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TECHNICAL SPECIFICATION

General requirements for residual current operated protective devices for DC systems

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GENERAL REQUIREMENTS FOR RESIDUAL CURRENT OPERATED PROTECTIVE DEVICES FOR DC SYSTEMS

FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 63053, which is a technical specification, has been prepared by subcommittee 23E: Circuit-breakers and similar equipment for household use, of IEC technical committee 23: Electrical accessories.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
23E/1006/DTS	23E/1021/RVDTS

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

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

In this standard, the following print types are used:

– *conformity statements: in italic type*

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

In AC systems, residual current devices are used to provide protection against the risk of electric shocks. In IEC 60364 (all parts), residual current devices are used for automatic disconnection of supply in case of fault (see Clause 411 of IEC 60364-4-41:2005) and residual current devices with rated residual operating current not exceeding 30 mA are used as additional protection (see 415 of IEC 60364-4-41:2005). IEC SC 23E has developed a set of standards for residual current operated protective devices intended to be used in AC systems.

DC systems are used for applications such as photovoltaic installations, data centres and telecom centres, and electric vehicle charging systems. In addition, standards for plugs and socket-outlets for ICT equipment installed in date centres and telecom centre have been published. Therefore, a reference document for residual current devices intended to be used in DC supply systems is necessary.

Residual current devices for DC systems may be used to provide fault protection (automatic disconnection of supply according to Clause 411 of IEC 60364-4-41:2005); they may also be used to provide protection against direct contact. They provide protection against electric shock downstream of the device in DC networks.

This document defines the operating characteristics for residual current operated protective devices for DC systems. Details of how they should be installed to provide the desired level of protection are specified in the various parts of the IEC 60364 series.

The operating characteristics given in this document are based on the information contained in IEC 60479 (all parts) and the requirements in IEC 60364-4-41.

This document is intended for use by technical committees in the preparation of standards for residual current devices. It is not intended to be used as a stand-alone document, for example, for certification.

GENERAL REQUIREMENTS FOR RESIDUAL CURRENT OPERATED PROTECTIVE DEVICES FOR DC SYSTEMS

1 Scope

This document provides general minimum requirements, recommendations and information for the drafting and testing procedures of standards for residual current operated protective devices, intended to be used in DC systems having a rated voltage not exceeding 400 V DC and a rated current not exceeding 125 A, hereafter referred to as DC-RCDs.

NOTE 1 This document can also be used as a guide for DC-RCDs with voltages up to 1 500 V DC.

This document is primarily intended to be used as a reference for drafting product safety standard for DC-RCDs.

This document cannot be used alone but is intended for use by technical committees in the preparation of standards for products similar to those mentioned in the scope of this standard.

This document applies to a device

– which detects a residual current,
– compares it to a reference value, and
– opens the contacts or poles when the residual current exceeds this reference value.

Any association of devices, each one of them performing separately one or two of the above-mentioned functions, but acting together in order to accomplish all three functions, is also covered by this document.

NOTE 2 RCMs (residual current monitor according to IEC 62020) whose purpose is to monitor an electrical installation and not to provide protection are not covered by this document and cannot be considered similar or equivalent to DC-RCDs.

DC-RCDs are intended to provide fault protection, the exposed conductive parts of the installation being connected to an appropriate earth electrode, in accordance with IEC 60364-4-41.

DC-RCDs having a rated residual operating direct current not exceeding 80 mA are also used as a provision for additional protection in case of failure of the protective means against electric shock.

In accordance with IEC 60364-4-42, residual current devices with a rated residual operating current not exceeding 300 mA can also be used to provide protection against fire hazards due to a persistent earth fault current.

DC-RCDs are suitable for isolation. They are suitable for all supply systems, with the exception of single-pole DC-RCDs with two current paths which are not suitable for use in IT systems.

DC-RCDs of the general type are resistant to unwanted tripping including the case where surge voltages (as a result of switching transients or induced by lightning) cause loading currents in the installation without occurrence of flashover.

NOTE 3 Installation and application rules of RCDs are given in IEC 60364 (all parts).

NOTE 4 Surge protective devices installed downstream of DC-RCDs and connected in common mode can cause unwanted tripping.

The requirements of this document apply for normal environmental conditions (see 7.1). Additional requirements can apply for RCDs type DC used in locations having severe environmental conditions.

NOTE 5 For DC-RCDs having a degree of protection higher than IP 20 special constructions can be applicable.

DC-RCDs which include batteries are not covered by this document.

Specific additional requirements for RCDs incorporated or embedded in equipment are covered in IEC TR 60755. Those specific additional requirements are also applicable for DC-RCDs.

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

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

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

IEC 60068-3-4, *Environmental testing – Part 3-4: Supporting documentation and guidance – Damp heat tests*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60417, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

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

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3 Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

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

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-16, *Electromagnetic compatibility (EMC) – Part 4-16: Testing and measurement techniques – Test for immunity to conducted common mode disturbances in the frequency range 0 Hz to 150 kHz*

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

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

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

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61543:1995*, Residual current-operated protective devices (RCDs) for household and similar use – Electromagnetic compatibility*
IEC 61543:1995/AMD1:2004
IEC 61543:1995/AMD2:2005

IEC 62873-2, *Residual current operated circuit-breakers for household and similar use – Part 2: Residual current devices (RCDs) – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62873-2 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
residual operating direct current
value of residual direct current which causes the DC-RCD to operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-20, modified – Adapted to DC-RCDs.]

3.2
residual non-operating direct current
value of residual direct current at and below which the DC-RCD does not operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-21, modified – Adapted to DC-RCDs.]

3.3
residual direct making and breaking capacity
value of a residual prospective direct current which a DC-RCD can make, carry for its opening time and break under specified conditions of use and behaviour

[SOURCE: IEC 60050-442:1998, 442-05-27, modified – Adapted to DC-RCDs.]

3.4
conditional direct short-circuit current
value of a prospective direct current, which a DC-RCD without integral short-circuit protection, but protected by a short-circuit protective device in series, can withstand under specified conditions of use and behaviour

3.5
conditional residual direct short-circuit current
value of a residual direct prospective current, which a DC-RCD without integral short-circuit protection, but protected by a SCPD in series, can withstand under specified conditions of use and behaviour

[SOURCE: IEC 60050-442;1998, 442-05-22, modified – Adapted to DC-RCDs.]

3.6
mid-point
common point between two symmetrical circuit elements the opposite ends of which are electrically connected to different line conductors of the same circuit

[SOURCE: IEC 60050-195:1998, 195-02-04]

3.7
M-pole
part of a DC-RCD associated exclusively with one electrically separated conducting path intended to connect and to disconnect the mid-point

3.8
time constant
rise time $T = L/R$ (ms) of a prospective direct current to reach a value of 0,632 times the maximum peak current

4 Classification

4.1 According to the type of installation

4.1.1 DC-RCD for fixed installation and fixed wiring.

4.1.2 Portable DC-RCD with corded connection.

4.2 According to the possibility of adjusting the residual operating current

4.2.1 DC-RCD with a single value of rated residual operating current.

4.2.2 DC-RCD with multiple settings of residual operating current by fixed steps.

4.3 According to time-delay (in presence of a residual current)

4.3.1 DC-RCD without time-delay: for general use, with normal resistance to unwanted tripping.

4.3.2 DC-RCD with time-delay: for selectivity, with increased resistance to unwanted tripping.

4.4 According to the protection against external influences

4.4.1 Enclosed-type DC-RCD (not requiring an appropriate enclosure).

4.4.2 Unenclosed-type DC-RCD (for use with an appropriate enclosure).

4.5 According to the method of mounting

4.5.1 Surface-type DC-RCD.

4.5.2 Flush-type DC-RCD.

4.5.3 Panel board type DC-RCD, also referred to as distribution board type.

NOTE These types can be intended to be mounted on rails.

4.6 According to the method of connection

4.6.1 DC-RCD, the electrical connections of which are not associated with the mechanical mounting.

4.6.2 DC-RCD, the electrical connections of which are associated with the mechanical mounting.

NOTE 1 Specific requirements for this classification are under consideration.

NOTE 2 Examples of this type are:

– plug-in type;
– bolt-on type;
– screw-in type.

Some DC-RCDs can be of the plug-in type or bolt-on type on the line side only, the load terminals being usually suitable for wiring connection.

4.7 According to the type of terminals

4.7.1 DC-RCD with screw-type terminals for external copper conductors.

4.7.2 DC-RCD with screwless type terminals for external copper conductors.

NOTE 1 The requirements for DC-RCDs equipped with these types of terminals are given in IEC 62873-3-1.

4.7.3 DC-RCD with flat quick-connect terminals for external copper conductors.

NOTE 2 The requirements for DC-RCDs equipped with these types of terminals are given in IEC 62873-3-2.

4.7.4 DC-RCD with screw-type terminals for external aluminium conductors.

NOTE 3 The requirements for DC-RCDs equipped with these types of terminals are given in IEC 62873-3-3.

4.8 According to the number of poles and current paths

4.8.1 Single-pole DC-RCD with two current paths.

4.8.2 Two-pole DC-RCD.

4.8.3 Two-pole DC-RCD with three current paths.

4.8.4 Three-pole DC-RCD.

4.9 According to the instantaneous tripping current

This classification applies to the residual current function combined with the circuit-breaker and is defined in the relevant product standard.

4.10 According to the I^2t characteristics

This classification applies to the residual current function combined with the circuit-breaker and is defined in the relevant product standard.

4.11 According to overcurrent protection

4.11.1 Residual current devices without integral overcurrent protection.

4.11.2 Residual current devices with integral overcurrent protection.

4.11.3 Residual current devices with integral overload protection only.

4.11.4 Residual current devices with integral short-circuit protection only.

4.12 According to the method of construction

4.12.1 DC-RCD completely assembled by the manufacturer as one device (standalone DC-RCD)

4.12.2 DC-RCD comprised of a circuit-breaker and r.c. unit to be assembled on site

4.12.3 Any association of devices acting together in order to accomplish the three main functions of a DC-RCD – detection of a residual current, comparison to a reference value and opening the contacts or poles when the residual current exceeds this reference value.

NOTE The current sensing means and/or the processing device can be mounted separately from the current breaking device.

4.13 According to the range of ambient air temperature

4.13.1 Residual current devices intended for use between –5 °C and +40 °C.

4.13.2 Residual current devices intended for use between –25 °C and +40 °C.

4.13.3 Residual current devices intended for use in more severe conditions.

4.14 According to the time constant

4.14.1 Residual current devices suitable for DC circuits with a time constant of $T \leq 4$ ms.

4.14.2 Residual current devices suitable for DC circuits with a time constant of $T \leq 15$ ms.

NOTE It is assumed that short-circuit currents of 1 500 A are not exceeded in installations in which, due to the loads connected, time constants in normal service up to 15 ms can occur. Where higher short-circuit currents can occur, the time constant of $T = 4$ ms is considered sufficient.

4.15 According to the current direction through the poles

4.15.1 Polarised DC-RCD.

4.15.2 Non-polarised DC-RCD.

5 Characteristics of residual current devices

5.1 Summary of characteristics

The characteristics of the DC-RCD are given in the relevant DC-RCD standard in accordance with this document.

The characteristics of a DC-RCD shall be stated in the following terms:

– rated voltages (see 5.2.1);
– rated direct current I_n (see 5.2.2);
– rated making and breaking capacity I_m (see 5.2.3);
– rated residual operating direct current $I_{\Delta n}$ (see 5.2.4);
– rated residual non-operating direct current $I_{\Delta no}$ (see 5.2.5);
– rated residual direct making and breaking capacity $I_{\Delta m}$ (see 5.2.6);
– rated conditional direct short-circuit current I_{nc} (see 5.2.7);
– rated conditional residual direct short-circuit current $I_{\Delta c}$ (see 5.2.8);
– time-delay, if applicable (see 5.2.9);
– operating characteristics (see 5.2.10)
– degree of protection (see IEC 60529).

5.2 Rated quantities and other characteristics

5.2.1 Rated voltages

5.2.1.1 Rated operational voltage (U_e)

The rated operational voltage (hereafter referred to as "rated voltage") of a DC-RCD is the value of direct voltage, assigned by the manufacturer, to which its performance is referred.

5.2.1.2 Rated insulation voltage (U_i)

The rated insulation voltage of a DC-RCD is the value of voltage, assigned by the manufacturer, to which dielectric test voltages and creepage distances are referred.

Unless otherwise stated, the rated insulation voltage is the value of the maximum rated voltage of the DC-RCD. In no case shall the maximum rated voltage exceed the rated insulation voltage.

5.2.1.3 Rated impulse withstand voltage (U_{imp})

The rated impulse withstand voltage of a DC-RCD is defined in the relevant product standard taking into account the overvoltage category and the rated operational voltage, according to IEC 60664-1.

5.2.2 Rated direct current (I_n)

A direct current assigned by the manufacturer as the current which the DC-RCD can carry in uninterrupted duty (see IEC 62873-2), at a specified reference ambient air temperature.

5.2.3 Rated making and breaking capacity (I_m)

The value of the prospective direct current assigned by the manufacturer, which a DC-RCD can make, carry and break under specified conditions.

5.2.4 Rated residual operating direct current ($I_{\Delta n}$)

The value of residual operating direct current, assigned to the DC-RCD by the manufacturer, at which the DC-RCD shall operate under specified conditions.

For a DC-RCD having multiple settings of residual operating direct current, the highest setting is used to designate it.

5.2.5 Rated residual non-operating direct current ($I_{\Delta no}$)

The value of residual non-operating direct current, assigned to the DC-RCD by the manufacturer, at which the DC-RCD does not operate under specified conditions.

5.2.6 Rated residual direct making and breaking capacity ($I_{\Delta m}$)

The value of the residual prospective direct current, assigned by the manufacturer, which a DC-RCD can make, carry and break under specified conditions.

5.2.7 Rated conditional direct short-circuit current (I_{nc})

The value of the prospective direct current, assigned by the manufacturer, which a DC-RCD, protected by a specified SCPD, can withstand under specified conditions without undergoing alterations impairing its functions.

5.2.8 Rated conditional residual direct short-circuit current ($I_{\Delta c}$)

The value of residual prospective direct current, assigned by the manufacturer, which a DC-RCD, protected by a specified SCPD, can withstand under specified conditions without undergoing alterations impairing its functions.

5.2.9 Time-delay DC-RCD

Time-delay DC-RCD which complies with the relevant part of Table 3 if applicable.

5.2.10 Operating characteristics

DC-RCD ensures tripping for residual smooth direct currents, whether suddenly applied or slowly rising, independent of polarity.

5.3 Standard and preferred values

5.3.1 Preferred values of rated operational voltage (U_e)

Preferred values of rated operational voltage are given in Table 1.

Examples for the connection of DC-RCDs in different DC supply systems are given in Figure 2 a) to d).

Table 1 – Preferred values of rated operational voltage (U_e)

		DC voltage	
DC-RCD	**Supply system**	**Rated operational direct voltage**	**Examples of DC supply systems**
Single-pole with two-current path	2 wires (± to M)	200 V	Figures 2 a) and b)
Two poles	2 wires (L+ to L-)	200 V 400 V	Figures 2 b)
Two-pole with three-current path	3 wires (L+ to L-)	400 V	Figures 2 c)
Three-pole	3 wires (L+ to L-)	400 V	Figures 2 d)
The rated voltage for one pole shall not exceed 220 V DC. NOTE The two-wire supply system refers to Figure 6 of IEC 60364-1:2005, the three-wire supply system refers to Figure 7 of IEC 60364-1:2005.			

5.3.2 Preferred values of rated current (I_n)

Preferred values of rated currents are:

10 A – 13 A – 16 A – 20 A – 25 A – 32 A – 40 A – 63 A – 80 A –100 A – 125 A.

5.3.3 Standard values of rated residual operating direct current ($I_{\Delta n}$)

Standard values of rated residual operating direct current are:

0,02 A – 0,08 A – 0,3 A – 0,6 A – 1 A.

NOTE The value of 80 mA was the result of a calculation based on the content of 5.3.4 of IEC TS 60479-2:2007.

5.3.4 Standard value of residual non-operating direct current ($I_{\Delta no}$)

The standard value of residual non-operating direct current is 0,5 $I_{\Delta n}$.

5.3.5 Standard values of rated impulse withstand voltage (U_{imp})

The standard values of rated impulse withstand voltages as a function of voltage line-to-neutral and overvoltage category shall be given in the relevant product standard.

5.3.6 Standard values of operating time

5.3.6.1 Standard values of maximum break time for non-time delay DC-RCDs

Table 2 – Standard values of maximum break time for non-time-delay DC-RCDs

Type	I_n (A)	$I_{\Delta n}$ (A)	Standard values of break time at a residual operating direct current equal to (s)			
			$I_{\Delta n}$	2 $I_{\Delta n}$	3 $I_{\Delta n}$	1, 2, 5, 10, 20, 50, 100 A
General	Any value	Any value	0,3 [a]	0,15 [a]	0,04 [a]	0,4 [b]

NOTE The disconnection time of 0,4 s refers to the maximum disconnection time according to IEC 60364-4-41 for U_0 ≤ 230 V.

[a] For residual currents of 1 A and above, due to the arc extinction, the maximum break time shall not exceed 0,4 s.

[b] Due to the arc extinction, the overall disconnection time shall not exceed 0,4 s.

5.3.6.2 Standard values of actuating and non-actuating times for time-delay DC-RCDs

For time-delay type residual current devices, the non-actuating time at 2 $I_{\Delta n}$ shall be declared by the manufacturer.

Preferred values of minimum non-actuating time at 2 $I_{\Delta n}$:

0,06 s – 0,1 s – 0,2 s – 0,3 s – 0,4 s – 0,5 s – 1 s.

Type S DC-RCDs shall have a rated time delay equal to 0,06 s.

Time-delay type DC-RCDs are permitted only for $I_{\Delta n}$ higher than 0,08 A.

Table 3 – Standard values of break time and non-actuating time for time-delay DC-RCDs

Rated time delay (s)		Standard values of break and non-actuating time at (s)			
		$I_{\Delta n}$	2 $I_{\Delta n}$	3 $I_{\Delta n}$	(1, 2, 5, 10, 20, 50, 100) A
0,06	Maximum break time[c]	0,5 [d]	0,2 [d]	0,15 [d]	0,4 [e]
	Minimum non actuating time	[b]	0,06	[b]	[b]
Rated time delay	Maximum break time [c]	[a] [b]	[b]	[b]	[b]
	Minimum non actuating time	[b]	rated delay	[b]	[b]

NOTE The standard break times required by Table 3 are applicable for fault voltages up to 200 V to earth.

[a] To ensure fault protection, the maximum operating time shall be in accordance with IEC 60364-4-41.

[b] Defined either by the relevant product standard or by the manufacturer.

[c] For residual current devices with $I_{\Delta ndc}$ ≤ 0,08 A, the value for the maximum break time is given in Table 2.

[d] For residual currents of 1 A and above, due to the arc extinction, the maximum break time shall not exceed 0,4 s.

[e] Due to the arc extinction, the overall disconnection time shall not exceed 0,4 s.

5.3.7 Minimum value of the rated making and breaking capacity (I_m)

The minimum value of the rated making and breaking capacity I_m is 10 I_n or 500 A, whichever is the greater.

This applies to DC-RCDs without integral overcurrent protection.

5.3.8 Minimum value of the rated residual direct making and breaking capacity ($I_{\Delta m}$)

The minimum value of the rated residual direct making and breaking capacity ($I_{\Delta m}$) is 10 I_n or 500 A, whichever is the greater.

5.4 Coordination with short-circuit protective devices (SCPDs)

5.4.1 General

DC-RCDs shall be protected against short-circuits by means of circuit-breakers or fuses complying with their relevant standards according to the installation rules of IEC 60364 (all parts).

The association of a short-circuit protective device with a residual current device is intended to ensure adequate protection to the residual current device from the effects of short-circuit currents.

The short-circuit protective device shall be selected according to the following characteristics in line with the characteristics of the DC-RCD:

a) maximum let-through I^2t;

b) maximum value of let-through peak current I_p.

The rating and type of SCPD shall be the same for 5.4.2 and 5.4.3.

Coordination between DC-RCDs and the SCPD is verified according to the relevant test clauses which are designed to verify that there is an adequate protection of the DC-RCDs against short-circuit currents up to the conditional short-circuit current I_{nc} and up to the conditional residual direct short-circuit current $I_{\Delta c}$.

5.4.2 Preferred values of the rated conditional direct short-circuit current (I_{nc})

The preferred values of the rated conditional direct short-circuit current for DC-RCDs without integral short-circuit protection are:

1 500 A – 3 000 A – 4 500 A – 6 000 A – 10 000 A – 20 000 A – 50 000 A.

5.4.3 Preferred values of the rated conditional residual direct short-circuit current ($I_{\Delta c}$)

The preferred values of the rated conditional direct short-circuit current for DC-RCDs without integral short-circuit protection are:

1 500 A – 3 000 A – 4 500 A – 6 000 A – 10 000 A – 20 000 A – 50 000 A.

6 Marking and other product information

Table 4 – Marking for DC-RCDs

	Marking or Information item
A	The manufacturer's name or trade mark
B	Type designation, catalogue number or serial number
C	Rated voltage(s), for example 400 V DC followed by "DC" **DC**
D	Rated current, for example 40 A DC followed by "DC" **DC**
E	Void
F	Rated residual operating direct current followed by "DC" **DC**
G	Settings of residual operating direct current for DC-RCDs with multiple residual operating currents
H	Rated making and breaking capacity or rated short-circuit capacity (in amperes) for DC-RCDs with overcurrent protection
I	Reference calibration temperature, if different from 30 °C, for DC-RCDs with overcurrent protection
J	Rated residual direct making and breaking capacity
K	The degree of protection (only if different from IP 20)
L	The position of use, if necessary
M	The symbol S (S in a square) for type S devices
N	Void
O	Operating means of the test device, by the letter T
P [a]	Wiring diagram, see Figures 2 a) to d)
Q	Void
R	Void
S	Reference of the product standard, for example IEC 6xxxx
T	Void
U	Void
V	Rated time delay, if applicable
W	Rated conditional short-circuit direct current, if applicable, and in such a case characteristics for the associated short-circuit protective device, according to 5.4.1
X	Range of operating temperature
Y	Symbols I/O to distinguish between the open and closed states of the device
Z	Mark supply and load terminals (e.g. by "line" and "load") if it is necessary to distinguish between the supply and the load terminals
AA	Symbol M if terminals are specifically intended for the connection of the mid-point
AB	Time constant T15 within a rectangle, if applicable
AC	Marking of polarity for devices according to classification 4.15.1

[a] This information may be on the inside of any cover which has to be removed in order to connect the supply wires.

The information given in column 2 of Table 4 shall be provided. The position of the marking shall be specified in the relevant product standard (e.g. visible after installation, on the product, in the leaflet or manufacturer catalogue).

In addition, for r.c. units,

– they shall be marked with the maximum rated current of the circuit-breaker with which they can be assembled or associated, and

– information shall be given to indicate on which circuit-breaker the r.c. unit can be assembled or associated.

All relevant information for the correct assembly, if any, installation and use of the product shall be provided.

Compliance is checked by visual inspection and by the tests in the relevant product standard.

For DC-RCDs other than those operated by means of a push-button, the open position shall be indicated by the symbol "O" and the closed position by the symbol "|" (a short straight line). Additional national symbols are allowed for this indication. Provisionally, the use of national indications only is allowed. These indications shall be readily visible when the DC-RCD is installed.

For DC-RCDs operated by means of two push-buttons, the push-button designed for the opening operation only shall be red and/or be marked with the symbol "O".

Red shall not be used for any other push-button of the DC-RCD.

If a push-button is used for closing the contacts and is evidently identified as such, its depressed position is sufficient to indicate the closed position.

If a single push-button is used for closing and opening the contacts and is identified as such, the button remaining in its depressed position is sufficient to indicate the closed position. On the other hand, if the button does not remain depressed, an additional means indicating the position of the contacts shall be provided.

Terminals intended for the protective conductor, if any, shall be indicated by the symbol ⏚ (IEC 60417-5019:2006-08).

Marking shall be indelible, easily legible and not be placed on screws, washers or other removable parts.

For universal terminals (for rigid-solid, rigid-stranded and flexible conductors): no marking.

For non-universal terminals:

– terminals declared for rigid-solid conductors only shall be marked by the letters "s" or "sol";
– terminals declared for rigid (solid and stranded) conductors only shall be marked by the letter "r".

The markings should appear on the DC-RCD or, if the space available is not sufficient, on the smallest package unit or in the technical information.

7 Conditions for operation in service and for installation

7.1 Preferred ranges of application, reference values of influencing quantities/factors and associated test tolerances

DC-RCDs complying with this document shall be capable of operating under the standard conditions shown in Table 5.

Table 5 – Values of influencing quantities

Influencing quantity	Preferred range of application	Reference value	Test tolerances [f]
Ambient air temperature [a,g]	–5 °C to +40 °C –25 °C to +40 °C [a,b]	As stated by the relevant product standard	As permitted by the test requirements in the relevant product standard
Altitude	Not exceeding 2 000 m		
Relative humidity maximum value at 40 °C	50 % [c]		
External magnetic field	Not exceeding 5 times the earth's magnetic field in any direction	Earth's magnetic field	[d]
Position	As stated by the manufacturer, with a tolerance of 2° in any direction [e]	As stated by the manufacturer	2º in any direction
DC supply voltage	Maximum ripple of 5 % [f]	Rated value	±5 %

[a] The maximum value of the mean daily temperature is +35 °C.

[b] Values outside the range are admissible where more severe climatic conditions prevail, subject to agreement between manufacturer and user.

[c] Higher relative humidities are admitted at lower temperatures (for example 90 % at 20 °C).

[d] When a DC-RCD is installed in proximity to a strong magnetic field, supplementary requirements may be necessary.

[e] The device shall be fixed in such a way that it does not cause deformation liable to impair its functions.

[f] The tolerances given apply unless otherwise specified in the relevant test.

[g] Extreme limits of –20 °C and +60 °C are admissible during storage and transportation, and should be taken into account in the design of the device.

7.2 Conditions of installation

DC-RCDs shall be installed in accordance with the manufacturer's instructions.

7.3 Pollution degree

DC-RCDs complying with this document are intended for an environment with pollution degree 2, i.e. normally, only non-conductive pollution occurs; occasionally, however, a temporary conductivity caused by condensation may be expected.

The product standard may specify a higher value of pollution degree.

8 Requirements for construction and operation

8.1 Mechanical design

8.1.1 General

8.1.1.1 Requirements for any type of DC-RCDs

DC-RCDs shall be designed and constructed so that, in normal use, their use is safe and without danger to the user or to the environment.

The residual current detection and the residual current release may be located in different components, but the consequences of possible disconnection of the components shall be considered.

It shall not be possible to alter the operating characteristics of the DC-RCD by means of external interventions other than those specifically intended for changing the setting of the residual operating current or of the time delay.

Changing from one setting to another shall not be possible without a tool. It shall not be possible to disable or inhibit the DC-RCD function by any means.

NOTE For household and similar uses, in Argentina, Australia, Germany, Denmark, Italy, the UK and Switzerland, multiple settings are not allowed.

In case of a DC-RCD having multiple settings of residual operating current, the rating refers to the highest setting.

8.1.1.2 RC unit to be assembled on site to a circuit-breaker

Requirements for safe assembly and correct function shall be given in the relevant product standard.

8.1.2 Mechanism

The moving contacts of all poles of multipole DC-RCDs shall be coupled so that all poles, except the mid-point M-pole, if any, make and break substantially together, whether operated manually or automatically.

The mid-point M-pole of three-pole DC-RCDs shall not close after and shall not open before the other poles.

Compliance is checked by inspection and by manual tests, using any appropriate means (example: indicator lights, oscilloscope, etc.).

DC-RCDs shall have a trip-free mechanism.

It shall be possible to switch the DC-RCD on and off by manual operation.

DC-RCDs shall be so constructed that the moving contacts can come to rest only in the closed position (see IEC 62873-2) or in the open position (see IEC 62873-2), even when the operating means is released in an intermediate position.

DC-RCDs shall provide in the open position (see IEC 62873-2) an isolation distance in accordance with the requirements necessary to satisfy the isolating function (see 8.3).

Indication of the position of the main contacts shall be provided by one or both of the following means:

– the position of the actuator (this being preferred); or

– a separate indicator.

If a separate indicator is used to indicate the position of the main contacts, this shall show the colour red for the closed position and the colour green for the open position.

NOTE In the US, the colours red and green are not used for contact position indication.

The means of indication of the contact position shall be reliable.

Compliance is checked by inspection and/or tests, taking into account the instructions of the manufacturer.

8.1.3 Clearance and creepage distances

DC-RCDs shall have clearance and creepage distances capable of withstanding the voltage stresses during their anticipated lifetime, taking into account the overvoltage category and the pollution degree of the installation for which their use is intended.

The clearances and creepage distances for insulation and for isolation shall be in accordance with IEC 60664-1.

Compliance is checked by the tests of the relevant product standard.

8.1.4 Screws, current-carrying parts and connections

8.1.4.1 Connections

Connections, whether electrical or mechanical, shall withstand the mechanical stresses occurring in normal use.

Screws operated when mounting the DC-RCD during installation shall not be of the thread-cutting type.

NOTE Screws (or nuts) which are operated when mounting the DC-RCD include screws for fixing covers or cover-plates, but not connecting means for screwed conduits and for fixing the base of a DC-RCD.

Compliance is checked by the tests of the relevant product standard.

8.1.4.2 Screws in engagement with a thread of insulating material

For screws in engagement with a thread of insulating material and which are operated when mounting the DC-RCD during installation, correct introduction of the screw into the screw hole or nut shall be ensured.

Compliance is checked by inspection and by manual test.

NOTE The requirement with regard to correct introduction is met if introduction of the screw in a slanting manner is prevented, for example by guiding the screw by the part to be fixed, by a recess in the female thread or by the use of a screw with the leading thread removed.

8.1.4.3 Electrical connections

Electrical connections shall be so designed that contact pressure is not transmitted through insulating material other than ceramic, pure mica or other material with characteristics no less suitable, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or yielding of the insulating material.

Compliance is checked by inspection.

NOTE The suitability of the material is considered in respect of the stability of the dimensions.

8.1.4.4 Current-carrying parts

Current-carrying parts including parts intended for protective conductors, if any, shall be made of a metal having, under the conditions occurring in the equipment, mechanical strength, electrical conductivity and resistance to corrosion adequate for their intended use.

Examples of suitable materials are given below:

– copper;
– an alloy containing at least 58 % copper for parts worked cold, or at least 50 % copper for other parts;

– other metal or suitably coated metal, no less resistant to corrosion than copper and having mechanical properties no less suitable.

The requirements of 8.1.4.4 do not apply to contacts, magnetic circuits, heater elements, bimetals, shunts, parts of electronic devices nor to screws, nuts, washers, clamping plates, similar parts of terminals and parts of the test circuit.

Compliance is checked by the tests of the relevant product standard.

8.1.5 Terminals for external conductors

Terminals for external conductors, if any, shall be such that the conductors may be connected so as to ensure that the necessary contact pressure is maintained permanently.

NOTE For the purpose of defining requirements and tests, IEC 60999 (all parts) can be referred to.

Compliance is checked by the tests of the relevant product standard.

8.2 Protection against electric shock

DC-RCDs shall be so designed that, when they are mounted and wired as for normal use, live parts are not accessible.

A part is considered to be "accessible" if it can be touched by the jointed test finger, according to IEC 60529.

NOTE The term "normal use" implies that DC-RCDs be installed according to the manufacturer's instructions.

Metallic operating means shall be insulated from live parts and their conductive parts which otherwise would be "exposed conductive parts" shall be covered by insulating material, with the exception of means for coupling insulated operating means of several poles.

Metal parts of the mechanism shall not be accessible.

Lacquer and enamel are not considered to provide adequate insulation for the purpose of 8.2.

Compliance is checked by the tests of the relevant product standard.

8.3 Dielectric properties and isolating capability

DC-RCDs shall have adequate dielectric properties.

Control circuits connected to the main circuit shall not be damaged by high DC voltage due to insulation measurements which are normally carried out after DC-RCDs are installed.

When drafting product standards, consideration shall be given to the requirements for isolation capability included in IEC 61140 and IEC 60364-4-41.

Compliance is checked by the tests of the relevant product standard.

8.4 Temperature-rise

The DC-RCDs shall not suffer damage impairing their functions and their safe use taking into account the ambient temperature at which they are intended to be used.

Compliance is checked by the tests of the relevant product standard.

8.5 Operating characteristics

8.5.1 General

DC-RCDs shall operate according to the requirements of the 8.5.2 and 8.5.3, as applicable.

Compliance is checked by the tests of the relevant product standard.

8.5.2 Operation in response to a residual current equal to and greater than $I_{\Delta n}$

The tripping characteristic of DC-RCDs shall ensure adequate protection against residual current without premature operation.

DC-RCDs shall operate in response to a steady increase of smooth direct residual current within specified limits of the non-operating current and the operating current in accordance with Table 6.

Table 6 – Tripping current limits

Number of poles	Current shape	Tripping current	
		Lower limit	Upper limit
All classifications	Smooth DC	$0{,}5\ I_{\Delta n}$	$I_{\Delta n}$

The limits shall be independent of the polarity of the smooth direct residual current.

8.5.3 Operation in response time in presence of a residual current equal to and greater than $I_{\Delta n}$

8.5.3.1 General

Compliance is checked by the tests of the relevant product standard.

8.5.3.2 DC-RCDs without time-delay

The operation of DC-RCDs to a suddenly applied residual current shall be in accordance with Table 2 and independent of polarity.

8.5.3.3 DC-RCDs with time-delay

The operation and non-operation of DC-RCDs to a suddenly applied residual current shall be in accordance with Table 3 and independent of polarity.

8.6 Mechanical and electrical endurance

DC-RCDs shall be capable of performing an adequate number of mechanical and electrical operations.

Compliance is checked by the tests of the relevant product standard.

8.7 Performance at short-circuit currents

DC-RCDs shall be capable of performing a specified number of short-circuit operations during which they shall neither endanger the operator nor initiate a flashover between live conductive parts or between live conductive parts and earth.

Compliance is checked by the tests of the relevant product standard.

8.8 Resistance to mechanical shock and impact

DC-RCDs shall have adequate mechanical behaviour so as to withstand the stresses imposed during installation and use.

Compliance is checked by the tests of the relevant product standard.

8.9 Resistance to heat

DC-RCDs shall be sufficiently resistant to heat.

Compliance is checked by the tests of the relevant product standard.

8.10 Resistance to abnormal heat and to fire

External parts of DC-RCDs made of insulating material shall not be liable to ignite and to spread fire if current-carrying parts in their vicinity, under fault or overload conditions, attain a high temperature. The resistance to abnormal heat and to fire of the other parts made of insulating material is considered as checked by the other tests of this document.

Compliance is checked by the tests of the relevant product standard.

8.11 Test device

DC-RCDs shall be provided with a test device to simulate the passing through the detecting device of a residual current in order to allow a periodic testing of the ability of the residual current device to operate.

NOTE The test device is intended to check the tripping function, not the value at which this function is effective with respect to the rated residual operating current and the break times.

The test current produced when operating the test device of DC-RCDs supplied at rated voltage or at the highest value of the voltage range shall be defined by technical committees when drafting product standards.

It is recommended that for household application and similar uses the value of the simulated test current does not exceed the equivalent of 2,5 times the residual current $I_{\Delta n}$ through one of the poles of the DC-RCD.

The protective conductor of the installation shall not become live when the test device is operated.

It shall not be possible to energize the circuit on the load side by operating the test device when the DC-RCD is in the open position and connected as in normal use.

The test device shall not be the sole means of performing the opening operation, except for DC-RCDs providing the possibility of unplugging the protected circuit.

Compliance is checked by the tests of the relevant product standard.

8.12 Requirements for DC-RCDs in case of loss of supply

The minimum operating voltage of DC-RCDs shall not exceed 90 V.

DC-RCDs classified according to 4.8.3 or 4.8.4 shall operate also in case of loss of one supply conductor, line or mid-point M.

Compliance is checked by the tests of the relevant product standard.

8.13 Behaviour of DC-RCDs in case of overcurrent in the main circuit

DC-RCDs without integral overcurrent protection shall not operate under specified conditions of overcurrents.

Compliance is checked by the tests of the relevant product standard.

8.14 Behaviour of DC-RCDs in the case of current surges caused by impulse voltages

DC-RCDs shall adequately withstand the current surges to earth due to the loading of the capacitances of the installation and the current surges to earth due to flashover in the installation. DC-RCDs of the type S shall additionally show adequate resistance against unwanted tripping in case of current surges to earth due to flashover in the installation.

Compliance is checked by the tests of the relevant product standard.

8.15 Void

8.16 Reliability

DC-RCDs shall operate reliably even after long service, taking into account the ageing of their components.

Compliance is checked by the tests of the relevant product standard.

8.17 Electromagnetic compatibility (EMC)

DC-RCDs shall operate reliably, even in presence of electromagnetic disturbances, and shall comply with relevant EMC requirements.

The operating characteristics shall not be affected by high frequency ripple.

Compliance is checked by the tests of the relevant product standard.

8.18 Resistance to temporary overvoltages (TOVs)

DC-RCDs shall adequately withstand temporary overvoltages due to various phenomena.

NOTE Overvoltages can be caused by a fault in the high-voltage network; break of mid-point conductor; short-circuit between line conductor and mid-point conductor.

Withstand values of overvoltage and duration are given in the following Table 7, $U_{(\text{L to M})}$ being the nominal value between L+ or L- to mid-point M.

Table 7 – Withstand values and duration of temporary overvoltages

TOV		
Occurrence	**Voltage**	**Duration**
Between mid-point M-pole and all other poles	2 x $U_{(\text{L to M})}$	1 h

Compliance is checked by the tests of the relevant product standard.

8.19 Performance of DC-RCDs at inrush currents

DC-RCDs shall withstand inrush currents resulting from the charging of cable and load capacitance. They shall have a sufficient withstand against unwanted tripping and also against contact welding.

Compliance is checked by the tests of 9.10.4.

9 Preparation of test clauses for DC-RCDs product standard

9.1 General

9.1.1 General test conditions

Clause 9 defines the specific rules in order to prepare the test clauses of a DC-RCD product standard, taking into account the requirements of this document.

Clause 9 is not intended to be used as a testing procedure for DC-RCDs, but the tests shall be specified in the relevant DC-RCD standard, according to the requirements of this document.

A testing procedure shall be introduced in the product standard for DC-RCDs. This testing procedure shall ensure that each requirement included in this document is fulfilled by the DC-RCD. Technical committees may provide additional testing.

The test procedure of the DC-RCD product standard shall specify the following items, as applicable:

– the ambient and electrical test conditions and tolerances, according to the standard conditions for operation in service (see Table 5);
– the conditions of installation of the DC-RCD (see 7.2) for the tests;
– cross-section, type, length of conductors to be connected to the DC-RCD for the tests;
– tightening torque to be applied to the terminals;
– compliance criteria.

NOTE The information for instrument measurement is available in IECEE OD-5014.

The test sequences, number of samples and acceptance criteria shall be given by the relevant product standard.

9.1.2 Test clauses not specified in this document

The following tests are not specified in this document, but shall be specified in the relevant product standard:

– terminals for external conductors;
– reliability of screws and current carrying parts;
– protection against electric shocks;
– dielectric properties;
– temperature rise;
– resistance to mechanical shocks;
– resistance to heat;
– resistance to abnormal heat and fire.

9.2 Operating characteristics

9.2.1 General requirements for operating characteristics tests

The test procedure shall define the test circuit for performing operating characteristics tests. The instruments for the measurement of the residual current shall display (or allow to determine) the true RMS value.

The test procedure for the DC-RCD shall include tests based on the requirements of 9.2.2, 9.2.3, 9.2.4, 9.2.5, 9.2.6, 9.2.7, 9.2.8 as applicable. Each test shall be made with smooth DC residual current on one pole only, taken at random, with at least two measurements; the polarity of the smooth DC current is changed after each measurement.

All tests are performed at 1,1 U_n and minimum operating voltage, with no load, unless otherwise specified.

For DC-RCDs having multiple settings of residual operating current, the tests shall be made at the lowest setting, highest setting and at least at one intermediate setting.

9.2.2 Steady increase of residual current

Correct operation of the DC-RCD shall be tested where the RCD being in the closed position, a residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, trying to attain the value of $I_{\Delta n}$ within 30 s, and the tripping current shall be measured. The measured values shall be situated between $I_{\Delta no}$ and $I_{\Delta n}$.

9.2.3 Closing on a residual current

Correct operation of the DC-RCD shall be tested with the circuit being calibrated at the rated value of the operating residual current, the DC-RCD being in open position, and the RCD is suddenly closed on the circuit. The measurements of the break time shall not exceed the value of Table 2 or Table 3, according to the type of DC-RCD.

9.2.4 Sudden appearance of residual current

Correct operation of the DC-RCD shall be tested with the circuit being calibrated at each value of residual current of Table 2 or Table 3 as applicable, the DC-RCD being in closed position, and the residual current is suddenly established. The measurements of the break time shall not exceed the value of Table 2 or Table 3, according to the type of DC-RCD.

9.2.5 Residual current higher than 3 $I_{\Delta n}$

Correct operation of the DC-RCD, according to 9.2.4, shall be tested for values of residual current higher than 3 $I_{\Delta n}$ and lower than the rated residual direct making and breaking capacity ($I_{\Delta m}$). The values of residual current for these tests shall be specified in the relevant DC-RCD standard.

9.2.6 Tests with load

Correct operation of the DC-RCD shall be tested, according to 9.2.3 and 9.2.4, the DC-RCD being loaded with the rated current.

9.2.7 Tests at the temperature limits

Correct operation of the DC-RCD, according to 9.2.4, shall be tested at the minimum ambient temperature, with no load, and then at the maximum ambient temperature, the DC-RCD being loaded at the rated current.

9.2.8 Additional test for delay type RCDs

Correct operation of delay type DC-RCDs shall be tested according to Table 3: the DC-RCD being in the closed position, the residual current is suddenly established for periods corresponding to the relevant minimum non-actuating times. The DC-RCD shall not trip during these tests.

9.3 Tests of electrical endurance

The test procedure shall be specified in the relevant product standard and shall specify the test circuit for performing electrical endurance tests. The product standard shall include the following testing conditions:

– number of electrical operations;

– time constant according to classification 4.15.

The tests shall be performed at the rated current and the rated operational voltage. At least 25 % of all electrical operations shall be performed by actuating the test device and a further 25 % (at least) shall be performed by applying a residual current of $I_{\Delta n}$ to any pole.

The relevant product standard shall also specify the acceptance criteria after this test.

9.4 Tests of behaviour of the DC-RCD under short-circuit conditions

9.4.1 General

The test procedure shall define the test circuit for performing short-circuits tests.

The test procedure for the DC-RCD shall include the tests based on the requirements of 9.4.2 a), b), c), d), e), f), g), as applicable. After the tests, the DC-RCD shall be tested according to test procedure of 9.4.3.

For residual current devices with integral overcurrent protection, the tests 9.4.2 a), c), d), e), f), g) need not be introduced in the test procedure. These tests and the consequent verification are replaced by specific short-circuit tests based on the relevant circuit-breaker standard.

The test procedure of the DC-RCD product standard shall specify the following items, as applicable:

– test circuit;

– minimum I^2t and I_p values of the SCPD to be associated with the DC-RCD for coordination tests according to 9.4.2 c), d) and e);

– time constant according to classification 4.15;

– power recovery voltage;

– tolerances on test quantities: current, time constant, voltage;

– the coordination tests 9.4.2 c), d) and e) shall be performed with an SCPD as declared by the manufacturer.

9.4.2 Short-circuit tests

The recommended diagram for short-circuit tests is given in Annex A.

a) Test of verification of the rated making and breaking capacity (I_m)

This test is intended to verify the ability of the DC-RCD to make, to carry for a specified time, and to break short-circuit currents, while a residual current causes the DC-RCD to operate.

The DC-RCD is tested with a current of I_m in a circuit according to the general test conditions specified in 9.4.1, no SCPD being inserted in the circuit.

With a residual operating current equal to 10 $I_{\Delta n}$, the following sequence of operation is performed:

CO – t – CO – t – CO

b) Test of verification of the rated residual direct making and breaking capacity ($I_{\Delta m}$)

This test is intended to verify the ability of the DC-RCD to make, to carry for a specified time, and to break a residual short-circuit current.

The DC-RCD is tested according to the general test conditions specified in 9.4.1, no SCPD being inserted in the circuit, but connected in such a manner that the short-circuit current is a residual current.

The current paths which do not have to carry the residual short-circuit current are connected to the supply voltage at their line terminals.

The following sequence of operations is performed:

O – t – CO – t – CO

c) Test of verification of the coordination between the DC-RCD and the SCPD at the rated conditional short-circuit current (I_{nc})

This test is intended to verify that the DC-RCD, protected by the SCPD, is able to withstand, without damage, the rated conditional short-circuit current. The test is made without establishing any residual current.

The short-circuit current is interrupted by the association of the DC-RCD and the SCPD. The following sequence of operations is performed:

O – t – CO

d) Test of verification of the coordination at the rated making and breaking capacity (I_m)

This test is intended to check that at short-circuit currents of a value corresponding to the rated making and breaking capacity I_m, the SCPD operates and protects the DC-RCD. The test is made without establishing any residual current.

The short-circuit current is interrupted by the association of the DC-RCD and the SCPD. The following sequence of operations is performed:

O – t – CO – t – CO

e) Test of verification of the coordination at rated conditional residual short-circuit current ($I_{\Delta c}$)

This test is intended to check that in the case of phase-to-earth short-circuits with currents up to the value of the rated conditional residual short-circuit current $I_{\Delta c}$, the DC-RCD is able to withstand the corresponding stresses.

The short-circuit current is interrupted by the association of the DC-RCD and the SCPD. The DC-RCD shall be tested in such a manner that the short-circuit current is a residual current.

The following sequence of operations is performed:

O – t – CO – t – CO

f) Test of verification of behaviour in IT systems

This test is applicable for DC-RCDs intended to be used in IT systems. The test is performed in the following conditions:

– at a voltage 105 % of the rated L+ to L- voltage for the poles intended to be connected to the line conductors and at a voltage of 105 % of line to midpoint voltage for the pole marked M if any;
– at a current of 500 A or 10 In whichever is the greater.

Each pole is subjected individually to a test.

The test sequence is:

O – t – CO

g) Verification of small DC currents

The DC-RCD condition and method of installation shall be as specified in 9.4.1, but with a time constant of 2 ms.

The test shall be made at the maximum operational DC voltage assigned by the manufacturer to the DC-RCD.

The DC-RCD is closed three times for each of the test currents listed below. During the test, the operating means are operated as in normal use. If the DC-RCD does not open, it will be opened manually.

Test currents: 1 A, 2 A, 4 A, 8 A, 16 A, 32 A, 63 A, 150 A.

The time interval between the individual operating cycles CO shall be at least 10 s, and the closing time shall not exceed 2 s. The time interval between the tests for different currents shall be at least 2 min.

During the test, the time required for the arc to be extinguished shall not exceed 1 s.

9.4.3 Behaviour of the DC-RCD during and after the tests

During these tests, it shall be verified that the indicating means show the open position when the contacts are in the open position and show the closed position when the contacts are in the closed position.

After each of the tests applicable, carried out in accordance with 9.4.2 a), b), c), d), e), f) and g), the DC-RCD shall show no damage impairing its further use and shall be capable, without maintenance, of withstanding the following tests:

– leakage current across open contacts, not higher than 2 mA at 1,1 times the rated voltage;
– dielectric strength tests after the short-circuit test at a voltage at least equal to twice the rated voltage, for 1 min;
– making and breaking its rated current at its rated voltage.

Under the test conditions of 9.2.4, the DC-RCD shall trip with a test current of 1,25 $I_{\Delta n}$. One test only is made on one pole taken at random, without measurement of break time.

9.5 Test of the trip-free mechanism

A test procedure shall be introduced in the relevant DC-RCD standard in order to verify the trip-free mechanism. The test procedure shall verify that when the operating means are held in the closed position, the DC-RCD trips when a residual current is applied. This test is performed with a residual current greater than $I_{\Delta n}$.

9.6 Verification of the operation of the test device

A test procedure shall be introduced in the relevant DC-RCD standard covering at least the following:

a) the DC-RCD being supplied with a voltage equal to 0,85 times the rated voltage, the test device is momentarily actuated 25 times at intervals of 5 s, the DC-RCD being reclosed before each operation;

b) test a) is then repeated at 1,1 times the rated voltage;

c) test b) is then repeated, but only once, the operating means of the test device being held in the closed position for 30 s.

In case of DC-RCDs with unidentified line and load terminals, the supply shall be connected to each set of terminals in turn or alternatively to both sets of terminals simultaneously. For each test, the DC-RCD shall operate. After the test, the sample shall show no change impairing its further use.

It shall be verified that the simulated test current does not exceed the equivalent of 2,5 times the residual current $I_{\Delta n}$ through one of the poles of the DC-RCD. For example, the resistance of the circuit of the test device may be measured and the test current calculated, taking into account the configuration of the circuit of the test device.

9.7 Test of behaviour of DC-RCDs in case of current surges caused by impulse voltages

9.7.1 Current surge test for all DC-RCDs (0,5 µs/100 kHz ring wave test)

A test procedure shall be introduced in the relevant DC-RCD standard covering at least the following.

The DC-RCD is tested using a surge generator capable of delivering a damped oscillator current wave as shown in Figure 1. One pole of the DC-RCD, chosen at random, shall be submitted to 10 applications of the surge current. The polarity of the surge wave shall be inverted after every two applications. The interval between two consecutive applications shall be about 30 s.

The current impulse flowing through the DC-RCD shall be measured by appropriate means to meet the following requirements:

– peak value: 200 A with a tolerance of 0 % + 10 %;

– virtual front time: 0,5 µs ± 30 %;

– period of the following oscillatory wave: 10 µs ± 20 %.

During the tests, when supplied with rated voltage, the DC-RCD shall not trip. Technical committees shall define the appropriate operating characteristics tests to be performed after the ring-wave test.

9.7.2 Verification of behaviour with surge currents (8/20 µs surge current test)

For DC-RCDs, technical committees shall include the following test. The DC-RCD is tested using a current generator capable of delivering a damped surge current 8/20 µs according to IEC 60060-1 and IEC 60060-2.

One pole of the DC-RCD chosen at random shall be submitted to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications.

The interval between two consecutive applications shall be about 30 s.

The current impulse flowing through the DC-RCD shall be measured by appropriate means to meet the following requirements:

– peak value: 350 A 0 % + 10 %, with no tripping, and 3 000 A 0 % + 10 %, with tripping allowed;
– virtual front time: 8 µs ± 20 %;
– virtual time to half value: 20 µs ± 20 %;
– peak of reverse current: less than 30 % of peak value.

After the surge current tests, the correct operation of the DC-RCD is verified by a test according to 9.2.4, at $I_{\Delta n}$ only, with the measurement of the break time.

9.8 Tests of reliability

9.8.1 Climatic test

A test procedure shall be introduced in the relevant DC-RCD standard covering at least the following requirements.

The test is carried out according to IEC 60068-2-30, taking into account IEC 60068-3-4.

The chamber shall be constructed as stated in Clause 4 of IEC 60068-2-30:2005. Condensed water shall be continuously drained from the chamber and not used again until it has been re-purified.

Only distilled water having resistivity of not less than 500 Ω and a pH value of 7,0 ± 0,2 shall be used for the maintenance of chamber humidity.

The upper temperature shall be 55 °C ± 2 °C (variant 1 according to IEC 60068-2-30) and the number of cycles shall be 28.

During the test, the DC-RCD shall be supplied with rated voltage.

At the end of the cycles, the DC-RCD shall be capable of complying with the tests of 9.2.4, but with a residual operating current of 1,25 $I_{\Delta n}$ and without measurement of break time.

9.8.2 Test with temperature of 40 °C

For standards covering DC-RCDs for household and similar applications, a test procedure shall be introduced in the relevant DC-RCD standard covering at least the following requirements.

The DC-RCD is mounted as for normal use on a dull black painted plywood board, about 20 mm thick.

The assembly is placed in a heating cabinet.

The DC-RCD is loaded with a current equal to the rated current at any convenient voltage and is subjected, at a temperature of 40 °C ± 2 °C, to 28 cycles, each cycle comprising 21 h with current passing and 3 h without current and without supply voltage. The current is interrupted by an auxiliary switch, the DC-RCD not being operated.

At the end of the last period of 21 h with current passing, a temperature rise test of terminals shall be required by the product standard.

After this test, the DC-RCD in the cabinet is allowed to cool down to approximately room temperature without current passing.

The DC-RCD shall be capable of complying with the tests of 9.2.4, but with a residual operating current of 1,25 $I_{\Delta n}$ and without measurement of break time.

9.9 Verification of ageing of electronic components

The DC-RCD is placed for a period of 168 h in an ambient temperature of 40 °C ± 2 °C and loaded with the rated current. The voltage on the electronic parts shall be 1,1 times the rated voltage.

After this test, the DC-RCD in the cabinet is allowed to cool down to approximately room temperature without current passing. The electronic parts shall show no damage.

Under the conditions of tests specified in 9.2.4, the DC-RCD shall trip with a test current of 1,25 $I_{\Delta n}$. One test only is made on one pole taken at random without measurement of break time.

An example of the test circuit for this verification is given in Figure 4.

9.10 Tests of electromagnetic compatibility (EMC)

9.10.1 General

Technical committees shall introduce EMC tests based on the intended use of the DC-RCD and on the possible environmental influences that may affect the correct operation of the DC-RCD.

When drafting standards, technical committees shall at least consider the requirements of the following IEC generic standards:

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

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

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

Test levels and acceptance criteria shall be defined by the technical committees taking into account that DC-RCDs are used to protect people against electric shock. Higher test levels than those specified in the generic standards may be appropriate.

9.10.2 General requirements

For DC-RCDs, technical committees shall introduce EMC tests according to IEC 61543 (see Table 8).

– **Criteria C1**

During the test making reference to these performance criteria, the DC-RCD shall remain closed at a continuously applied residual current of 0,3 $I_{\Delta n}$, and shall trip at 1,25 $I_{\Delta n}$.

– **Criteria C2**

During the test making reference to these performance criteria, the DC-RCD shall not trip. After the test, compliance with 9.2.4 at $I_{\Delta n}$ only shall be checked.

– **Criteria C3**

During the test making reference to these performance criteria, the DC-RCD may trip. After the test, compliance with 9.2.4 at $I_{\Delta n}$ only shall be checked.

Table 8 – List of electromagnetic phenomena covered by IEC 61543

Reference to Tables 1, 2, 3, 4, 5 and 6 of IEC 61543:1995, IEC 61543:1995/AMD1:2004 and IEC 61543:1995/AMD2:2005	Electromagnetic phenomena	Applicability of IEC 61543
T1.1	Harmonics, interharmonics	Applicable
T1.2	Signalling voltage	Applicable
T1.3	Voltage amplitude variations	To be covered by DC-RCDs product standard
T1.4	Voltage unbalance	To be covered by DC-RCDs product standard
T1.5	Power-frequency variations	Not applicable
T1.8	Magnetic fields	To be covered by DC-RCDs product standard
T2.1	Conducted sine-wave form voltages or currents	Applicable with specific performance criteria: **C1** The test level shall be 3 V according to IEC 61000-4-6.
T2.2	Fast transients (burst) – Common mode	Applicable with specific performance criteria: **C2** The test level 4 shall be according to IEC 61000-4-4.
T2.3a	Surges	Applicable with specific performance criteria: **C2** or **C3** The test level shall be 5 kV / 12 Ω (peak) for common mode and the test level shall be 4 kV/2 Ω (peak) for differential mode according to IEC 61000-4-5
T2.3b	Surges	Applicable with specific performance criteria: **C2** The test level shall be 4 kV/12 Ω (peak) for common mode and the test level shall be 2 kV/2 Ω (peak) for differential mode according to IEC 61000-4-5
T2.4	Current oscillatory transients (ring wave)	To be covered by DC-RCDs product standard
T2.5	Radiated electromagnetic field	Applicable with specific performance criteria: **C1** The test level shall be 3 V/m according to IEC 61000-4-3
T2.6	Conducted common mode disturbances in the frequency range lower than 150 kHz	Applicable with specific performance criteria: **C1** The test level 3 shall be according to IEC 61000-4-16.

Reference to Tables 1, 2, 3, 4, 5 and 6 of IEC 61543:1995, IEC 61543:1995/AMD1:2004 and IEC 61543:1995/AMD2:2005	Electromagnetic phenomena	Applicability of IEC 61543
T3.1	Electrostatic discharges	Applicable with specific performance criteria: **C3** The test level 3 shall be according to IEC 61000-4-2.

9.10.3 Specific requirements on ripple immunity

IEC 61000-4-17 ripple on DC input power port immunity test: the test level 3 shall be according to IEC 61000-4-17 with performance criteria **C1**.

9.10.4 Verification of behaviour during inrush currents

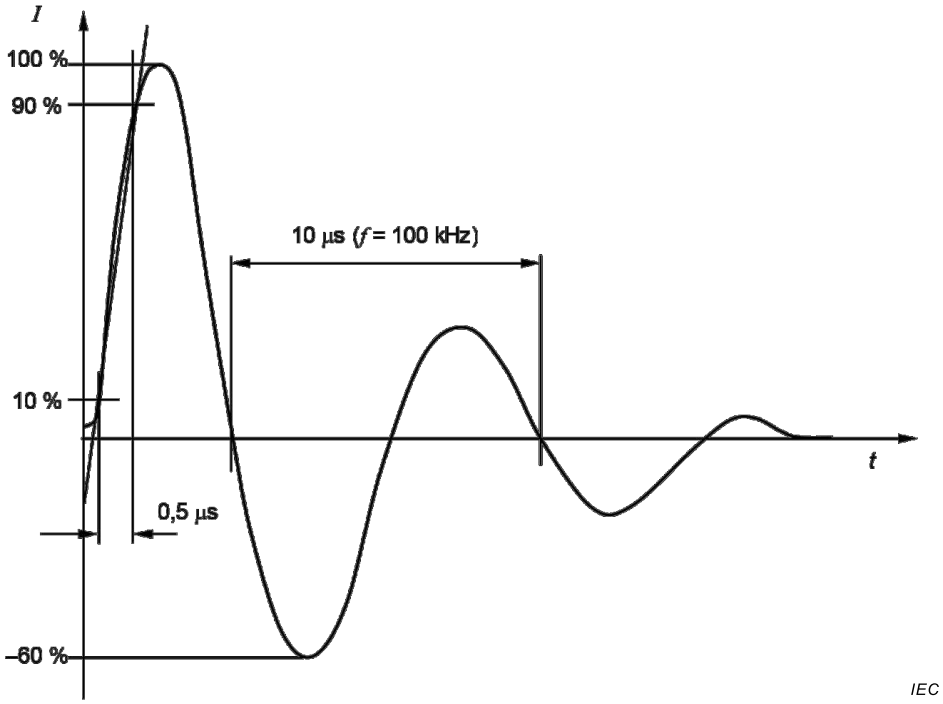
The DC-RCD shall be tested with a downstream circuit simulating inrush currents in a real DC application.

The downstream circuit is shown in Figure 3.

One pole of the DC-RCD chosen at random shall be submitted to 10 applications of the inrush current. The polarity of the inrush current wave shall be inverted after every 2 applications. The interval between 2 consecutive applications shall be about 30 s, whereas always after 15 s the current is switched OFF.

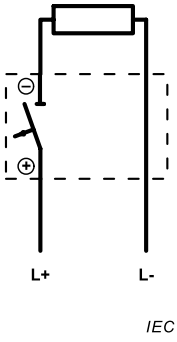
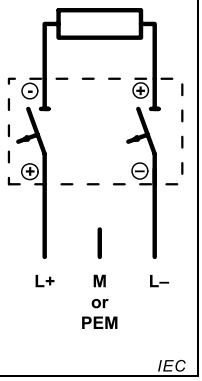
The peak value of the prospective inrush current shall be adjusted to 350 A (-0 %, +10 %) and the load current in the steady state shall be the rated current I_n.

During the tests, the DC-RCD shall not trip.

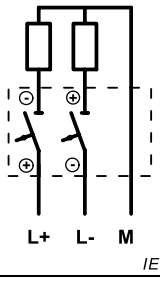
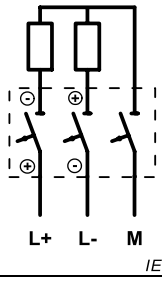


Care has to be taken that the oscillating wave is guaranteed at least up to the 5th full period (50 µs).

Figure 1 – Damped oscillator current wave 0,5 µs/100 kHz

	a)	b)
Rated operational voltage of the DC-RCD	200 V	400 V
Maximum voltage between lines	200 V	400 V
Maximum voltage between line and earth	200 V	200 V
DC-RCD	single-pole with two current paths	two-pole
Circuit		

Figures 2 a) and b) – Examples of installations with DC-RCDs in different DC supply systems

	c)	d)
Rated operational voltage of the DC-RCD	400 V	400 V
Maximum voltage between lines	400 V	400 V
Maximum voltage between line and earth	200 V	200 V
DC-RCD	two-pole with three current paths	three-pole
Circuit		

Figures 2 c) and d) – Examples of installations with DC-RCDs in different DC supply systems

Figure 2 – Examples of installation

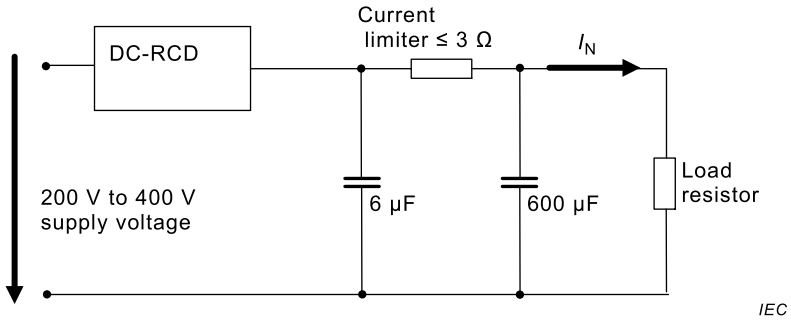


Figure 3 – Downstream circuit for simulating inrush currents

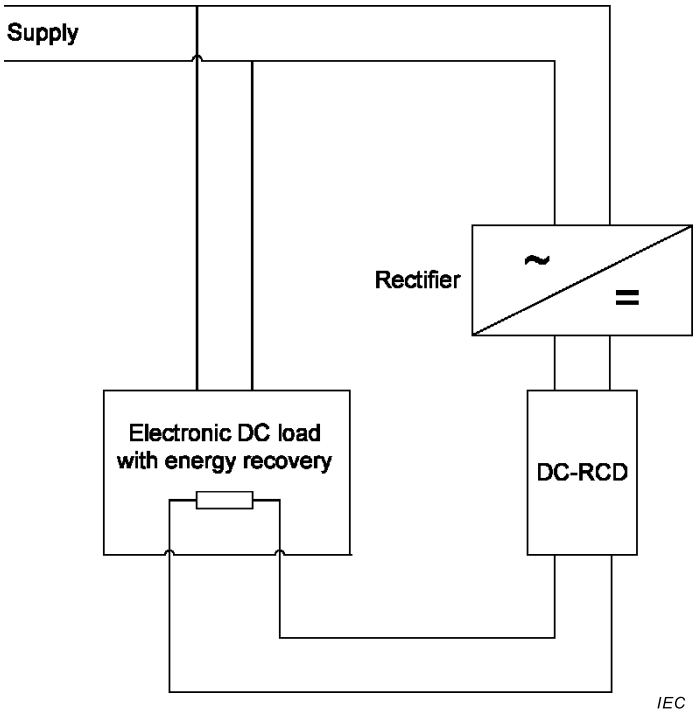


Figure 4 – Example of test circuit for verification of ageing of electronic components

Annex A
(informative)

Recommended diagram for short-circuit tests

Figure A.1and Figure A.2 give diagrams of the circuits to be used for the short-circuit tests concerning:

– a single-pole DC-RCD with two current paths;
– a two-pole DC-RCD (with one or two current paths);
– a two-pole DC-RCD (with three current paths);
– a three-pole DC-RCD.

The resistances and reactances of the impedances Z and Z_1 (Figure A.2) shall be adjustable to satisfy the specified test conditions. The reactors shall preferably be air-cored; they shall always be connected in series with the resistors and their value shall be obtained by series coupling of individual reactors; parallel connecting of reactors is permitted when these reactors have practically the same time-constant.

Since the transient recovery voltage characteristics of test circuits, including large air-cored reactors, are not representative of normal service conditions, the air-cored reactor in any phase shall be shunted by a resistor r taking approximately 0,6 % of the current through the reactor.

If iron-core reactors are used, the iron-core power losses of these reactors shall not exceed the losses that would be absorbed by the resistors connected in parallel with the air-cored reactors.

In each test circuit for testing the rated short-circuit capacity, the impedances Z are inserted between the supply source S and the device under test.

When tests are made with current less than the rated short-circuit capacity, the additional impedances Z_1 shall be inserted on the load side of the circuit-breaker.

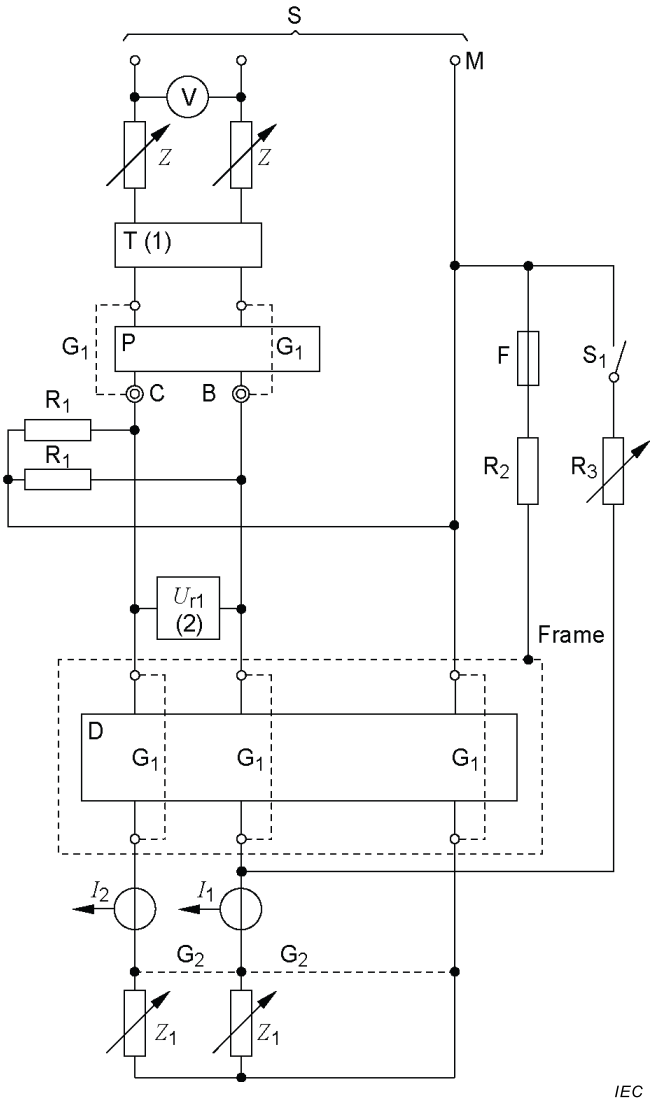
A resistor R_2 of about 0,5 Ω is connected in series with a copper wire F as shown in Figure A.1.

Single-pole DC-RCDs are tested in a circuit the diagram of which is shown in Figure A.1.

Two-pole DC-RCDs are tested in a circuit, the diagram of which is shown in Figure A.1, both poles being in the circuit irrespective of the number of current paths.

Three-pole DC-RCDs are tested in a circuit the diagrams of which are shown in Figure A.1.

The grid circuit shall be connected to the points B and C (see Figure A.1).



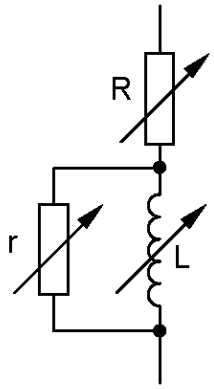
Key

M	=	Midpoint conductor
S	=	Supply (depending on the number of current paths of the device under test)
Z	=	Adjustable impedances
Z_1	=	Adjustable impedance to adjust the current below the rated short-circuit current
P	=	Short-circuit protective device (SCPD). It may be connected anywhere in the phase circuit upstream of the device under test
D	=	Device under test
frame	=	All conductive parts normally earthed in service
G_1	=	Temporary connection(s) for calibration
G_2	=	Connection(s) for the test with rated conditional short-circuit current
T	=	Device making the short-circuit. It may be connected anywhere in the phase circuit.
I_1, I_2	=	Current sensor(s). They may be placed before or after the device under test "D"
U_{r1}	=	Voltage sensor(s)
F	=	Device for the detection of a fault current
R_1	=	Resistor to draw a current of 10 A per phase on request of the manufacturer
R_2	=	Resistor limiting the current in the device F
R_3	=	Adjustable resistor for the calibration of I_Δ
S_1	=	Auxiliary switch
B and C	=	Points of connections of the grid(s)

NOTE 1 The closing device T can alternatively be situated between the load side terminals of the device under test and current sensors I_1, I_2, as applicable.

NOTE 2 The voltage sensors U_{r1} can, alternatively, be connected between phase and M.

Figure A.1 – Diagram for all the short-circuit tests



IEC

Key

r	=	Resistor(s) taking approximately 0,6 % of the current
L	=	Adjustable air cored inductance(s)
R	=	Adjustable resistor

NOTE The adjustable loads L, R and r can be located at the high-voltage side of the supply circuit, if applicable.

Figure A.2 – Detail of impedance Z or Z_1

Bibliography

IEC 60050-195:1998, *International Electrotechnical Vocabulary – Part 195: Earthing and protection against electric shock*

IEC 60050-442:1998, *International Electrotechnical Vocabulary – Part 442: Electrical accessories*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-42, *Low-voltage electrical installations – Part 4-42: Protection for safety – Protection against thermal effects*

IEC 60479 (all parts), *Effects of current on human beings and livestock*

IEC TS 60479-2:2007, *Effects of current on human beings and livestock – Part 2: Special aspects*

IEC TR 60755, *General safety requirements for residual current operated protective devices*

IEC 60999 (all parts), *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units*

IEC 62020, *Electrical accessories – Residual current monitors for household and similar uses (RCMs)*

IEC 62873-3-1, *Residual current operated circuit-breakers for household and similar use – Part 3-1: Particular requirements for RCDs with screwless-type terminals for external copper conductors*

IEC 62873-3-2, *Residual current operated circuit-breakers for household and similar use – Part 3-2: Particular requirements for RCDs with flat quick-connect terminations*

IEC 62873-3-3, *Residual current operated circuit-breakers for household and similar use – Part 3-3: Specific requirements for RCDs with screw-type terminals for external untreated aluminium conductors and with aluminium screw-type terminals for use with copper or with aluminium conductors*

CISPR 14-1, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

IECEE OD-5014, IECEE Operational document, IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE System), Committee of Testing Laboratories (CTL) Instrument Accuracy Limits. Available at: https://www.iecee.org/documents/refdocs/

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