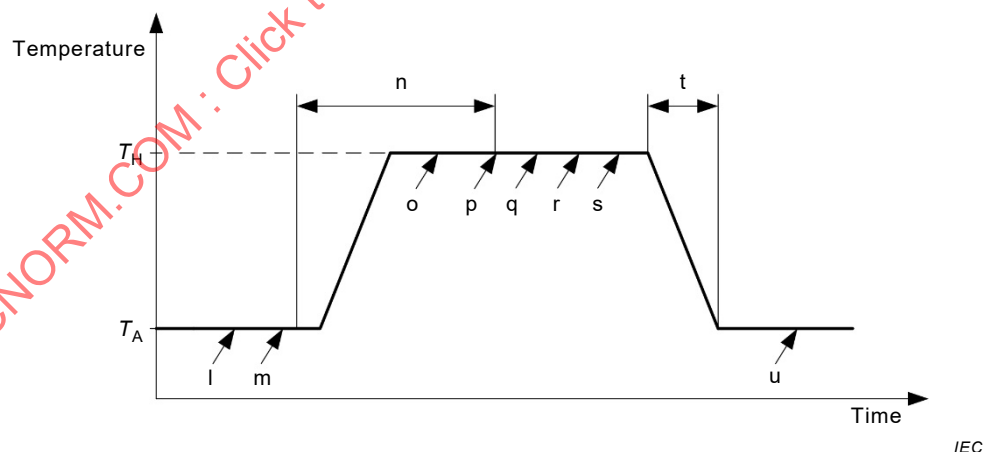
The maximum temperature deviation over the height of the apparatus shall not exceed 5 K, measured at a distance of 1 m from the apparatus.

7.104.3 Low-temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 10 a).



a) Low temperature test



b) High temperature test

NOTE Letters a to u identify application points of tests specified in 7.104.3 and 7.104.4.

Figure 10 – Test sequences for low and high temperature tests

If the low-temperature test is performed immediately after the high-temperature test and using the same sample, the low-temperature test can proceed after completion of item (t) of the high-temperature test. In this case, items (a) and (b) are omitted.

a) The test object shall be adjusted in accordance with the manufacturer's instructions.

- b) Characteristics and settings of the test object shall be recorded in accordance with 7.102.3.2 and at an ambient air temperature of $(20 \pm 5) ^\circ\text{C}$ (T_A). The tightness test for insulation pressure systems shall be performed according to 7.8.
- c) With the disconnecter in close position and/or the earthing switch in open position, the air temperature shall be decreased to the appropriate, minimum ambient air temperature (T_L), according to the service conditions defined by the manufacturer and in accordance with Clause 2, at a rate of change of approximately 10 K per hour. The disconnecter shall be kept in close position and/or the earthing switch in open position for a minimum of 12 h after the ambient air temperature stabilises at T_L .
- d) During the 12-h period with the disconnecter in the closed position and/or the earthing switch in the open position at temperature T_L , a tightness test shall be performed on insulation pressure systems. An increased leakage rate is acceptable, provided that it returns to the original value when the apparatus is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate should not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017. This tightness test shall be integral and performed by the accumulation method with appropriate apparatus for measurement of SF_6 concentration at the low temperature of the air in the testing room. For uniform diffusion of the SF_6 leaked inside the control volume, the use of a mixer or fan is highly recommended.
- e) After 12 h at temperature T_L , the disconnecter shall be opened and closed and/or the earthing switch shall be closed and opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- f) The low-temperature behaviour of the apparatus shall be verified, if applicable, by disconnecting the supply of all heating devices, including also the anti-condensation heating elements, for a duration t_x . At the end of the interval t_x , an operating order, at rated values of supply voltage and operating pressure, shall be given, if applicable. Then the disconnecter shall open and/or the earthing switch shall close. The operating characteristics shall be recorded.

The value of t_x up to which the apparatus is still operable without auxiliary power to the heaters, is stated by the manufacturer (not less than 2 h). In the absence of such a statement, the value is equal to 2 h.
- g) The disconnecter shall be left in open position and/or the earthing switch shall be left in close position for minimum 4 h.
- h) During the 4-h period with the disconnecter in open position and/or the earthing switch in closed position at temperature T_L , a tightness test shall be performed according to 7.8 for insulation pressure systems using a cumulative leakage method as indicated in item (d).
- i) After 4 h at temperature T_L , the disconnecter shall be closed and/or the earthing switch shall be opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- j) After completing the three closing and the three opening operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.
- k) After the apparatus has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the apparatus settings, and the operating characteristics shall be recorded and verified according to 7.102.3.2. A tightness test shall be made as in item b) for comparison with the initial characteristics.

For combined function earthing switches including a disconnecter function, the operation of the disconnecter and the operation of the earthing switch as described in items (e) and (i) shall be spaced by 4 h or by $t_x + 4$ h in case of heating devices are switched off. For insulation pressure systems a tightness test shall be performed at least once when both disconnecter and earthing switch are in the open position.

After the complete low temperature test the pressure shall not be under the minimum functional pressure.

7.104.4 High-temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 10 b).

If the high-temperature test is performed immediately after the low-temperature test and using the same sample, the high-temperature test can proceed after completion of item (j) of the low-temperature test. In this case, items (l) and (m) below are omitted.

- l) The test object shall be adjusted in accordance with the manufacturer's instructions.
- m) Characteristics and settings of the test object shall be recorded in accordance with 7.102.3.2 and at an ambient air temperature of $(20 \pm 5) ^\circ\text{C}$ (T_A). The tightness test for insulation pressure systems shall be performed according to 7.8.
- n) With the disconnecter in closed position and/or the earthing switch in open position, the air temperature shall be increased to the maximum ambient air temperature (T_H), declared by the manufacturer, at a rate of change of approximately 10 K per hour. The disconnecter shall be kept in close position and/or the earthing switch in open position for 12 h after the ambient air temperature stabilises at T_H .
- o) During the 12 h period with the disconnecter in close position and/or the earthing switch in open position at temperature T_H , a tightness test shall be performed for insulation pressure systems.
- p) After 12 h at temperature T_H , the disconnecter shall be opened and/or the earthing switch shall be closed three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- q) The disconnecter shall be left in open position and/or the earthing switch shall be left in the closed position for 4 h.
- r) During the 4-h period with the disconnecter in the open position and/or the earthing switch in the closed position at temperature T_H , a tightness test shall be performed for insulation pressure systems using a cumulative leakage method as indicated in item (d) of subclause 7.104.3.
- s) After 4 h at temperature T_H , the disconnecter shall be closed and/or the earthing switch shall be opened three times at rated values of supply voltage and operating pressure, if applicable. The operating characteristics shall be recorded.
- t) After completing the three closing and the three opening operations, the air temperature shall be decreased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.
- u) After the apparatus has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the apparatus settings, operating characteristics and tightness as in items (l) and (m) for comparison with the initial characteristics.

For combined function earthing switches including a disconnecter function, the operation of the disconnecter and the operation of the earthing switch as described in items (p) and (s) shall be spaced by 4 h. A tightness test shall be performed at least once when both disconnecter and earthing switch are in the open position.

After the complete high-temperature test the pressure shall not be under the minimum functional pressure.

7.105 Tests to verify the proper functioning of the position-indicating device

7.105.1 General

These tests apply, when a position indicator according to 6.104.3.2 is used.

The equipment shall pass all the tests defined in 7.105.2, in order to verify both the sufficient strength of the power kinematic chain and the reliability of the position-indicating kinematic chain.

One specimen may be used for each operation mode.

7.105.2 Tests on the power kinematic chain and the position-indicating kinematic chain

The moving contact is locked in closed position for a disconnecter and in open position for an earthing switch.

In the case of a three phase disconnecter or earthing switch operated by a common operating device, only the moving contact of the pole located farthest from the point of transmission of the energy from the power source along the power kinematic chain is locked.

The tests consist of three attempts performed on the switching device with its own complete operating device equipped with a strain limiting device (if any) and/or with a torque (force) controlling system (if any).

- For manual operation (for dependent and for independent), the normal operation handle shall be used to perform the attempts. During the tests, double the normal forces shall be employed, with a minimum of 200 N, but limited to a force of 750 N or to the operation of a strain-limiting device or torque (force) controlling system. This force shall be applied halfway along the length of the gripping part of the operating handle. Where the operating handle or the operating device incorporates a feature which limits the operating torque (force), the switching device shall be operated until the strain-limiting device operates, provided that the operating handle with strain-limiting device is not interchangeable with other handles.
- For power operation (for dependent and for independent), the maximum supply voltage or pressure for operation (if power operated or if release operated) as defined in 5.9 and 5.11.102 shall be applied respectively during the attempts. In the case of the presence of a strain-limiting device or torque (force) controlling system, the switching device shall be operated until the strain-limiting device or torque (force) controlling system operates.

No adjustment or replacement shall be made along the position indicating chain between the attempts. No break on the mechanical kinematic chain shall be produced during the test, except for strain limiting devices designed to break, which will have to be replaced after they break. The test is considered passed if after each attempt the three moving contacts remain in the same position and the position-indicating device indicates correctly the position of the moving contacts.

If the position-indicating device is marked directly on a mechanical part of the power kinematic chain no additional test is required.

The enclosure providing protection to the position-indicating kinematic chain shall be tested for its IP and IK (in accordance with 6.104.3.1). The blows shall be applied to the points of the enclosure that are likely to be the weakest in relation to the protection of the indicating kinematic chain.

7.106 Bus-transfer current switching tests on disconnectors

7.106.1 General

These tests shall be performed only on disconnectors with a rated bus-transfer current switching capability.

7.106.2 Making and breaking tests

7.106.2.1 Arrangement of the disconnecter for tests

The disconnecter under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be used in the manner prescribed and in

particular, if it is power operated either electrically or pneumatically, it shall be operated at the minimum supply voltage or minimum functional pressure for operation, respectively.

Before commencing making and breaking tests, no-load operations shall be made to establish the mechanical operating characteristics of the disconnecter such as speed of travel, closing time and opening time.

For gas-insulated disconnectors, tests shall be performed at the minimum functional pressure for switching.

Disconnectors having an independent manual operation may be operated by remote control, using a power operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

Consideration shall be given to the effects of energization of both terminals of the disconnecter. When the physical arrangement of one side of the disconnecter differs from that of the other side, the supply side of the test circuit shall be connected to the side which represents the most severe condition. In case of doubt, 50 % of the breaking and making tests shall be carried out with the supply side of the test circuit connected to one side of the disconnecter and 50 % with the supply connected to the other side.

Only single-phase tests on one pole of a three-pole disconnecter need to be performed provided that the pole is not in a more favourable condition than the complete three-pole disconnecter with respect to:

- speed of make;
- speed of break;
- influence of adjacent phases.

Single-phase tests are adequate to demonstrate the making and breaking performance of a disconnecter, provided that it can be demonstrated that the arcing time and arc reach are such that there is no possibility of involvement of an adjacent phase. If, on the basis of a single-phase test, it is shown that the arc may reach an adjacent phase, then three-phase tests shall be performed using the specific disconnecter configuration.

7.106.2.2 Earthing of the test circuit and disconnecter

The frame of the disconnecter shall be earthed as well as the test circuit, see 7.106.2.6.

7.106.2.3 Test frequency

Disconnectors shall be tested at rated frequency, however disconnectors rated 50 Hz or 60 Hz may be tested with either of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of $\pm 10\%$ in accordance with Table C.1.

7.106.2.4 Test voltage

The test voltage U_{BT} shall be set so as to yield the required rated bus-transfer voltage ($^{+10}_0\%$) and shall be measured during the test across the open disconnecter terminals.

As noted in 7.106.2.1, only single-phase tests are normally required. If three-phase tests are required, then the test voltage of each phase shall not differ from the average test voltage by more than 10 %.

The power frequency recovery voltage shall be maintained for at least 0,3 s after interruption.

7.106.2.5 Test current

The test current shall be equal to the rated bus-transfer current ($+10\%$ to 0%) as defined in 5.108.1.

The current to be interrupted shall be symmetrical. The contacts of the disconnector shall not be separated until transient currents, due to the closing of the circuit, have subsided.

If three-phase tests are performed, the test current is the average of the current in all three phases. The test current in each phase shall not differ from the average test current by more than 10 %.

7.106.2.6 Test circuits

The test circuit as shown in Figure 11 shall have a power factor not exceeding 0,5. Two examples of test circuit are shown in Figure 11.

If three-phase tests are required, the neutral of the supply circuit and the load-side circuit shall be earthed.

Phase-to-earth insulation is not verified during the test when using the circuit given in Figure 11. If insulation performance has to be verified, other test circuits providing the rated phase-to-earth voltage are necessary.

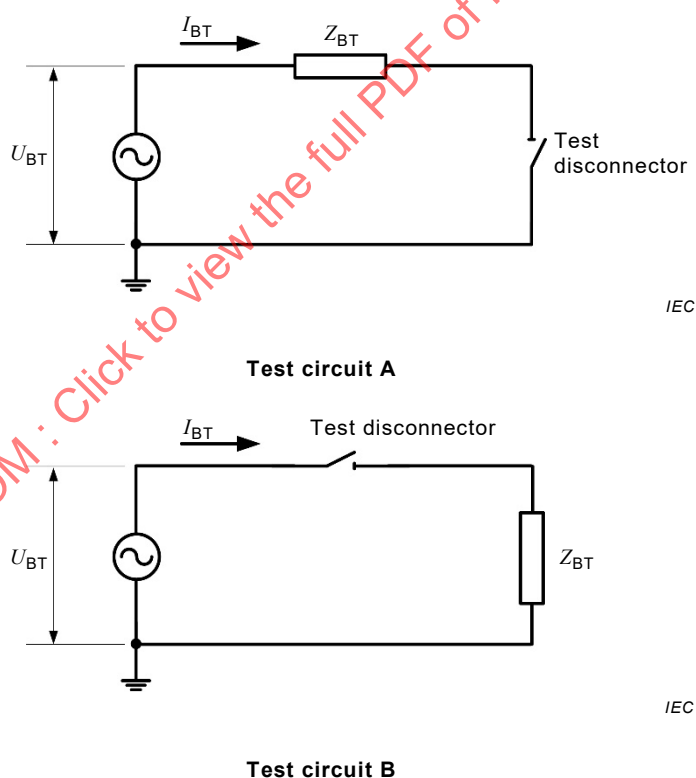


Figure 11 – Example of test circuit for bus-transfer current switching tests

7.106.2.7 Test duty

One hundred make-break operating cycles shall be made.

NOTE These 100 operating cycles are not considered adequate to demonstrate electrical life but they do provide an indication of contact erosion.

The opening operation shall follow the closing operation with a time delay between the two operations at least sufficient for any transient currents to subside. As well, the time between

operations shall be sufficient to cool down the disconnecter if specified by the manufacturer instructions.

The tests shall be performed without reconditioning of the disconnecter during the test duty.

7.106.2.8 Behaviour of the disconnecter during tests

The disconnecter shall perform successfully without undue mechanical or electrical distress.

Outward emission of flame or metallic particles from the disconnecter during operation is permitted, if this does not impair its insulation level. Flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.106.2.9 Condition of disconnecter after tests

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the disconnecter shall be essentially in the same condition as before the test.

It is recognized that mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, will impair the switching capability of the disconnecter. However, the current-carrying capability and the isolating properties of the disconnecter shall not be impaired. The quality of the material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level.

The isolating properties of a disconnecter in the open position shall not be reduced below what corresponds to normal wear and ageing, by deterioration of insulating parts.

No-load operation and visual inspection of the disconnecter after tests are usually sufficient for verification of the isolating properties and the current-carrying capability of the disconnecter. In case of doubt, it can be necessary to perform the appropriate tests as mentioned below.

- If the isolating properties are doubted, a voltage test as condition check according to 7.2.12 is to be performed to verify the insulating properties. Alternative test methods given in 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For disconnectors that are sealed-for-life, the voltage test as a condition check is mandatory;
- If the current-carrying capacity is doubted, main circuit resistance measurement may be used where ever it is possible to measure the resistance close to the contacts. The increase in main circuit resistance after test shall not exceed 20 %. If the contact resistance exceeds this value, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017, by monitoring the temperature at the points as close as possible to the main contacts.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % from the value measured before the test. A visual inspection of the resistor shall be made after the type tests. No evidence of flashover across the resistor or any mechanical damage shall be observed. It can be necessary to disassemble the disconnecter for the visual inspection.

7.106.2.10 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017 the type test report shall contain the following information:

- a) typical oscillographic or similar records of the tests performed (at least one oscillogram for each 10 operations);
- b) test circuit;
- c) test currents;
- d) test voltages;
- e) power frequency recovery voltages;
- f) void;
- g) arcing times;
- h) number of making and breaking operations;
- i) condition of the contacts after test (see 7.106.2.9).

General information concerning the supporting structure of the disconnector should be included. The operating time of the disconnector and the type of operating devices employed during the tests shall be recorded.

7.107 Induced current switching tests on earthing switches

7.107.1 General

Type tests for earthing switches having a rated induced current switching capability shall include:

- tests to prove the electromagnetically induced current making and breaking capability;
- tests to prove the electrostatically induced current making and breaking capability.

7.107.2 Arrangement of the earthing switch for tests

The earthing switch under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be operated in the manner prescribed and, in particular, if it is electrically or pneumatically operated, it shall be operated either at the minimum supply voltage or supply pressure, respectively.

Before commencing making and breaking tests, no-load operations shall be made and details of the operating characteristics of the earthing switch, such as speed of travel, closing time and opening time, shall be recorded (see 7.102.3.2).

For gas-insulated earthing switches, tests shall be performed at the minimum functional gas pressure (density) for switching.

Earthing switches having a manual operating device may be operated by remote control using a power-operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

Only single-phase tests on one pole of a three-pole earthing switch need to be performed provided that it is not in a more favourable condition than the complete three-pole earthing switch with respect to:

- speed of closing;
- speed of opening;
- influence of adjacent poles or proximity of energized phases.

Single-phase tests are adequate to demonstrate the making and breaking performance of an earthing switch provided that it can be demonstrated that the arcing time and arc-reach are such that there is no possibility that involvement of an adjacent energized phase can occur. If, on the basis of a single-phase test, it is determined that the arc may reach an adjacent

energized phase, then three-phase tests shall be performed using the specific earthing switch configuration.

7.107.3 Earthing of test circuit and earthing switch

The test circuit shall be earthed through the terminal of the earthing switch which is normally connected to earth.

7.107.4 Test frequency

Earthing switches shall be tested at rated frequency, however earthing switches rated 50 Hz or 60 Hz may be tested with any of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of $\pm 10\%$ according Table C.1.

7.107.5 Test voltage

The test voltages shall be set so as to yield the voltage specified in Table 9 before making and after breaking, and shall be measured across the earthing switch terminals during the test.

As noted in 7.107.2, only single-phase tests are normally required. If three-phase tests are required, then the test voltage of each phase shall not be different from the average test voltage by more than 10 %.

The power frequency test voltage shall be maintained for at least 0,3 s after interruption.

7.107.6 Test currents

The test currents shall be equal to the rated induced currents ($^{+10}_{-0}\%$). The current to be interrupted shall be symmetrical. The contacts of the earthing switch shall not be separated until transient currents due to closing of the circuit have subsided.

If three-pole making and breaking tests are performed, the test current shall be measured as the average of the current in all three poles. The test current for each phase shall not be different from the average test current by more than 10 %.

Before contact separation, the waveform of the test current for electrostatically induced current breaking tests should be, as nearly as possible, sinusoidal (see IEC/TR 62271-305). This condition is considered to be met if the ratio of the RMS value of the total current to the RMS value of the fundamental component does not exceed 1,2. The test current shall not go through zero more than once per half cycle of power frequency before contact separation.

7.107.7 Test circuits

7.107.7.1 General

For type tests, the transmission lines may be replaced by elements consisting of capacitors, inductors and resistors.

If three-phase tests are required, the test circuit shall incorporate the same elements in each phase as for the single-phase test circuit in order to yield the appropriate test voltages and currents. The neutral of the supply circuit shall be earthed.

As an alternative, other test circuits than those specified may be used provided they fulfil the requirements for test currents, voltages and the transient recovery voltage parameters.

7.107.7.2 Test circuit for electromagnetically induced current making and breaking tests

The single-phase test circuit (Figure 12) consists of a supply circuit yielding the appropriate test voltage and test current such that the circuit power factor does not exceed 0,15. The components R and C are selected to yield the appropriate transient recovery voltage parameters. The damping resistance R may be connected in series or in parallel with the capacitance C .

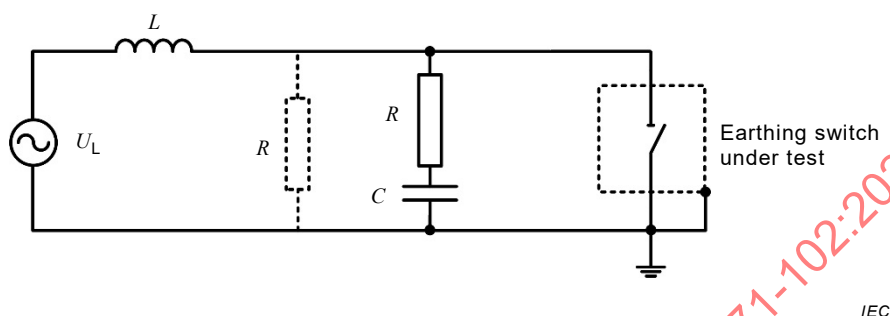


Figure 12 – Test circuit for electromagnetically induced current switching tests

The values of supply voltage (U_L) and inductance (L) can be calculated from the values of voltage and current given in Table 9, so as to produce the proper values of test current and power frequency recovery voltage.

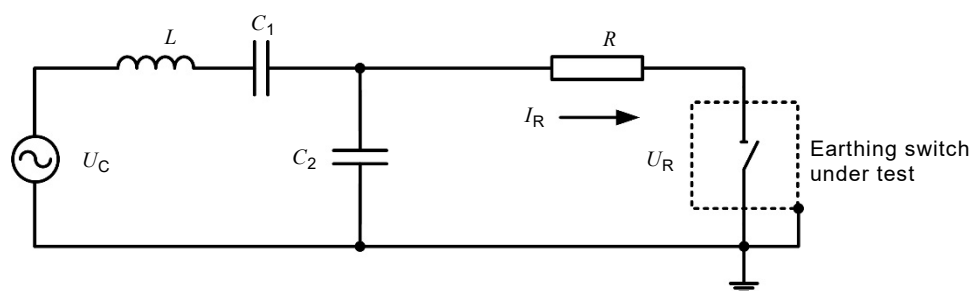
The prospective transient recovery voltage waveforms should have the form of a triangular wave due to the surge impedance of the connected transmission lines. As an alternative, transient recovery voltages having a $(1 - \cos)$ form may be used. Values of R and C may be selected to yield the proper transient recovery voltage parameters specified in Table 17.

Table 17 – Standard values of recovery voltages for electromagnetically induced current breaking tests

Rated voltage U_r kV	Class A			Class B			
	Power frequency recovery voltage	TRV peak	Time to peak	Power frequency recovery voltage	TRV peak	Time to peak	
	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} 0 \\ -10 \end{smallmatrix}$ %)	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$ %)	($\begin{smallmatrix} 0 \\ -10 \end{smallmatrix}$ %)	
	kV RMS	kV	μ s	kV RMS	kV	μ s	
72,5	0,5	1,1	100	2	4,5	300	
100							
123							
145	1	2,3	200				
170							
245	1,4	3,2				850	
300							
362	2	4,5	325	10	23	1 000	
420							
550				20	45	2 000	
800							
1 100	5	11,3	750	65	145	2 400	
1 200							

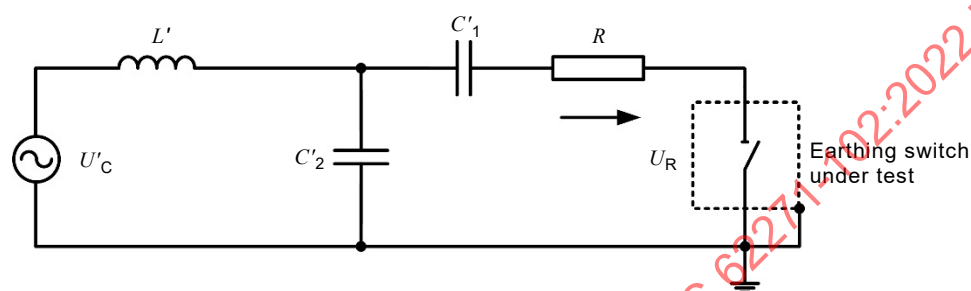
NOTE 1 Recovery voltages are valid for single-phase or three-phase tests.

NOTE 2 The prospective TRV waveform may be of a triangular or (1 – cos) form (see 7.107.7.2). The time to peak is valid for either waveform type.



Test circuit 1

IEC



Test circuit 2

IEC

$$L = Z_0^2 \times C_1$$

$$L' = L \times \left[\frac{C_1}{C_1 + C_2} \right]^2$$

$$u_C = \frac{i_R}{\omega C_1}$$

$$u'_C = \left[\frac{C_1}{C_1 + C_2} \right] \times u_C, \text{ or } u'_C = u_R$$

$$C_2 = C_1 \times \left[\frac{u_C}{u_R} - 1 \right]$$

$$C'_1 = C_1 + C_2 \quad C'_2 = C_2 \left(1 + \frac{C_2}{C_1} \right)$$

where

Z_0 is the surge impedance of the line:

- 425 Ω for 52 kV < $U_r \leq 170$ kV;
- 380 Ω for 245 kV $\leq U_r \leq 300$ kV;
- 325 Ω for 362 kV $\leq U_r \leq 800$ kV;
- 290 Ω for 1 100 kV $\leq U_r \leq 1\,200$ kV.

Key

i_R is the rated induced current from Table 9

u_R is the rated induced voltage from Table 9

C_1 is the test circuit capacitance given in Table 18

Figure 13 – Test circuits for electrostatically induced current-switching tests

7.107.7.3 Test circuits for electrostatically induced current switching tests

Either test circuit 1 or 2 in Figure 13 shall be selected as suitable for the test laboratory, since they are equivalent, as long as the equations within the circuit parameters are satisfied.

The power factor of the test circuit shall not exceed 0,15. The values of supply voltage (U_C), inductance L and capacitance C_2 for test circuit 1 can be calculated from the given values of C_1 in Table 18 and the rated current and voltage values in Table 9, by using the equations noted in Figure 13. This will result in the appropriate values of test current and voltage as well as the proper inrush current frequency and test-circuit surge impedance. Values for test circuit 2 can be calculated from the values derived for test circuit 1.

A resistance (R), not exceeding 10 % of the capacitive impedance [$1 / \omega (C_1 + C_2) = 1 / \omega C_1'$], as seen from the earthing switch, may be inserted in the circuits as shown in Figure 13. The value chosen, however, should not be greater than the surge impedance of the transmission line considered (see Table 18), nor lead to an aperiodic damping of the inrush current when closing the earthing switch.

Table 18 – Test circuit capacitances (C_1 values) for electrostatically induced current switching tests

Rated voltage U_r kV	Test circuit capacitance	
	Class A μF	Class B μF
72,5 – 100 – 123	0,07	0,27
145 – 170	0,13	
245	0,15	
300		0,80
362 – 420	0,29	1,18
550 – 800	0,35	1,47
1 100 – 1 200	0,8	2,63

NOTE Values of C_1 can be calculated from the expression:

$$C_1 = (6D) / (\pi Z_0)$$

where

D is the line length, in km;

Z_0 is the line surge impedance, in Ω .

Surge impedance assumed:

- 72,5 kV $\leq U_r \leq$ 170 kV: 425 Ω ;
- 245 kV $\leq U_r \leq$ 300 kV: 380 Ω ;
- 362 kV $\leq U_r \leq$ 800 kV: 325 Ω .
- 1 100 kV $\leq U_r \leq$ 1 200 kV: 290 Ω .

7.107.7.4 Test duties

Ten make-break operating cycles shall be made for each of the electrostatically and electromagnetically induced current-switching tests.

NOTE Ten operating cycles are not considered adequate to demonstrate electrical life, but will provide an indication of contact erosion.

The opening operation shall follow the closing operation with sufficient time delay between the two operations for any transient currents to subside.

The tests shall be performed without reconditioning of the earthing switch during the test programme.

7.107.7.5 Behaviour of earthing switch during tests

The earthing switch shall perform successfully without undue mechanical or electrical distress.

Outward emission of flame or metallic particles from the earthing switch during operation is permitted, if this does not impair its insulation level. Flame or metallic particles shall not be projected beyond the boundaries specified by the manufacturer in the operating instructions.

7.107.7.6 Condition of earthing switch after tests

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the earthing switch shall be essentially in the same condition as before the test. The earthing switch shall be capable of carrying its rated peak withstand current and its rated short-time withstand current.

Mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, are acceptable.

Visual inspection and no-load operation of the earthing switch after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests as mentioned below.

If the isolating properties are doubted, a voltage test as condition check according to 7.2.12 is to be performed to verify the isolating properties. As an alternative, 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable. For earthing switches that are sealed for life, the voltage test as a condition check is mandatory.

7.107.7.7 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017, the type test report shall contain the following information:

- a) typical oscillographic or similar records;
- b) test circuits;
- c) test currents;
- d) test voltages;
- e) power frequency recovery voltages;
- f) prospective transient recovery voltages;
- g) arcing times;
- h) number of making and breaking operations;
- i) condition of earthing switch after test.

General information concerning the supporting structure of the earthing switch should be included. The operating time of the earthing switch and the type of operating devices employed during the tests shall be recorded.

7.108 Bus-charging current switching tests on disconnectors

7.108.1 General

These tests shall be performed on disconnectors forming part of gas-insulated switchgear classified for bus-charging current switching.

NOTE The limit of 300 kV is derived from SF₆-insulated switchgear experience. The dielectric performance of disconnectors during bus-charging current switching and the performance against VFTO during the switching depends on the insulating gas used. For more information, refer to CIGRE Technical Brochure No. 260, 2004 [7].

7.108.2 Test duties

Three test duties are defined:

- *test duty 1*: switching of a very short section of busbar duct, this test duty shall be performed on disconnectors of $U_r \geq 300$ kV;
- *test duty 2*: switching of parallel capacitors of circuit-breakers under 180° out-of-phase condition; this test duty is not mandatory;
- *test duty 3*: current-switching capability test; this test duty is not mandatory.

NOTE 1 Test duty 2 is a special type test for disconnectors placed close to circuit-breakers that are equipped with parallel capacitors.

NOTE 2 Test duty 3 is a special type test to be carried out according to this specification by agreement between the manufacturer and the user. It serves to demonstrate the current interruption capability of the disconnector when de-energizing long busbars. Typical current values are given in Table 11.

7.108.3 Arrangement of the disconnector for tests

The operating device of the disconnector under test shall be operated in the manner specified by the manufacturer and, in particular, if it is power operated, it shall be operated at the specified minimum supply voltage and/or minimum supply pressure. The time delay between operations shall be sufficient to cool down the disconnector if specified by the manufacturer instructions.

Before commencing the making and breaking tests, no-load operations shall be made and details of the operating characteristics of the disconnector such as closing time and opening time shall be recorded (see 7.102.3.2).

Tests shall be performed at the minimum functional gas pressure (density) for switching of the disconnector under test. Associated compartments shall be at their minimum functional gas pressure (density) as well.

In most cases the design of the disconnector involves asymmetries (for example asymmetrical shields, or moving contact/fixed contact differences, etc.). For these cases, the test arrangement of the disconnector shall be such as to perform the test under the most severe conditions. For test duty 1, the most severe test arrangement is considered to be that which results in maximum pre-striking distance for the closing operation. For test duty 2 and test duty 3, the test arrangement of the disconnector is considered to be of minor importance.

Only single-phase tests on one pole of a three-pole operated disconnector need to be performed, provided that this does not mean a change of operating speed of more than ± 15 %.

For disconnectors having three poles in one enclosure, a three-phase test arrangement is required. One phase is connected to the testing circuit, and the two remaining poles not involved in the switching process shall be grounded at both terminals.

7.108.4 Test frequency

Disconnectors shall be tested at rated frequency, however disconnectors rated 50 Hz or 60 Hz may be tested with any of those two frequencies as they are considered to be equivalent for this test. The tolerance on the test frequency shall be within the limits of ± 10 % in accordance with Table C.1.

7.108.5 Test voltages for making and breaking tests

During making and breaking tests, the power frequency voltage shall be applied and maintained for at least 0,3 s before and after the switching operation. In the case of a DC pre-charge voltage at the load side (test duty 1), the DC voltage shall be applied according to the specified level for about 1 min before the close operation. The load side shall not be grounded between the open and close operations. The test circuit should not contain elements that cause a decay of the trapped charge.

With reference to Figures 14, 16 and 17, the test voltages at source side and load side of the test arrangement shall be applied as given in Table 19.

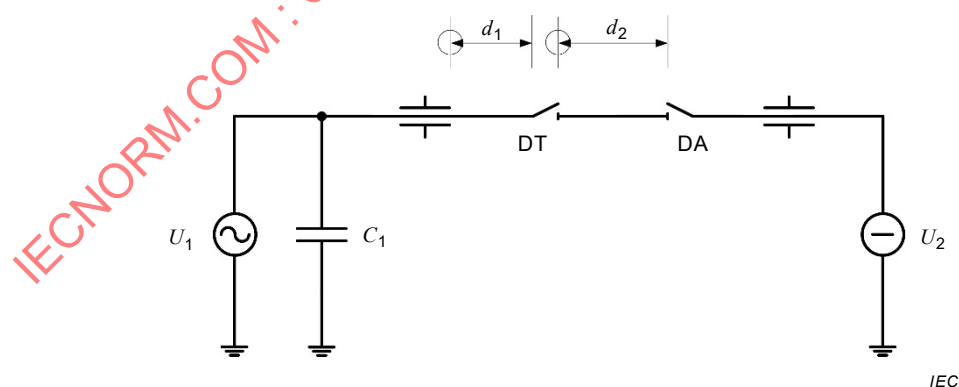
The test voltages in Table 19 are valid for the disconnector in the open position.

NOTE In the case of test duty 3, the test voltage can be considerably higher when the disconnector is in the closed position. This is caused by resonance phenomena, especially if the impedance of the supplying transformer is high, which is normal for transformers used for dielectric AC voltage tests. This voltage will increase severity of the test conditions. It will normally not be more than 10 %.

Table 19 – Test voltages for making and breaking tests

Test duty	Test voltage	
	Source side U_1	Load side U_2
1	$1,1 \times U_r / \sqrt{3}$	Pre-charge with negative DC voltage $-1,1 \times U_r \times \sqrt{2} / \sqrt{3}$
2	$1,1 \times U_r / \sqrt{3}$	AC voltage in phase opposition $1,1 \times U_r / \sqrt{3}$
3	$U_r / \sqrt{3}$	–

NOTE The factor 1,1 has been chosen to take into account statistical effects which are inherent in this kind of switching phenomena, and to restrict the number of test operations to those specified in Table 20. As test duty 3 should only indicate the switching capability of the disconnector, this increase of the test voltage is not necessary.



Key

DT Disconnector under test

DA Auxiliary disconnector

Busbar lengths d_1 and d_2 are understood to be taken as the following distances:

d_1 : open contact of the disconnector under test (DT) to the bushing connection;

d_2 : open contact of the disconnector under test (DT) to the open contact of the auxiliary disconnector (DA).

Figure 14 – Test circuit for test duty 1

7.108.6 Test circuits for making and breaking tests

7.108.6.1 Switching of a very short section of busbar duct, test duty 1

7.108.6.1.1 General

Figure 14 shows the test circuit for test duty 1. The load side shall be represented by a section of busbar, d_2 3 m to 5 m in length. The connection to the supply side shall be realised by another section of busbar, d_1 in length. In order to obtain representative very fast transient (VFT) conditions, the ratio d_2/d_1 , shall be in the range of 0,36 to 0,52. The source-side circuit shall have an added lumped capacitance, C_1 . The value of C_1 shall be chosen so that the peak value of the voltage to earth at the disconnector terminals is met as defined in 7.108.6.1.2.

Before starting a closing operation, the load side shall be charged by DC voltage according to Table 18, and the DC voltage source disconnected by the auxiliary disconnector, DA.

7.108.6.1.2 Transient voltage values

The voltage transients at the disconnector location during a close operation are used to characterize the behaviour of the test circuit and to ensure consistent overvoltage characteristics under test conditions. Two distinct aspects of transient voltages are of importance: these are the very fast transient (VFT) phenomena and the fast transient (FT) phenomena. The VFT phenomena are determined by the circuit arrangement as described in 7.108.6.1.1. The circuit response for the fast transient phenomena shall be verified at least once for the test arrangement by direct measurement (see 7.108.11) under the following conditions:

- source-side test voltage: $U_r/\sqrt{3}$;
- load-side voltage: 0 (no pre-charge).

For these conditions, the maximum peak value of the transient voltage to earth U_{TVE} at the first prestrike during a close operation shall be not less than $1,4 \times U_r \sqrt{2}/\sqrt{3}$ (for practical purposes a variation of 5 % is considered acceptable) and the time to maximum peak shall be less than 500 ns, (Figure 15).

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear the resistor shall be short-circuited or replaced by a solid conductor before the tests in order to verify the test circuit conditions described above.

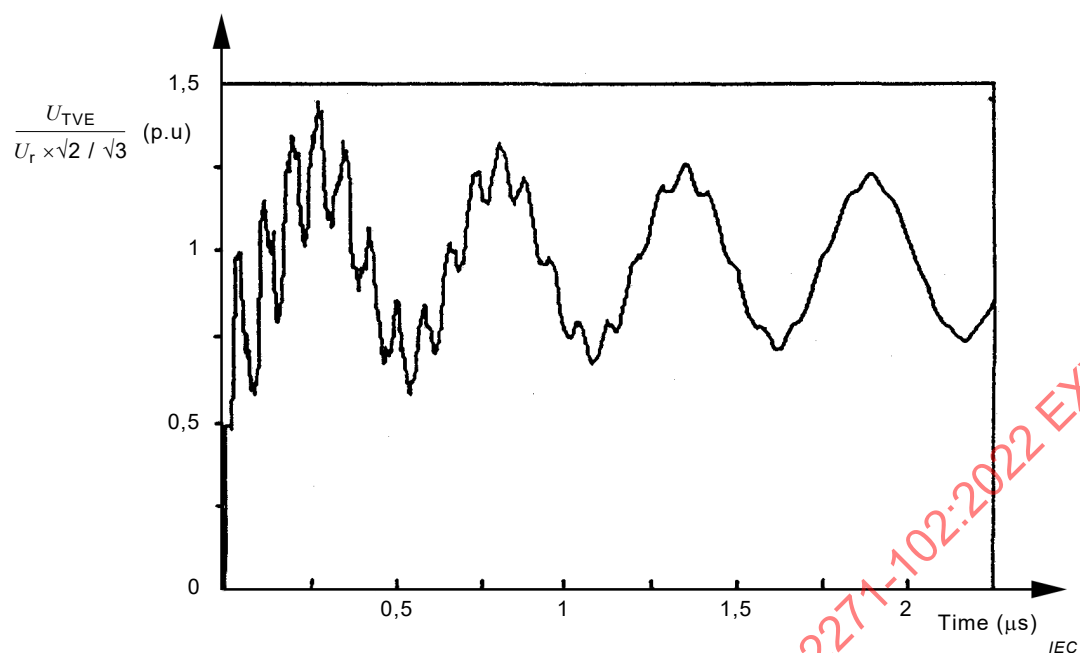


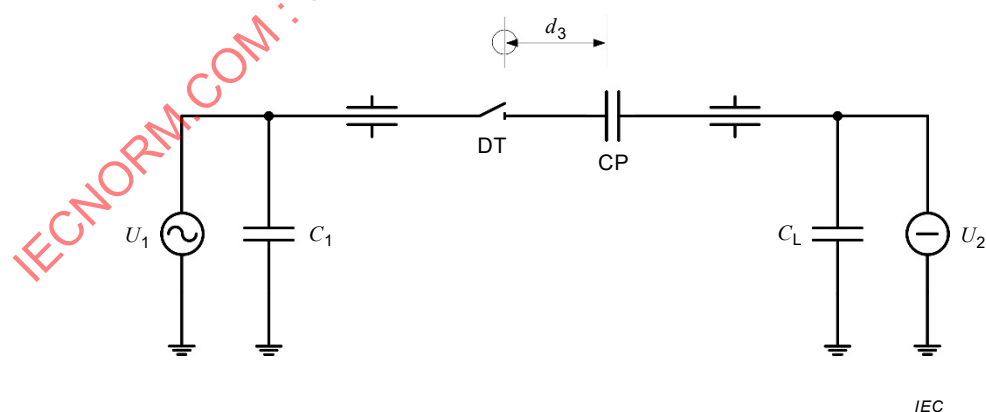
Figure 15 – Typical voltage waveform (Including VFT and FT components)

7.108.6.2 Out-of-phase switching, test duty 2

Figure 16 shows the test circuit for out-of-phase switching. The parallel capacitor CP of a circuit-breaker may be represented by the actual circuit-breaker with its own capacitor or by an adequate capacitance of equal or higher value than the capacitance used in service.

The shortest possible distance d_3 between capacitor CP and disconnector shall be established. The lengths of the other test circuit parts are not specified, but they should be as short as possible in order to minimize their influence on the capacitance of the test circuit.

The lumped capacitance C_L (Figure 16) shall be of a value not less than 400 pF. The ratio C_1/C_L shall be in the range of 4 to 6.



Key

- DT Disconnector under test
- CP Circuit-breaker parallel capacitor or equivalent capacitor

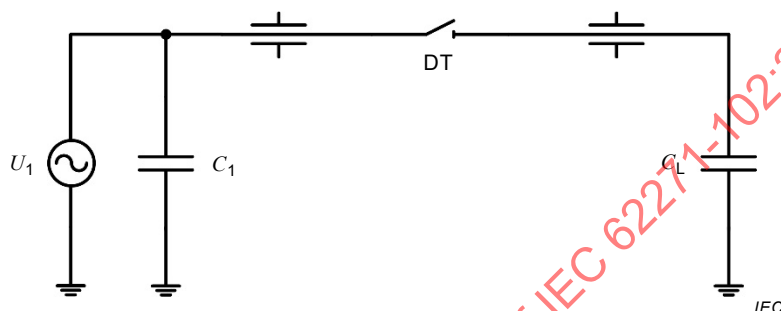
Figure 16 – Test circuit for test duty 2

7.108.6.3 Current switching capability test, test duty 3

The test circuit shown in Figure 17 applies. For this type of switching, the specific lengths of the busbar sections are of no significance. On the load side, a lumped capacitance C_L should be added in order to achieve the bus-charging current as given in Table 11 with a tolerance of $\pm 10\%$.

In order to reduce resonance effects, which can be caused due to a high source impedance, connection of a lumped capacitance C_1 of any value is acceptable to the source side.

Further testing conditions that affect the transient recovery conditions are subject to agreement between the manufacturer and the user.



Key

DT Disconnector under test

Figure 17 – Test circuit for test duty 3

7.108.7 Performance of making and breaking tests

During each test duty, the test series shall be performed without reconditioning the disconnector. The number of tests is given in Table 20.

Table 20 – Number of tests

Test duty	Number of make and break operations	
	Standard disconnector	Fast-acting disconnector ^a
1	50 ^b	200 ^{a, c}
2	50	200
3	50	50
^a Disconnectors having a contact speed in the range of 1 m/s or higher at the moment of contact separation. ^b If the most severe disconnector arrangement cannot be determined clearly (with reference to 7.108.3), test duty 1 shall be repeated with reversed disconnector terminals. ^c Reduction of the number of tests down to 50 is acceptable if the test voltage is increased (to cover statistical effects) to the following values: – source side: $U_r \times 1,2/\sqrt{3}$; – load side: (DC pre-charge): $-U_r \times 1,2 \sqrt{2}/\sqrt{3}$.		

7.108.8 Behaviour of the disconnector during making and breaking tests

The disconnector shall perform successfully without mechanical or electrical damage.

Disruptive discharges from phase to earth or from phase to phase are not permitted. Additionally, for resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear disruptive discharges are not permitted across the resistor.

NOTE It is essential that disruptive discharges to earth or between phases can be detected properly by adequate measuring or detecting equipment.

7.108.9 Condition after test

The mechanical operating characteristics shall be within the tolerances given by the manufacturer and the insulation of the disconnector shall be essentially in the same condition as before the test.

Mechanical wear and erosion due to arcing, as well as deposits on the insulators caused by the decomposition of the arc extinguishing medium, are acceptable. However, the current-carrying capability and the isolating properties of the disconnector shall not be impaired. The quality of the material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level. There may be deposits on the insulators caused by the decomposition of the arc extinguishing medium.

The isolating properties of a disconnector in the open position shall not be reduced below what corresponds to normal wear and ageing, by deterioration of insulating parts.

No-load operation and visual inspection of the disconnector after tests are usually sufficient for verification of the isolating properties and the current-carrying capability of the disconnector. In case of doubt, it can be necessary to perform the appropriate tests as mentioned below. For disconnectors that are sealed for life, it is mandatory to perform the voltage test as a condition check.

If the isolating properties are doubted, a voltage test as condition check in accordance with 7.2.12 is to be performed to verify the insulating properties. Alternative test methods given in 6.2.11 of IEC 62271-100:2008 + AMD1:2012 + AMD2:2017 may be used for $U_r > 72,5$ kV. The minimum functional pressure of the gas for insulation shall be used, if applicable.

In case of doubt of current-carrying capacity, main circuit resistance measurement may be used where ever it is possible to measure the resistance close to the contacts. The increase in main circuit resistance after test shall not exceed 20 %. If the contact resistance exceeds this value, a test under rated continuous current (7.5) shall demonstrate that the temperature rise in the contacts does not exceed the limits given in Table 14 of IEC 62271-1:2017 by monitoring the temperature at the points as close as possible to the main contacts.

For resistor-fitted disconnectors in metal-enclosed gas-insulated switchgear, the maximum variation of the ohmic resistance of the complete resistor after the test shall not exceed 5 % of the value measured before the test. A visual inspection of the resistor shall be made after the type tests. No evidence of flashover across the resistor or any mechanical damage shall be observed. It can be necessary to disassemble the disconnector for the visual inspection.

7.108.10 Type test reports

In addition to the requirements given in 7.1.2 and 7.1.3 of IEC 62271-1:2017, the type test report shall contain the following information:

- a) representative oscillographic record of one make and one break operation;
- b) test circuit(s);
- c) steady-state test current (only for test duty 3);
- d) test voltage(s);
- e) transient voltage characteristics;

- f) record of operating characteristics;
- g) insulating-gas pressure during the tests;
- h) number of make and break switching operations;
- i) condition after test;
- j) type of fault detection system;
- k) supply voltage or pressure of mechanism operated.

7.108.11 Requirements for U_{TVE} measurements

Requirements for the measurements:

- U_{TVE} verification shall be carried out at least once during each performed test-duty. Configurational changes such as different connecting lead length, equipment orientation, etc., are considered as changes to the test circuit and will require additional measurements;
- U_{TVE} measurements shall be made within 1 m of the arcing contacts of the disconnecter. If this is not possible, U_{TVE} verification may be done by computer calculation, provided that other measurements (within the test section but outside the 1 m zone) are performed at least once to check the validity of the calculation technique;
- care shall be taken to ensure that possible stray power frequency interference is taken into account;
- U_{TVE} measurement shall be made with sufficient bandwidth to properly record the VFT component.

8 Routine tests

8.1 General

Clause 8 of IEC 62271-1:2017 is applicable with the following additions.

Addition to the list of routine tests.

- f) mechanical operating tests in accordance with 8.101.
- g) verification of earthing function in accordance with 8.102

Disconnectors and earthing switches integrated in enclosed switchgear shall be tested as part of the switchgear assembly in accordance with IEC 62271-200, IEC 62271-201 or IEC 62271-203.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 is applicable with the following additions and/or deviations.

In case of disconnectors or earthing switches placed

- inside sealed pressure systems, the dielectric test may be performed at rated filling pressure for insulation;
- inside controlled or closed pressure systems, the dielectric test shall be performed at minimum functional pressure for insulation.

If the conditions indicated in the third paragraph of 8.2 of IEC 62271-1:2017 are not fulfilled, the following applies:

- for testing of disconnectors the test conditions shall be in accordance with Table 21. For an explanation of the reference designations for connections, see Figure 2 of IEC 62271-1:2017;

Table 21 – Power frequency voltage tests

Test condition no.	Disconnector position	Voltage applied to	Earth connected to
1 ^a	Closed	Aa	BbCcF
2 ^a	Closed	Bb	AaCcF
3 ^a	Closed	Cc	AaBbF
4	Open	ABC	abcF
5	Open	abc	ABCF
6 ^b	Open	ABC or abc	Earthing switch

^a If the insulation between poles is air at atmospheric pressure and if the dimensions are checked, test conditions nos. 1, 2 and 3 may be combined, the test voltage being applied between all parts of the main circuit connected together and the base.

^b Earthing switch in the position resulting in the shortest gap between its moving parts and ABC or abc. The test is applicable only to disconnectors with integrated earthing switch.

- for testing of earthing switches, the test voltage shall be applied with the earthing switch in the open position:
 - 1) between adjacent insulated terminals with the bases earthed (e.g. A to B with F earthed);
 - 2) between all the insulated terminals connected together and the bases earthed (e.g. ABC to F earthed).

8.3 Tests on auxiliary and control circuits

Subclause 8.3 of IEC 62271-1:2017 is applicable.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 is applicable only to disconnectors.

8.5 Tightness test

Subclause 8.5 of IEC 62271-1:2017 is applicable.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 is applicable.

8.101 Mechanical operating tests

Operating tests are made to ensure that the disconnectors or earthing switches show the specified operating behaviour within the specified supply voltage, if any, and supply pressure limits, if any, of their operating mechanisms.

During these tests, which are performed without voltage on, or current flowing through the main circuit, it shall be verified that:

- the disconnectors or earthing switches open and close correctly when their operating mechanisms are energized;
- the interlocks work properly in any interlocked position;

- the position-indicating and -signalling devices indicate correctly the open and closed positions.

The disconnector or earthing switch shall be subjected to the following tests:

- at specified minimum supply voltage and/or pressure (if any): five operating cycles;
- at specified maximum supply voltage and/or pressure (if any): five operating cycles;
- if a disconnector or earthing switch can be operated manually: five manual operating cycles.

During these operating cycles, the operating characteristics such as, if applicable, operating times, power consumption, maximum forces for manual operation, shall be verified. Satisfactory operation of control and auxiliary contacts, and position-indicating devices (if any) shall be verified. The values of each parameter shall be within the tolerances specified by the manufacturer.

During these tests no adjustment shall be made and the operation shall be faultless. The closed and open position shall be reached with the specified indication and signalling during each operating cycle.

After these tests, no parts of the disconnector or earthing switch shall be damaged.

For disconnectors and earthing switches of $U_r > 52$ kV, the mechanical operating routine tests may be performed on sub-assemblies.

Where mechanical routine tests are performed on separate components, they shall be repeated at site on a complete assembled disconnector during the commissioning tests. The same total number of operations as specified in 7.102.3.2 shall be performed.

8.102 Verification of earthing function

The earthing function shall be verified according to the manufacturer's specification. However, test of electrical continuity shall be performed. Some examples of other routine tests that can be specified are as follows:

- contact resistance;
- contact pressure;
- visual inspection;
- dimension check;
- electrical continuity.

9 Guide to the selection of disconnectors and earthing switches (informative)

9.1 General

Clause 9.1 of IEC 62271-1:2017 is applicable with the following additions.

For the selection of disconnectors and earthing switches, the following conditions and requirements at site should be considered:

- continuous current load and overload conditions;
- existing fault conditions;
- static and dynamic terminal loads resulting from the substation design;
- use of rigid or flexible conductors to be connected to the disconnector or earthing switch or to which the separated contact is mounted;
- environmental conditions (climate, pollution, etc.);