INTERNATIONAL STANDARD

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Aircraft — Solid-state remote power controllers — General requirements

Aéronefs — Contacteurs-disjoncteurs statiques commandés à distance — Prescriptions générales

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8816 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Sub-Committee SC 1, *Aerospace electrical requirements*.

Aircraft — Solid-state remote power controllers — General requirements

1 Scope

This International Standard specifies the general design and performance requirements of solid-state (remote) power controllers for use in aircraft electrical power systems. The solid-state (remote) power controller consists of solid-state switching device(s) and associated solid-state circuitry for protection, actioning of control signals, and providing status information.

NOTE 1 Phrases, clauses and/or sentences in parentheses are intended to refer strictly to remote power controllers.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2678:1985, *Environmental tests for aircraft equipment — Insulation resistance and high voltage tests for electrical equipment.*

ISO 3389:1975, *Aircraft — Radio frequency flexible coaxial cables — Dimensions and electrical characteristics.*

ISO 7137:1992, *Aircraft — Environmental conditions and test procedures for airborne equipment (Endorsement of EUROCAE/ED-14C and RTCA/DO-160C).*

IEC 50(446):1983, *International electrotechnical vocabulary, Chapter 446: Electrical relays.*

3 Definitions

For the purposes of this International Standard, the following definitions apply. See also IEC 50(446).

3.1 (remote) power controller: Device providing a power switch which presents a low impedance to the flow of current from its supply to its load terminal when in the ON state and a high impedance in the OFF state.

NOTES

2 The state of the power switch normally conforms to that represented by the last command signal applied to the controller.

3 The controller reverts to the OFF state on detection of an electrical overload or other specified condition. A resetting operation is required to terminate the trip state. Trip-free action prevents the ON state being held in the presence of an overload trip condition.

4 (The state of the power switch is represented by an indication signal supplied by the controller.)

5 A (remote) power controller may be fully solid-state or hybrid.

3.1.1 solid-state (remote) power controller: A (remote) power controller design utilizing solid-state technology exclusively.

3.1.2 hybrid remote power controller: A remote power controller design utilizing a combination of solid-state and electromechanical technology.

3.2 temperature cycling: The imposition of extreme high and low temperatures in a repetitive cyclical manner to determine the effect of alternate exposures to these extremes.

3.3 load conditioning: The imposition of step function voltage inputs to (remote) power controllers to energize and de-energize the devices at a given duty cycle at maximum rated current.

3.4 burn-in: The exercise of (remote) power controllers by applying a step voltage input to energize the devices for a specified length of time at maximum rated current.

3.5 lot: All (remote) power controllers covered by a single specification sheet, produced and sealed under essentially the same conditions, and offered for inspection at one time within a period not exceeding one month.

3.6 AUX input: An input other than bias, control or status which is specified for operation of the (remote) power controller, i.e. ENABLE, SET, RESET, voltage supply, or other.

3.7 resistive load: A load consisting of resistors which have a ratio of inductance to resistance that does not exceed 10^{-4} H/Ω.

3.8 stabilization time: The minimum time required for the power controller to attain thermal stability under specified environmental and electrical load conditions.

3.9 power dissipation: The total electrical power losses under specified conditions of electrical load and ambient temperature.

3.10 temperature derating: A reduction of the rated steady-state current of the power controller at higher operating temperatures, based on the thermal properties of the power controller.

3.11 turn-on time

(1) d.c. devices and non-zero crossing turn-on a.c. devices: The time interval between initiation of turn-on signal and the time when the output signal has come to within 10 % of its steady-state value. See figure 1.

(2) a.c. devices with zero-crossing turn-on: The time interval between initiation of turn-on signal and the time when the output switch is ON at zero crossing.

3.12 turn-off time

(1) d.c. devices and non-zero crossing turn-off a.c. devices: The time interval between initiation of turn-off signal and the time when the output signal has come to within 10 % of its steady-state value. See figure 1.

(2) a.c. devices with zero-crossing turn-off: The time interval between initiation of turn-off signal and the time when the output switch is OFF at zero crossing.

3.13 prospective current: The maximum current that will flow in a circuit in which the power controller operates when the power controller is replaced by a short-circuit link of zero impedance.

3.14 rupture current: The maximum current the power circuit is capable of interrupting at maximum system voltage without damage.

3.15 short-circuit current: The maximum current that the power circuit will pass without damage for a specified maximum time under the most adverse combination of electrical and environmental conditions.

3.16 current limiting: A method of limiting the peak let-through current under overcurrent conditions.

3.17 trip: The automatic reversion to the OFF state of the power controller output caused by an overcurrent condition.

3.18 trip free: When a controller has tripped due to an overcurrent condition, a trip-free feature will prevent subsequent re-closing unless preceded by a reset signal.

3.19 trip time: The time interval between the application of an overcurrent condition and the 10 % value of rated output current.

NOTE 6 In general, the higher is the overcurrent condition the shorter is the trip time.

3.20 fault-clearing delay time: The time interval between the occurrence of a fault, i.e. a short circuit or overload condition, and the fault-detection circuit initiating turn-off.

3.21 fault-clearing time: Summation of the fault-clearing delay time and the turn-off time.

3.22 reset time: The minimum time interval the control signal must be in the OFF state before re-application of the ON state command, or application of a dedicated reset signal that will cause reset after trip.

3.23 peak let-through current: Peak value of the current at maximum system voltage that a controller will conduct for a specified time interval without damage.

3.24 switch status: An indication showing the actual state of the power switch (ON or OFF).

3.25 current-flow status: An indication that current flowing through the power switch of the (remote) power controller has reached a minimum level.

3.26 status turn-off time: The time interval between initiation of a trigger signal (turn-off signal or other as specified) and the time when the status signal has changed to 10 % of its steady-state value. See figure 1.

3.27 status turn-on time: The time interval between initiation of a trigger signal (turn-on signal or other as specified) and the time when the status signal has changed to 10 % of its steady-state value. See figure 1.

3.28 zero voltage turn-on/zero current turn-off (a.c. devices only)**:** A characteristic that requires the power controller to turn ON and turn OFF only at the half-cycle zero-crossing point, regardless of when the control signal is applied or removed.

3.29 d.c. offset voltage (a.c. devices only)**:** The difference in the measured d.c. content of the a.c. supply at the load terminal of the (remote) power controllers between the measurement with a short circuit applied to the devices from line terminal to load terminal and the measurement with the short circuit removed.

3.30 minimum current (a.c. devices only)**:** The lowest load current with resistive load for which a conducting device is rated such that the EMI limits and d.c. offset voltage limits are within specifications.

4 General requirements

4.1 Materials

Materials shall be used which will enable the controllers to meet the performance requirements of this International Standard.

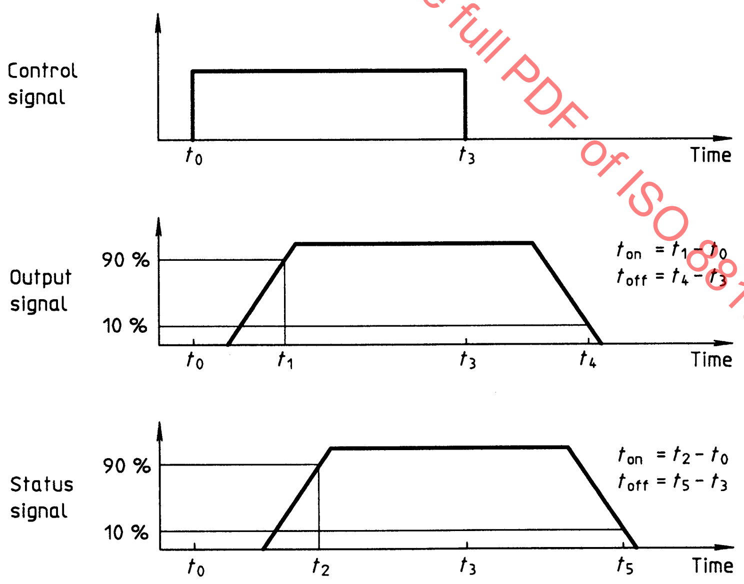
Materials used shall not support combustion, give off noxious gases in harmful quantities, give off gases in quantities sufficient to cause explosion of sealed enclosures, cause functional contamination of any part of the controller, or form unintended current-carrying tracks when subjected to any of the tests specified herein.

Unless otherwise specified, the selection of material shall be such as to provide a shelf-life of ideally 20 years without affecting the operation of the controller.

4.2 Construction

Power controllers shall be of design, construction, minimum mass and physical dimensions compatible with requirements. Controllers shall be designed so as to ensure proper operation when mounted in any attitude.

The construction of the controllers shall preclude mechanical damage, flaking of the finish, loosening of terminals, or deterioration of marking when subjected to the test methods of this International Standard.



NOTES

1 Output signal can be output current or output voltage.

2 All logic is considered to be positive.

Figure 1 — Timing diagram

4.3 Terminals

There are three acceptable types of terminal as follows.

4.3.1 Stud terminals (threaded)

These terminals shall accept connections using aircraft-approved crimped-type lugs. A flat washer having a diameter at least equal to that of the base of the terminal, and a standard nut with suitable locking washer shall be used on each terminal. Suitable insulation barriers shall be placed between the terminals in order to prevent an accidental short circuit. The height and extent of these barriers shall be sufficient to prevent the short-circuiting of any adjacent terminals through the presence over these partitions of a flat conducting part.

No rotation or other loosening of a terminal, or any fixed portion of a terminal, shall be caused by material flow or shrinkage, or any mechanical force (specified in tables 1 and 2) involved in connection or disconnection, throughout the life of the controller.

The equivalent metric threads given in table 2 may be used.

Each terminal shall have a terminal seat that shall provide the normal current-conduction path. The diameter of the seat shall not be less than the area necessary to assure that the current density does not exceed 1,55 A/mm^2. The seat does not include the cross-sectional area of the stud.

Stud terminals shall be capable of accommodating two crimped-type lugs, with hardware as specified. A minimum of one and a half threads shall remain above the nut, with all parts tightened in place.

4.3.2 Plug-in terminals

Plug-in terminals, where applicable, shall conform to the dimensions and requirements necessary for proper mating with the associated sockets.

Units shall have the electrical and environmental tests performed with the associated socket or connector assembled to the unit.

4.3.3 Solder terminals

Solder terminals used for 2 A rating or less shall be designed to allow the securing of two 0,6 mm^2 wires with 19 strands. Terminals used for more than 2 A rating shall be designed to allow the securing of three wires, the size of which shall comply with the requirements of the detail specification.

Solder terminals for printed circuit board mounting shall comply with the requirements of the detailed specification.

The finish of the terminals shall provide a good electrical contact and meet the performance requirements specified in this International Standard. All terminals used for external soldered connections shall meet the requirements of the solderability test specified in the detail specification.

Table 1 — Strength of threaded terminals (static value of pull and torque)

Thread designation[1)]	Force		Installation torque		Design torque	
	N	lbf	N·m	lbf·in	N·m	lbf·in
No. 4-40 UNC	22,2	5	0,3	2,4	0,5	4,4
No. 6-32 UNC	133,4	30	0,5	4,5	1,1	10
No. 8-32 UNC	155,7	35	1	9	2,3	20
No. 10-32 UNF	177,9	40	1,7	14,5	3,7	32
No. 10-24 UNC	177,9	40	1,8	16	4	35
1/4-28 UNF	222,4	50	3,9	34	8,6	75
5/16-24 UNF	311,4	70	5,2	45	11,5	100
3/8-24 UNF	444,8	100	7,8	68	17,3	150
7/16-20 UNF	444,8	100	7,8	68	17,3	150
1/2-20 UNF	444,8	100	7,8	68	17,3	150

1) See ISO 263:1973, *ISO inch screw threads — General plan and selection for screws, bolts and nuts — Diameter range 0.06 to 6 in.*

Table 2 — Strength of threaded terminals — Metric units (static value of pull and torque)

Thread designation	Force		Installation torque		Design torque	
	N	lbf	N·m	lbf·in	N·m	lbf·in
M2,5	22,2	5	0,3	2,4	0,5	4,4
M3	133,4	30	0,5	4,5	1,1	10
M4	155,7	35	1	9	2,3	20
M5	177,9	40	1,8	16	4	35
M8	311,4	70	5,2	45	11,5	100
M10	444,8	100	7,8	68	17,3	150
M12 × 1,25	444,8	100	7,8	68	17,3	150
M14 × 1,25	444,8	100	7,8	68	17,3	150

NOTE — There is no direct metric equivalent to the thread size 1/4-28 UNF. M7 would correspond but is not used.

4.4 Enclosures

The enclosure design is identified by a single digit, in accordance with table 3.

Table 3 — Enclosure design

Type	Enclosure
1	Open
2	Enclosed (ventilated, explosion-proof)
3	Sealed (other than hermetically)
4	Hermetically sealed

4.4.1 Open enclosures

Type 1 controllers shall be uniformly coated on all surfaces with the exception of the mounting and terminals.

4.4.2 Enclosed enclosures (ventilated explosion-proof)

Unsealed units shall be totally enclosed for mechanical and dust protection and shall be explosion-proof.

4.4.3 Sealed (other than hermetically) enclosures

Environmentally sealed enclosures shall be constructed by any means other than that defined under hermetically sealed enclosures to achieve the degree of seal specified. Environmentally sealed units shall be purged and filled with a suitable gas of such characteristics that the leakage rate may be determined by conventional means. The units shall be designed to ensure that the essential electrical performance is not jeopardized in the event of a failure of the environmental seal in service.

4.4.4 Hermetically sealed enclosures

Hermetically sealed enclosures shall be constructed as gas-tight enclosures which have been completely sealed by fusion of glass or ceramic to metal, or by welding, brazing or soldering of metal to metal. Hermetically sealed units shall be purged and filled with a suitable inert gas of such characteristics that the leakage rate may be determined by conventional means.

4.4.5 Grounding of enclosures

The enclosures for type 2, 3 and 4 controllers shall be electrically isolated and provide means for grounding where appropriate.

The mountings shall provide an effective electrical contact to ground when the unit is mounted as specified. Alternatively, the enclosures shall be provided with a grounding connection such as a terminal or lug.

The covers shall be rugged in design, constructed of high-impact materials and securely mounted to the unit. Metal covers shall be provided with a means of grounding.

4.4.6 Heat sinking

For the purposes of maximizing reliability and minimizing size, the amount of heat which is generated within the enclosure shall be kept as low as possible.

If a heat sink is necessary, the thermal resistance of the heat sink and an adequate method of mounting shall be stated for type 2, 3 and 4 controllers.

5 Design characteristics

Solid-state (remote) power controllers provide both control and protection functions (as well as status feedback information).

5.1 General design of solid-state (remote) power controllers

5.1.1 The controller shall incorporate a current-sensing means to measure output current flow and to detect specified overcurrents. The controller shall incorporate specified trip-time characteristics.

5.1.2 Up to a specified fault-current level, the device shall follow a defined trip characteristic. Above this level, the device shall current-limit or provide a near instantaneous trip.

5.1.3 After the controller has tripped on overcurrent, it shall exhibit a trip-free characteristic remaining in the OFF state (and providing trip status information) until reset.

5.1.4 Reset is accomplished by cycling the control input from ON to OFF and then back to ON, or employing a dedicated RESET (auxiliary) input.

5.1.5 In the event of repeated attempts to switch into a fault, the controller shall not be damaged.

In order to prevent damage to associated wiring, as well as the overheating of the controller, a duty cycle for switching into various overload conditions shall be specified.

5.1.6 The controller shall meet the specified stabilization times after power-up, after a momentary power outage and during a supply voltage drop due to a fault, until the controller opens, clearing the fault and allowing supply voltage recovery.

5.1.7 The specified turn-on and turn-off characteristics of the controller shall minimize the effects of current inrush and capacitive loading on turn-on and control inductive kick on turn-off.

5.1.8 Coordination of trip times for given controllers with multiple current rating may not be assured for those controllers exhibiting the instant-trip feature. The response time, of the order of several microseconds, is nearly constant and independent of the current rating of the controller.

5.2 Control signal

Each controller shall be designed to operate from one of the following types of input signal.

a) Nominal voltage 28 V d.c.

b) Grounded controller input to switch controller ON; in the ON state the impedance seen by the input control shall not exceed 600 Ω.

c) Logic level signal for interfacing to a control bus (TTL or CMOS).

d) Impedance control multiplexed with status and BITE.

e) 10 mA source at 1 V to 12 V (to switch controller ON). This allows compatibility with existing remote-control circuit breakers.

5.3 Status signals for remote power controllers

As a minimum, one status signal shall be provided. The preferred status signals are switch status and/or current-flow status.

5.4 Fail-safe considerations

When a fail-safe feature is incorporated, its characteristics shall be specified. When tested, the fail-safe element shall open the circuit at specified currents and times.

5.5 Safety of personnel

Since solid-state devices in the ON or OFF state may present deadly hazards, precautions shall be taken to ensure the safety of personnel.

6 Operating characteristics

6.1 General

All controllers shall function satisfactorily over the full specified range of applied electrical and mechanical steady-state and transient conditions.

6.2 Timing sequence

The timing sequence shall be as specified.

6.3 Dielectric strength

Tests shall be carried out in accordance with ISO 2678. Any restrictions arising from the semiconductors shall be declared.

The test voltage shall be in accordance with ISO 2678.

6.4 Insulation resistance

Tests shall be carried out at 500 V d.c. A controller shall exhibit insulation resistance greater than 100 MΩ at all authorized temperature extremes at ground level and greater than 20 MΩ at all authorized temperature extremes at maximum altitude.

6.5 Control/power isolation

The controller shall exhibit an isolation resistance greater than 100 MΩ when tested with 500 V d.c. applied between mutually isolated groups of control/power terminals.

6.6 Electrical characteristics

6.6.1 Direct-current controllers

6.6.1.1 Voltage drop

The controllers shall exhibit ON-state impedance values such that the voltage drop across the controller is a minimum at rated load.

6.6.1.2 Leakage current

The controllers shall exhibit OFF-state impedance values such that the leakage current through the rated load is a minimum.

6.6.1.3 Ripple voltage

The ripple voltage introduced by the controller onto the d.c. supply input shall be a minimum at rated current.

6.6.2 Alternating-current controllers

6.6.2.1 Voltage drop

The controllers shall exhibit ON-state impedance values such that the voltage drop across the controller is a minimum at rated load.

6.6.2.2 Leakage current

The controllers shall exhibit OFF-state impedance values such that the leakage current through the rated load is a minimum.

6.6.2.3 D.c. offset voltage

The d.c. offset introduced by the controller (d.c. content at the output terminal minus the d.c. content at the a.c. input terminal — see 3.29) shall be a minimum at rated load. The maximum guidelines are ± 100 mV.

6.6.3 Quiescent power dissipation

The controller power dissipation in the OFF-state for a normally open device, or in the ON-state for a normally closed device, shall be a minimum.

6.6.4 Rupture capacity

The prospective currents are those which would be broken by an ideal controller of no internal impedance. They are defined in table 4 and shall be reached as follows:

— between 2 ms and 10 ms for 28 V d.c. systems, counted from fault application;

— between 2 ms and 5 ms for 115/200 V/400 Hz systems, counted from fault application.

Recovery voltages after interruption of fault current for 28 V d.c. systems and 115/200 V/400Hz systems are as defined in ISO 7137.

Table 4 — Prospective short-circuit currents

	Systems	
	d.c.	**400 Hz a.c.**
Voltage at controller power terminals in open circuit	28 V $^{+4}_{0}$ V	115 V $^{+10}_{0}$ V (effective value)
Connecting mode	—	star connection
Prospective currents	6 000 A (all ratings)	3 000 A *) (all ratings)

*) Assuming current-limiting in the electrical power system.

7 Environmental conditions and test procedures

These shall be in accordance with ISO 7137 and in accordance with the categories given in table 5.

8 Qualification

The object of qualification tests is to ensure that the design is capable of meeting the specifications of this International Standard. Production units shall be used for the tests.

Table 5 — Environmental conditions and test procedures

No.	Test	Procedure given in ISO 7137	Category	Comment
7.1	Temperature and altitude	1.1	E1	Unpressurized, uncontrolled temperature up to 21 300 m (70 000 ft)
7.2	Temperature variation	1.2	B	Internal, temperature not controlled
7.3	Humidity	1.3	A	Standard humidity environment
7.4	Shock	2.1	Standard as specified	No malfunction
7.5	Vibration	2.2	Severe category	Severe conditions, to meet all applications
7.6	Explosion	4.1	Environment II tests according to sealing category	Flammable mixtures can be expected to occur as a result of fault or spillage
7.7	Waterproofness	1.5	W	Subject to falling water, i.e. condensation
7.8	Fluids contamination	1.6	F	See table 11-1 in ISO 7137:1992
7.9	Sand and dust	1.7	D	
7.10	Fungus resistance	1.8	F	Subjected to severe fungus contamination
			X	For applications not subjected to fungus resistance test
7.11	Salt spray	1.9	S	
7.12	Magnetic effect	3.1	A	
7.13	Power input	3.2	Z	
7.14	Voltage spike	3.3	A	Installations for lower level of transient withstand
7.15	Audio frequency susceptibility	3.4	Z	For all types of electrical system
7.16	Induced signal susceptibility	3.5	B	Installations where mutual interference is held to a tolerable level
7.17	Radio frequency susceptibility (radiated and conducted)	3.6	U	Installations in a partially protected environment
7.18	Emission of radio frequency energy	3.7	B	Installations where mutual interference is held to a tolerable level
7.19	Lightning-induced transient susceptibility	3.8	K	Installations in a moderate environment

NOTE — The same samples may be used for non-damaging tests such as 7.12 to 7.17.

Subsequent production acceptance tests have the objective of ensuring that the performance standard is maintained, based on short-duration tests.

Additional quality assurance tests based on random sampling are designed to verify that performance is sustained in the areas requiring longer-term tests.

Detailed specifications for qualification approval testing, production testing and additional quality assurance shall be based on the detailed performance specification, and this International Standard can only identify the basic requirements.

Physical attributes, such as size, mass or appearance, shall be derived from the detailed performance specification and are 100 % tests.

8.1 Qualification tests

Qualification tests shall be carried out according to the specifications of table 6.

Table 6 — Qualification tests

No.	Test	Reference	Number of samples	Number of failures
8.1.1	**Qualification** 1)			
8.1.1.1	Visual and mechanical inspection Solderability Seal Insulation resistance Dielectric withstanding voltage Electrical requirements	8.3.1 8.3.21 8.3.22 8.3.6 8.3.7 8.3.8	14	0
8.1.1.2	Thermal shock	8.3.12	2	0
	Resistance to solvents Shock Vibrations Terminal strength Moisture resistance Seal Insulation resistance Dielectric withstanding voltage Electrical requirements Visual and mechanical inspection	8.3.13 8.3.14 8.3.15 8.3.16 8.3.17 8.3.22 8.3.6 8.3.7 8.3.8 8.3.1	4	1
8.1.1.3	Crosstalk Isolation Resistance to soldering heat Salt atmosphere Seal Insulation resistance Dielectric withstanding voltage Electrical requirements Visual and mechanical inspection	8.3.9 8.3.10 8.3.18 8.3.19 8.3.22 8.3.6 8.3.7 8.3.8 8.3.1	4	1
8.1.1.4	Life Seal Insulation resistance Dielectric withstanding voltage Electrical requirements Visual and mechanical inspection	8.3.20 8.3.22 8.3.6 8.3.7 8.3.8 8.3.1	4	1
8.1.2	**Periodic qualification** 1)			
	Thermal shock Terminal strength Vibrations Moisture resistance Insulation resistance Electrical requirements Visual and mechanical inspection	8.3.12 8.3.16 8.3.15 8.3.17 8.3.6 8.3.8 8.3.1	6 2)	0

1) Electromagnetic interference (EMI) shall be tested between transient voltage and d.c. offset voltage, on two units only.

2) Use six units that have passed production testing:

a) 2 units for thermal shock;

b) 4 units for the other tests.

Periodic qualification tests shall be carried out every 6 months, and EMI tests every 12 months.

8.2 Production acceptance tests

Production acceptance tests shall be carried out in the order given in table 7. Unless otherwise specified, devices shall be 100 % tested.

Table 7 — Production acceptance test

No.	Test	Reference
1	Visual and mechanical inspection	8.3.1
2	Stabilization bake	8.3.2
3	Temperature cycling	8.3.3
4	Load conditioning	8.3.4
5	Burn in	8.3.5
6	Insulation resistance	8.3.6
7	Dielectric withstanding voltage	8.3.7
8	Electrical requirements	8.3.8
9	Solderability	8.3.21
10	Seal	8.3.22

8.3 Test procedures

8.3.1 Visual and mechanical examination

(Remote) power controllers shall be examined to verify that the materials, external design and construction, physical dimensions, mass, marking and workmanship are in accordance with the applicable requirements given in clause 4.

8.3.2 Stabilization bake

This is optional.

8.3.3 Temperature cycling

(Remote) power controllers shall be tested by temperature cycling in order to determine the resistance of a part to extremes of high and low temperature, and to the effect of alternate exposures to these extremes. The following procedure shall apply.

a) Suspend the devices in the test chamber by twine or another non-heat-conducting material, in a plane parallel to the normal air flow.

b) Subject the devices to a minimum of 10 cycles of the following steps:

   cold: $-55\ °C\ _{-10}^{\ 0}\ °C$ for 30 min;

   hot: $+125\ °C\ ^{+15}_{\ \ 0}\ °C$ for 30 min.

   One cycle consists of both steps. The total transfer time from hot to cold or from cold to hot shall not exceed 1 min.

8.3.4 Load conditioning

(Remote) power controllers shall be tested under load conditioning by applying rated bias, status and AUX voltages, when specified, and a step function voltage to the control input (the input shall be energized at zero or rated input voltage). The load shall be the maximum rated current, without auxiliary heat sink, and each output circuit shall be loaded with the maximum rated resistive current at the highest rated voltage, for 3 h, at a rate not less than one and not more than 30 operations per second. When applicable, the bias voltage and the AUX voltages shall be applied at the rated values. The (remote) power controller shall be turned off 10 % of the time and turned on 90 % of the time. For SPDT and DPDT (remote) power controllers, cycling shall be 50 % turned on and 50 % turned off or, for 1,5 h of test, 10 % on and 90 % off, and 90 % on and 10 % off for an additional 1,5 h of test.

8.3.5 Burn-in

(Remote) power controllers shall be tested under burn-in by applying rated bias, status and AUX voltages, when specified, and a step function voltage to the control input (the input shall be energized at zero or rated input voltage). The load shall be the maximum rated current, without auxiliary heat sink, and each output circuit shall be loaded with the maximum rated resistive current at the highest rated voltage. The duration of this test is as given in the specification and the devices shall remain energized for this amount of time.

8.3.6 Insulation resistance

(Remote) power controllers shall be tested for insulation resistance in accordance with ISO 2678:1985, 4.2. See 6.4. Unless otherwise specified, devices shall be tested only at 25 °C.

8.3.7 Dielectric withstanding voltage

(Remote) power controllers shall be tested for dielectric withstanding voltage at atmospheric pressure and the test voltage shall be as specified in ISO 2678. When reduced barometric pressure is specified, the test voltage shall be 1/3 of the value specified. See 6.3. Unless otherwise specified, devices shall be tested only at 25 °C.

8.3.8 Electrical requirements

Unless otherwise specified, devices shall be tested in accordance with ISO 7137:1992, table 4-1.

8.3.8.1 Electrical system spike

(Remote) power controllers shall be tested for electrical system spikes (when applicable) at 25 °C in accordance with the test procedure ISO 7137-3.3, category A.

8.3.8.2 Input signals

a) **Input current**

(Remote) power controllers shall be tested for input current (when applicable) using following procedure.

1) See figure 2 for test set-up.

2) Apply the specified bias voltage, AUX and status voltages (when specified).

3) Apply the specified control voltage.

4) Verify with ammeter A1 that the input current is within specification.

b) **Turn-off voltage**

(Remote) power controllers shall be tested for turn-off voltage using the following procedure.

1) See figure 2 for test set-up.

2) Apply the rated resistive output load, voltage and frequency (if applicable).

3) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage to turn the device ON. Adjust the control voltage to the value specified to turn the device OFF.

4) Verify that the device is OFF with the aid of ammeter A4 mounted in parallel with switch S1, or oscilloscope CH2 (or equivalent instrument), or voltmeter V4 across the output.

c) **Turn-on voltage**

(Remote) power controllers shall be tested for turn-on voltage using the following procedure.

1) See figure 2 for test set-up.

2) Apply the rated output load, voltage and frequency (if applicable).

3) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage to turn the device ON.

4) Verify as in 8.3.8.2 b) 4) that the device is ON.

d) **Control current**

(Remote) power controllers shall be tested for control current using the following procedure.

1) See figure 2 for test set-up.

2) Apply the rated load, voltage and frequency (if applicable).

3) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage.

4) Verify with ammeter A2 that the control current is within specification.

8.3.8.3 Short-circuit protection

a) **"Will-not-trip" current**

(Remote) power controllers shall be tested for a "will-not-trip" current using the following procedure.

1) See figure 2 for test set-up.

2) Apply the rated "will-not-trip" load, rated voltage and rated frequency (if applicable).

3) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the control voltage for the specified "will-not-trip" time.

4) Verify that the device stays ON for the specified time by observing oscilloscope CH2 or CH1 (or equivalent instrument).

5) Repeat steps 3) and 4) for a minimum of three cycles.

b) **"Must-trip" current**

(Remote) power controllers shall be tested for a "must-trip" current using the following procedure.

1) See figure 2 for test set-up.

2) Apply the rated "must-trip" load, rated voltage and rated frequency (if applicable).

3) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the control voltage for a time equal to or greater than the specified "must-trip" time.

4) Verify that the device shuts OFF within the specified time, as in 8.3.8.3 a) 4).

5) Repeat steps 3) and 4) for a minimum of three times. Verify that the device shuts OFF within the specified "must-trip" time.

c) **Turn-on into a shorted load**

(Remote) power controllers shall be tested for turn-on into a shorted load using the following procedure.

1) See figure 2 for test set-up.

2) Apply the rated load, voltage and frequency (if applicable).

3) Close switch S1 and then S2.

4) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the control voltage.

5) Verify with oscilloscope CH1 (or equivalent instrument) that the device shuts OFF within the specified time.

6) Repeat steps 4) and 5) a minimum of three times at the specified repetition rate.

d) **Shorted load with device ON**

(Remote) power controllers shall be tested by shorting the load while the device is ON using the following procedure.

1) See figure 2 for test set-up.

2) Apply the rated load, voltage and frequency (if applicable).

3) Close switch S1.

4) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage to turn the device ON.

5) Close switch S2.

6) Verify with oscilloscope CH1 (or equivalent instrument) that the device shuts OFF within the specified time.

7) Open switch S2 and repeat steps 4) to 6) for a minimum of three times.

8.3.8.4 Turn-off time

(Remote) power controllers shall be tested for turn-off time using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated output load, voltage and frequency (if applicable).

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the control voltage to turn the device ON. Adjust the control voltage to the value specified to turn the device OFF.

d) Verify on oscilloscope CH2 (or equivalent instrument) that the device shuts OFF in the specified time.

See 6.2.

8.3.8.5 Turn-on time

(Remote) power controllers shall be tested for turn-on time using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated output load, voltage and frequency (if applicable).

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage to turn the device ON.

d) Verify on oscilloscope CH2 (or equivalent instrument) that the device turns ON in the specified time.

See 6.2.

8.3.8.6 ON resistance

(Remote) power controllers shall be tested for ON resistance using the following procedure.

a) See figure 2 for test set-up.

b) Adjust the load so that the output current is 5 % of the rated current at the rated voltage.

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage to turn the device ON.

d) Verify with voltmeter V4 that the voltage drop is within specified limits given the specified ON resistance.

For an a.c. (remote) power controller, a true RMS voltmeter shall be used.

8.3.8.7 Output voltage drop

(Remote) power controllers shall be tested for output voltage drop using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable).

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage to turn the device ON.

d) Verify with voltmeter V4 that the voltage drop is within the specified limits.

For an a.c. (remote) power controller, a true RMS voltmeter shall be used.

See 6.6.1.1 and 6.6.2.1.

8.3.8.8 Output leakage current

(Remote) power controllers shall be tested for output leakage current using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable).

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage to turn the device OFF.

d) Measure the current with ammeter A4 when the device is in the non-conducting mode.

See 6.6.1.2 and 6.6.2.2.

8.3.8.9 Power dissipation

(Remote) power controllers shall be tested for power dissipation using the following procedure.

a) **ON state**

1) See figure 2 for test set-up.

2) Apply the rated load, voltage and frequency, if applicable.

3) Apply the maximum specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified maximum control voltage to turn the device ON.

4) Read the instruments and calculate the power dissipation by adding the products of the control voltage × control current, bias voltage × bias current (when applicable), output voltage drop × output current, for each output switch, in addition to any power dissipated by internal power supplies (and the status voltage × status current for each status).

5) Take measurements after the device has reached thermal equilibrium.

b) **OFF state**

1) See figure 2 for test set-up.

2) Apply the rated load, voltage and frequency, if applicable.

3) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified maximum turn-off control signal.

4) Read the instruments and calculate the power dissipation by adding the products of the control voltage × control current, bias voltage × bias current (when applicable), output voltage drop × output current, for each output switch, in addition to any power dissipated by internal power supplies (and the status voltage × status current for each status).

See 3.9.

8.3.8.10 Transient voltage

(Remote) power controllers shall be tested for transient voltage in accordance with test procedure ISO 7137-3.2. The category of the device and all relevant restrictions shall be declared.

8.3.8.11 Direct-current offset voltage (a.c. devices only)

(Remote) power controllers shall be tested for d.c. offset voltage (when applicable) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency, and a load to provide a current value between 10 % and 100 % of the rated current.

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control turn-on voltage.

d) With switch S3 closed, measure the d.c. content of the a.c. supply with voltmeter V5.

e) With switch S3 open, measure the d.c. content at the load terminals with voltmeter V4.

f) Verify that the difference between the two measurements does not exceed the specified value.

8.3.8.12 Minimum load current rating (a.c. devices only)

(Remote) power controllers shall be tested for minimum load current rating (when applicable) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated minimum load, output voltage and frequency.

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control turn-on voltage.

d) Verify with ammeter A4, or voltmeter V4, or oscilloscope CH2 (or equivalent instrument), that the device turns ON and remains ON.

8.3.8.13 Zero crossover (a.c. devices only)

(Remote) power controllers shall be tested for zero crossover (when applicable) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency.

c) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified turn-on control voltage.

d) Apply and then remove the control voltage, and observe on oscilloscope CH2 (or equivalent instrument) the output voltage waveform at turn-on. The value of the "zero voltage turn-on" shall be within specification.

e) Apply and then remove the control voltage at random and monitor the output current on oscilloscope CH1 (or equivalent instrument) at turn-off. The value of the "zero current turn-off" shall be within specification.

See 3.28.

8.3.8.14 Exponential rate of voltage rise

(Remote) power controllers shall be tested for exponential rate of voltage rise (when applicable) using the following procedure.

a) See figure 3 for test set-up.

b) Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control turn-off voltage.

c) Adjust voltmeter V1 to the maximum rated voltage. For a.c. (remote) power controllers V_1 is the maximum rated voltage:

$$V_1 = \sqrt{2}\, V_{\text{rated, RMS}}$$

d) With the output terminals of the device disconnected, adjust resistor R1 to a value determined by

$$R_1 = 0{,}632 \times \frac{V_1}{C_1(\mathrm{d}V/\mathrm{d}t)}$$

where $\mathrm{d}V/\mathrm{d}t$ is as specified in figure 3.

e) Reconnect the output terminals of the device under test to the circuit shown in figure 3.

f) Close and open switch S1 for a minimum of 10 times. After five cycles, reverse the leads to the device under test (for a.c. devices only).

g) Verify with oscilloscope CH1 (or equivalent instrument) that the device achieves the specified output voltage within the specified time.

8.3.8.15 Status blocking voltage

(Remote) power controllers shall be tested for status blocking voltage using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage.

c) Apply the specified blocking voltage to the status terminal with the status resistor, R(STATUS), as specified.

d) Verify with ammeter A3 that the status current is within specification.

8.3.8.16 Status leakage current

(Remote) power controllers shall be tested for status leakage current using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the specified bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage.

c) Apply the specified voltage to the status terminal with R(STATUS) as specified.

d) Verify with ammeter A3 that the status leakage current is within specification.

8.3.8.17 Status output current

(Remote) power controllers shall be tested for status output current using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the bias voltage (if applicable), AUX and status voltages (when specified) and the specified control voltage.

c) Apply the specified status load, R(STATUS), and the specified status voltage.

d) Apply the necessary conditions to activate the status output.

e) Verify with ammeter A3 that the status output current is within specification and determine with voltmeter V3 that the status output voltage drop is within specification.

8.3.8.18 Status turn-off time

(Remote) power controllers shall be tested for status turn-off time (when specified) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the specified bias voltage (if applicable), AUX when specified, and the specified control voltage.

c) Apply the specified voltage to the status terminal with R(STATUS) as specified.

d) With the oscilloscope (or other equivalent measuring instrument) triggering on the specified trigger signal, apply the necessary conditions to activate the status output.

e) Verify that the time required for the status signal to reach 10 % of the final value is within specification. Measure the status signal at voltmeter V3.

8.3.8.19 Status turn-on time

Remote power controllers shall be tested for status turn-on time (when specified) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the specified bias voltage (if applicable), AUX when specified, and the specified control voltage.

c) Apply the specified voltage to the status terminal with R(STATUS) as specified.

d) With the oscilloscope (or other equivalent measuring instrument) triggering on the specified trigger signal, apply the necessary conditions to de-activate the status output.

e) Verify that the time required for the status signal to reach 10 % of the final value is within specification. Measure the status signal at voltmeter V3.

8.3.8.20 AUX blocking voltage

Remote power controllers shall be tested for AUX blocking voltage (when specified) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the specified bias voltage (if applicable) and status voltages (when specified) and the specified control voltage.

c) Apply the specified blocking voltage to the AUX terminal with auxiliary resistor R(AUX) as specified.

d) Verify with ammeter A5 that the AUX current is within specification.

8.3.8.21 AUX leakage current

Remote power controllers shall be tested for AUX leakage current (when specified) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the specified bias voltage (if applicable) and status voltages (when specified) and the specified control voltage.

c) Apply the specified blocking voltage to the AUX terminal with auxiliary resistor R(AUX) as specified.

d) Verify with ammeter A5 that the AUX leakage current is within specification.

8.3.8.22 AUX current

Remote power controllers shall be tested for AUX current (when specified) using the following procedure.

a) See figure 2 for test set-up.

b) Apply the rated load, voltage and frequency (if applicable). Apply the specified bias voltage (if applicable) and status voltages (when specified) and the specified control voltage.

c) Apply the specified blocking voltage to the AUX terminal with auxiliary resistor R(AUX) as specified.