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INTERNATIONAL STANDARD

colour inside

**Low-voltage switchgear and controlgear –
Part 2: Circuit-breakers**

IEC 60947-2:2016-06 RLV(en)

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

FOREWORD

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International Standard IEC 60947-2 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low-voltage.

This fifth edition cancels and replaces the fourth edition published in 2006, Amendment 1:2009 and Amendment 2:2013. This edition constitutes a technical revision.

This edition includes the following significant additions with respect to the previous edition:

- tests for verification of selectivity in Annex A (see A.5.3);
- critical load current tests for d.c. circuit-breakers (see 8.3.9);
- new Annex P for circuit-breakers for use in photovoltaic applications;
- new Annex R for residual-current circuit-breakers with automatic reclosing functions.

The text of this standard is based on the following documents:

FDIS	Report on voting
121A/71/FDIS	121A/83/RVD

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

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

A list of all parts in the IEC 60947 series, published under the general title *Low-voltage switchgear and controlgear*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 60947-1:2007 and its Amendment 1:2010 and Amendment 2:2014.

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1 and its amendments when applicable, for example, 1.2.3 of IEC 60947-1:2007, Table 4 of IEC 60947-1:2007/AMD1:2010, or Annex A of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

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

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- withdrawn,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

The contents of the corrigendum of November 2016 have been included in this copy.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

1 General

~~The provisions of the general rules dealt with in IEC 60947-1 are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1, for example, 1.2.3 of IEC 60947-1, Table 4 of IEC 60947-1, or Annex A of IEC 60947-1.~~

1.1 Scope and object

This part of IEC 60947 series applies to circuit-breakers, the main contacts of which are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.; it also contains additional requirements for integrally fused circuit-breakers.

Circuit-breakers rated above 1 000 V a.c. but not exceeding 1 500 V a.c. may also be tested to this standard.

It applies whatever the rated currents, the method of construction or the proposed applications of the circuit-breakers may be.

The requirements for circuit-breakers which are also intended to provide earth leakage protection are contained in Annex B.

The additional requirements for circuit-breakers with electronic over-current protection are contained in Annex F.

The additional requirements for circuit-breakers for IT systems are contained in Annex H.

The requirements and test methods for electromagnetic compatibility of circuit-breakers are contained in Annex J.

The requirements for circuit-breakers not fulfilling the requirements for over-current protection are contained in Annex L.

The requirements for modular residual current devices (without integral current breaking device) are contained in Annex M.

The requirements and test methods for electromagnetic compatibility of circuit-breaker auxiliaries are contained in Annex N.

The requirements and test methods for d.c. circuit-breakers for use in photovoltaic (PV) applications are contained in Annex P.

The requirements and test methods for circuit-breakers incorporating residual current protection with automatic reclosing functions are contained in Annex R.

Supplementary requirements for circuit-breakers used as direct-on-line starters are given in IEC 60947-4-1, applicable to low-voltage contactors and starters.

The requirements for circuit-breakers for the protection of wiring installations in buildings and similar applications, and designed for use by uninstructed persons, are contained in IEC 60898.

The requirements for circuit-breakers for equipment (for example electrical appliances) are contained in IEC 60934.

For certain specific applications (for example traction, rolling mills, marine service) particular or additional requirements may be necessary.

NOTE Circuit-breakers which are dealt with in this standard ~~may~~ can be provided with devices for automatic opening under predetermined conditions other than those of over-current and undervoltage as, for example, reversal of power or current. This standard does not deal with the verification of operation under such pre-determined conditions.

The object of this standard is to state:

a) the characteristics of circuit-breakers;

b) the conditions with which circuit-breakers shall comply with reference to:

   1) operation and behaviour in normal service;
   2) operation and behaviour in case of overload and operation and behaviour in case of short-circuit, including co-ordination in service (~~discrimination~~ selectivity and back-up protection);
   3) dielectric properties;

c) tests intended for confirming that these conditions have been met and the methods to be adopted for these tests;

d) information to be marked on or given with the apparatus.

1.2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*~~
~~Amendment 1 (2000)~~

~~IEC 60051 (all parts) *Direct acting indicating analogue electrical measuring instruments and their accessories*~~

IEC 60068-2-14~~:1984~~, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*
~~Amendment 1 (1986)~~

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

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

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

~~IEC 60364-4-41:2001, *Electrical installations of buildings – Part 4-41: Protection for safety – Protection against shock*~~

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

~~IEC 60695-2-10:2000, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*~~

~~IEC 60695-2-11:2000, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products*~~

~~IEC 60695-2-12:2000, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability test method for materials*~~

~~IEC 60695-2-13:2000, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignitability test method for materials*~~

~~IEC 60755:1983, *General requirements for residual current operated protective devices*~~
~~Amendment 1 (1988)~~
~~Amendment 2 (1992)~~

~~IEC 60898, *Circuit-breakers for over-current protection for household and similar installations*~~

~~IEC 60934, *Circuit-breakers for equipment (CBE)*~~

IEC 60947-1:~~2004~~ 2007, *Low-voltage switchgear and controlgear – Part 1: General rules*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1~~:2000~~, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*
~~Amendment 1 (2002)~~

IEC 61000-3-2~~:2000~~, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*
~~Amendment 1 (2001)~~
~~Amendment 2 (2004)~~

IEC 61000-3-3~~:1994~~, *Electromagnetic compatibility (EMC) – Part 3: Limits – ~~Section 3:~~ Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*
~~Amendment 1 (2001)~~

IEC 61000-4-2~~:1995~~, *Electromagnetic compatibility(EMC) – Part 4-2: Testing and measurement techniques – ~~Section 2:~~ Electrostatic discharge immunity test*
~~Amendment 1 (1998)~~
~~Amendment 2 (2000)~~

IEC 61000-4-3:~~2002~~ 2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
IEC 61000-4-3:2006/AMD1:~~2002~~ 2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:~~1995~~ 2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – ~~Section 4:~~ Electrical fast transient/burst immunity test*
~~Amendment 1 (2000)~~
~~Amendment 2 (2001)~~

IEC 61000-4-5:1995 2014, *Electromagnetic compatibility(EMC) – Part 4-5: Testing and measurement techniques – Section 5: Surge immunity test*
Amendment 1 (2000)

IEC 61000-4-6:2003 2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio frequency fields*
Amendment 1 (2004)

IEC 61000-4-11:2004, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-13:2002, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*

IEC 61000-5-2:1997, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*

IEC 61008-1:1996, *Residual current operated circuit-breakers without integral over-current protection for household and similar uses (RCCBs) – Part 1: General rules*
Amendment 1 (2002)

IEC 61009-1:1996, *Residual current operated circuit-breakers with integral over-current protection for household and similar uses (RCBOs) – Part 1: General rules*
Amendment 1 (2002)

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

IEC 62475:2010, *High-current test techniques – Definitions and requirements for test currents and measuring systems*

CISPR 11:2003, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic Radio-frequency disturbance characteristics – Limits and methods of measurement*
Amendment 1 (2004)

CISPR 22:2005, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*
Amendment 1 (2005)

2 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60947-1, as well as the following apply.

NOTE Where these definitions are taken unchanged from the *International Electrotechnical Vocabulary (IEV)*, IEC 60050-441, the reference to this publication is given in brackets.

2.1
circuit-breaker
a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20]

2.1.1
frame size
a term designating a group of circuit-breakers, the external physical dimensions of which are common to a range of current ratings.

Note 1 to entry: Frame size is expressed in amperes corresponding to the highest current rating of the group.

Note 2 to entry: Within a frame size, the width may vary according to the number of poles.

Note 3 to entry: This definition does not imply dimensional standardization.

2.1.2
construction break
a significant difference in construction between circuit-breakers of a given frame size, requiring additional type testing ~~(see 7.1.5)~~

2.2
integrally fused circuit-breaker
a combination, in a single device, of a circuit-breaker and fuses, one fuse being placed in series with each pole of the circuit-breaker intended to be connected to a phase conductor

[SOURCE: IEC 60050-441:1984, 441-14-22]

2.3
current-limiting circuit-breaker
~~circuit-breaker with a break-time short enough to prevent the short-circuit current reaching its otherwise attainable peak value~~
circuit-breaker that, within a specified range of current, prevents the let-through current reaching the prospective peak value and which limits the let-through energy (I^2t) to a value less than the let-through energy of a half-cycle wave of the symmetrical prospective current

Note 1 to entry: Reference may be made to either the symmetrical or asymmetrical prospective peak value of let-through current.

Note 2 to entry: The let-through current is also referred to as the cut-off current (see IEC 60050-441:1984, 441-17-12).

Note 3 to entry: Templates for the graphical representation of the cut-off current characteristic and the let-through energy characteristic are given from Figure K.2 to Figure K.5 and examples of the use of the templates in Figure K.6 and in Figure K.7.

~~[IEV 441-14-21]~~

2.4
plug-in circuit-breaker
a circuit-breaker which, in addition to its interrupting contacts, has a set of contacts which enable the circuit-breaker to be removed

Note 1 to entry: Some circuit-breakers may be of the plug-in type on the line side only, the load terminals being usually suitable for wiring connection.

2.5
withdrawable circuit-breaker
circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be ~~disconnected~~ withdrawn from the main circuit, and, in the ~~withdrawn~~ disconnected position, to achieve an isolating distance in accordance with specified requirements

2.6
moulded-case circuit-breaker
a circuit-breaker having a supporting housing of moulded insulating material forming an integral part of the circuit-breaker

[SOURCE: IEC 60050-441:1984, 441-14-24]

2.7
air circuit-breaker
a circuit-breaker in which the contacts open and close in air at atmospheric pressure

[SOURCE: IEC 60050-441:1984, 441-14-27]

2.8
vacuum circuit-breaker
a circuit-breaker in which the contacts open and close within a highly evacuated envelope

[SOURCE: IEC 60050-441:1984, 441-14-29]

2.9
gas circuit-breaker
a circuit-breaker in which the contacts open and close in a gas other than air at atmospheric or higher pressure

2.10
making-current release
a release which permits a circuit-breaker to open, without any intentional time-delay, during a closing operation, if the making current exceeds a predetermined value, and which is rendered inoperative when the circuit-breaker is in the closed position

2.11
short-circuit release
an over-current release intended for protection against short circuits

2.12
short-time delay short-circuit release
an over-current release intended to operate at the end of the short-time delay ~~(see 2.5.26 of IEC 60947-1)~~

2.13
alarm switch
an auxiliary switch which operates only upon the tripping of the circuit-breaker with which it is associated

2.14
circuit-breaker with lock-out device preventing closing
a circuit-breaker in which each of the moving contacts is prevented from closing sufficiently to be capable of passing current if the closing command is initiated while specified conditions remain established

2.15
short-circuit breaking (or making) capacity
a breaking (or making) capacity for which the prescribed conditions include a short circuit

2.15.1
ultimate short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence do not include the capability of the circuit-breaker to carry its rated current continuously

2.15.2
service short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence include the capability of the circuit-breaker to carry its rated current continuously

2.16
opening time
~~subclause 2.5.39 of IEC 60947-1 applies, with the following additions:~~
interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry:

- in the case of a directly operated circuit-breaker, the instant of initiation of the opening time is the instant of initiation of a current large enough to cause the circuit-breaker to operate;
- in the case of a circuit-breaker operated by any form of auxiliary power, the instant of initiation of the opening time is the instant of application or removal of the auxiliary power to the opening release.

Note 2 to entry: For circuit-breakers "opening time" is commonly referred to as "tripping time", although, strictly speaking, tripping time applies to the time between the instant of initiation of the opening time and the instant when the opening command becomes irreversible.

[SOURCE: IEC 60947-1:2007, 2.5.39, modified – addition of Notes to entry.]

2.17
over-current protective co-ordination
~~subclause 2.5.22 of IEC 60947-1 applies~~

~~**2.17.1**~~
~~**over-current discrimination**~~
~~subclause 2.5.23 of IEC 60947-1 applies~~

~~[IEV 441-17-15]~~

2.17.1
over-current selectivity
co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the other(s) does (do) not

2.17.2
~~**total discrimination (**~~**total selectivity**~~**)**~~
over-current ~~discrimination~~ selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection without causing the other protective device to operate

2.17.3
~~**partial discrimination (**~~**partial selectivity**~~**)**~~
over-current ~~discrimination~~ selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection up to a given level of over-current, without causing the other protective device to operate

2.17.4
selectivity limit current
I_s
~~the selectivity limit current is the~~ current co-ordinate of the intersection between the total time-current characteristic of the protective device on the load side and the pre-arcing (for fuses), or tripping (for circuit-breakers) time-current characteristic of the other protective device

Note 1 to entry: The selectivity limit current (see Figure A.1) is a limiting value of current:

– below which, in the presence of two over-current protective devices in series, the protective device on the load side completes its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is ensured);
– above which, in the presence of two over-current protective devices in series, the protective device on the load side may not complete its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is not ensured).

~~2.17.5~~
~~**back-up protection**~~
~~subclause 2.5.24 of IEC 60947-1 applies~~

2.17.5
take-over current
II_B
~~subclause 2.5.25 of IEC 60947-1 is amplified as follows:~~

~~For the purpose of this standard, 2.5.25 of IEC 60947-1 applies to two over-current protective devices in series for operating times ≥0,05 s. For operating times <0,05 s the two over-current devices in series are considered as an association, see Annex A.~~

~~NOTE The take-over current is the~~ current co-ordinate of the intersection between the maximum break time current characteristics of two over-current protective devices in series

Note 1 to entry: This applies to two over-current protective devices in series for operating times ≥ 0,05 s. For operating times < 0,05 s, the two over-current devices in series are considered as an association (see Annex A).

2.18
I^2t characteristic of a circuit-breaker
information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (r.m.s. symmetrical for a.c.) up to the maximum prospective current corresponding to the rated short-circuit breaking capacity and associated voltage

2.19
resetting time
time elapsed between a circuit-breaker tripping due to an overcurrent and subsequently reaching a condition where it can be reclosed

2.20
rated instantaneous short-circuit current setting
I_i
rated value of the current causing the operation of a release without any intentional time-delay

2.21
overload current setting
I_r
current setting of an adjustable overload release

Note 1 to entry: In case of a non-adjustable overload release, this value is equal to the rated current I_n.

2.22
programmable logic controller
PLC
digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analogue inputs and outputs, various types of machines or processes. Both the PLC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions

[SOURCE: IEC 61131-1:2003, 3.5, modified – deletion of the note.]

3 Classification

Circuit-breakers may be classified:

3.1 According to their ~~utilization~~ selectivity category, A or B (see 4.4)

3.2 According to the interrupting medium, for example:

– air-break;
– vacuum break;
– gas-break.

3.3 According to the design, for example:

– open construction;
– moulded case.

3.4 According to the method of controlling the operating mechanism, viz:

– dependent manual operation;
– independent manual operation;
– dependent power operation;
– independent power operation;
– stored energy operation.

3.5 According to the suitability for isolation:

– suitable for isolation;
– not suitable for isolation.

3.6 According to the provision for maintenance:

– maintainable;
– non-maintainable.

3.7 According to the method of installation, for example:

– fixed;
– plug-in;
– withdrawable.

3.8 According to the degree of protection provided by the enclosure (see 7.1.12 of IEC 60947-1:2007)

4 Characteristics of circuit-breakers

4.1 Summary of characteristics

The characteristics of a circuit-breaker shall be stated in terms of the following, as applicable:

– type of circuit-breaker (4.2);
– rated and limiting values of the main circuit (4.3);
– ~~utilization~~ selectivity categories (4.4);
– control circuits (4.5);
– auxiliary circuits (4.6);

– releases (4.7);
– integral fuses (integrally fused circuit-breakers) (4.8).

4.2 Type of circuit-breaker

The following shall be stated:

~~4.2.1~~ – number of poles;

~~4.2.2~~ – kind of current (a.c. or d.c.) and, in the case of a.c., number of phases and rated frequency.

4.3 Rated and limiting values of the main circuit

4.3.1 General

The rated values established for a circuit-breaker shall be stated in accordance with 4.3.2 to 4.4, but it is not necessary to establish all the rated values listed.

4.3.2 Rated voltages

~~A circuit-breaker is defined by the following rated voltages:~~

4.3.2.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of IEC 60947-1:2007 applies with the following amplification:

– Circuit-breakers covered by item a) of Note 2 (of IEC 60947-1:2007)

U_e is generally stated as the voltage between phases.

NOTE 1 In Canada and the USA, the rated operational voltage U_e is stated as

a) the voltage between phases and earth, together with the voltage between phases (for example 277 V/480 V) for three-phase four-wire neutral earthed systems;

b) the voltage between phases (for example 480 V) for three-phase three-wire unearthed or impedance earthed systems.

Circuit-breakers for unearthed or impedance earthed systems (IT) require additional tests according to Annex H.

– Circuit-breakers covered by item b) of Note 2:

These circuit-breakers require additional tests according to Annex C.

U_e shall be stated as the voltage between phases preceded by the letter C.

NOTE 2 According to present practice in Canada and the USA, circuit-breakers covered by item b) of Note 2 (of IEC 60947-1:2007) are identified by the voltage between phases only.

4.3.2.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

4.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

4.3.3 Currents

~~A circuit-breaker is defined by the following currents:~~

4.3.3.1 Conventional free-air thermal current (I_{th})

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

4.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

4.3.3.3 Rated current (I_n)

For circuit-breakers, the rated current is the rated uninterrupted current (I_u) (see 4.3.2.4 of IEC 60947-1:2007) and is equal to the conventional free-air thermal current (I_{th}).

4.3.3.4 Current rating for four-pole circuit-breakers

Subclause 7.1.9 of IEC 60947-1:2007 applies.

4.3.4 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

4.3.5 Rated duty

The rated duties considered as normal are ~~as follows~~:

~~4.3.4.1~~ – the eight-hour duty (see 4.3.4.1 of IEC 60947-1:2007),

~~4.3.4.2~~ – the uninterrupted duty (see 4.3.4.2 of IEC 60947-1:2007).

4.3.6 Short-circuit characteristics

4.3.6.1 Rated short-circuit making capacity (I_{cm})

The rated short-circuit making capacity of a circuit-breaker is the value of short-circuit making capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage at rated frequency and at a specified power factor for a.c., or time constant for d.c. It is expressed as the maximum prospective peak current.

For a.c. the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity, multiplied by the factor *n* of Table 2 (see 4.3.6.3).

For d.c., the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity.

A rated short-circuit making capacity implies that the circuit-breaker shall be able to make the current corresponding to that rated capacity at the appropriate applied voltage related to the rated operational voltage.

4.3.6.2 Rated short-circuit breaking capacities

4.3.6.2.1 General

The rated short-circuit breaking capacities of a circuit-breaker are the values of short-circuit breaking capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage, under specified conditions.

A rated short-circuit breaking capacity requires that the circuit-breaker shall be able to break any value of short-circuit current up to and including the value corresponding to the rated capacity at a power-frequency recovery voltage corresponding to the prescribed test voltage values and:

– for a.c., at any power factor not less than that of Table 11 (see 8.3.2.2.4);
– for d.c., with any time constant not greater than that of Table 11 (see 8.3.2.2.5).

For power-frequency recovery voltages in excess of the prescribed test voltage values (see 8.3.2.2.6), no short-circuit breaking capacity is guaranteed.

For a.c., the circuit-breaker shall be capable of breaking a prospective current corresponding to its rated short-circuit breaking capacity and the related power factor given in Table 11, irrespective of the value of the inherent d.c. component, on the assumption that the a.c. component is constant.

The rated short-circuit breaking capacities are stated as:

– rated ultimate short-circuit breaking capacity;
– rated service short-circuit breaking capacity.

4.3.6.2.2 Rated ultimate short-circuit breaking capacity (I_{cu})

The rated ultimate short-circuit breaking capacity of a circuit-breaker is the value of ultimate short-circuit breaking capacity (see 2.15.1) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.5. It is expressed as the value of the prospective breaking current, in kA (r.m.s. value of the a.c. component in the case of a.c.).

4.3.6.2.3 Rated service short-circuit breaking capacity (I_{cs})

The rated service short-circuit breaking capacity of a circuit-breaker is the value of service short-circuit breaking capacity (see 2.15.2) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.4. It is expressed as a value of prospective breaking current, in kA, ~~corresponding to one of the specified percentages of the rated ultimate short-circuit breaking capacity, in accordance with Table 1, and rounded up to the nearest whole number. It may be expressed~~ or as a % of I_{cu} (for example I_{cs} = 25 % I_{cu}).

I_{cs} shall be at least equal to 25 % of I_{cu}.

~~Alternatively, when the rated service short-circuit breaking capacity is equal to the rated short-time withstand current (see 4.3.5.4), it may be stated as that value, in kA, provided that it is not less than the relevant minimum value of Table 1.~~

~~Where I_{cu} exceeds 200 kA for utilization category A (see 4.4), or 100 kA for utilization category B, the manufacturer may declare a value I_{cs} of 50 kA.~~

Table 1 ~~– Standard ratios between I_{cs} and I_{cu}~~ (void)

~~Utilization category A~~ ~~% of I_{cu}~~	~~Utilization category B~~ ~~% of I_{cu}~~
~~25~~	
~~50~~	~~50~~
~~75~~	~~75~~
~~100~~	~~100~~

4.3.6.3 Standard relationship between short-circuit making and breaking capacities and related power factor, for a.c. circuit-breakers

The standard relationship between short-circuit breaking capacity and short-circuit making capacity is given in Table 2.

Table 2 – Ratio *n* between short-circuit making capacity and short-circuit breaking capacity and related power factor (for a.c. circuit-breakers)

Short-circuit breaking capacity kA r.m.s.	Power factor	Minimum value required for *n* $n = \frac{\text{short-circuit making capacity}}{\text{short-circuit breaking capacity}}$
$I \leq 1{,}5$	0,95	1,41
$1{,}5 < I \leq 3$	0,9	1,42
$3 < I \leq 4{,}5$	0,8	1,47
$4{,}5 < I \leq 6$	0,7	~~1,5~~ 1,53
$6 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

~~NOTE For values of breaking capacity lower than 4,5 kA, for certain applications, see Table 11 for the power factor~~

The rated short-circuit making and breaking capacities are only valid when the circuit-breaker is operated in accordance with the requirements of 7.2.1.1 and 7.2.1.2.

For special requirements, the manufacturer may assign a value of rated short-circuit making capacity higher than that required by Table 2. Tests to verify these rated values shall be the subject of agreement between manufacturer and user.

4.3.6.4 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of a circuit-breaker is the value of short-time withstand current assigned to that circuit-breaker by the manufacturer under the test conditions specified in 8.3.6.3.

For a.c., the value of this current is the r.m.s. value of the a.c. component of the prospective short-circuit current, assumed constant during the short-time delay.

The short-time delay associated with the rated short-time withstand current shall be at least 0,05 s, preferred values being as follows:

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

The rated short-time withstand current shall be not less than the appropriate values shown in Table 3.

Table 3 – Minimum values of rated short-time withstand current

Rated current I_n A	Rated short-time withstand current I_{cw} – Minimum values kA
$I_n \leq 2\ 500$	12 I_n or 5 kA, whichever is the greater
$I_n > 2\ 500$	30 kA

4.4 Utilization Selectivity categories

The utilization category of a circuit-breaker shall be stated with reference to whether or not it is specifically intended for selectivity by means of an intentional time delay with respect to other circuit-breakers in series on the load side, under short-circuit conditions (see Figure A.3).

Circuit-breakers according to this standard are divided into two selectivity categories:

– **Selectivity category B** comprises circuit-breakers providing selectivity by having a short-time withstand current rating and an associated short-time delay according to 4.3.6.4.

Selectivity of circuit-breakers of selectivity category B is not necessarily ensured up to the ultimate short-circuit breaking capacity (e.g. in the case of operation of an instantaneous release) but at least up to the value specified in Table 3.

– **Selectivity category A** comprises all other circuit-breakers.

These circuit-breakers may provide selectivity under short-circuit conditions by other means.

A circuit-breaker of selectivity category A may have an intentional short-time delay with a short-time withstand current less than that according to 4.3.6.4. In that case, the tests include test sequence IV (see 8.3.6) at the assigned short-time withstand current.

Attention is drawn to the differences of the tests applying to the two utilization selectivity categories (see Table 9 and 8.3.4, 8.3.5, 8.3.6 and 8.3.8).

Utilization categories are defined in Table 4.

Table 4 – Utilization categories (void)

Utilization category	Application with respect to selectivity
A	Circuit-breakers not specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. without an intentional short-time delay provided for selectivity under short-circuit conditions, and therefore without a short-time withstand current rating according to 4.3.5.4.
B	Circuit-breakers specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. with an intentional short-time delay (which may be adjustable), provided for selectivity under short-circuit conditions. Such circuit-breakers have a short-time withstand current rating according to 4.3.5.4. NOTE Selectivity is not necessarily ensured up to the ultimate short-circuit breaking capacity of the circuit-breakers (for example in the case of operation of an instantaneous release) but at least up to the value specified in Table 3.

NOTE 1 The power factor or time constant associated with each value of rated short-circuit current is given in Table 11 (see 8.3.2.2.4 and 8.3.2.2.5).

NOTE 2 Attention is drawn to the different requirements for the minimum required percentage of I_{cs} for utilization categories A and B, in accordance with Table 1.

NOTE 3 A circuit-breaker of utilization category A may have an intentional short-time delay provided for selectivity under conditions other than those of short circuit, with a short-time withstand current less than that according to Table 3. In that case, the tests include test sequence IV (see 8.3.6) at the assigned short-time withstand current.

4.5 Control circuits

4.5.1 Electrical control circuits

Subclause 4.5.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, with the following addition:

If the rated control supply voltage is different from that of the main circuit, it is recommended that its value be chosen from Table 5.

Table 5 – Preferred values of the rated control supply voltage, if different from that of the main circuit

Direct current V	**Single-phase alternating current** V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230
NOTE The manufacturer should be prepared to state the value or values of the current taken by the control circuits at the rated control supply voltage.	

4.5.2 Air-supply control circuits (pneumatic or electro-pneumatic)

Subclause 4.5.2 of IEC 60947-1:2007 applies.

4.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies.

4.7 Releases

4.7.1 Types

For the purpose of this standard, the following types of releases are considered:

1) shunt release;
2) over-current release:
   a) instantaneous;
   b) definite time delay;
   c) inverse time delay:
      – independent of previous load;
      – dependent on previous load (for example thermal type release).

   NOTE 1 The term "overload release" is used to identify over-current releases intended for protection against overloads (see 2.4.30 of IEC 60947-1:2007). The term "short-circuit release" is used to identify over-current releases intended for protection against short circuits (see 2.11).

   NOTE 2 The term "adjustable release" used in this standard also includes interchangeable releases.
3) undervoltage release (for opening);

4) other releases.

4.7.2 Characteristics

The following characteristics shall be considered:

1) shunt release and undervoltage release (for opening):
   – rated control circuit voltage (U_c);
   – kind of current;
   – rated frequency, if a.c.
2) over-current release:
   – rated current (I_n);
   – kind of current;
   – rated frequency, if a.c.;
   – current setting (or range of settings);
   – time setting (or range of settings) if applicable.

The rated current of an over-current release is the value of current (r.m.s. if a.c.) corresponding to the maximum current setting which it shall be capable of carrying under the test conditions specified in 8.3.2.5, without the temperature-rise exceeding the values specified in Table 7.

4.7.3 Current setting of over-current releases

For circuit-breakers fitted with adjustable releases (see Note 2 to 4.7.1, item 2)), the current setting (or range of current-settings, as applicable) shall be marked or displayed on the release or on its scale. The marking or display may be either directly in amperes or as a multiple of the current value ~~marked on the release~~. Means shall be available from the manufacturer to read the display regardless of the status of the circuit-breaker.

For circuit-breakers fitted with non-adjustable releases, the marking may be on the circuit-breaker. If the operating characteristics of the overload release comply with the requirements of Table 6, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

In the case of indirect releases operated by current transformers, the marking may refer either to the primary current of the current transformer through which they are supplied, or to the current setting of the overload release. In either case, the ratio of the current transformer shall be stated.

Unless otherwise specified

– the operating value of overload releases other than those of the thermal type is independent of the ambient air temperature within the limits of –5 °C to +40 °C;
– for releases of the thermal type, the values stated are for a reference temperature of +30 °C ± 2 °C. The manufacturer shall be prepared to state the influence of variations in the ambient air temperature (see 7.2.1.2.4, item b)).

4.7.4 Tripping time setting of over-current releases

The tripping time shall be stated as follows, depending on the type of over-current release:

1) Definite time-delay over-current releases

   The time-delay of such releases is independent of the over-current. The tripping time setting shall be stated as the duration in seconds of the opening time of the circuit-breaker, if the time-delay is not adjustable, or the extreme values of the opening time, if the time-delay is adjustable.

2) Inverse time-delay over-current releases

The time-delay of such releases is dependent on the over-current.

The time/current characteristics shall be given in the form of curves supplied by the manufacturer. These shall indicate how the opening time, starting from the cold state, varies with current within the range of operation of the release. The manufacturer shall indicate, by suitable means, the tolerances applicable to these curves.

These curves shall be given for each extreme value of the current setting and, if the time setting for a given current setting is adjustable, it is recommended that they be given in addition for each extreme value of the time setting.

~~NOTE~~ It is recommended that the current be plotted as abscissa and the time as ordinate, using logarithmic scales. Furthermore, in order to facilitate the study of co-ordination of different types of over-current protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheets detailed in 5.6.1 of IEC 60269-1:2006~~ and in Figures 4(I), 3(II) and 4(II) of IEC 60269-2-1~~.

4.8 Integral fuses (integrally fused circuit-breakers)

Subclause 4.8 of IEC 60947-1:2007/AMD1:2010 applies.

The manufacturer shall provide the necessary information.

5 Product information

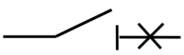
5.1 Nature of the information

Subclause 5.1 of IEC 60947-1:2007 applies, as far as appropriate for a particular design.

In addition the manufacturer shall make available, upon request, information concerning typical power losses for the various frame sizes (see 2.1.1). See Annex G.

5.2 Marking

Each circuit-breaker shall be marked in a durable manner.

a) The following data shall be marked on the circuit-breaker itself or on a nameplate or name-plates attached to the circuit-breaker, and located in a place such that they are visible and legible when the circuit-breaker is installed;
   - rated current (I_n);
   - suitability for isolation, if applicable, with the symbol ;
   - indication of the open and closed positions, with O and | respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007).

b) The following data shall also be marked externally on the circuit-breaker, as specified in item a), except that they need not be visible when the circuit-breaker is installed;
   - manufacturer's name or trade mark;
   - type designation or serial number;
   - IEC 60947-2 if the manufacturer claims compliance with this standard;
   - ~~utilization~~ selectivity category;
   - rated operational voltage(s) U_e (see 4.3.2.1 and, where applicable, Annex H);
   - rated impulse withstand voltage (U_{imp});
   - value (or range) of the rated frequency (for example 50 Hz), and/or the indication "d.c." (or the symbol ⎓);

- rated service short-circuit breaking capacity (I_{cs}) at the corresponding rated voltage (U_e);
- rated ultimate short-circuit breaking capacity (I_{cu}) at the corresponding rated voltage (U_e);
- rated short-time withstand current (I_{cw}), and associated short-time delay, for ~~utilization~~ selectivity category B;
- line and load terminals, unless their connection is immaterial;
- neutral pole terminals, if applicable, by the letter N;
- protective earth terminal, where applicable, by the symbol ⏚ (see 7.1.10.3 of IEC 60947-1:2007);
- reference temperature for non-compensated thermal releases, if different from 30 °C;
- range of the current setting (I_r) of adjustable overload release;
- range of the rated instantaneous short-circuit current setting (I_i), for ajustable releases.

Where applicable, I_r and I_i ranges may be displayed instead of being marked on the circuit-breaker.

c) The following data shall either be marked on the circuit-breaker as specified in item b), or shall be made available in the manufacturer's published information:

- rated short-circuit making capacity (I_{cm}), if higher than that specified in 4.3.6.1;
- rated insulation voltage (U_i), if higher than the maximum rated operational voltage;
- pollution degree if other than 3;
- conventional enclosed thermal current (I_{the}) if different from the rated current;
- IP Code, where applicable (see Annex C of IEC 60947-1:2007/AMD1:2010);
- minimum enclosure size and ventilation data (if any) to which marked ratings apply;
- details of minimum distance between circuit-breaker and earthed metal parts for circuit-breakers intended for use without enclosures;
- suitability for environment A or environment B, as applicable;
- r.m.s. sensing, if applicable, according to F.4.1.1;
- minimum cable cross-section, if different from Table 9 of IEC 60947-1:2007, for ratings ≤ 20 A according to rated ultimate short-circuit breaking capacity I_{cu};
- values of tightening torque for the circuit-breaker terminals.

d) The following data concerning the opening and closing devices of the circuit-breaker shall be placed either on their own nameplates or on the nameplate of the circuit-breaker; alternatively, if space available is insufficient, they shall be made available in the manufacturer's published information:

- rated control circuit voltage of the closing device (see 7.2.1.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014) and rated frequency for a.c.;
- rated control circuit voltage of the shunt release (see 7.2.1.4 of IEC 60947-1:2007/AMD2:2014) and/or of the under-voltage release (or of the no-voltage release) (see 7.2.1.3 of IEC 60947-1:2007), and rated frequency for a.c.;
- rated current of indirect over-current releases;
- number and type of auxiliary contacts and kind of current, rated frequency (if a.c.) and rated voltages of the auxiliary switches, if different from those of the main circuit.

e) Terminal marking

Subclause 7.1.8.4 of IEC 60947-1:2007 applies (see also item b) above).

5.3 Instructions for installation, operation and maintenance

Subclause 5.3 of IEC 60947-1:2007/AMD2:2014 applies.

6 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1:2007/AMD2:2014 applies with the following addition:

Pollution degree (see 6.1.3.2 of IEC 60947-1:2007).

Unless otherwise stated by the manufacturer, a circuit-breaker is intended for installation under environmental conditions of pollution degree 3.

7 Constructional and performance requirements

7.1 Constructional requirements

7.1.1 General

~~Subclause 7.1 of IEC 60947-1 applies except that the text of 7.1.1.1 is replaced by the following:~~

~~Parts of insulating materials which might be exposed to thermal stresses due to electrical effects and the deterioration of which might impair the safety of the equipment shall not be adversely affected by abnormal heat and fire.~~

~~Tests on equipment shall be made by the glow-wire tests of IEC 60695-2-10, IEC 60695-2-11, IEC 60695-2-12 and IEC 60695-2-13.~~

~~Parts of insulating materials necessary to retain in position current-carrying parts of the main circuit in service shall conform to the glow-wire test of 8.2.1.1.1 of IEC 60947-1, at a temperature of 960 °C.~~

~~Parts of insulating materials other than those specified in the previous paragraph shall conform to the requirements of the glow-wire tests of 8.2.1.1.1 of IEC 60947-1 at a temperature of 650 °C.~~

Subclause 7.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies. Where, in 7.1.2.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, the test temperature is to be specified, the test temperature required by this standard is 960 °C.

7.1.2 Withdrawable circuit-breakers

In the disconnected position, the isolating contacts of the main circuit and, where applicable, auxiliary circuits of withdrawable circuit-breakers shall have isolating distances which comply with the requirements specified for the isolating function, taking account of manufacturing tolerances and changes in dimensions due to wear.

The withdrawable mechanism shall be fitted with a reliable indicating device which indicates unambiguously the positions of the isolating contacts.

The withdrawable mechanism shall be fitted with interlocks which only permit the isolating contacts to be separated or reclosed when the main contacts of the circuit-breaker are open.

In addition, the withdrawable mechanism shall be fitted with interlocks which only permit the main contacts to be closed

- when the isolating contacts are fully closed, or
- when the specified isolating distance is achieved between the fixed and moving parts of the isolating contacts (disconnected position).

When the circuit-breaker is in the disconnected position, means shall be provided to ensure that the specified isolating distances between the isolating contacts cannot be inadvertently reduced.

7.1.3 Additional requirements for circuit-breakers suitable for isolation

For additional requirements concerning performance, see 7.2.7.

Subclause 7.1.7 of IEC 60947-1:2007/AMD1:2010 applies with the following addition:

~~NOTE~~ If the tripped position is not the indicated open position, it should be clearly identified.

~~The indicated open position is the only position in which the specified isolating distance between the contacts is ensured.~~

7.1.4 Clearances and creepage distances

Minimum values are given in Table 13 of IEC 60947-1:2007 and in Table 15 of IEC 60947-1:2007/AMD1:2010.

For U_{imp} values exceeding the values given in Table 13 of IEC 60947-1:2007, clearances shall be obtained from Table F.2 of IEC 60664-1:2007.

7.1.5 Requirements for the safety of the operator

There shall be no path or opening which allows incandescent particles to be discharged from the area of the manual operating means.

Compliance is checked by the provisions of 8.3.2.6.1, item b).

7.1.6 List of construction breaks

Circuit-breakers of a given frame size are considered to have a construction break (see 2.1.2) if any one of the following features are not the same:

– material, finish and dimensions of internal current-carrying parts, admitting, however, the variations listed in a), b), c), f) and g) below;
– size, material, configuration and method of attachment of the main contacts;
– any integral manual operating mechanism, its materials and physical characteristics;
– moulding and insulating materials;
– the principle of operation, materials and construction of the arc extinction device;
– the basic design of the over-current tripping devices, admitting, however, the variations detailed in a), b) and c) below.

Variations in the following do not constitute a construction break:

a) dimensions of terminals, provided that creepage and clearance distances are not reduced;
b) in the case of thermal and magnetic releases those dimensions and materials of the release components, including flexible connections, which determine the current rating;
c) secondary windings of current transformer operated releases;
d) external operating means, additional to the integral operating means;
e) type designation and/or purely aesthetic features (e.g. labels);
f) in the case of the 2-pole and 4-pole variants, replacement of the trip unit in one pole by a link, to provide an unprotected neutral;
g) creating a 2-pole breaker from a 3-pole breaker by removing the centre current path;

h) difference in embedded software (firmware) in electronic trip units, which has no impact on the required performance, in particular the tripping function;

i) electronic trip unit hardware, due to omitted components on identical printed circuit board layout (e.g. rotary knobs, display, etc.).

7.1.7 Additional requirements for circuit-breakers provided with a neutral pole

Subclause 7.1.9 of IEC 60947-1:2007 applies with the following addition:

If a pole with an appropriate making and breaking capacity is used as a neutral pole, then all poles, including the neutral pole, may operate substantially together.

7.1.8 Digital inputs and outputs for use with programmable logic controllers (PLCs)

Annex S of IEC 60947-1:2007 applies. For the purposes of this standard, this requirement does not apply to digital inputs and outputs dedicated to devices other than PLCs.

7.2 Performance requirements

7.2.1 Operating conditions

7.2.1.1 Closing

7.2.1.1.1 General

For a circuit-breaker to be closed safely on to the making current corresponding to its rated short-circuit making capacity, it is essential that it should be operated with the same speed and the same firmness as during the type test for proving the short-circuit making capacity.

7.2.1.1.2 Dependent manual closing

For a circuit-breaker having a dependent manual closing mechanism, it is not possible to assign a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

Such a circuit-breaker should not be used in circuits having a prospective peak making current exceeding 10 kA.

However, this does not apply in the case of a circuit-breaker having a dependent manual closing mechanism and incorporating an integral fast-acting opening release which causes the circuit-breaker to break safely, irrespective of the speed and firmness with which it is closed on to prospective peak currents exceeding 10 kA; in this case, a rated short-circuit making capacity can be assigned.

7.2.1.1.3 Independent manual closing

A circuit-breaker having an independent manual closing mechanism can be assigned a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

7.2.1.1.4 Dependent power closing

The power-operated closing mechanism, including intermediate control relays where necessary, shall be capable of securing the closing of the circuit-breaker in any condition between no-load and its rated making capacity, when the supply voltage, measured during the closing operation, remains between the limits of 110 % and 85 % of the rated control supply voltage, and, when a.c., at the rated frequency.

At 110 % of the rated control supply voltage, the closing operation performed on no-load shall not cause any damage to the circuit-breaker.

At 85 % of the rated control supply voltage, the closing operation shall be performed when the current established by the circuit-breaker is equal to its rated making capacity within the limits allowed by the operation of its relays or releases and, if a maximum time limit is stated for the closing operation, in a time not exceeding this maximum time limit.

7.2.1.1.5 Independent power closing

A circuit-breaker having an independent power closing operation can be assigned a rated short-circuit making capacity irrespective of the conditions of power closing.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating in accordance with the manufacturer's specification.

7.2.1.1.6 Stored energy closing

This type of closing mechanism shall be capable of ensuring closing of the circuit-breaker in any condition between no-load and its rated making capacity.

When the stored energy is retained within the circuit-breaker, a device shall be provided which indicates when the storing mechanism is fully charged.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating when the auxiliary supply voltage is between 85 % and 110 % of the rated control supply voltage.

It shall not be possible for the moving contacts to move from the open position unless the charge is sufficient for satisfactory completion of the closing operation.

When the energy storing mechanism is manually operated, the direction of operation shall be indicated.

This last requirement does not apply to circuit-breakers with an independent manual closing operation.

7.2.1.2 Opening

7.2.1.2.1 General

Circuit-breakers which open automatically shall be trip-free (see 2.4.23 of IEC 60947-1:2007) and, unless otherwise agreed between manufacturer and user, circuit-breakers shall have their energy for the tripping operation stored automatically prior to the completion of the closing operation.

7.2.1.2.2 Opening by undervoltage releases

Subclause 7.2.1.3 of IEC 60947-1:2007 applies.

7.2.1.2.3 Opening by shunt releases

Subclause 7.2.1.4 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.1.2.4 Opening by over-current releases

a) Opening under short-circuit conditions

   The short-circuit release shall cause tripping of the circuit-breaker with an accuracy of ±20 % of the tripping current value of the current setting for all values of the current setting of the short-circuit current release.

Where necessary for over-current co-ordination (see 2.17), the manufacturer shall provide information (usually curves) showing:

– maximum cut-off (let-through) peak current (see 2.5.19 of IEC 60947-1:2007) as a function of prospective current (r.m.s. symmetrical);

– I^2t characteristics (see 2.18) for circuit-breakers of ~~utilization~~ selectivity category A and, if applicable, category B for circuit-breakers with instantaneous override (see note to 8.3.5.1).

Conformity with this information may be checked during the relevant type tests in test sequences II and III (see 8.3.4 and 8.3.5).

NOTE 1 It ~~may be~~ is possible to provide other forms of data to verify co-ordination characteristics of circuit-breakers, for example, tests on combinations of short-circuit protective devices.

b) Opening under overload conditions

1) Instantaneous or definite time-delay operation

The release shall cause tripping of the circuit-breaker with an accuracy of ±10 % of the tripping current value of the current setting for all values of current setting of the overload release.

2) Inverse time-delay operation

Conventional values for inverse time-delay operation are given in Table 6.

At the reference temperature (see 4.7.3) and at 1,05 times the current setting (see 2.4.37 of IEC 60947-1:2007), i.e. with the conventional non-tripping current (see 2.5.30 of IEC 60947-1:2007), the opening release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 2.5.30 of IEC 60947-1:2007) from the cold state, i.e. with the circuit-breaker at the reference temperature.

Moreover, when at the end of the conventional time the value of current is immediately raised to 1,30 times the current setting, i.e. with the conventional tripping current (see 2.5.31 of IEC 60947-1:2007), tripping shall then occur in less than the conventional time later.

NOTE 2 The reference temperature is the ambient air temperature on which the time-current characteristic of the circuit-breaker is based.

Table 6 – Characteristics of the opening operation of inverse time-delay over-current opening releases at the reference temperature

All poles loaded		Conventional time h
Conventional non-tripping current	**Conventional tripping current**	
1,05 times current setting	1,30 times current setting	2 [a]
[a] 1 h when $I_n \leq 63$ A		

If a release is declared by the manufacturer as substantially independent of ambient temperature, the current values of Table 6 shall apply within the temperature band declared by the manufacturer, within a tolerance of 0,3 %/K.

The width of the temperature band shall be at least 10 K on either side of the reference temperature.

7.2.2 Temperature-rise

7.2.2.1 Temperature-rise limits

The temperature-rises of the several parts of a circuit-breaker, measured under the conditions specified in 8.3.2.5, shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.3.7. The temperature-rises of the terminals shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.4.5 and 8.3.6.4.

7.2.2.2 Ambient air temperature

The temperature-rise limits given in Table 7 are applicable only if the ambient air temperature remains within the limits given in 6.1.1 of IEC 60947-1:2007/AMD2:2014.

7.2.2.3 Main circuit

The main circuit of a circuit-breaker, including the over-current releases which may be associated with it, shall be capable of carrying ~~the conventional thermal current (I_{th} or I_{the}, as applicable, see 4.3.2.1 and 4.3.2.2)~~ its rated current I_n, under the conditions of Clause 8, without the temperature-rises exceeding the limits specified in Table 7.

7.2.2.4 Control circuits

The control circuits, including control circuit devices, used for the closing and opening operations of a circuit-breaker, shall permit the rated duty, as specified in 4.3.5, and also the temperature-rise tests under the test conditions specified in 8.3.2.5, to be made without the temperature rises exceeding the limits specified in Table 7.

The requirements of this subclause shall be verified on a new circuit-breaker. Alternatively, at the discretion of the manufacturer, the verification may be made during the temperature-rise test of 8.3.3.7.

7.2.2.5 Auxiliary circuits

Auxiliary circuits, including auxiliary devices, shall be capable of carrying their conventional thermal current without the temperature-rises exceeding the limits specified in Table 7 when tested in accordance with 8.3.2.5.

Table 7 – Temperature-rise limits for terminals and accessible parts

Description of part [a]	Temperature-rise limits [b] K
– Terminals for external connections	80
– Manual operating means:	
Metallic	25
non-metallic	35
– Parts intended to be touched but not hand-held:	
Metallic	40
non-metallic	50
– Parts which need not be touched for normal operation:	
Metallic	50
non-metallic	60

[a] No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.

[b] The temperature-rise limits specified are not intended to apply to a new sample, but are those applicable to the temperature-rise verifications during the appropriate test sequences specified in Clause 8.

7.2.3 Dielectric properties

7.2.3.1 General

Subclauses 7.2.3 a) and 7.2.3 b) of IEC 60947-1:2007 apply.

Type tests shall be made in accordance with 8.3.3.3.

The verification of dielectric withstand during all test sequences shall be made in accordance with 8.3.3.6.

Routine tests shall be made in accordance with 8.4.6.

7.2.3.2 Impulse withstand voltage

Subclause 7.2.3.1 of IEC 60947-1:2007 applies.

For circuit-breakers rated above 1 000 V a.c., the impulse withstand voltage shall be agreed between the manufacturer and the user but shall not be less than the corresponding values for 1 000 V a.c.

7.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

Power-frequency tests are used in the following cases:

– dielectric tests as type tests for the verification of solid insulation;
– dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;
– routine tests.

7.2.3.4 Clearances

Subclause 7.2.3.3 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.3.5 Creepage distances

Subclause 7.2.3.4 of IEC 60947-1:2007 applies.

7.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with 8.3.3.4.1, item 3) of IEC 60947-1:2007/AMD1:2010/AMD2:2014, or d.c. tests (test voltages for d.c. tests are under consideration).

For the purposes of this standard, circuits incorporating solid-state devices shall be disconnected for the tests.

7.2.3.7 Spacing between separate circuits

Subclause 7.2.3.6 of IEC 60947-1:2007 applies.

7.2.4 Ability to make and break under no load, normal load and overload conditions

7.2.4.1 Overload performance

This requirement applies to circuit-breakers of rated current up to and including 630 A.

The circuit-breaker shall be capable of carrying out the number of operating cycles with current in the main circuit exceeding its rated current, under the test conditions according to 8.3.3.5.

Each operating cycle consists of a making operation followed by a breaking operation.

7.2.4.2 Operational performance capability

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following additions:

The circuit-breaker shall be capable of meeting the requirements of Table 8:

– for the test of operational performance without current in the main circuit under the test conditions specified in 8.3.3.4.3;
– for the test of operational performance with current in the main circuit under the test conditions specified in 8.3.3.4.4.

Each operating cycle consists of, either a closing operation followed by an opening operation (test of operational performance without current), or a making operation followed by a breaking operation (test of operational performance with current).

Table 8 – Number of operating cycles

1	2	3	4	5
Rated current [a]	**Number of operating cycles per hour** [b]	**Number of operating cycles**		
A		**Without current**	**With current** [c]	**Total**
$I_n \leq 100$	120	8 500	1 500	10 000
$100 < I_n \leq 315$	120	7 000	1 000	8 000
$315 < I_n \leq 630$	60	4 000	1 000	5 000
$630 < I_n \leq 2\,500$	20	2 500	500	3 000
$2\,500 < I_n$	10	1 500	500	2 000

a This means the maximum rated current for a given frame size.

b Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

c During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

7.2.5 Ability to make and break under short-circuit conditions

Subclause 7.2.5 of IEC 60947-1:2007 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 4.3.6.1 and 4.3.6.3.

The rated short-circuit breaking capacity shall be in accordance with 4.3.6.2.

The rated short-time withstand current shall be in accordance with 4.3.6.4.

NOTE It is the manufacturer's responsibility to ensure that the tripping characteristic of the circuit-breaker is compatible with the capability of the circuit-breaker to withstand the inherent thermal and electrodynamic stresses.

7.2.6 Vacant

7.2.7 Additional requirements for circuit-breakers suitable for isolation

Subclause 7.2.7 of IEC 60947-1:2007 applies and tests shall be made in accordance with 8.3.3.3, 8.3.3.6, 8.3.3.10, 8.3.4.4, 8.3.5.4 and 8.3.7.8, as applicable.

7.2.8 Specific requirements for integrally fused circuit-breakers

NOTE For the co-ordination between circuit-breakers and separate fuses associated in the same circuit, see 7.2.9.

An integrally fused circuit-breaker shall comply with this standard in all respects up to the rated ultimate short-circuit breaking capacity. In particular, it shall meet the requirements of test sequence V (see 8.3.7).

The circuit-breaker shall function, without causing the fuses to operate, at the occurrence of over-currents not exceeding the selectivity limit current I_s declared by the manufacturer.

For all over-currents up to and including the rated ultimate short-circuit breaking capacity assigned to the composite unit, the circuit-breaker shall open when one or more fuses operate (in order to prevent single-phasing). If the circuit-breaker is stated by the manufacturer to be with lock-out device preventing closing (see 2.14), it shall not be possible to reclose the circuit-breaker until either the melted fuse-links or any missing fuse-links have been replaced or the lock-out means has been reset.

7.2.9 Co-ordination between a circuit-breaker and another short-circuit protective device

For the co-ordination between a circuit-breaker and another short-circuit protective device, see Annex A.

7.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

8 Tests

8.1 Kind of tests

8.1.1 General

Subclause 8.1 of IEC 60947-1:2007 applies, with the following additions:

The tests to verify the characteristics of circuit-breakers are:

– type tests (see 8.3);
– routine tests (see 8.4);
– special tests (see 8.5).

8.1.2 Type tests

Type tests include the following tests:

Test	Subclause
Temperature-rise	8.3.2.5
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Short-circuit breaking capacities	8.3.4 and 8.3.5
Short-time withstand current (where applicable)	8.3.6
Performance of integrally fused circuit-breakers	8.3.7
Critical d.c. load current	8.3.9

Type tests shall be carried out by the manufacturer, in his workshop or at any suitable laboratory of his choice.

8.1.3 Routine tests

Routine tests comprise the tests listed in 8.4.

8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

8.3 Type tests

In order to avoid repetition of identical tests applicable to the various test sequences, the general test conditions have been grouped together at the beginning of this subclause under three headings:

– test conditions applicable to all sequences (8.3.3 to 8.3.8);
– test conditions applicable to temperature-rise tests (8.3.2.5);
– test conditions applicable to short-circuit tests (8.3.2.6).

Wherever appropriate, these general test conditions refer back to, or are based on, the general rules of IEC 60947-1.

Each test sequence refers back to the general test conditions applicable. This requires the use of cross-references, but enables each test sequence to be presented in a much simplified form.

Throughout this clause the term "test" has been used for every test to be made; "verification" should be interpreted as "test for the verification" and has been used where it is intended to verify the condition of the circuit-breaker following an earlier test in a test sequence whereby it may have been adversely affected.

In order to facilitate locating a particular test condition or test, an alphabetical index is given in 8.3.1.3, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

8.3.1 Test sequences

8.3.1.1 General

Type tests are grouped together in a number of sequences, as shown in Table 9.

For each sequence, tests shall be made in the order listed unless otherwise specified in this standard.

8.3.1.2 Tests omitted from sequence I and made separately

With reference to 8.1.1 of IEC 60947-1:2007, the following tests of test sequence I (see 8.3.3) may be omitted from the sequence and made on separate samples:

– tripping limits and characteristics (8.3.3.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 8.3.3.2.3 only on the phase poles at the maximum setting ~~only~~, at room temperature and without the additional test of item b) to verify the time-current characteristic;
– test of dielectric properties (8.3.3.3);
– test of under-voltage releases of 8.3.3.4.2.3 and 8.3.3.4.3 to verify the requirements of 7.2.1.3 of IEC 60947-1:2007, and tests of under-voltage releases at alternative frequencies (see 8.3.2.1);
– test of shunt ~~trip~~ releases of 8.3.3.4.2.4 and 8.3.3.4.3 to verify the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014, and tests of shunt releases at alternative frequencies (see 8.3.2.1);
– additional tests for operational performance capability without current for withdrawable circuit-breakers (8.3.3.4.5).

8.3.1.3 Applicability of sequences according to the relationship between short-circuit ratings

The applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} is given in Table 9a.

Alphabetical index of tests

General test conditions	Subclause
Arrangement of circuit-breakers, general	8.3.2.1
Arrangement of circuit-breakers for short-circuit tests	8.3.2.6.1
Frequency	8.3.2.2.3
Power factor	8.3.2.2.4
Records (interpretation of)	8.3.2.6.6
Recovery voltage	8.3.2.2.6
Short-circuit test circuits	8.3.2.6.2
Short-circuit test procedure	8.3.2.6.4
Temperature-rise test	8.3.2.5
Time constant	8.3.2.2.5
Tolerances	8.3.2.2.2
Tests (for overall schema of test sequences, see Table 9)	**Subclause**
Critical d.c. load current	8.3.9
Dielectric properties	8.3.3.3
Dielectric withstand (verification)	8.3.3.6 – 8.3.4.4 – 8.3.5.4 – 8.3.6.6 – 8.3.7.4 – 8.3.7.8 – 8.3.8.6
Individual pole short-circuit test (for phase-earthed systems)	Annex C
Individual pole short-circuit test (for IT systems)	Annex H – see H.2
Indication of main contact position	8.3.3.10
Integrally fused circuit-breakers (short-circuit tests)	8.3.7.2 – 8.3.7.6 – 8.3.7.7
Operational performance capability	8.3.3.4 – 8.3.4.3 – 8.3.4.5
Overload performance	8.3.3.5
Overload releases (verification)	8.3.3.8 – 8.3.4.5 – 8.3.5.2 – 8.3.5.5 – 8.3.6.2 – 8.3.6.7 – 8.3.7.5 – 8.3.7.9 – 8.3.8.2 – 8.3.8.8
Service short-circuit breaking capacity	8.3.4.2 – 8.3.8.4
Short-circuit breaking capacity test at maximum short-time withstand current	8.3.6.5
Short-time withstand current	8.3.6.3 – 8.3.8.3
Temperature-rise (verification)	8.3.3.7 – 8.3.4.5 – 8.3.6.4 – 8.3.7.3 – 8.3.8.7
Tripping limits and characteristics	8.3.3.2
Ultimate short-circuit breaking capacity	8.3.5.3
Withdrawable circuit-breakers (additional tests)	8.3.3.4.5

Table 9 – Overall schema of test sequences[a]

Test sequence	Applicable to	Tests
I General performance characteristics (8.3.3)	All circuit-breakers	Tripping limits and characteristics Dielectric properties Mechanical operation and operational performance capability Overload performance (where applicable) Verification of dielectric withstand Verification of temperature-rise Verification of overload releases Verification of undervoltage and shunt releases (where applicable) Verification of main contact position (where applicable)
II Rated service short-circuit breaking capacity (8.3.4)	All circuit-breakers [b]	Rated service short-circuit breaking capacity Verification of operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
III Rated ultimate short-circuit breaking capacity (8.3.5)	All circuit-breakers [c] of utilization selectivity category A and circuit-breakers of utilization selectivity category B with instantaneous override* [d]	Verification of overload releases Rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
IV Rated short-time withstand current (8.3.6)	Circuit-breakers of utilization selectivity category B [b] and circuit-breakers of selectivity category A with a rated short-time withstand current (see 4.4)	Verification of overload releases Rated short-time withstand current Verification of temperature-rise Short-circuit breaking capacity at maximum short-time withstand current Verification of dielectric withstand Verification of overload releases
V Performance of integrally fused circuit-breakers (8.3.7)	Stage 1	Short-circuit at the selectivity limit current Verification of temperature-rise Verification of dielectric withstand
	Integrally fused circuit-breakers Stage 2	Verification of overload releases Short-circuit at 1,1 times the take-over current Short-circuit at rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
VI Combined test sequence (8.3.8)	Circuit-breakers of utilization selectivity category B: when $I_{cw} = I_{cs}$ (replaces test sequences II and IV) when $I_{cw} = I_{cs} = I_{cu}$ (replaces test sequences II, III and IV)	Verification of overload releases Rated short-time withstand current Rated service short-circuit breaking capacity Operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
Critical d.c. load current (8.3.9)	Circuit-breakers with d.c. ratings	Critical d.c. load current tests
Individual pole short-circuit test sequence (Annex C)	Circuit-breakers for use on phase-earthed systems	Individual pole short-circuit breaking capacity (I_{su}) Verification of dielectric withstand Verification of overload releases
Individual pole short-circuit test sequence Test sequence for circuit-breakers for IT systems (Annex H)	Circuit-breakers for use in IT systems	Individual pole short-circuit breaking capacity (I_{IT}) Verification of dielectric withstand Verification of overload releases

a For the selection of circuit-breakers for tests and the applicability of the various test sequences according to the relationship between I_{cs} , I_{cu} and I_{cw}, see Table 9a.

b Except where ~~the combined test~~ Sequence VI is applied.

c Except

– where I_{cs} = I_{cu} (but see 8.3.5),

– where ~~the combined test~~ sequence VI is applied,

– for integrally fused circuit-breakers.

~~*~~ d See note to 8.3.5.1

Table 9a – Applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} [a]

I_{cs}, I_{cu} and I_{cw} relationship	Test sequence	Selectivity category			
		A	A Integrally fused	B	B Integrally fused
CASE 1	I	X	X	X	X
	II	X	X	X	X
$I_{cs} \neq I_{cu}$ for selectivity category A	III	X		X [b]	
$I_{cs} \neq I_{cu} \neq I_{cw}$ for ~~utilization~~ selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 2	I			X	X
$I_{cs} = I_{cw} \neq I_{cu}$ for ~~utilization~~ selectivity	II			X	X
category B	III			X [b]	
	IV			X	X
	V				X
	VI (combined)			X [c]	X [c]
CASE 3	I	X	X	X	X
	II	X	X	X	X
$I_{cs} = I_{cu}$ for ~~utilization~~ selectivity category A	III				
$I_{cs} = I_{cu} \neq I_{cw}$ for ~~utilization~~ selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 4	I			X	
	II			X	
$I_{cs} = I_{cu} = I_{cw}$ for ~~utilization~~ selectivity	III				
category B	IV			X	
	V				
	VI (combined)			X [c]	

[a] This table applies to any one value of U_e. For multiple U_e ratings, the table applies to each U_e rating. The applicability of a test sequence is indicated by X in the relevant space.

[b] Test applicable only if $I_{cu} > I_{cw}$.

[c] At the discretion of, or in agreement with the manufacturer, this sequence may be applied to circuit-breakers of selectivity category B, in which case it replaces test sequences II and IV.

[d] Test sequence IV applies only ~~in the case of circuit-breakers covered by note 3 of Table 4~~ to circuit-breakers with a rated short-time withstand current (see 4.4).

8.3.1.4 Alternative test programmes for a.c. circuit-breakers having a different number of poles

These alternative test programmes may only be applied to a.c. ratings and when all the ratings are the same or lower than the variant submitted to the full programme of Table 9, and construction breaks are the same for all variants. In the case of 1-pole circuit-breakers the voltage ratings shall be equal to or lower than the line-to neutral voltage of the variant tested to Table 9. A 2-pole circuit-breaker produced by removing the centre current path from a 3-pole circuit-breaker tested to programme 1 or programme 2 of this subclause need not be tested as it is considered to be covered by the tests on the 3-pole variant.

Compliance with the test requirements is met by carrying out one of the alternative programmes 1 or 2 below.

– Programme 1: The applicable test sequences according to Table 9 shall be carried out on the three-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9b shall be carried out on the other variants.

– Programme 2: The applicable test sequences according to Table 9 shall be carried out on the four-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9c shall be carried out on the other variants.

The principle for the application of the alternative test programmes is illustrated below:

	Programme 1					**Programme 2**			
	1-pole	2-poles	3-poles	4-poles		1-pole	2-poles	3-poles	4-poles
Construction 1[a]	□	□	■	□		○	○	○	■
Construction 2	–	–	■	□		–	–	–	■
Construction 3	–	–	■	□		–	–	–	■
…	–	–	■	□		–	–	–	■
Construction *n*	–	–	■	□		–	–	–	■
Key	■ fully tested per Table 9 □ tested per Table 9b ○ tested per Table 9c – no test required								

[a] Construction 1 is the construction which covers the max rating.

Table 9b – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers according to the alternative programme 1 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 4-pole variant[f, h]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General	X	X
	8.3.3.2.2	Short-circuit releases	X[a]	X[e]
	8.3.3.2.3 a)[k]	Overload releases: – instantaneous/definite time-delay – inverse time-delay	X	
	or 8.3.3.2.3 b)[k] (as applicable)		X	X[e]
	8.3.3.2.4	Additional test for definite time-delay releases:		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation	X[d]	X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers	X	
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current	X 4th pole and adjacent pole only (see 8.3.2.6.4)	
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breakers for IT systems		
NOTE The applicability of a test or test sequence is indicated by X in the relevant space.				

[a] One test on one pair of phase poles chosen at random. In the case of an electronic trip unit, this test may be made on one pole chosen at random.

[b] This test sequence also applies when, for the 3-pole testing, Sequence III on the 3-poles variant is replaced by Sequence II or Sequence VI (see Table 9).

[c] One sample of maximum current rating only, tested at max kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).

[e] Applicable only to 1-pole variant; not required for 2-poles variants.

[f] In case of 4-poles devices with different levels of neutral protection (e.g. 60 % or 100 %), only the variant with the highest level has to be tested according to Table 9b.

[g] One sample of maximum current rating only, for each test sequence.

[h] One sample of maximum current rating for each test sequence; in the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction.

[i] Vacant.

[j] Vacant.

[k] This test is not required for electronic trip units.

Table 9c – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers according to the alternative programme 2 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 3-pole variant[g]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General		X
	8.3.3.2.2	Short-circuit releases		X[e]
	8.3.3.2.3 a)[k]	Overload releases: – instantaneous/definite time-delay – inverse time-delay		X[e]
	or 8.3.3.2.3 b)[k] (as applicable)			
	8.3.3.2.4	Additional test for definite time-delay releases		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation		X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers		
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current		
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breaker for IT systems		

NOTE The applicability of a test or test sequence is indicated by X in the relevant space.

a Vacant.

b This test sequence also applies when, for the 4-poles testing, Sequence III on the 4-poles variant is replaced by Sequence II or Sequence VI (see Table 9).

c One sample of maximum current rating only, tested at max kVA rating (I_{cu} × corresponding U_e).

d Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).

e Applicable only to 1-pole variant; not required for 2-poles variants.

f Vacant.

g One sample of maximum current rating only, for each test sequence.

h Vacant.

i Vacant.

j Vacant.

k This test is not required for electronic trip units.

8.3.2 General test conditions

~~NOTE 1 Test conditions for the verification of switching overvoltages are under consideration.~~

NOTE ~~2~~ Tests according to the requirements of this standard do not preclude the need for additional tests concerning circuit-breakers incorporated in assemblies, for example tests in accordance with IEC ~~60439~~ 61439 series.

8.3.2.1 General requirements

Unless otherwise agreed by the manufacturer, each test sequence shall be made on a sample circuit-breaker (or set of samples) in a clean and new condition.

The number of samples to be tested for each test sequence and the test conditions (for example setting of overload releases, terminal connections), according to the circuit-breaker parameters, are given in Table 10 or, where applicable, for the alternative test programmes in Table 9b and Table 9c (see 8.3.1.4).

Where necessary, additional information is given in the relevant subclauses.

Unless otherwise specified, tests are to be performed on a circuit-breaker having the maximum rated current for a given frame size and are deemed to cover all rated currents of that frame size.

In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, further samples shall be tested in accordance with Table 9b and/or Table 10 as applicable.

Unless otherwise stated, short-circuit releases shall be set at maximum (time and current) for all tests.

The circuit-breakers to be tested shall, in all their essential details, correspond to the design of the type which they represent.

Unless otherwise stated, the tests shall be made with the same kind of current and, in the case of a.c., at the same rated frequency and with the same number of phases as in the intended service. Tests performed at 50 Hz cover 60 Hz applications and vice-versa, except for the performance of under-voltage and shunt releases (see 7.2.2 of IEC 60947-1:2007/AMD2:2010 and 7.2.2.6 of IEC 60947-1:2007).

If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as specified in 7.2.1.1.4. In addition, electrically controlled mechanisms shall be energized via the appropriate circuit-breaker control circuits complete with switching devices. It shall be verified that the circuit-breaker operates correctly on no-load when it is operated under the above conditions.

In case of circuit-breakers with dependent manual operation (see 2.4.12 of 60947-1:2007), the circuit-breaker shall be operated with an operating speed, during actuation, of 0,1 m/s ± 25 %, this speed being measured where the operating means of the test apparatus touches the actuating means of the circuit-breaker under test. For rotary handles the angular velocity shall correspond substantially to the above conditions, referred to the speed of the operating means (at its extremities) of the circuit-breaker under test.

The circuit-breaker under test shall be mounted complete on its own support or an equivalent support.

Circuit-breakers shall be tested in free air.

If a circuit-breaker may be used in specified individual enclosures and has been tested in free air, it shall be additionally tested in the smallest of such enclosures stated by the manufacturer, using a new sample, according to 8.3.5, at U_e max/corresponding I_{cu}, with release settings at maximum (see note 1 to Table 10) for each of the following:

a) A short-circuit test according to 8.3.5, at U_e max, and corresponding I_{cu}, with release settings at maximum (see Footnote [a] of Table 10).

b) A temperature rise test according to the general conditions of 8.3.2.5 on a circuit-breaker having a maximum I_{th}, at the conventional enclosed thermal rating I_{the} (see 4.3.3.2). The temperature rises shall meet the requirements of 7.2.2 except that the temperature rise of the terminals shall not exceed 70 K.

Details of these tests, including the dimensions of the enclosure, shall be stated in the test report.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one circuit-breaker only.

However, if a circuit-breaker may be used in specified individual enclosures and is tested throughout in the smallest of such enclosures stated by the manufacturer, the tests in free air need not be made provided that such enclosure is bare metallic, without insulation. Details, including the dimensions of the enclosure, shall be stated in the test report.

For the tests in free air, for tests concerning overload performance (8.3.3.5), short-circuit (8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.6, 8.3.7.7 and 8.3.8.4), and short-time withstand current (8.3.6.3 and 8.3.8.3) where applicable, a metallic screen shall be placed on all sides of the circuit-breaker in accordance with the manufacturer's instructions. Details, including distances of the metallic screen from the circuit-breaker, shall be stated in the test report.

The characteristics of the metallic screen shall be as follows:

- structure: woven wire mesh; or
  perforated metal; or
  expanded metal;
- ratio hole area/total area: 0,45 to 0,65;
- size of hole: not exceeding 30 mm^2;
- finish: bare or conductive plating;
- resistance: shall be included in the calculation for the prospective fault current in the fusible element circuit (see 8.3.4.1.2, item d) of IEC 60947-1:2007) when measured from the furthest point on the metallic screen likely to be reached by arc emissions.

The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions or, in the absence of such instructions, in accordance with Table 4 of IEC 60947-1 (see 5.2 e)).

Maintenance or replacements of parts is not permitted.

If, for convenience of testing, it appears useful to increase the severity of a test (for example to adopt a higher frequency of operation in order to reduce the duration of the test), this shall not be done without the consent of the manufacturer.

For single-phase tests on individual poles of multipole circuit-breakers intended for use on phase-earthed systems, see Annex C.

For additional tests for circuit-breakers for unearthed or impedance earth systems (IT), see Annex H.

Table 10 – Number of samples for test *(1 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Temperature-rise verification	Notes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	See 8.3.3		X	h j
II	X			X		2	1		X	U_e	X		X	h i j
(I_{cs})							2	X		U_e	X			b
and							1		X	U_e	X		X	h, i, j
VI (combined)	X				X	3	2	X		U_e	X			b
							3		X	U_e	X		X	c, j
							1		X	U_e max corr		X	X	h, i, j
		X		X	X	3	2	X		U_e max corr		X		b
							3		X	U_e max	X		X	d, j
			X	X	X	4	1		X	U_e max corr		X	X	h, i, j
							2	X		U_e max corr		X		b
							3		X	U_e intermed	X		X	f, j
							4		X	U_e max	X		X	d, j
III	X			X		2	1		X	U_e	X			h
(I_{cu})							2	X		U_e	X			b
							1		X	U_e	X			h
	X				X	3	2	X		U_e	X			b
							3		X	U_e	X			c
							1		X	U_e max corr		X		h
		X		X	X	3	2	X		U_e max corr		X		b
							3		X	U_e max	X			d
			X	X	X	4	1		X	U_e max corr		X		h
							2	X		U_e max corr		X		b
							3		X	U_e intermed	X			f
							4		X	U_e max	X			d
IV (I_{cw})	As for test sequence III													e
V	X	X	X	X	X	2	1		X	U_e max	X		X	g, h, j
(I_{cu})							2	X		U_e max	X			b
Individual pole (Annex C) (I_{su})	X	X	X	X	X	2	1		X	U_e max	I_{su}			h
							2	X		U_e max	I_{su}			–
Individual pole (Annex H) (I_{IT})	X	X	X	X	X	1			X	U_e max	I_{IT}			h

Notes for Table 10

Mul = multiple; Corr = corresponding; Intermed = intermediate

[a] Min means the minimum I_n of a given frame size; in the case of adjustable overload releases, it means the minimum setting of the minimum I_n. Max means the maximum I_n of a given frame size.

[b] This sample is omitted in the following cases:

– a circuit-breaker having a single non-adjustable current setting for a given frame size;

– a circuit-breaker provided only with a shunt release (i.e. without an integral overcurrent release);

– a circuit-breaker with electronic overcurrent protection, of a given frame size, having an adjustable current rating by electronic means only (i.e. without change of current sensors).

c Connections reversed.

d Connections reversed, if terminals unmarked.

e Applies to category B circuit-breakers and also to category A circuit-breakers covered by note 3 of Table 4.

f To be agreed between test station and manufacturer.

g If terminals unmarked an additional sample shall be tested with connections reversed.

h In the case of one or more construction breaks (see 2.1.2 and 7.1.5) within the frame size a further sample is tested at the maximum rated current corresponding to each construction, under the conditions applicable to sample 1.

i The requirement of footnote h applies only to the combined sequence.

j For circuit-breakers where the value of I_n differs through external current carrying parts (i.e. interchangeable terminals or draw-out cradle connections), the minimum and maximum ratings of this construction shall be subjected to the full sequence. At the end of the sequence, the maximum rating sample shall then be adapted to perform a verification of temperature-rise on each variation of external current-carrying parts.

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Temperature-rise verification	Footnotes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	See 8.3.3		X	g
II (I_{cs}) and VI (combined)	X			X		2	1		X	U_e	X		X	h
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X		X	h
							2	X		U_e	X			b
							3		X	U_e	X		X	j
		X		X	X	3	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e max	X		X	k
			X	X	X	4	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e intermed.	X		X	e
							4		X	U_e max	X		X	k
III (I_{cu})	X			X		2	1		X	U_e	X			g
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X			g
							2	X		U_e	X			b
							3		X	U_e	X			c
		X		X	X	3	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e max	X			d
			X	X	X	4	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e intermed.	X			e
							4		X	U_e max	X			d

Table 10 *(2 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Time delay		Temperature-rise verification	Foot-notes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.	Corr.	Max.		
IV (I_{cw}) [l]	X			X	X	2	1		X	U_e max		X		X	X	g
							2		X	U_e max		X		X	X	m
			X	X	X	3	1		X	U_e max corr.		X	X		X	g
							2		X	U_e max corr.	X		X		X	i
							3		X	U_e max	X		X		X	n, d
V Integral fused (I_{cu})	X	X	X	X	X	2	1		X	U_e max	X				X	f, g
							2	X		U_e max	X					b
Individual pole (Annex C) (I_{su})	X	X	X	X	X	2	1		X	U_e max	I_{su}					g
							2	X		U_e max	I_{su}					–
Individual pole (Annex H) (I_{IT})	X	X	X	X	X	1	1		X	U_e max	I_{IT}					g

Key

Mul. = multiple; Corr. = corresponding; Intermed. = intermediate

NOTE 1 Table 10 applies to the test programmes of Table 9. In the case of the alternative test programmes (see 8.3.1.4), Table 9b and Table 9c are applicable.

NOTE 2 The applicability of a test or test sequence is indicated by X in the relevant space.

[a] Min means the minimum I_n of a given frame size; in the case of adjustable overload releases, it means the minimum setting of the minimum I_n. Max means the maximum I_n of a given frame size.

[b] This sample is omitted in the following cases:

– a circuit-breaker having a single non-adjustable current setting for a given frame size;

– a circuit-breaker provided only with a shunt release (i.e. without an integral overcurrent release);

– a circuit-breaker with electronic overcurrent protection, of a given frame size, having an adjustable current rating by electronic means only (i.e. without change of current sensors).

[c] Connections reversed.

[d] Connections reversed, if terminals unmarked.

[e] To be agreed between test station and manufacturer.

[f] If terminals unmarked, an additional sample shall be tested with connections reversed.

[g] In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction, under the conditions applicable to sample 1.

[h] The requirement of footnote g applies to sequence VI (combined) and also to sequence II where $I_{cs} = I_{cu}$.

[i] This sample is selected based on the highest value of thermal energy ($I_{cw}{}^2t$; where "t" is the corresponding short-time delay, see 4.3.6.4). This sample is omitted if the highest thermal energy condition is met by sample 1 or 3.

[j] This sample, with connections reversed, is only required when sequence III is replaced by sequence II (I_{cu}= I_{cs}, see 8.3.5).

[k] Connections reversed, if terminals unmarked, when sequence III is replaced by sequence II ($I_{cu} = I_{cs}$, see 8.3.5) or when sequence VI replaces sequences II, III and IV ($I_{cu} = I_{cs} = I_{cw}$, see 8.3.8), otherwise this sample is tested forward connected.

[l] Applies only to circuit breakers with a rated short-time withstand current (see 4.4).

[m] This sample, with connections reversed, is only required when terminals unmarked and sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

[n] This sample is only required when sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

8.3.2.2 Test quantities

8.3.2.2.1 Values of test quantities

Subclause 8.3.2.2.1 of IEC 60947-1:2007 applies.

8.3.2.2.2 Tolerances on test quantities

Subclause 8.3.2.2.2 of IEC 60947-1:2007 applies.

8.3.2.2.3 Frequency of the test circuit for a.c.

All tests shall be made at the rated frequency of the circuit-breaker. For all short-circuit tests, if the rated breaking capacity is essentially dependent on the value of the frequency, the tolerance shall not exceed ±5 %.

If the manufacturer declares the rated breaking capacity to be substantially unaffected by the value of the frequency, the tolerance shall not exceed ±25 %.

8.3.2.2.4 Power factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

Table 11 – Values of power factors and time constants corresponding to test currents

Test current *I* kA	Power factor			Time constant ms		
	Short-circuit	Operational performance capability	Overload	Short-circuit	Operational performance capability	Overload
$I \leq 3$	0,9	0,8	0,5	5	2	2,5
$3 < I \leq 4,5$	0,8			5		
$4,5 < I \leq 6$	0,7			5		
$6 < I \leq 10$	0,5			5		
$10 < I \leq 20$	0,3			10		
$20 < I \leq 50$	0,25			15		
$50 < I$	0,2			15		

8.3.2.2.5 Time constant of the test circuit

Subclause 8.3.4.1.4 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

8.3.2.2.6 Power-frequency recovery voltage

Subclause 8.3.2.2.3, item a) of IEC 60947-1:2007/AMD2:2014 applies.

8.3.2.2.7 Ripple of the test current for d.c.

The test current shall comply with the requirements of 6.3.1 of IEC 62475:2010.

8.3.2.3 Evaluation of test results

The condition of the circuit-breaker after tests shall be checked by the verifications applicable to each sequence.

A circuit-breaker is deemed to have met the requirements of this standard if it meets the requirements of each sequence as applicable.

The case shall not be broken but hairline cracks are acceptable.

NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of a superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

8.3.2.4 Test reports

Subclause 8.3.2.4 of IEC 60947-1:2007 applies.

8.3.2.5 Test conditions for temperature-rise test

The circuit-breaker shall meet the requirements of 7.2.2.

Subclause 8.3.3.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except 8.3.3.3.6, with the following addition:

The circuit-breaker shall be mounted in accordance with 8.3.2.1.

~~Coils of undervoltage releases (if applicable) shall be energized at the maximum rated control supply voltage.~~

During the temperature rise test of sequence I (see 8.3.3.7) coils of under-voltage releases, where applicable, shall be supplied at one rated frequency and corresponding voltage, chosen at random. Additional tests to verify coils at other rated frequencies and voltages shall be made outside the sequence.

For four-pole circuit-breakers, a test shall first be made on the three poles which incorporate over-current releases. For a circuit-breaker having a value of rated current not exceeding 63 A, an additional test shall be made by passing the test current through the fourth pole and its adjacent pole. For higher rated current values, the method of testing shall be the subject of a separate agreement between manufacturer and user.

8.3.2.6 Test conditions for short-circuit tests

8.3.2.6.1 General requirements

~~NOTE 1 Attention is drawn to note 3, which has been introduced to avoid unnecessary retesting due to the new requirement of item b).~~

Subclause 8.3.4.1.1 of IEC 60947-1:2007 is amplified as follows:

a) The circuit-breaker shall be mounted in accordance with 8.3.2.1.

b) Unless it can be shown that, with the manual operating means in any position, there is no opening around the manual operating means through which a music wire of 0,26 mm diameter can be inserted so as to reach the arc chamber area, the following test arrangement shall apply:

For opening operations only, a clear, low density polyethylene sheet, 0,05 mm ± 0,01 mm thick, of a size 100 mm × 100 mm, positioned as shown in Figure 1, fixed and reasonably stretched in a frame, is placed at a distance of 10 mm from:

- either the maximum projection of the manual closing means of a circuit-breaker without recess for this closing means;
- or the rim of the recess for the manual closing means of a circuit-breaker with recess for this closing means.

The polyethylene sheet shall have the following physical properties:

- density at 23 °C: 0,92 g/cm^3 ± 0,05 g/cm^3;
- melting point: 110 °C to 120 °C.

On the side remote from the circuit-breaker there shall be an appropriate backing to obviate tearing of the polyethylene sheet due to the pressure wave which may occur during the short-circuit test (see Figure 1).

For tests other than those in an individual enclosure, a shield which may be of insulating material or of metal is placed between the metallic screen and the polyethylene sheet (see Figure 1).

NOTE ~~2~~ This test arrangement applies to O operations only, since it is difficult to arrange for CO operations and it is accepted that O operations are no less severe than CO operations (see 8.3.2.6.4).

~~NOTE 3 In order to obviate the need for making a new series of short-circuit test sequences to prove compliance with this subclause, it is permitted provisionally, with the agreement of the manufacturer, to verify this by means of a separate O operation for each test sequence applicable.~~

c) The circuit-breaker shall be operated during tests to simulate service conditions as closely as possible

A circuit-breaker having a dependent power operation shall be closed during tests with the control supply (voltage or pressure) at 85 % of its rated value.

A circuit-breaker having an independent power operation shall be closed during tests with the operating mechanism charged to its maximum value stated by the manufacturer.

A circuit-breaker having a stored energy operation shall be closed during tests with the operating means charged at 85 % of the rated voltage of the auxiliary supply.

d) If a circuit-breaker is fitted with adjustable over-current releases, the setting of these releases shall be as specified for each test sequence.

For circuit-breakers without over-current releases but fitted with a shunt release, this release shall be energized by the application of a voltage equal to 70 % of the rated control supply voltage of the release (see 7.2.1.2.3), at a time not earlier than that of the initiation of the short-circuit nor later than 10 ms after the initiation of the short-circuit.

e) For all these tests, the line side of the test circuit shall be connected to the corresponding terminals of the circuit-breaker as marked by the manufacturer. In the absence of such markings, the test connections shall be as specified in Table 10.

8.3.2.6.2 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies.

8.3.2.6.3 Calibration of the test circuit

Subclause 8.3.4.1.5 of IEC 60947-1:2007 applies.

8.3.2.6.4 Test procedure

8.3.2.6.4.1 General

Subclause 8.3.4.1.6 of IEC 60947-1:2007 applies, with the following ~~amplification~~ addition.

8.3.2.6.4.2 Tests on one-, two- and three-pole circuit-breakers

After calibration of the test circuit in accordance with 8.3.2.6.3, the temporary connections are replaced by the circuit-breaker under test and its connecting cables if ~~any~~ applicable.

Tests for the performance under short-circuit conditions shall be made according to the sequences in Table 9 (see 8.3.1).

For circuit-breakers having a rated current up to and including 630 A, a cable of maximum length 75 cm, having a cross-section corresponding to the conventional thermal current (see 8.3.3.3.4, Tables 9 and 10 of IEC 60947-1:2007) shall be included as follows:

– approximately 50 cm on the supply side;
– approximately 25 cm on the load side.

For ratings ≤ 20 A, the manufacturer may specify a larger cross-section, in which case this cross-section shall be used for all relevant short-circuit tests, and stated in the test report. In addition, a verification of inverse-time delay releases according to 8.3.3.2.3 b) shall be made with this cross-section.

The sequence of operations shall be that which is applicable to each test sequence, as specified in 8.3.4.2, 8.3.5.3, 8.3.6.5 and 8.3.7.7.

~~For four-pole circuit-breakers, an additional sequence of operations on one or more new samples, in accordance with Table 10, shall be made on the fourth pole and its adjacent pole, for sequences III and IV, or IV and V, as applicable, at an applied voltage of $U_e/\sqrt{3}$, using the circuit shown in Figure 12 of IEC 60947-1. The test current shall be agreed between manufacturer and user, but shall be not less than 60 % of I_{cu} or I_{cw}, as applicable.~~

~~At the manufacturer's request, these additional tests may be made on the same samples, each test in the relevant test sequence comprising the appropriate tests:~~

~~– on three adjacent phase poles;~~
~~– on the fourth pole and the adjacent pole.~~

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.3 Tests on four-pole circuit-breakers

The requirements of 8.3.2.6.4.2 apply.

Additional sequences of operations on one or more new samples, in accordance with Table 10, shall be made on the fourth pole and its adjacent pole, according to sequences III or V, as applicable, and sequence IV if applicable. This requirement applies even when sequence III is replaced by sequence II ($I_{cu} = I_{cs}$) or sequence IV is replaced by sequence VI ($I_{cw} = I_{cs}$).

Alternatively, at the request of the manufacturer, these tests may be combined with the three-pole tests of 8.3.2.6.4.2 and made on the same samples, in which case the test in each relevant test sequence shall comprise

– the test on three adjacent poles,
– the test on the fourth pole and the adjacent pole.

The tests on the fourth pole and the adjacent pole are made at an applied voltage of $U_e/\sqrt{3}$, in the circuit shown in Figure 12 of IEC 60947-1:2007/AMD1:2010 with the connections C1 and C2 removed. The test current shall be agreed between manufacturer and user but shall be not less than 60 % of I_{cu} or I_{cw}, as applicable.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.4 Test operations

The following symbols are used for defining the sequence of operations:

O represents a breaking operation;

CO represents a making operation followed, after the appropriate opening time, by a breaking operation:

t represents the time interval between two successive short-circuit operations which shall be as short as possible, allowing for the resetting time of the circuit-breaker (see 2.19), but not less than 3 min. The actual value of *t* shall be stated in the test report.

The maximum resetting time shall be 15 min or such longer time as may be stated by the manufacturer, but not exceeding 1 h, during which time the circuit-breaker shall not be displaced. Attempts to reclose the circuit-breaker during the resetting time shall be spaced by at least 1 min.

The maximum value of I^2t (see 2.5.18 of IEC 60947-1:2007) during these tests may be recorded in the test report (see 7.2.1.2.4, item a)).

~~NOTE The maximum value of I^2t recorded during the tests may not be the maximum possible value for the prescribed conditions. Additional tests are necessary if this maximum value needs to be determined.~~

8.3.2.6.5 Behaviour of the circuit-breaker during short-circuit making and breaking tests

Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies.

8.3.2.6.6 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1:2007 applies.

8.3.2.6.7 Verification after short-circuit tests

After the opening operations of the short-circuit making and breaking capacity tests of 8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.7, 8.3.8.4, as applicable, the following conditions shall be met:

– there shall be no damage to the insulation on conductors used to wire the device;
– the polyethylene sheet, where applicable, shall show no holes visible with normal or corrected vision without additional magnification. Minuscule holes of less than 0,26 mm diameter can be ignored;
– the case shall not be broken but hairline cracks are acceptable.

NOTE ~~Minute visible holes of less than 0,26 mm diameter can be ignored.~~ Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

Additionally, after the short-circuit tests, the circuit-breaker shall comply with the verifications specified for each test sequence, as applicable.

8.3.3 Test sequence I: General performance characteristics

8.3.3.1 General

This test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Mechanical operation and operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Verification of dielectric withstand	8.3.3.6
Verification of temperature-rise	8.3.3.7
Verification of overload releases	8.3.3.8
Verification of undervoltage and shunt releases (if applicable)	8.3.3.9
Verification of main contact position (for circuit-breakers suitable for isolation)	8.3.3.10

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

See 8.3.1 for tests that may be omitted from the sequence and made on separate samples.

8.3.3.2 Test of tripping limits and characteristics

8.3.3.2.1 General

Subclause 8.3.3.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 is amplified as follows:

The ambient air temperature shall be measured as for the temperature-rise tests (see 8.3.2.5).

When the over-current opening release is normally a built-in part of the circuit-breaker, it shall be verified inside the corresponding circuit-breaker.

Any separate release shall be mounted approximately as under normal service conditions. The complete circuit-breaker shall be mounted in accordance with 8.3.2.1. The equipment under test shall be protected against undue external heating or cooling.

The connections of the separate release, if appropriate, or of the complete circuit-breaker shall be made as for normal service, with conductors of cross-section corresponding to the rated current (I_n) (see Tables 9 and 10 of 8.3.3.3.4 of IEC 60947-1:2007) and of length according to 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

For circuit-breakers with adjustable over-current releases, tests shall be made at:

a) minimum current setting and minimum time-delay setting, as applicable; and
b) maximum current setting and maximum time-delay setting, as applicable,

in each case with conductors corresponding to the rated current I_n (see 4.7.2).

~~NOTE~~ For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

For circuit-breakers having a neutral pole provided with an overload release, the verification of this overload release shall be made on the neutral pole alone.

The tests may be made at any convenient voltage.

8.3.3.2.2 ~~Opening under short-circuit conditions~~ Short-circuit releases

The operation of short-circuit releases (see 4.7.1) shall be verified at 80 % and 120 % of the short-circuit current setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms.

At a test current having a value equal to 80 % of the short-circuit current setting, the release shall not operate, the current being maintained:

- for 0,2 s in the case of instantaneous releases (see 2.20);
- for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 120 % of the short-circuit current setting, the release shall operate:

- within 0,2 s in the case of instantaneous releases (see 2.20);
- within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers with an electronic overcurrent release, the operation of the short-circuit releases shall be verified by one test only on each pole individually.

For circuit-breakers with electromagnetic overcurrent releases, the operation of multipole short-circuit releases shall be verified by one test only on each combination of two phase poles in series. For circuit-breakers having an identified neutral pole provided with a short-circuit release, the neutral pole shall be tested in series with one phase pole chosen at random. In addition, the operation of the short-circuit releases shall be verified once on each pole individually, at 120 % of either the value ~~of the tripping current~~ declared by the manufacturer for individual poles, or the short-circuit current setting (if no value is declared for indivudal poles), at which value they shall operate:

- within 0,2 s in the case of instantaneous releases (see 2.20);
- within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

8.3.3.2.3 ~~Opening under overload conditions~~ Overload releases

a) Instantaneous or definite time-delay releases

The operation of instantaneous or definite time-delay overload releases (see Note 1 of 4.7.1) shall be verified at 90 % and 110 % of the overload setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms. The operation of multipole overload releases shall be verified with all phase poles loaded simultaneously with the test current.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

At a test current having a value equal to 90 % of the current setting, the release shall not operate, the current being maintained

- for 0,2 s in the case of instantaneous releases (see 2.20),
- for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 110 % of the current setting, the release shall operate

- within 0,2 s in the case of instantaneous releases (see 2.20),

– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.3), the test current for this release shall have a value equal to 1,2 times 110 % of the current setting.

b) Inverse time-delay releases

The operating characteristics of inverse time-delay overload releases shall be verified in accordance with the performance requirements of 7.2.1.2.4, item b), 2).

For circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.4), the test currents for this release shall be those given in Table 6 except that the test current at the conventional tripping current shall be multiplied by the factor 1,2.

For releases dependent on ambient air temperature, the operating characteristic shall be verified at the reference temperature (see 4.7.3 and 5.2 item b)), the release being energized on all phase poles.

If this test is made at a different ambient air temperature, a correction shall be made in accordance with the manufacturer's temperature/current data.

For thermal-magnetic releases declared by the manufacturer to be independent of ambient air temperature, the operating characteristic shall be verified by two measurements, one at 30 °C ± 2 °C, the other at 20 °C ± 2 °C or at 40 °C ± 2 °C, the release being energized on all phase poles.

For electronic releases, the operating characteristic shall be verified at the ambient temperature of the test room (see 6.1.1 of IEC 60947-1:2007/AMD2:2014), the release being energised on all phase poles.

An additional test, at a current value to be agreed between manufacturer and user, shall be made to verify that the time/current characteristics of the release conform (within the stated tolerances) to the curves provided by the manufacturer.

NOTE In addition to the tests in this subclause, the releases of circuit-breakers are also verified on each pole singly, during test sequences III, IV, V and VI (see 8.3.5.2, 8.3.5.5, 8.3.6.2, 8.3.6.7, 8.3.7.5, 8.3.7.9, 8.3.8.2 and 8.3.8.8).

8.3.3.2.4 Additional tests for definite time-delay releases

Definite time-delay releases shall be tested to verify the values of the time-delay and the non-tripping duration

a) Time-delay

This test is made at a current equal to 1,5 times the current setting:

– in the case of overload releases, with all phase poles loaded;

– for circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.1), the test current for this release shall be 1,5 times the current setting;

– in the case of electromagnetic short-circuit releases, with two poles in series carrying the test current, using successively all possible combinations of phase poles having a short-circuit release.

– in the case of electronic short-circuit releases, on one pole chosen at random.

The time-delay measured, shall be between the limits stated by the manufacturer.

If the test current overlaps with another tripping characteristic (e.g. an instantaneous tripping characteristic), the trip setting (e.g. I_{sd}, see Figure K.1) and the test current shall be reduced as necessary ~~and recorded in the test report~~ to prevent premature tripping. Both values shall be recorded in the test report.

b) Non-tripping duration

This test is made under the same conditions as for the test of item a) above for both overload and short-circuit releases:

Firstly, the test current equal to 1,5 times the current setting is maintained for a time interval equal to the non-tripping duration stated by the manufacturer; then, the current is reduced to the ~~rated~~ value corresponding to the overload current setting (I_r) and maintained at this value for twice the time-delay stated by the manufacturer. The circuit-breaker shall not trip.

8.3.3.3 Test of dielectric properties

Subclause 8.3.3.4.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except for item 5), with the following additions:

(i) with reference to 8.3.3.4.1, item 2) c) i) and ii), of IEC 60947-1:2007: the normal positions of operation include the tripped position, if any;

(ii) with reference to 8.3.3.4.1, item 3 c), of IEC 60947-1:2007/AMD1:2010/AMD2:2014: for the purposes of this standard circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the test;

(iii) circuit-breakers not declared as suitable for isolation shall be tested with the test voltage applied across the poles of the main circuit, the line terminals being connected together and the load terminals being connected together. The test voltage shall be in accordance with Table 12 of IEC 60947-1:2007;

(iv) for circuit-breakers suitable for isolation (see 3.5) and having an operational voltage greater than 50 V, the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA;

(v) circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater;

(vi) withdrawable circuit-breakers (see 7.1.2) shall be subject to verification of impulse withstand voltage, as per 8.3.3.4.1, item 2) b) of IEC 60947-1:2007. The test voltage shall be selected from Table 14 of IEC 60947-1:2007, and shall be applied between the withdrawable unit's main contacts and their associated fixed contacts, in the disconnected position. Acceptance criteria are as per 8.3.3.4.1, item 2) d) of IEC 60947-1:2007.

8.3.3.4 Tests of mechanical operation and of operational performance capability

8.3.3.4.1 General test conditions

The circuit-breaker shall be mounted in accordance with 8.3.2.1 except that, for the purpose of these tests, the circuit-breaker may be mounted on a metal frame. The circuit-breaker shall be protected against undue external heating or cooling.

The tests shall be made at the ambient temperature of the test room.

The control supply voltage of each control circuit shall be measured at its terminals at the rated current.

All resistors or impedances forming part of the control device shall be in circuit, However, no supplementary impedances shall be inserted between the current source and the terminals of the device.

The tests of 8.3.3.4.2, 8.3.3.4.3 and 8.3.3.4.4 shall be made on the same circuit-breaker but the order in which these tests are carried out is optional. However, for the tests of undervoltage and shunt releases the tests of 8.3.3.4.2 and 8.3.3.4.3 may, alternatively, be made on a new sample.

In the case of maintainable circuit-breakers, if it is desired to carry out a number of operations greater than that specified in Table 8, these additional operations shall be carried out first, followed by maintenance in accordance with the manufacturer's instructions, and then by the number of operations in accordance with Table 8, without any further maintenance being permitted during the remainder of this test sequence.

NOTE For convenience of testing it is permissible to subdivide each of the tests into two or more periods. No such period should, however, be less than 3 h.

8.3.3.4.2 Construction and mechanical operation

8.3.3.4.2.1 Construction

A withdrawable circuit-breaker shall be checked for the requirements stated in 7.1.2.

A circuit-breaker with stored energy operation shall be checked for compliance with 7.2.1.1.6, regarding the charge indicator and the direction of operation of manual energy storing.

8.3.3.4.2.2 Mechanical operation

Tests shall be made as specified in 8.3.3.4.1 for the following purposes:

– to prove satisfactory tripping of the circuit-breaker with the closing device energized;
– to prove satisfactory behaviour of the circuit-breaker when the closing operation is initiated with the tripping device actuated;
– to prove that the operation of a power-operated device, when the circuit-breaker is already closed, shall neither cause damage to the circuit-breaker nor endanger the operator.

The mechanical operation of a circuit-breaker may be checked under no-load conditions.

A circuit-breaker with dependent power operation shall comply with the requirements stated in 7.2.1.1.4.

A circuit-breaker with dependent power operation shall operate with the operating mechanism charged to the minimum and maximum limits stated by the manufacturer.

A circuit-breaker with stored energy operation shall comply with the requirements stated in 7.2.1.1.6 with the auxiliary supply voltage at 85 % and 110 % of the rated control supply voltage. It shall also be verified that the moving contacts cannot be moved from the open position when the operating mechanism is charged to slightly below the full charge as evidenced by the indicating device.

For a trip-free circuit-breaker it shall not be possible to maintain the contacts in the touching or closed position when the tripping release is in the position to trip the circuit-breaker.

If the closing and opening times of a circuit-breaker are stated by the manufacturer, such times shall comply with the stated values.

8.3.3.4.2.3 Undervoltage releases

Undervoltage releases shall comply with the requirements of 7.2.1.3 of IEC 60947-1:2007. For this purpose, the release shall be fitted to a circuit-breaker having the maximum current rating for which the release is suitable.

i) Drop-out voltage

   It shall be verified that the release operates to open the circuit-breaker between the voltage limits specified.

   The voltage shall be reduced from rated control supply voltage at a rate to reach 0 V in approximately 30 s.

   The test for the lower limit is made without current in the main circuit and without previous heating of the release coil.

   In the case of a release with a range of rated control supply voltage, this test applies to the maximum voltage of the range.

The test for the upper limit is made starting from a constant temperature corresponding to the application of rated control supply voltage to the release and rated current in the main poles of the circuit-breaker. This test may be combined with the temperature-rise test of 8.3.3.7.

In the case of a release with a range of rated control supply voltage, this test is made at both the minimum and maximum rated control supply voltages.

ii) Test for limits of operation

Starting with the circuit-breaker open, at the temperature of the test room, and with the supply voltage at 30 % rated maximum control supply voltage, it shall be verified that the circuit-breaker cannot be closed by the operation of the actuator. When the supply voltage is raised to 85 % of the minimum control supply voltage, it shall be verified that the circuit-breaker can be closed by the operation of the actuator.

iii) Performance under overvoltage conditions

With the circuit-breaker closed and without current in the main circuit, it shall be verified that the undervoltage release will withstand the application of 110 % rated control supply voltage for 4 h without impairing its functions.

8.3.3.4.2.4 Shunt releases

Shunt releases shall comply with the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. For this purpose, the release shall be fitted to a circuit-breaker having the maximum rated current for which the release is suitable.

It shall be verified that the release will operate to open the circuit-breaker at 70 % rated control supply voltage when tested at an ambient temperature of +55 °C ± 2 °C without current in the main poles of the circuit-breaker. In the case of a release having a range of rated control supply voltages, the test voltage shall be 70 % of the minimum rated control supply voltage.

8.3.3.4.3 Operational performance capability without current

These tests shall be made under the conditions specified in 8.3.2.1. The number of operating cycles to be carried out on the circuit-breaker is given in column 3 of Table 8; the number of operating cycles per hour is given in column 2 of this table.

The tests shall be carried out without current in the main circuit of the circuit-breaker.

For circuit-breakers which can be fitted with shunt releases, 10 % of the total number of operating cycles shall be closing/tripping operations, with the shunt release energized at maximum rated control supply voltage.

For circuit-breakers which can be fitted with undervoltage releases, 10 % of the total number of operating cycles shall be closing/tripping operations at the minimum rated control supply voltage, this voltage to the release being removed after each closing operation, to trip the circuit-breaker.

In each case, half the relevant number of operating cycles shall be made at the beginning and the other half at the end of the tests.

For circuit-breakers fitted with undervoltage releases, prior to the operational performance test, without the undervoltage release being energized, it shall be verified that the circuit-breaker cannot be closed by attempting 10 times to effect a closing operation of the circuit-breaker.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing devices, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature-rises of the electrical components do not exceed the limits indicated in Table 7.

In the case of manually operated circuit-breakers, they shall be operated as in normal use.

8.3.3.4.4 Operational performance capability with current

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, the test circuit being in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The operating rate and the number of operating cycles to be carried out are given in columns 2 and 4 of Table 8.

The circuit-breaker shall be operated so as to make and break its rated current at its maximum rated operational voltage, assigned by the manufacturer, at a power factor or time constant as applicable in accordance with Table 11, the tolerance being in accordance with 8.3.2.2.2.

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

For circuit-breakers fitted with adjustable releases, the tests shall be made with the overload setting at maximum and the short-circuit setting at minimum.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing devices, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature rises of the electrical components do not exceed the values indicated in Table 7.

Manually operated circuit-breakers shall be operated as in normal use.

8.3.3.4.5 Additional test of operational performance capability without current for withdrawable circuit-breakers

A test of operational performance capability without current shall be carried out on the withdrawal mechanism and associated interlocks of withdrawable circuit-breakers.

The number of operating cycles shall be 100.

After this test, the isolating contacts, withdrawal mechanism and interlocks shall be suitable for further service. This shall be verified by inspection.

8.3.3.5 Overload performance

This test applies to circuit-breakers of rated current up to and including 630 A.

NOTE 1 At the request of the manufacturer, the test ~~may~~ can also be made on circuit-breakers of rated current higher than 630 A.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The test shall be made at a voltage corresponding to the maximum operational voltage $U_{e\ max}$ assigned by the manufacturer to the circuit-breaker, taking into account the requirement for recovery voltage of Table 12 (see also 8.3.2.2.3 a) of IEC 60947-1:2007/AMD2:2014).

For circuit-breakers fitted with adjustable releases, the test shall be made with its releases set at maximum.

The circuit-breaker shall be opened nine times manually and three times automatically by the action of an overload release, except for circuit-breakers having a short-circuit release of a maximum setting less than the test current, in which case all 12 operations shall be automatic.

~~NOTE 2~~ If the testing means do not withstand the let-through energy occurring during the automatic operation, the test may be performed as follows, with the agreement of the manufacturer:

– 12 manual operations;
– three additional operations with automatic opening, made at any convenient voltage.

During each of the manually operated cycles, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The number of operating cycles per hour shall be that specified in column 2 of Table 8. If the circuit-breaker does not latch in at the specified rate, this rate may be reduced sufficiently so that the circuit-breaker may be closed, the full current being established.

If test conditions at the testing station do not permit testing at the operating rate given in Table 8, a slower rate may be used, but details shall be stated in the test report.

The values of the test current and of the recovery voltage shall be in accordance with Table 12, at the power factor or time constant, as applicable, in accordance with Table 11, the tolerances being in accordance with 8.3.2.2.2.

NOTE 2 With the agreement of the manufacturer the test ~~may~~ can be made under more severe conditions than specified.

Table 12 – Test circuit characteristics for overload performance

	Alternating current	Direct current
Current	6 I_n	2,5 I_n
Recovery voltage	1,05 $U_{e\ max}$	1,05 $U_{e\ max}$
$U_{e\ max}$ = maximum operational voltage of the circuit-breaker.		

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

The prospective current at the supply terminals of the circuit-breaker shall be at least 10 times the test current, or at least 50 kA, whichever of the two values is the lower.

8.3.3.6 Verification of dielectric withstand

8.3.3.6.1 General

The test shall be performed on the circuit-breaker whilst it remains mounted for the preceding test. If this is not practicable it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

8.3.3.6.2 Test voltage

Subclause 8.3.3.4.1, item 3) b), of IEC 60947-1:2007/AMD1:2010 applies.

The value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s., or 1 415 V d.c. if an a.c. voltage ~~test~~ cannot be applied. The value of U_e referred to is that at which the preceding switching and/or short-circuit tests have been performed.

8.3.3.6.3 Application of the test voltage

The test voltage shall be applied for 5 s in accordance with 8.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:2007 and, in addition, between the incoming and outgoing terminals of each pole with the circuit-breaker open. The use of the metal foil as specified in 8.3.3.4.1, item 1), of

IEC 60947-1:2007/AMD1:2010/AMD2:2014 is not required. For the purposes of this standard, circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the tests. The normal positions of operation include the tripped position, if any.

For circuit-breakers suitable for isolation the leakage current shall be measured in accordance with 8.3.3.3, item (iv), except that the leakage current shall not exceed 2 mA.

8.3.3.6.4 Acceptance criteria

Subclause 8.3.3.4.1, item 3) d), of IEC 60947-1:2007 applies.

8.3.3.7 Verification of temperature-rise

Following the test according to 8.3.3.6, a temperature-rise test shall be made at the conventional thermal current according to 8.3.2.5. At the end of the test, the values of temperature-rise shall not exceed those specified in Table 7.

8.3.3.8 Verification of overload releases

Immediately following the test according to 8.3.3.7, the operation of overload releases shall be verified at 1,45 times the value of their current setting at the reference temperature (see 7.2.1.2.4, item b), 2)).

For this test, all poles shall be connected in series. Alternatively, this test may be made using a 3-phase supply.

This test may be made at any convenient voltage.

The operating time shall not exceed the conventional tripping time.

~~NOTE 1~~ With the manufacturer's consent, a time interval between the tests of 8.3.3.7 and 8.3.3.8 may occur.

~~NOTE 2~~ The test may, alternatively, be made at the ambient air temperature at a test current corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

8.3.3.9 Verification of undervoltage and shunt releases

Circuit-breakers fitted with undervoltage releases shall be subjected to the test of 8.3.3.4.2.3 i), except that the tests for upper and lower limits shall be made at the temperature of the test room without current in the main circuit. The release shall not operate at 70 % of the minimum control supply voltage and shall operate at 35 % of the maximum rated control supply voltage.

Circuit-breakers fitted with shunt releases shall be subjected to the test of 8.3.3.4.2.4, except that the test may be made at the temperature of the test room. The release shall operate at 70 % of the minimum rated control supply voltage.

8.3.3.10 Verification of the main contact position

For circuit-breakers suitable for isolation (see 3.5), following the verification of 8.3.3.8, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 8.2.5 of IEC 60947-1:2007/AMD1:2010.

8.3.4 Test sequence II: Rated service short-circuit breaking capacity

8.3.4.1 General

Except when the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Rated service short-circuit breaking capacity	8.3.4.2
Verification of operational performance capability	8.3.4.3
Verification of dielectric withstand	8.3.4.4
Verification of temperature-rise	8.3.4.5
Verification of overload releases	8.3.4.6

For the case where $I_{cs} = I_{cu}$, see 8.3.5.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.4.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{cs}, as declared by the manufacturer, in accordance with 4.3.6.2.3.

The power factor for this test shall be according to Table 11, for the appropriate test current.

The sequence of operations shall be:

$$O - t - CO - t - CO$$

In the case of integrally fused circuit-breakers, any blown fuse shall be replaced after each operation. The time interval t may need to be extended for this purpose.

8.3.4.3 Verification of operational performance capability

Following the test according to 8.3.4.2, the operational performance capability shall be verified in accordance with 8.3.3.4.4 except that this verification shall be made at the same rated operational voltage as used for the test of 8.3.4.2, and that the number of operations shall be 5 % of the number given in column 4 of Table 8.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting as specified in Table 10.

8.3.4.4 Verification of dielectric withstand

Following the test according to 8.3.4.3, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured in accordance with 8.3.3.6.

8.3.4.5 Verification of temperature-rise

Following the test according to 8.3.4.4, the temperature-rise at the main terminals shall be verified in accordance with 8.3.2.5. The temperature-rise shall not exceed the values given in Table 7.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.4.6 Verification of overload releases

Immediately following the test according to 8.3.4.5, the operation of overload releases shall be verified in accordance with 8.3.3.8.

~~NOTE~~ With the manufacturer's consent, a time interval between the tests of 8.3.4.5 and 8.3.4.6 may occur.

8.3.5 Test sequence III: Rated ultimate short-circuit breaking capacity

8.3.5.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers of ~~utilization~~ selectivity category A and to circuit-breakers of ~~utilization~~ selectivity category B having a rated ultimate short-circuit breaking capacity higher than the rated short-time withstand current.

NOTE For this type of ~~utilization~~ selectivity category B circuit-breaker, the instantaneous release operates at values of current in excess of those stated in column 2 of Table 3 (4.3.6.4); this type of release ~~may~~ can be referred to as "instantaneous override".

For circuit-breakers of ~~utilization~~ selectivity category B having a rated short-time withstand current equal to their rated ultimate short-circuit breaking capacity, this test sequence need not be made, since, in this case, the ultimate short-circuit breaking capacity is verified when carrying out test sequence IV.

For integrally fused circuit-breakers, test sequence V applies in place of this sequence.

Where $I_{cs} = I_{cu}$, this test sequence need not be made, in which case construction break tests are required in Sequence II (see Table 10) and the following verifications shall additionally be made in test sequence II:

– the verification of 8.3.5.2, at the beginning of the test sequence;
– the verification of 8.3.5.5, at the end of the test sequence.

This test sequence comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.5.2
Rated ultimate short-circuit breaking capacity	8.3.5.3
Verification of dielectric withstand	8.3.5.4
Verification of overload releases	8.3.5.5

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.5.2 Verification of overload releases

The operation of overload releases shall be verified at twice the value of their current setting on each pole separately. This test may be made at any convenient voltage.

~~NOTE 1~~ If the ambient temperature differs from the reference temperature, the test current ~~should~~ shall be corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

~~NOTE 2~~ For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the current setting at the reference temperature, on a pole singly.

8.3.5.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to 8.3.5.2, a short-circuit breaking capacity test is made with a value of prospective current equal to the ultimate rated short-circuit breaking capacity as declared by the manufacturer, under the general conditions according to 8.3.2.

The sequence of operations shall be:

$$O – t – CO$$

8.3.5.4 Verification of dielectric withstand

Following the test according to 8.3.5.3 the dielectric withstand shall be verified according to 8.3.3.6. For circuit breakers suitable for isolation, the leakage current shall not exceed 6 mA.

8.3.5.5 Verification of overload releases

Following the test according to 8.3.5.4, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.6 Test sequence IV: Rated short-time withstand current

8.3.6.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers ~~of utilization category B and to those circuit-breakers of category A covered by note 3 of Table 4~~ with a rated short-time withstand current (see 4.4); it comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.6.2
Rated short-time withstand current	8.3.6.3
Verification of temperature-rise	8.3.6.4
Short-circuit breaking capacity at maximum short-time withstand current	8.3.6.5
Verification of dielectric withstand	8.3.6.6
Verification of overload releases	8.3.6.7

Where integrally fused circuit-breakers are of ~~utilization~~ selectivity category B, they shall meet the requirements of this sequence.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.6.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.6.3 Test of rated short-time withstand current

Subclause 8.3.4.3 of IEC 60947-1:2007 applies with the following addition:

For the purpose of this test only, any over-current release, including the instantaneous override, if any, likely to operate during the test, shall be rendered inoperative.

8.3.6.4 Verification of temperature-rise

Following the test according to 8.3.6.3, the temperature-rise at the main terminals shall be verified according to 8.3.2.5. The temperature-rise shall not exceed the value given in Table 7.

With the manufacturer's agreement the verification of the temperature-rise may be made after the verification of the dielectric withstand (8.3.6.6). This verification need not be made where, for a given frame size, the test of 8.3.7.3 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.6.5 Test of short-circuit breaking capacity at the maximum short-time withstand current

Following the test according to 8.3.6.4, a short-circuit test shall be made with the following sequence of operations:

$$O - t - CO$$

under the general conditions of 8.3.2, with a value of prospective current equal to that of the short-time withstand current test (see 8.3.6.3) and at the highest voltage applicable to the rated short-time withstand current.

The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release, and the instantaneous override, if any, shall not operate. If the circuit-breaker has a making current release (see 2.10), this requirement does not apply to the CO operation, if the prospective current exceeds the pre-determined value, since it will then operate.

8.3.6.6 Verification of dielectric withstand

Following the test carried out according to 8.3.6.5, the dielectric withstand shall be verified according to 8.3.3.6.

8.3.6.7 Verification of overload releases

Following the test according to 8.3.6.6, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.7 Test sequence V: Performance of integrally fused circuit-breakers

8.3.7.1 General

This test sequence applies to integrally fused circuit-breakers. It replaces test sequence III and comprises the following tests:

	Test	Subclause
Stage 1	Short-circuit at the selectivity limit current	8.3.7.2
	Verification of temperature-rise	8.3.7.3
	Verification of dielectric withstand	8.3.7.4
Stage 2	Verification of overload releases	8.3.7.5
	Short-circuit at 1,1 times take-over current	8.3.7.6
	Short-circuit at ultimate short-circuit breaking capacity	8.3.7.7
	Verification of dielectric withstand	8.3.7.8
	Verification of overload releases	8.3.7.9

This test sequence is divided into two stages:

– Stage 1 comprises the tests according to 8.3.7.2 to 8.3.7.4;
– Stage 2 comprises the tests according to 8.3.7.5 to 8.3.7.9.

The two stages may be carried out:

– on two separate circuit-breakers, or
– on the same circuit-breaker, with maintenance between them, or
– on the same circuit-breaker, without any maintenance, in which case the test according to 8.3.7.4 may be omitted.

The test according to 8.3.7.3 need only be made if $I_{cs} > I_s$.

Tests according to 8.3.7.2, 8.3.7.6 and 8.3.7.7 shall be made at the maximum operational voltage of the circuit-breaker.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.7.2 Short-circuit at the selectivity limit current

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current equal to the selectivity limit current, as declared by the manufacturer (see 2.17.4).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one O operation at the conclusion of which the fuses shall still be intact.

8.3.7.3 Verification of temperature-rise

NOTE This verification of temperature-rise is made since the fuses ~~may~~ can have blown during the short-circuit test of test sequence II, 8.3.4.2, in which case the test of 8.3.7.2 is more severe.

Following the test according to 8.3.7.2 the temperature-rise at the main terminals shall be verified, in accordance with 8.3.2.5.

The temperature-rise shall not exceed the value given in Table 7.

8.3.7.4 Verification of dielectric withstand

Following the test according to 8.3.7.3 the dielectric withstand shall be verified according to 8.3.3.6.

8.3.7.5 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.7.6 Short-circuit at 1,1 times the take-over current

Following the test according to 8.3.7.5 a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to 1,1 times the take-over current declared by the manufacturer (see 2.17.5).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one "O" operation at the conclusion of which at least two of the fuses shall have blown.

8.3.7.7 Short-circuit at rated ultimate short-circuit breaking capacity

Following the test according to 8.3.7.6, a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to the ultimate short-circuit breaking capacity I_{cu}, as declared by the manufacturer.

For the purpose of this test, a new set of fuses shall be fitted.

The sequence of operations shall be:

$$O – t – CO$$

a further new set of fuses being fitted during the time interval t, which may need to be extended for that purpose.

8.3.7.8 Verification of dielectric withstand

Following the test according to 8.3.7.7 and with a new set of fuses fitted, the dielectric withstand shall be verified according to 8.3.5.4.

8.3.7.9 Verification of overload releases

Following the test according to 8.3.7.8, the operation of overload releases shall be verified in accordance with 8.3.5.2 except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.8 Test sequence VI: combined test sequence

8.3.8.1 General

At the discretion of, or in agreement with the manufacturer, this test sequence may be applied to circuit-breakers of ~~utilization~~ selectivity category B:

a) when the rated short-time withstand current and the rated service short-circuit breaking capacity have the same value ($I_{cw} = I_{cs}$); in this case it replaces test sequences II and IV;

b) when the rated short-time withstand current, the rated service short-circuit breaking capacity and the rated ultimate short-circuit breaking capacity have the same value ($I_{cw} = I_{cs} = I_{cu}$); in this case it replaces test sequences II, III and IV.

This test sequence comprises the following tests:

Test	Subclauses
Verification of overload releases	8.3.8.2
Rated short-time withstand current	8.3.8.3
Rated service short-circuit breaking capacity*	8.3.8.4
Verification of operational performance capability	8.3.8.5
Verification of dielectric withstand	8.3.8.6
Verification of temperature-rise	8.3.8.7
Verification of overload releases	8.3.8.8
* For circuit-breakers falling into the case of 8.3.8.1b) above, this is also the rated ultimate short-circuit breaking capacity.	

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.8.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.8.3 Test of rated short-time withstand current

Following the test according to 8.3.8.2, a test shall be made at the rated short-time withstand current according to 8.3.6.3.

This test does not need to be made on the sample of minimum I_n specified in Table 10.

8.3.8.4 Test of rated service short-circuit breaking capacity

Following the test according to 8.3.8.3, a test shall be made at the rated service short-circuit breaking capacity according to 8.3.4.2, at the highest voltage applicable to the rated short-time withstand current. The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release.

During this test the instantaneous override (if any) shall not operate, and the making current release (if any) shall operate.

8.3.8.5 Verification of operational performance capability

Following the test according to 8.3.8.4, the operational performance capability shall be verified in accordance with 8.3.4.3.

8.3.8.6 Verification of dielectric withstand

Following the test according to 8.3.8.5, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured according to 8.3.3.6.

8.3.8.7 Verification of temperature-rise

Following the test according to 8.3.8.6, the temperature-rise at the main terminals shall be verified in accordance with 8.3.4.5.

The temperature-rise shall not exceed the value given in Table 7.

This verification need not be made where, for a given frame size, the test of 8.3.8.4 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.8.8 Verification of overload releases

After cooling down following the test according to 8.3.8.7, the operation of overload releases shall be verified in accordance with 8.3.3.8.

Thereafter, the operation of the overload releases shall be verified on each pole individually in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.9 Critical d.c. load current test

This test applies only to circuit-breakers with d.c. ratings.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007 except that the metallic screen and the fusible element shall not be used.

Samples to be tested shall be selected according to Table 10 – sequence I, except that for application of footnote g, construction breaks relative to the over-current tripping devices shall not be considered.

The test shall be made at the maximum operational d.c. voltage (U_e max) assigned by the manufacturer to the circuit-breaker.

For circuit-breakers fitted with adjustable releases, the test shall be made with the releases set at the maximum.

The circuit-breaker shall be closed and opened 5 times on to each of the test currents listed below. If the direction of current flow is specified by the manufacturer, the test shall be made with the current flowing in the specified direction, as indicated by the polarity and line/load marking; if not, 5 operations shall be made in the forward direction, and 5 in the reverse direction.

During each CO cycle, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The time constant shall be in accordance with Table 11 as for operational performance; at the discretion of the manufacturer, a higher value may be used, in which case this value shall be stated in the test report.

The number of operating cycles per hour shall be in accordance with Table 8.

The arcing time during the test shall be recorded and shall not exceed 1 s.

The test current values shall be: 4 A, 8 A, 16 A, 32 A and 63 A d.c., with ± 10 % tolerance, but not exceeding the rated current; the critical value is determined by taking the maximum mean arcing time, for each direction of current if applicable. The highest and lowest values of test current shall demonstrate shorter mean arcing times than the critical value; if necessary, the range of test currents shall be extended upwards or downwards by applying a 2 times ratio as many times as necessary, up to, but not exceeding, the rated current to find the critical value. If no critical value of current is found within these criteria, no further test according to this subclause is required.

The tolerances on test quantities other than the current shall be in accordance with 8.3.2.2.2.

Following this test, the same sample shall be subjected to an operational performance verification of 50 operations, under the same conditions, at the current and in the direction corresponding to the critical value. After this test, the dielectric withstand shall be verified according to 8.3.3.6 with a d.c. test voltage.

8.4 Routine tests

8.4.1 General

For the definition of routine tests, see 2.6.2 and 8.1.3 of IEC 60947-1:2007.

The following tests apply:

– mechanical operation (8.4.2);
– verification of the calibration of overcurrent releases (8.4.3);
– verification of the operation of undervoltage and shunt releases (8.4.4);
– additional tests for CBRs to Annex B (8.4.5);
– dielectric tests (see note) (8.4.6);
– verification of clearances (8.4.7).

NOTE If by the control of materials and manufacturing processes, the integrity of the dielectric properties has been proven, these tests ~~may~~ can be replaced by sampling tests according to a recognized sampling plan (see IEC 60410).[1]

However, operation of the circuit-breaker during manufacture and/or other routine test may take the place of the tests listed above provided the same conditions apply and the number of operations is not less than that specified.

The tests of 8.4.3, 8.4.4 and 8.4.5 shall be made with the releases fitted to the circuit-breaker or to an appropriate test equipment simulating the behaviour of the circuit-breaker.

In the context of the tests of 8.4.2, 8.4.3, 8.4.4, 8.4.6 and 8.4.7, the term "circuit-breakers" covers CBRs, where applicable.

8.4.2 Mechanical operation tests

The following tests shall be carried out without current in the main circuit, except when required for the operation of releases. During the tests, no adjustments shall be made and the operation shall be satisfactory.

~~8.4.1.1~~ The following tests shall be made on manually-operated circuit-breakers:

– two close-open operations;

– two trip-free operations.

NOTE For the definition of a trip-free mechanical switching device, see 2.4.23 of IEC 60947-1:2007.

~~8.4.1.2~~ The following tests shall be made on power-operated circuit-breakers at 110 % of the maximum rated control supply voltage and/or of the rated supply pressure, and at 85 % of the minimum rated control supply voltage and/or of the rated supply pressure:

– two close-open operations;

– two trip-free operations;

– for automatic reclosing circuit-breakers, two automatic reclosing operations.

8.4.3 Verification of the calibration of overcurrent releases

8.4.3.1 Inverse time-delay releases

The verification of the calibration of inverse time-delay releases shall be made at a multiple of the current setting to check that the tripping time conforms (within tolerances) to the curve provided by the manufacturer.

This verification may be made at any convenient temperature, correction being made for any difference from the reference temperature (see 4.7.3).

8.4.3.2 Instantaneous and definite time-delay releases

The verification of the calibration of instantaneous and definite time-delay releases shall check the non-operation and operation of the releases at the values of current given in 8.3.3.2.2 or 8.3.3.2.3, item a), as applicable, without measurement of break time being required.

The tests may be made by loading two poles in series with the test current, using all possible combinations of poles having releases, or by loading each pole having a release individually with the test current.

[1] This publication was withdrawn.

One method of determining the tripping level consists in applying a slowly rising test current, starting from a value below the lower limit until tripping of the circuit-breaker occurs. Tripping shall occur between the lower and upper limits of test current.

8.4.4 Verification of the operation of undervoltage and shunt releases

8.4.4.1 Undervoltage releases

Tests shall be made to verify that the release will operate in accordance with 7.2.1.3 of IEC 60947-1:2007 as follows:

a) Hold-in voltage

The release shall close on to a voltage corresponding to 85 % of the minimum rated control supply voltage.

b) Drop-out voltage

The release shall open when the voltage is reduced to a value within the range corresponding to the limits of 70 % and 35 % of the rated control supply voltage, adjusted to take account of the need to operate under the conditions specified in 8.3.3.4.2.3 i). In the case of releases having a range of rated control supply voltages, the upper limit shall correspond to the minimum of the range and the lower limit to the maximum of the range.

8.4.4.2 Shunt releases (for opening)

A test shall be made to verify that the release will operate in accordance with 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. The test may be made at any convenient temperature provided the test voltage is reduced to take account of the need for the release to operate under the conditions specified in 8.3.3.4.2.4. In the case of a release having a range of rated control supply voltages, the test voltage shall be related to 70 % of the minimum rated control supply voltage.

8.4.5 Additional tests for CBRs

The following additional tests shall be made on CBRs or r.c. units.

a) Operation of the test device

The CBR shall be subjected to two close-trip operations or, in the case of r.c. units, to two reset-trip operations, tripping by the manual operation of the test device with the CBR supplied at the lowest rated operational voltage.

b) Verification of the calibration of the residual current tripping device of the CBR

Using an alternating sinusoidal residual current, it shall be verified that

- the CBR does not trip with a residual current of 0,5 times $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable;
- the CBR trips with a residual current of $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable.

8.4.6 Dielectric tests

The test conditions shall be in accordance with 8.3.3.4.1, item 1), of IEC 60947-1:2007/AMD1:2010/AMD2:2014, except that the use of metal foil is not required. The test voltage shall be applied as follows:

- with the circuit-breaker in the open position, between each pair of terminals which are electrically connected together when the circuit-breaker is closed;
- for circuit-breakers not incorporating electronic circuits connected to the main poles, with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable;
- for circuit-breakers incorporating electronic circuits connected to the main poles, with the circuit-breaker in the open position, between each pole and the adjacent pole(s), and

between each pole and the frame, if applicable, either on the incoming side or on the outgoing side, depending on the position of the electronic components.

Alternatively, disconnection of electronic circuits connected to the main poles is permitted, in which case the test voltage shall be applied with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable.

The method of test shall be as in a) or b) or c) below at the manufacturer's discretion:

a) Two tests shall be made:

   1) Impulse withstand voltage

      The test voltage shall not be less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or the peak value corresponding to 2 U_i whichever is the greater, and

   2) Power frequency withstand voltage

      The test apparatus shall be as stated in 8.3.3.4.1, item 3) b), of IEC 60947-1:2007/AMD1:2010, except that the overcurrent trip shall be set to 25 mA. However, at the discretion of the manufacturer, for safety reasons, test apparatus of a lower power or trip setting may be used, but the short-circuit current of the test apparatus shall be at least eight times the trip setting of the overcurrent relay; for example, for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be 5 mA ± 1 mA.

      The value of the test voltage shall be 2 U_e max, with a minimum of 1 000 V r.m.s., applied for not less than 1 s. The overcurrent relay shall not trip.

b) A single power frequency test in accordance with item a) 2) above at a test voltage such that the peak value of the sinusoidal wave corresponds to the highest of the peak values of the following: 30 % of U_{imp}, 2 U_i, 2 U_e max or 1 000 V r.m.s.

c) An insulation resistance test at 500 V d.c. The insulation resistance shall be not less than 1 MΩ at any point.

If dielectric properties are tested according to a sampling plan in accordance with the note to 8.4.1, a power frequency withstand test shall be made according to 8.4.6, item a) 2) of this subclause, but with a test voltage in accordance with Table 12A of IEC 60947-1:2007/AMD2:2010. Circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater.

8.4.7 Test for the verification of clearances less than those corresponding to case A of Table 13 of IEC 60947-1:2007

Subclause 8.3.3.4.3 of IEC 60947-1:2007 applies, except that for the purposes of this standard this test shall be a routine test.

NOTE The case of clearances greater than or equal to case A of Table 13 of IEC 60947-1:2007 is covered by the tests of 8.4.6.

8.5 Special tests – Damp heat, salt mist, vibration and shock

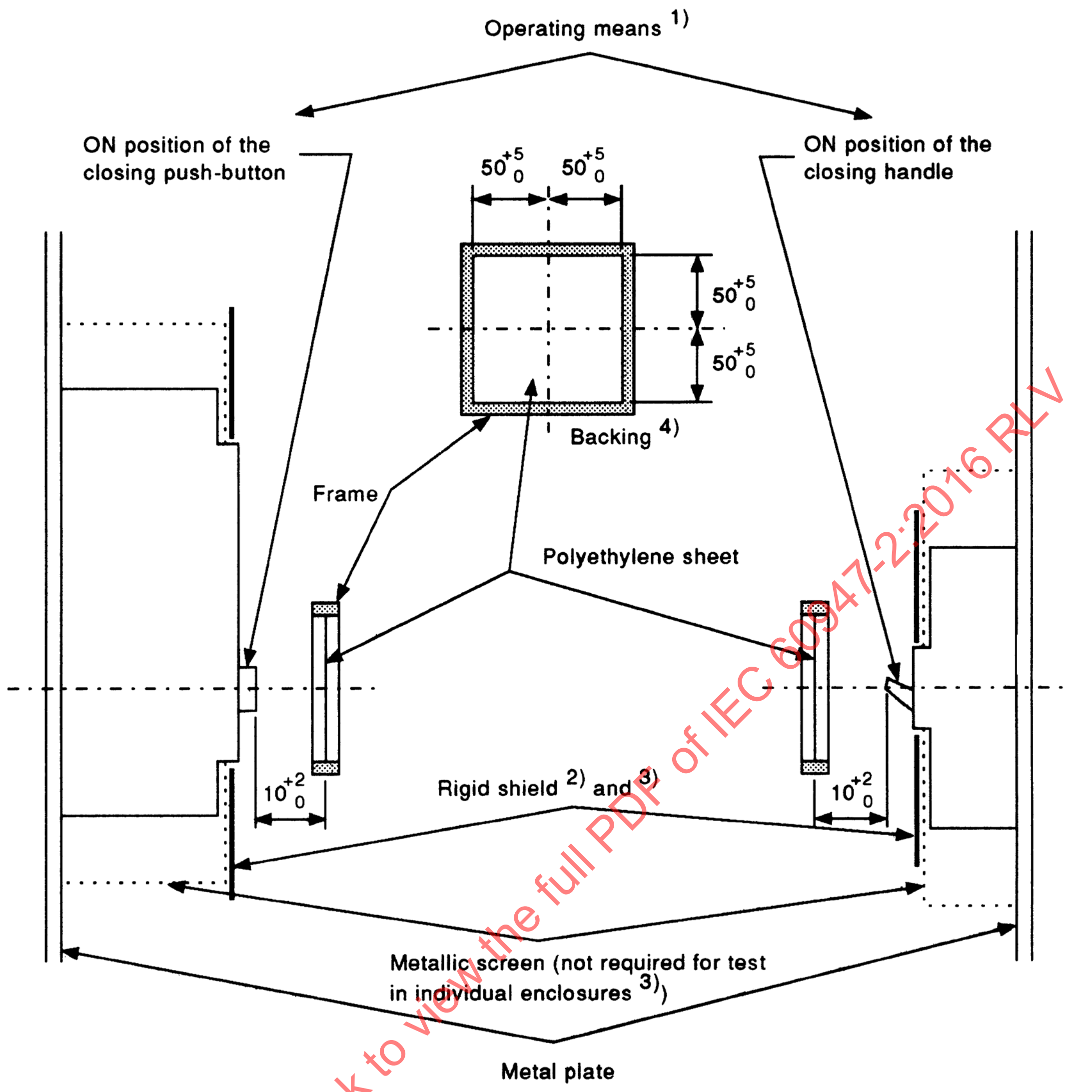
The following special tests shall be made either at the discretion of the manufacturer or according to agreement between the manufacturer and user (see 2.6.4 of IEC 60947-1:2007). As special tests, unless specifically called for, these additional tests are not mandatory, and it is not necessary for a circuit-breaker to satisfy any of these tests to conform to this standard.

Annex Q of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

During the test sequences according to Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, only the final verification of operational performance capability is required. It shall be made by carrying out the routine tests of 8.4 of this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote e) of Table Q.1 of IEC 60947-1:2007, for dry heat test, the circuit-breaker shall not carry current. Where an under-voltage release is fitted, it shall be energised with rated voltage. The circuit-breaker shall be operated according to 8.4.2 during the last hour of the test.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.



Case of circuit-breaker with closing push-button

Case of circuit-breaker with a closing handle

Dimensions in millimetres

1) The operating means includes any extension which is normally fitted for the closing operation.

2) The purpose of the rigid shield is to prevent emissions from areas other than those of the handle or push-button from reaching the polyethylene sheet (not required for tests in individual enclosures).

3) The rigid shield and the front of the metallic screen may be combined into one single conductive metal plate.

4) Made of any suitable rigid material to obviate tearing of the polyethylene sheet.

Figure 1 – Test arrangement (connecting cables not shown) for short-circuit tests

Annex A
(normative)

Co-ordination ~~under short-circuit conditions~~ between a circuit-breaker and another short-circuit protective device associated in the same circuit

A.1 ~~Introduction~~ General

To ensure co-ordination ~~under short-circuit conditions~~ between a circuit-breaker (C_1) and another short-circuit protective device (SCPD) associated with it in the same circuit, it is necessary to consider the characteristics of each of the two devices as well as their dynamic behaviour as an association.

NOTE An SCPD ~~may~~ can incorporate additional protective means, for example, overload releases.

The SCPD may consist of a fuse (or a set of fuses) – see Figure A.1 – or of another circuit-breaker (C_2) (see Figure A.2 and Figure A.3).

The comparison of the individual operating characteristics of each of the two associated devices may not be sufficient, when reference has to be made to the behaviour of these two devices operating in series, since the impedance of the devices is not always negligible. It is recommended that this should be taken into account. For short-circuit currents it is recommended that reference be made to I^2t instead of time. Preferred templates for the representation of cut-off current and let-through energy (I^2t) characteristics are given in Annex K.

C_1 is frequently connected in series with another SCPD for reasons such as the method of power distribution adopted for the installation or because the short-circuit breaking capacity of C_1 alone may be insufficient for the proposed application. In such instances the SCPD may be mounted in locations remote from C_1. The SCPD may be protecting a main feeder supplying a number of circuit-breakers C_1 or just an individual circuit-breaker.

For such applications, the user or ~~specifying authority~~ specifier may have to decide, on the basis of a desk study ~~alone~~, how the optimum level of co-ordination may best be achieved. This annex is intended to give guidance for this decision, and also on the type of information which the circuit-breaker manufacturer should make available ~~to the prospective user~~.

Guidance is also given on test requirements, where such tests are deemed necessary for the proposed application.

The term "co-ordination" includes consideration of ~~discrimination~~ selectivity (see 2.5.23 of IEC 60947-1:2007/AMD2:2014 and also 2.17.2 and 2.17.3 as well as consideration of back-up protection (see 2.5.24 of IEC 60947-1:2007).

Consideration of ~~discrimination~~ selectivity can ~~in general~~ either be carried out by desk study or by test (see A.5), whereas the verification of back-up protection normally requires the use of tests (see A.6).

When considering short-circuit breaking capacity, reference may be made to the rated ultimate short-circuit breaking capacity (I_{cu}), or to the rated service short-circuit breaking capacity (I_{cs}), according to the desired criterion.

A.2 Scope and object

This annex gives guidance on and requirements for the co-ordination of circuit-breakers with other SCPDs associated in the same circuit, as regards ~~discrimination~~ selectivity as well as back-up protection.

The object of this annex is to state:

– the general requirements for the co-ordination of a circuit-breaker with another SCPD;

– the methods and the tests (if deemed necessary) intended to verify that the conditions for co-ordination have been met.

A.3 General requirements for the co-ordination of a circuit-breaker with another SCPD

A.3.1 General considerations

Ideally, the co-ordination should be such that a circuit-breaker (C_1) alone will operate at all values of over-current up to the limit of its rated short-circuit breaking capacity I_{cu} ~~(or I_{cs})~~.

NOTE 1 If the value of the prospective fault current at the point of installation is less than the rated ultimate short-circuit breaking capacity of C_1, it ~~may~~ can be assumed that the SCPD is only in the circuit for considerations other than those of back-up protection.

In practice, the following considerations apply:

a) If the value of the selectivity limit current I_s (see 2.17.4) is too low, there is a risk of unnecessary loss of ~~discrimination~~ selectivity.

b) If the value of the prospective fault current at the point of installation exceeds the rated ultimate short-circuit breaking capacity of C_1, the SCPD shall be so selected that the behaviour of C_1 is in accordance with A.3.3 and the take-over current I_B (see 2.17.5), if any, complies with the requirements of A.3.2.

Whenever possible, the SCPD shall be located on the supply side of C_1. If the SCPD is located on the load side, it is essential that the connection between C_1 and the SCPD be so arranged as to minimize any risk of short circuit.

NOTE 2 In the case of interchangeable releases, these considerations ~~should~~ apply to each relevant release.

A.3.2 Take-over current

For the purpose of back-up protection the take-over current I_B shall not exceed the rated ultimate short-circuit breaking capacity I_{cu} of C_1 alone (see Figure A.3a)).

A.3.3 Behaviour of C_1 in association with another SCPD

For all values of over-current up to and including the short-circuit breaking capacity of the association, C_1 shall comply with the requirements of 7.2.5 of IEC 60947-1:2007, and the association shall comply with the requirements of 7.2.1.2.4, item a).

A.4 Type and characteristics of the associated SCPD

On request, the manufacturer of the circuit-breaker shall provide information on the type and the characteristics of the SCPD to be used with C_1, and on the maximum prospective short-circuit current for which the association is suitable at the stated operational voltage.

Details of the SCPD used for any tests made in accordance with this annex, i.e. manufacturer's name, type designation, rated voltage, rated current and short-circuit breaking capacity, shall be given in the test report.

The maximum conditional short-circuit current (see 2.5.29 of IEC 60947-1:2007) shall not exceed the rated ultimate short-circuit breaking capacity of the SCPD.

If the associated SCPD is a circuit-breaker, it shall meet the requirements of this standard, or any other relevant standard.

If the associated SCPD is a fuse, it shall be in accordance with the appropriate fuse standard.

A.5 Verification of ~~discrimination~~ selectivity

~~Discrimination can normally be considered by desk study alone, i.e. by a comparison of the operating characteristics of C_1 and the associated SCPD, for example, when the associated SCPD is a circuit-breaker (C_2) provided with an intentional time-delay.~~

~~The manufacturers of both the C_1 and the SCPD shall provide adequate data concerning the relevant operating characteristics so as to permit I_s to be determined for each individual association.~~

~~In certain cases, tests at I_s are necessary on the association, for example~~

- ~~when C_1 is of the current-limiting type and C_2 is not provided with an intentional time-delay;~~
- ~~when the opening time of the SCPD is less than that corresponding to one half-cycle.~~

~~To obtain the desired discrimination when the associated SCPD is a circuit-breaker, an intentional short-time delay may be necessary for C_2.~~

~~Discrimination may be partial (see Figure A.4) or total up to the rated short-circuit breaking capacity I_{cu} (or I_{cs}) of C_1. For total discrimination, the non-tripping characteristic of C_2 or the pre-arcing characteristic of the fuse shall lie above the tripping (break-time) characteristic of C_1.~~

~~Two illustrations of total discrimination are given in Figures A.2 and A.3.~~

A.5.1 General

Selectivity can normally be considered by the manufacturer by desk study alone, i.e. by a comparison of the operating characteristics of C_1 and the associated SCPD (see A.5.2). Selectivity can also be determined by tests (see A.5.3).

In certain cases, tests on the association will show a higher level of I_s than obtained by a desk study, for example:

- when C_1 is of the current-limiting type and C_2 is not provided with an intentional time-delay;
- when the opening time of the SCPD is less than that corresponding to one half-cycle.

To obtain improved selectivity when the associated SCPD is a circuit-breaker, an intentional short-time delay is sometimes provided for C_2.

Selectivity may be partial (see Figure A.3a)) or total up to the rated ultimate short-circuit breaking capacity I_{cu} of C_1.

Two illustrations of total selectivity are given in Figure A.2a) and Figure A.2b).

A.5.2 Consideration of selectivity by desk study

A.5.2.1 Selectivity in the overload zone

Two cases are considered hereafter, depending on whether the SCPD is a circuit-breaker or a fuse

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by comparison of characteristics

   Selectivity in the time-delayed over-current zone is verified by comparison of the time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to C_2, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by this standard.

b) Circuit-breaker (C_1) with fuse as SCPD – selectivity determination by comparison of characteristics

   Selectivity in the overload zone is determined by the comparison of time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to the fuse, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by the product standards.

A.5.2.2 Determination of selectivity in the fault current (short-circuit) zone

Determination from time/current characteristics, of selectivity between two circuit-breakers in the fault current (short-circuit) zone (see Figure A.2a)), is limited to the case where C_2 has a short-circuit release time-delay function provided by an electronic release.

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by consideration of peak let-through current

   In the case where the instantaneous tripping of C_2 depends on an electromagnetic effect (i.e. thermal/magnetic or magnetic-only circuit-breaker) or in the case of an electronic trip unit with an instantaneous release, the minimum level of selectivity between two circuit-breakers in the fault current zone may be determined as follows:

   Selectivity is assured up to the fault current level at which the peak current let-through of C_1 is less than the peak value corresponding to the instantaneous short-circuit current setting (I_i) of C_2, taking into account the tolerance.

   NOTE 1 Example of selectivity calculation

   C_2 = 800 A MCCB; I_i = 8 kA r.m.s. – 12 kA r.m.s. (10 kA setting ± 20 %); C_1 = 125 A MCCB.

   Minimum tripping level of C_2 is 8 × 1,414 = 11,3 kA peak.

   Let-through current of C_1 at 15 kA r.m.s. prospective, due to the current limitation of C_1, is 11 kA peak, from test data.

   Therefore the system is selective to at least 15 kA r.m.s. prospective.

   NOTE 2 The selectivity limit obtained by this method will be on the low side and the actual limit determined by test will be significantly higher in most cases.

b) Circuit-breaker (C_1) with fuse as SCPD

   Selectivity in the fault-current (short-circuit) zone (see Figure A.1) is determined from the I^2t characteristics. The selectivity limit current I_s is the maximum value at which let-through I^2t of the circuit-breaker is lower than the pre-arcing I^2t of the fuse. In the absence of an actual curve the manufacturer's quoted I^2t pre-arc value for the fuse is taken.

c) Fuse (C_1) with circuit-breaker as SCPD

   Selectivity in the instantaneous tripping short-circuit zone is determined from the let-through current of the fuse.

The selectivity limit current I_s is the maximum value at which the peak let-through current of the fuse is lower than the peak value corresponding to the instantaneous tripping level (I_i) of circuit-breaker taking into account the tolerance.

A.5.2.3 Determination of selectivity limit current for specific installation conditions

Data on selectivity limits may be supplied in tabulated form, graphically or as software media. Data obtained from either a desk study or tests, to this standard, will be based on the prospective fault current level at the incoming device (C_2) and assumes that the coordinated devices are in close proximity. In practice the selectivity limit will be influenced by the impedance between the two devices. Therefore, in the practical situation taking the prospective fault current at the downstream circuit-breaker will give a more precise value for the selectivity limit.

A.5.3 Selectivity determined by test

An example of the circuit diagram for the tests is shown in Figure A.5, where:

– C_1 may be a circuit-breaker in compliance with this standard or another IEC standard or a fuse in accordance with the appropriate IEC standard;
– settings of C_1 and C_2 are adjusted to the maximum instantaneous setting, if applicable.

Tests at other release settings may be made at the discretion of the manufacturer, in which case the settings of the releases shall be recorded in the test report.

The connecting cables shall be included as specified in 8.3.2.6.4 except the total length of the cables may be distributed between the supply side and the load side of C_1 and C_2 as convenient.

The test shall consist of an O – *t* – CO operation, the CO operation being made by closing the downstream device C_1. If the downstream device is a fuse, the operation shall be made by closing C_2.

The test is made at the level of prospective current for which the association of C_1 and C_2 is declared by the manufacturer to be selective.

Results to be obtained:

– Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies;
– During each operation, C_1 shall operate and C_2 shall not trip. If the contacts of C_2 separate momentarily during the operations, the time between the beginning of short-circuit and the end of C_2 contact separation shall be less than or equal to 30 ms. The actual value shall be stated in the test report;
– In addition, it shall be verified that the contacts of C_2 are able to be opened by the normal operating means.

A.6 Verification of back-up protection

A.6.1 Determination of the take-over current

Compliance with the requirements of A.3.2 can be checked by comparing the operating characteristics of C_1 and the associated SCPD for all settings of C_1 and, if applicable, for all settings of C_2.

A.6.2 Verification of back-up protection

Back-up protection can be verified either by tests, or by comparison of characteristics.

a) Verification by tests

Compliance with the requirements of A.3.3 is normally verified by tests in accordance with A.6.3. In this case, all the conditions for the tests shall be as specified in 8.3.2.6 with the adjustable resistors and inductors for the short-circuit tests on the supply side of the association.

b) Verification by comparison of characteristics

In some practical cases and where the SCPD is a circuit-breaker (see Figure A.3a) and Figure A.3b)), it may be possible for the manufacturer to compare the operating characteristics of C_1 and of the associated SCPD, special attention being paid to the following:

– the Joule integral value of C_1 at its I_{cu} and that of the SCPD at the prospective current of association;

– the effects on C_1 (e.g. by arc energy, by maximum peak current, cut-off current) at the peak operating current of the SCPD.

The suitability of the association may be evaluated by considering the maximum total operating I^2t characteristic of the SCPD, over the range from the rated short-circuit breaking capacity I_{cu} ~~(or I_{cs})~~ of C_1 up to the prospective short-circuit current of the application, but not exceeding the maximum let-through I^2t of C_1 at its rated short-circuit breaking capacity or other lower limiting value stated by the manufacturer.

NOTE Where the associated SCPD is a fuse, the validity of the desk study is limited up to I_{cu} of C_1.

A.6.3 Tests for verification of back-up protection

If C_1 is fitted with adjustable over-current opening releases, the operating characteristics shall be those corresponding to the minimum time and current settings.

If C_1 can be fitted with instantaneous over-current opening releases, the operating characteristics to be used shall be those corresponding to C_1 fitted with such releases.

If the associated SCPD is a circuit-breaker (C_2) fitted with adjustable over-current opening releases, the operating characteristics to be used shall be those corresponding to the maximum time and current settings.

If the associated SCPD consists of a set of fuses, each test shall be made using a new set of fuses, even if some of the fuses used during a previous test have not blown.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the associated SCPD is a circuit-breaker (C_2), the full length of cable (75 cm) associated with this circuit-breaker may be on the supply side (see Figure A.4).

Each test shall consist of a O – t – CO sequence of operations made in accordance with 8.3.5, the CO operation being made on C_1.

A test is made with the maximum prospective current for the proposed application. This shall not exceed the rated conditional short-circuit (see 4.3.6.4 of IEC 60947-1:2007/AMD2:2014).

A further test shall be made at a value of prospective current equal to the rated short-circuit breaking capacity I_{cu} (or I_{cs}) of C_1, for which test a new sample C_1 may be used, and also, if the associated SCPD is a circuit-breaker, a new sample C_2.

During each operation

a) If the associated SCPD is a circuit-breaker (C_2):

– either both C_1 and C_2 shall trip at both test currents, no further tests then being required.

This is the general case and provides back-up protection only.

– or C_1 shall trip and C_2 shall be in the closed position at the end of each operation, at both test currents, no further tests then being required.

The contacts of C_2 are allowed to separate momentarily during each operation. In this case restoration of the supply is provided, in addition to back-up protection (see Note 1 to Figure A.3a)). The duration of contact separation of C_2, if any, shall be recorded during these tests.

– or C_1 shall trip at the lower test current, and both C_1 and C_2 shall trip at the higher test current.

The contacts of C_2 are allowed to separate momentarily at the lower test current. Additional tests shall be made at intermediate currents to determine the lowest current at which both C_1 and C_2 trip, up to which current restoration of supply is provided. The duration of contact separation of C_2, if any, shall be recorded during these tests.

b) If the associated SCPD is a fuse (or a set of fuses):

– in the case of a single-phase circuit at least one fuse shall blow;

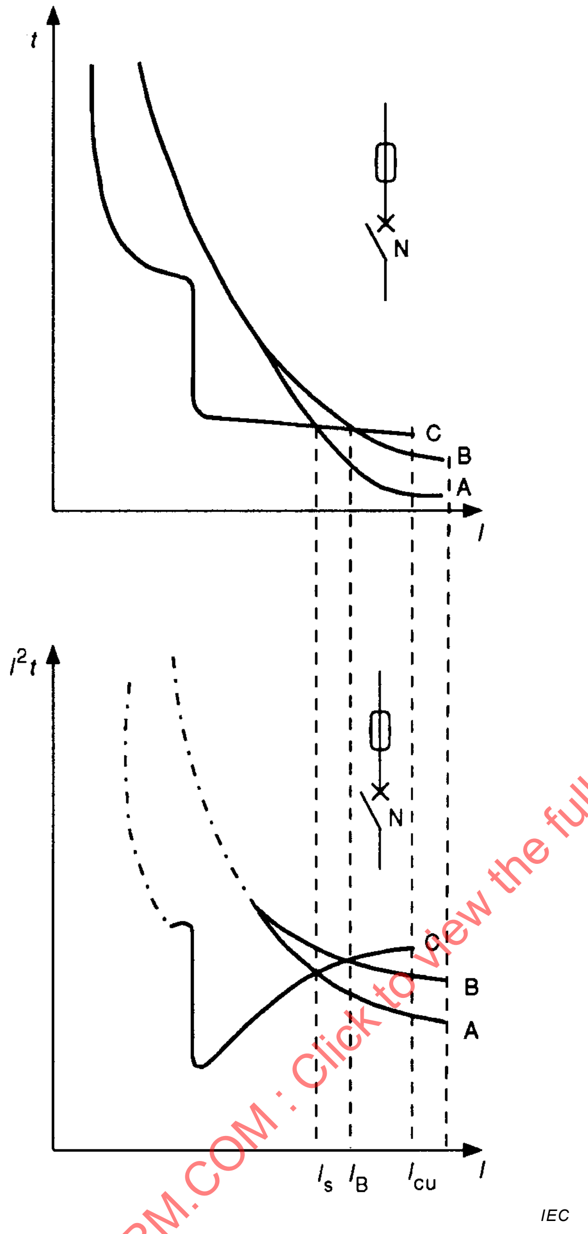
– in the case of a multi-phase circuit either two or more fuses shall blow, or one fuse shall blow and C_1 shall trip.

A.6.4 Results to be obtained

Subclause 8.3.4.1.7 of IEC 60947-1:2007 and 8.3.2.6.7 first paragraph of this standard apply, with the following addition:

Following the tests, if C_1 is a circuit-breaker, it shall comply with 8.3.5.4 and 8.3.5.5; if C_1 is a fuse, it shall comply with the applicable requirements of IEC 60269-1.

In addition, if the associated SPCD is a circuit-breaker (C_2), it shall be verified, by manual operation or other appropriate means, that the contacts of C_2 have not welded.



I = Prospective short-circuit current

I_{cu} = Rated ultimate short-circuit breaking capacity (4.3.6.2.2)

I_s = Selectivity limit current (2.17.40)

I_B = Take-over current (2.17.5)

A = Pre-arcing characteristic of the fuse

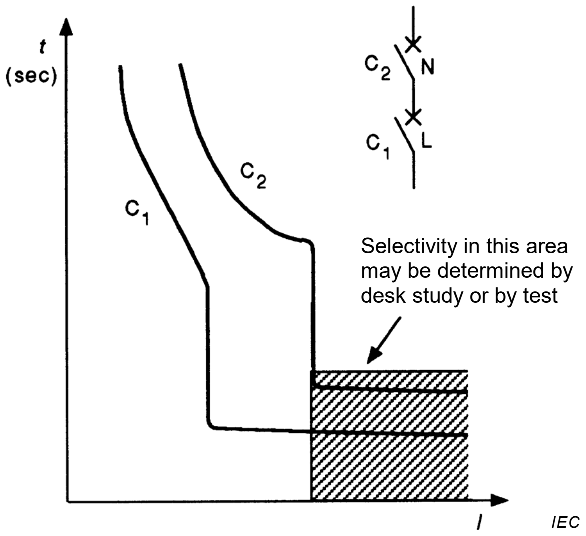
B = Operating characteristic of the fuse

C = Operating characteristic of the circuit-breaker, non-current-limiting (N) (break-time/current and I^2t /current)

NOTE 1 A is deemed to be the lower limit; B and C are deemed to be the upper limits.

NOTE 2 Non-adiabatic zone for I^2t shown chain-dotted.

Figure A.1 – Over-current co-ordination between a circuit-breaker and a fuse or back-up protection by a fuse: operating characteristics

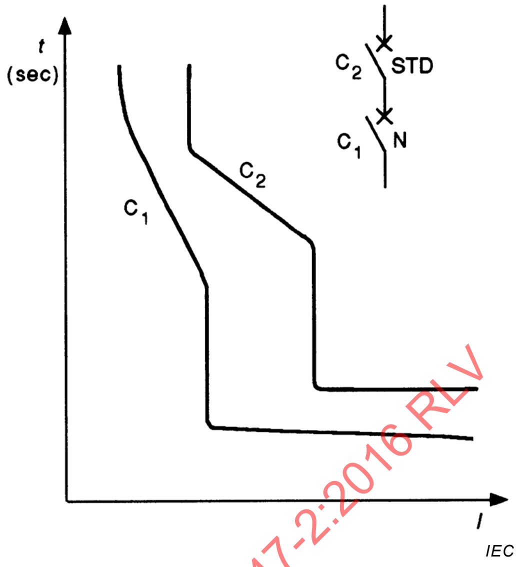


C_1 = Current-limiting circuit-breaker (L)
(break-time characteristic)

C_2 = Non Current-limiting circuit breaker or non current-limiting circuit-breaker (N)
(tripping characteristic)

Values of I_{cu} (or I_{cs}) are not shown.

Figure A.2a) – Current-limiting CB downstream

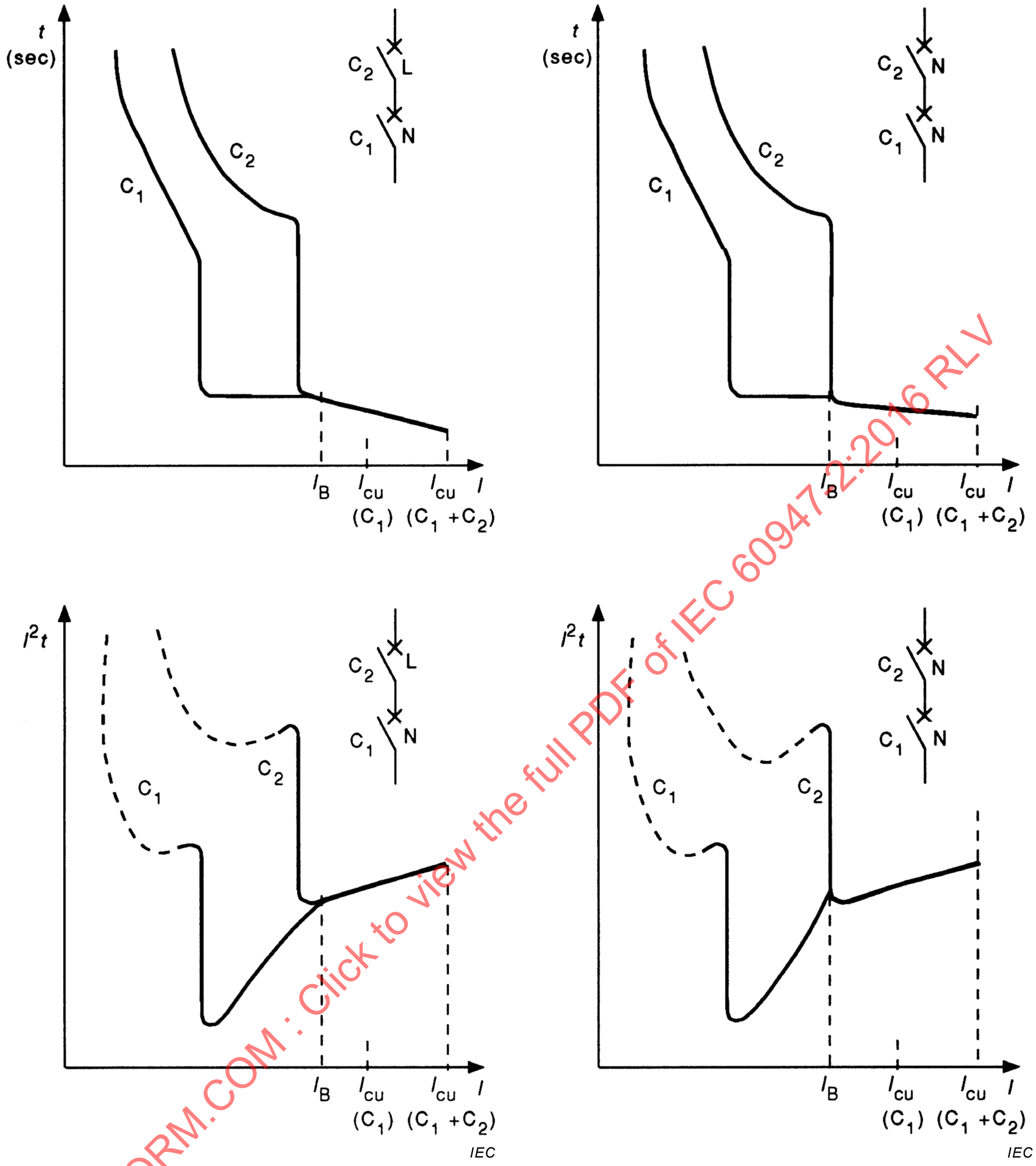


C_1 = Non-current-limiting circuit-breaker (N)
(break-time characteristic)

C_2 = Circuit-breaker with intentional short-time delay (STD) (tripping characteristic)

Figure A.2b) – Non current-limiting CB downstream

Figure A.2 – Total discrimination selectivity between two circuit-breakers



C_1 = Non current-limiting circuit-breaker (N)

C_2 = Current-limiting circuit-breaker (L)

C_1, C_2 = Non current-limiting circuit-breaker (N)

I_B = Take-over current

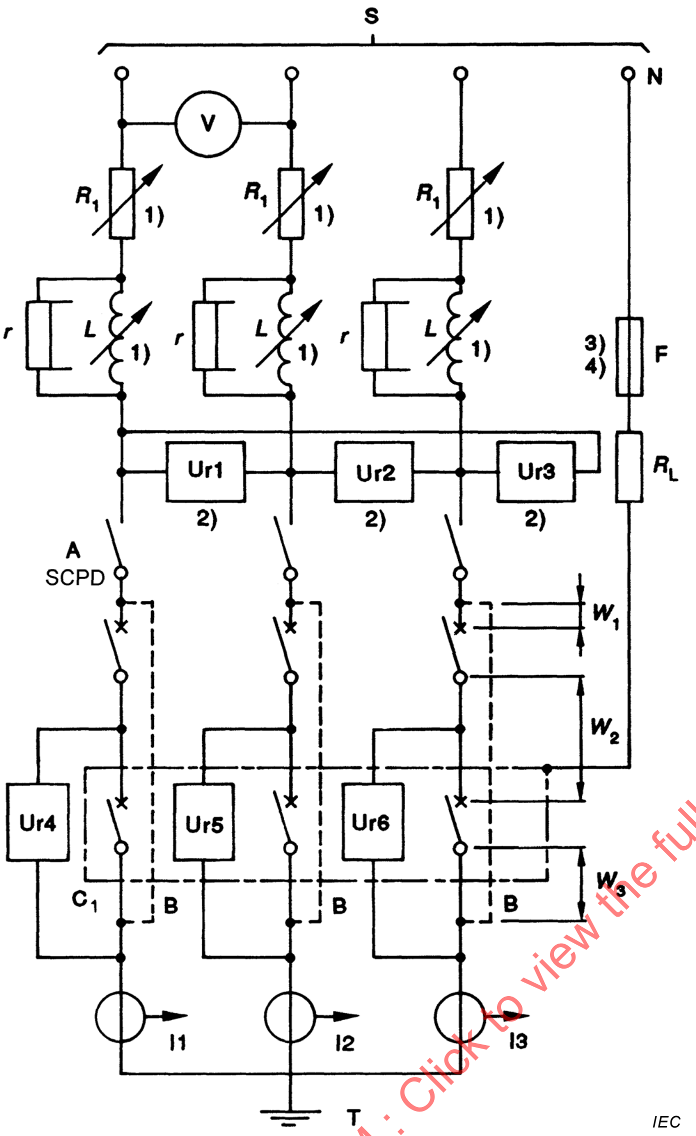
NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 I_{cu} (C_1 + C_2) ≤ I_{cu} (C_2)

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data ~~must be~~ are obtained by tests.

Figure A.3a) – Current-limiting CB upstream **Figure A.3b) – Non current-limiting CB upstream**

Figure A.3 – Back-up protection by a circuit-breaker – Operating characteristics



S	=	Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L	=	Adjustable reactors
R_L	=	Fault current limiting resistor
B	=	Temporary connections for calibration
I1, I2, I3	=	Current sensing devices
T	=	Earth: one earthing point only (load side or supply side)
r	=	Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1	=	75 cm of cable rated for SCPD
W_2	=	50 cm of cable rated for C_1
W_3	=	25 cm of cable rated for C_1
SCPD	=	Circuit-breaker C_2 or set of 3 fuses
C_1	=	Circuit-breaker under test

~~NOTE 1~~ Adjustable loads *L* and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

~~NOTE 2~~ Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

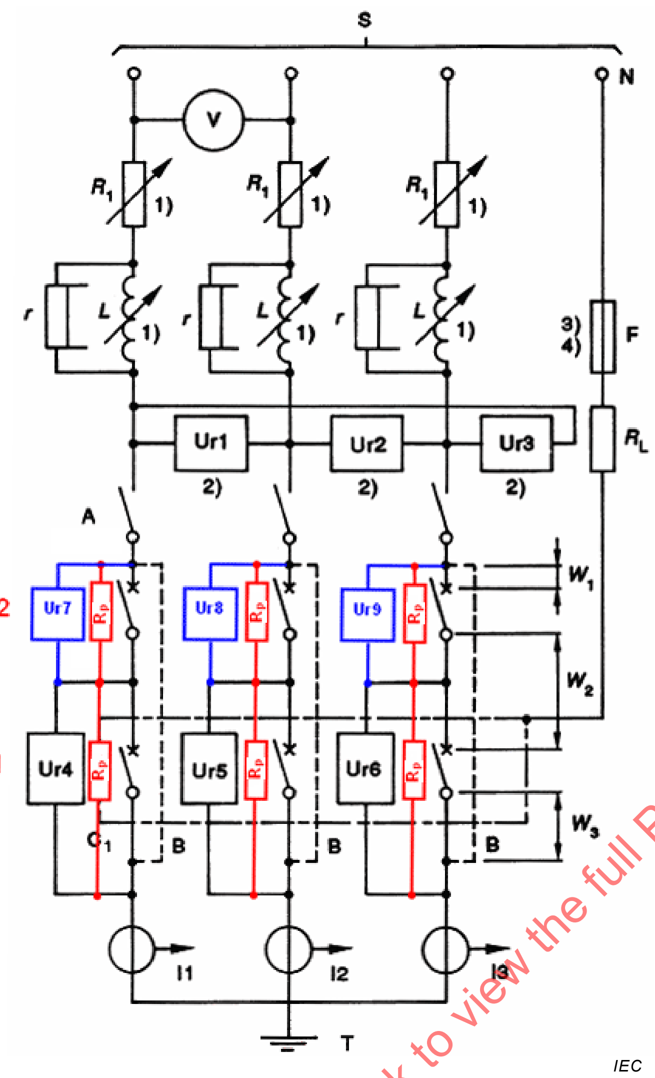
~~NOTE 3~~ In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

~~NOTE 4~~ In the USA and Canada (see notes to 4.3.2.1), F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage.

Figure A.4 – Example of test circuit for conditional short-circuit breaking capacity tests showing cable connections for a 3-pole circuit-breaker (C_1)



S	=	Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 Ur7, Ur8, Ur9	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L	=	Adjustable reactors
R_L	=	Fault current limiting resistor
R_p	=	Optional polarising resistors
B	=	Temporary connections for calibration
I1, I2, I3	=	Current sensing devices
T	=	Earth: one earthing point only (load side or supply side)
r	=	Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1	=	75 cm of cable rated for C_2
$W_2 + W_3$	=	75 cm of cable rated for C_1 (see A.5.2)
C_1, C_2	=	Circuit-breakers under test

Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

NOTE 1 In the USA and Canada (see notes to 4.3.2.1), F is connected:

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage.

NOTE 2 Polarizing resistors allow determination of contact opening time for the two devices in series, the value being high enough not to influence the devices under test.

Figure A.5 – Example of test circuit for the verification of selectivity

Annex B
(normative)

Circuit-breakers incorporating residual current protection

~~INTRODUCTION~~

B.1 General

B.1.1 Preamble

To provide protection against the effects of electric shock hazards, devices reacting to residual differential currents are used as protective systems. Such devices are frequently used in conjunction with or as an integral part of a circuit-breaker to achieve a two-fold goal, i.e.:

– providing protection of installations against overloads and short-circuit currents;
– providing protection of persons against indirect contact, i.e. hazardous increases of ground potential due to defective insulation.

Residual current devices may also provide additional protection against fire and other hazards which may develop as a result of an earth fault of a lasting nature which cannot be detected by the over-current protective device.

Residual current devices having a rated residual current not exceeding 30 mA are also used as a means for additional protection against direct contact in case of failure of the relevant protective means.

The requirements for the installation of such devices are specified in various sections of IEC 60364 series.

This annex is essentially based upon the relevant requirements of IEC 60755, IEC 61008-1 and IEC 61009-1.

B.1.2 Scope and object

This annex applies to circuit-breakers providing residual current protection (CBRs). It covers the requirements for units which concurrently perform residual current detection, compare such measurements with a preset value and cause the protected circuit to be switched off when this value is exceeded.

This annex applies to:

– circuit-breakers according to this standard which incorporate the residual current function as an integrated feature (hereinafter called integral CBRs);
– CBRs consisting of a combination of a residual current device (hereinafter referred to as r.c. units) and a circuit-breaker according to this standard; their combination both mechanically and electrically, may be carried out either at the factory or in the field by the user according to the manufacturer's instructions.

This annex also covers requirements for CBRs concerning electromagnetic compatibility (EMC).

NOTE The neutral current sensing means, if any, ~~may~~ can be external to the circuit-breaker or the combination, as the case may be.

This annex applies only to CBRs intended for use in a.c. circuits.

The residual current function of CBRs covered by this annex may or may not be functionally dependent on line voltage. CBRs depending on an alternative supply source are not covered by this annex.

This annex does not apply to equipment where the current sensing means (except the neutral current sensing means) or the processing device are mounted separately from the circuit-breaker.

The requirements for such devices are given in Annex M.

The object of this annex is to state:

a) the specific features of the residual current function;
b) the specific requirements which shall be complied with by the CBR
   – under normal circuit conditions;
   – under abnormal circuit conditions, whether of a residual current nature or not;
c) the tests which shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures;
d) the relevant product information.

B.2 Terms and definitions

As a complement to Clause 2 of this standard, the following definitions~~, taken from (or derived from) those of IEC 60755,~~ apply:

B.2.1 Terms and definitions relating to currents flowing from live parts to earth

B.2.1.1
earth fault current
current flowing to earth due to an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-23]

B.2.1.2
earth leakage current
current flowing from the live parts of the installation to earth in the absence of an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-24]

B.2.2 Terms and definitions relating to the energization of a CBR

B.2.2.1
energizing quantity
electrical energizing quantity which, alone or in combination with other such quantities, shall be applied to a CBR to enable it to accomplish its function under specified conditions

B.2.2.2
energizing input-quantity
energizing quantity by which the CBR is activated when it is applied under specified conditions

Note 1 to entry: These conditions ~~may~~ can involve, e.g., the energizing of certain auxiliary elements.

[SOURCE: IEC 60050-442:1998, 442-05-58, modified – adapted to CBRs]

B.2.2.3
residual current
I_{Δ}
vectorial sum of the currents flowing in the main circuit of the CBR, expressed as an r.m.s. value

[SOURCE: IEC 60050-442:1998, 442-05-19, modified – adapted to CBRs]

B.2.2.4
residual operating current
$I_{\Delta n}$
value of the residual current which causes the CBR to operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-20, modified – adapted to CBRs]

B.2.2.5
residual non-operating current
$I_{\Delta no}$
value of the residual current at which (and below which) the CBR does not operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-21, modified – symbol introduced and adapted to CBRs]

B.2.3 Terms and definitions relating to the operation and the functions of a CBR

B.2.3.1
circuit-breaker incorporating residual current protection
CBR
circuit-breaker (see 2.1) designed to cause the opening of the contacts when the residual current attains a given value under specified conditions

B.2.3.2
CBR functionally independent of line voltage
CBR for which the functions of detection and evaluation, and the actuating means of interruption (see B.2.3.6) do not depend on the line voltage

B.2.3.3
CBR functionally dependent on line voltage
CBR for which the functions of detection and/or evaluation, and/or the actuating means of interruption (see B.2.3.6) depend on the line voltage

Note 1 to entry: It is understood that the line voltage for detection, evaluation or interruption is applied to the CBR.

B.2.3.4
detection (of a residual current)
function consisting in sensing the presence of a residual current

Note 1 to entry: This function ~~may~~ can be performed, for example, by a transformer ~~effecting~~ integrating the vector sum of the currents.

[SOURCE: IEC 60050-442:1998, 442-05-24]

B.2.3.5
evaluation
function consisting in giving to the CBR the possibility to operate when the detected residual current exceeds a specified reference value

[SOURCE: IEC 60050-442:1998, 442-05-25, modified – without “(for a residual current)” and adapted to CBRs]

B.2.3.6
interruption
function consisting in bringing automatically the main contacts of the CBR from the closed position into the open position, thereby interrupting the current(s) flowing through them

[SOURCE: IEC 60050-442:1998, 442-05-26, modified – without “(for a residual current device)” and adapted to CBRs]

B.2.3.7
limiting non-actuating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the CBR without bringing it actually to operate

[SOURCE: IEC 60050-442:1998, 442-05-23, modified – addition of “rated” and adapted to CBRs]

B.2.3.8
time-delay CBR
CBR specially designed to attain a predetermined value of limiting non-actuating time, corresponding to a given value of residual current

Note 1 to entry: The residual current time-delay characteristic may or may not be of an inverse time/current nature.

[SOURCE: IEC 60050-442:1998, 442-05-05, modified – adapted to CBRs and addition of Note 1 to entry]

B.2.3.9
reset-CBR
CBR with an r.c. unit which must be intentionally reset by a means different from the operating means of the CBR, following the occurrence of a residual current, before it can be reclosed

[SOURCE: IEC 60050-442:1998, 442-05-10, modified – adapted to CBRs]

B.2.3.10
test device
device simulating a residual current for checking that the CBR operates

B.2.4 Terms and definitions relating to values and ranges of energizing quantities

B.2.4.1
limiting value of the non-operating over-current in the case of a single-phase load
maximum value of a single-phase over-current which, in the absence of a residual current, can flow through a CBR (whatever the number of poles) without causing it to operate

Note 1 to entry: See B.7.2.7.

B.2.4.2
limiting value of the non-operating current in the case of a balanced load
maximum value of the current which, in the absence of any fault to frame or earth or of any earth leakage current, can flow in the circuit monitored by the CBR with a balanced load (whatever the number of poles) without causing it to operate

B.2.4.3
residual short-circuit making and breaking capacity
a value of the a.c. component of a residual prospective short-circuit current which a CBR can make, carry for its opening time and break under specified conditions of use and behaviour

B.3 Classification

B.3.1 Classification according to the method of operation of the residual current function

B.3.1.1 CBR functionally independent of line voltage (see B.2.3.2)

B.3.1.2 CBR functionally dependent on line voltage (see B.2.3.3 and B.7.2.11)

B.3.1.2.1 Opening automatically in the case of failure of the line voltage with or without delay.

B.3.1.2.2 Not opening automatically in the case of failure of line voltage.

Not opening automatically in the case of failure of the line voltage, but able to trip under specified conditions in the case of an earth fault arising on failure of the line voltage.

NOTE Classification under this subclause includes CBRs unable to open automatically when no hazardous situation exists.

B.3.2 Classification according to the possibility of adjusting the residual operating current

B.3.2.1 CBR with single rated residual operating current

B.3.2.2 CBR with multiple settings of residual operating current (see note to B.4.1.1)

A CBR may have multiple settings of residual operating current, either by fixed steps or by continuous variation.

B.3.3 Classification according to time-delay of the residual current function

B.3.3.1 CBR without time-delay: non-time-delayed type

B.3.3.2 CBR with time-delay: time-delayed type (see B.2.3.8)

B.3.3.2.1 CBR with non-adjustable time-delay

B.3.3.2.2 CBR with adjustable time-delay

A CBR may have an adjustable time-delay, either by fixed steps or by continuous variation.

B.3.4 Classification according to behaviour in presence of a d.c. component

B.3.4.1 CBRs of type AC (see B.4.4.1)

B.3.4.2 CBRs of type A (see B.4.4.2)

B.4 Characteristics of CBRs concerning their residual current function

B.4.1 Rated values

B.4.1.1 Rated residual operating current ($I_{\Delta n}$)

The r.m.s. value of a sinusoidal residual operating current (see B.2.2.4) assigned to the CBR by the manufacturer, at which the CBR shall operate under specified conditions.

NOTE For a CBR with multiple settings of residual operating current, the highest setting is used to designate its rating. See, however, Clause B.5 concerning marking.

B.4.1.2 Rated residual non-operating current ($I_{\Delta no}$)

The r.m.s. value of sinusoidal residual non-operating current (see B.2.2.5) assigned to the CBR by the manufacturer at which the CBR does not operate under specified conditions.

B.4.1.3 Rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The r.m.s. value of the a.c. component of the prospective residual short-circuit current (see B.2.4.3) assigned to the CBR by the manufacturer, which the CBR can make, carry and break under specified conditions.

B.4.2 Preferred and limiting values

B.4.2.1 Preferred values of rated residual operating current ($I_{\Delta n}$)

Preferred values of rated residual operating current are

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A

Higher values may be required.

$I_{\Delta n}$ may be expressed as a percentage of the rated current.

B.4.2.2 Minimum value of rated residual non-operating current ($I_{\Delta no}$)

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

B.4.2.3 Limiting value of non-operating over-current in the case of a single-phase load

The limiting value of non-operating over-current in the case of a single-phase load shall be in accordance with B.7.2.7.

B.4.2.4 Operating characteristics

B.4.2.4.1 Non-time-delay type

The operating characteristic for a non-time-delay type is given in Table B.1.

Table B.1 – Operating characteristic for non-time-delay type

Residual current	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	10 $I_{\Delta n}$ [b]
Maximum break times s	0,3	0,15	0,04	0,04

[a] For CBRs having $I_{\Delta n} \leq$ 30 mA, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$.

[b] 0,5 A if 0,25 A is used according to footnote a.

CBRs having $I_{\Delta n} \leq$ 30 mA shall be of the non-time-delay type.

B.4.2.4.2 Time-delay type

B.4.2.4.2.1 Limiting non-actuating time (see B.2.3.7)

For a time-delay type, the limiting non-actuating time is defined at 2 $I_{\Delta n}$ and shall be declared by the manufacturer.

The minimum limiting non-actuating time at 2 $I_{\Delta n}$ is 0,06 s.

Preferred values of limiting non-actuating time at 2 I_{Δ} are

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

~~For protection against indirect contact the maximum time-delay at I_n is 1 s (see Clause 413.1 of IEC 60364-4-41).~~

B.4.2.4.2.2 Operating characteristic

For CBR's having a limiting non-actuating time higher than 0,06 s, the manufacturer shall declare the maximum break time at $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$, and 10 $I_{\Delta n}$.

For CBR's having limiting non-actuating time of 0,06 s the operating characteristic is given in Table B.2.

Table B.1 – Operating characteristic for time-delay type having a limiting non-actuating time of 0,06 s

Residual current	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	10 $I_{\Delta n}$
Maximum break time in s	0,5	0,2	0,15	0,15

In case of a CBR having an inverse current/time characteristic, the manufacturer shall state the residual current/break time characteristic.

B.4.3 Value of the rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The minimum value of $I_{\Delta m}$ is 25 % of I_{cu}.

Higher values may be tested and declared by the manufacturer.

B.4.4 Operating characteristics in case of an earth fault current in the presence or absence of a d.c. component

B.4.4.1 CBR of type AC

A CBR for which tripping is ensured for residual sinusoidal alternating currents, in the absence of a d.c. component whether suddenly applied or slowly rising.

B.4.4.2 CBR of type A

A CBR for which tripping is ensured for residual sinusoidal alternating currents in the presence of specified residual pulsating direct currents with or without a specified level of superimposed d.c., whether suddenly applied or slowly rising.

B.5 Marking

Each CBR shall be marked in a durable manner:

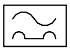
a) The following data shall be marked on integral CBRs (see B.1.1), in addition to the marking specified in 5.2, and be clearly visible in the installed position:
   - rated residual operating current $I_{\Delta n}$;
   - settings of residual operating current, when applicable;

– limiting non-actuating time at 2 $I_{\Delta n}$, for time-delay type, by the symbol Δt followed by the limiting non-actuating time in ms; alternatively, where the limiting non-actuating time is 0,06 s, the symbol may be [S] (S in a square);

– the operating means of the test device by the letter T (see also B.7.2.6);

– operating characteristic in case of residual currents in the presence or absence of a d.c. component:

for CBRs of type AC with the symbol 

for CBRs of type A with the symbol 

b) The following data shall be marked on r.c. units and be clearly visible in the installed position:

– rated voltage(s) if different from the rated voltage(s) of the circuit-breaker;

– value (or range) of the rated frequency if different from that of the circuit-breaker;

– the indication $I_n \leq$ ...A (I_n being the maximum current rating of the circuit-breaker with which the r.c. unit may be combined);

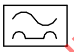
– rated residual operating current $I_{\Delta n}$;

– settings of residual operating current, when applicable;

– limiting non-actuating time, as specified in item a);

– the operating means of the test device, as specified in item a);

– operating characteristic in case of residual currents in the presence or absence of a d.c. component:

for CBRs of type A with the symbol 

for CBRs of type AC with the symbol 

c) The following data shall be marked on r.c. units and be visible after assembly with the circuit-breaker:

– manufacturer's name or trade mark;

– type designation or serial number;

– identification of the circuit-breaker(s) with which the r.c. unit may be assembled, unless incorrect assembly (such as to render the protection ineffective) is made impossible by the design;

– IEC 60947-2;

– suitability for use with a 3-phase supply only, with the symbol 

d) The following data shall be marked on integral CBRs or r.c. units, as applicable, or made available in the manufacturer's literature:

– rated residual short-circuit making and breaking capacity $I_{\Delta m}$ if higher than 25 % of I_{cu} (see B.4.3);

– diagram of connections, including those of the test circuit and, if applicable, those to the line, for CBRs dependent on the line voltage;

– value of rated residual non-operating current $I_{\Delta no}$ if greater than 0,5 $I_{\Delta n}$.

e) The following data shall be made available in the manufacturer's literature:

– suitability for use on:

- three-phase systems only, or
- three-phase and single phase systems.

B.6 Normal service, mounting and transport conditions

Clause 6 applies.

B.7 Design and operating requirements

B.7.1 Design requirements

It shall not be possible to modify the operating characteristic of a CBR except by means which are specifically provided for setting the rated residual operating current or the definite time-delay.

CBRs combining a r.c. unit device and a circuit-breaker shall be so designed and built that:

- the coupling system of the r.c. unit and the associated circuit-breaker does not require any mechanical and/or electrical connection that may adversely affect the installation or result in injury to the user;
- the addition of the r.c. unit does not adversely affect in any way either the normal operation or the performance capabilities of the circuit-breaker;
- the r.c. unit does not sustain any permanent damage due to the short-circuit currents during test sequences.

B.7.2 Operating requirements

B.7.2.1 Operation in case of a residual current

The CBR shall open automatically in response to any earth leakage current or earth fault current equal to or exceeding the rated residual operating current for a time exceeding the non-actuating time.

The operation of the CBR shall be in compliance with the time requirements specified in B.4.2.4. Compliance shall be checked by the tests of B.8.1.1.

B.7.2.2 Rated residual current short-circuit making and breaking capacity $I_{\Delta m}$

CBRs shall meet the test requirements of B.8.10.

B.7.2.3 Operational performance capability

CBRs shall comply with the tests of B.8.1.1.1.

B.7.2.4 Effects of environmental conditions

CBRs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the test of B.8.11.

B.7.2.5 Dielectric properties

CBRs shall withstand the tests of B.8.3.

B.7.2.6 Test device

CBRs shall be provided with a test device causing the passing through the detecting device of a current simulating a residual current, in order to allow periodic testing of the ability of the CBRs to operate.

The test device shall satisfy the tests of B.8.4.

The protective conductor, if any, shall not become live when the test device is operated.

It shall not be possible to energize the protected circuit by operating the test device when the CBR is in the open position.

The test device shall not be the sole means of performing the opening operation and is not intended to be used for this function.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; a light colour should preferably be used.

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

B.7.2.7 Value of the non-operating over-current in the case of a single-phase load

CBRs shall withstand the smaller of the following two over-current values without tripping:

– 6 I_n;
– 80 % of the maximum short-circuit release current setting.

Compliance is checked by the test of B.8.5.

However this test is not necessary in the case of CBRs of ~~utilization~~ selectivity category B since the requirements of this subclause are verified during test sequence IV (or the test sequence VI (combined)).

NOTE Tests for polyphase balanced loads are not necessary since they are considered to be covered by the requirements of this subclause.

B.7.2.8 Resistance of CBRs to unwanted tripping due to surge currents resulting from impulse voltages

B.7.2.8.1 Resistance to unwanted tripping in case of loading of the network capacitance

CBRs shall withstand the test of B.8.6.2.

B.7.2.8.2 Resistance to unwanted tripping in case of flashover without follow-on current

CBRs shall withstand the test of B.8.6.3.

B.7.2.9 Behaviour of CBRs of type A in case of an earth fault comprising a d.c. component

The behaviour of CBRs in case of an earth fault current comprising a d.c. component, shall be such that the maximum break times stated in Table B.1 and Table B.2, as applicable, shall also be valid, the test current values specified being, however, increased:

– by the factor 1,4 for CBRs having $I_{\Delta n} > 0{,}015$ A;
– by the factor 2 for CBRs having $I_{\Delta n} \leq 0{,}015$ A (or 0,03 A, whichever is the higher).

Compliance is checked by the tests of B.8.7.

B.7.2.10 Conditions of operation for reset-CBRs

It shall not be possible to reclose reset-CBRs (see B.2.3.9) after tripping due to a residual current, if they have not been reset.

Compliance is checked during the test of 8.3.3.4.4 in accordance with B.8.1.1.1.

B.7.2.11 Additional requirements for CBRs functionally dependent on line voltage

CBRs functionally dependent on line voltage shall operate correctly at any value of the line voltage between 0,85 and 1,1 times its rated value.

Compliance is checked by the tests of B.8.2.3.

Where a CBR has more than one rated frequency or a range of rated frequencies, the CBR shall be capable of operating in accordance with this subclause at all frequencies.

Compliance is verified by carrying out the tests of B.8.2 and B.8.4.

According to their classification CBRs functionally dependent on line voltage shall comply with the requirements given in Table B.3.

Table B.3 – Requirements for CBRs functionally dependent on line voltage

Classification of the device according to B.3.1		Behaviour in case of failure of line voltage
CBRs opening automatically in the case of failure of the line voltage (B.3.1.2.1)	Without delay	Opening without delay according to item a) of B.8.8.3
	With delay	Opening with delay according to item b) of B.8.8.3
CBRs not opening automatically in the case of failure of the line voltage but able to open in the case of a hazardous situation arising (B.3.1.2.2)		Operating according to B.8.9

B.7.3 Electromagnetic compatibility

The requirements of Annex J apply.

Additional test specifications are given in B.8.12.

Immunity to voltage variations is covered by the requirements of B.7.2.11.

B.8 Tests

B.8.1 General

This clause specifies tests for CBRs having a rated residual operating current $I_{\Delta n}$ up to and including 30 A.

The applicability of the tests specified in this clause when $I_{\Delta n} > 30$ A is subject to agreement between manufacturer and user.

The instruments for the measurement of the residual current shall be at least class 0,5 (see IEC 60051) and shall show (or permit to determine) the true r.m.s. value.

The instruments for the measurement of time shall have a relative error not greater than 10 % of the measured value.

Tests specified in this annex are supplementary to the tests of Clause 8.

a) Type tests

   CBRs shall be submitted to all relevant test sequences of Clause 8. For the dielectric withstand verifications during these test sequences (see 8.3.3.6), the control circuit of residual current devices functionally dependent on line voltage shall be disconnected from the main circuit.

The tests shall be made with substantially sinusoidal currents.

For CBRs comprising a separate r.c. unit and a circuit-breaker, the assembly shall be performed in compliance with the manufacturer's instructions.

In the case of CBRs with multiple settings of residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.

In the case of CBRs with adjustable time-delay (see B.3.3.2.2) the time-delay shall be set at maximum, unless otherwise stated.

In the case of CBRs with adjustable instantaneous tripping, the instantaneous trip shall be set at maximum, unless otherwise stated.

b) Routine tests

Subclause 8.4.5 applies.

B.8.1.1 Tests to be made during the test sequences of Clause 8

B.8.1.1.1 Operational performance capability

During the operating cycles with current (see 8.3.3.4.4) specified in Table 8 (see 7.2.4.2), a third of the breaking operations shall be performed by actuating the test device, and a further third by applying a residual current of value $I_{\Delta n}$ (or, if applicable, of the lowest setting of the residual operating current) to any one pole.

In the case of a reset-CBR, it shall be verified that it is not possible to reclose the CBR after tripping without the intentional resetting action. This verification shall take place at the beginning and at the end of the operational performance capability test with current (8.3.3.4.4).

No failure to trip shall be admitted.

B.8.1.1.2 Verification of the withstand capability to short-circuit currents

B.8.1.1.2.1 Rated service short-circuit breaking capacity (test sequence II)

Following the tests of 8.3.4, verification of the correct operation of the CBR in case of residual current shall be performed in accordance with B.8.2.4.2.

B.8.1.1.2.2 Rated ultimate short-circuit breaking capacity (test sequence III)

For the purpose of verifying the correct operation of the overload releases, the single pole tests specified in 8.3.5.2 and 8.3.5.5 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.5.2 and 8.3.5.5 but applicable to two poles.

Following the tests of 8.3.5, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.3 Rated short-time withstand current (test sequence IV or test sequence VI (combined))

The following requirements apply:

a) Behaviour during rated short-time withstand current test

No tripping shall occur during the test of 8.3.6.3 or 8.3.8.3, as applicable.

b) Verification of overload releases

– For test sequence IV

For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.6.2 and 8.3.6.7, the single pole tests specified in 8.3.5.2 shall be replaced by two-pole tests, made on all possible combinations of phase poles in turn.

– For the combined test sequence

For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.8.2, the single pole test specified in 8.3.5.2 shall be replaced by two-pole tests made on all possible combinations of phase poles in turn.

For the purpose of verifying the correct operation of overload releases in accordance with 8.3.8.7, the test specified in 8.3.3.8 shall be made using a three-phase supply.

c) Verification of the residual current tripping device

Following the tests of 8.3.6 or 8.3.8, as applicable, verification of the residual current tripping device shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.4 Integrally fused circuit-breakers (test sequence V)

For the purpose of verifying the correct operation of the overload releases, the single-pole tests specified in 8.3.7.5 and 8.3.7.9 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.7.5 and 8.3.7.9 but applicable to two poles.

Following the tests of 8.3.7, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.5 Test sequence VI (combined)

Following the tests of 8.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2 Additional test sequences

Additional test sequences shall be performed on CBRs in accordance with Table B.4.

Table B.4 – Additional test sequences

Sequences	Test	Subclause
B I	Operating characteristic	B.8.2
	Dielectric properties	B.8.3
	Operation of the test device at the limits of rated voltage	B.8.4
	Limiting value of the non-operating current under over-current conditions	B.8.5
	Resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Behaviour in the case of an earth fault current comprising a d.c. component	B.8.7
	Behaviour in the case of failure of line voltage for CBRs classified under B.3.1.2.1	B.8.8
	Behaviour in the case of failure of line voltage for CBRs classified under B.3.1.2.2.	B.8.9
B II	Residual short-circuit making and breaking capacity ($I_{\Delta m}$)	B.8.10
B III	Effects of environmental conditions	B.8.11
B IV	Immunity tests	B.8.12.1
	Emission tests	B.8.12.2

For CBRs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants construction is not identical to the variant tested then those variants shall also be tested.

One sample shall be tested for each of test sequences B I, B II and B III.

For test sequence B IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Test sequence B I

B.8.2 Verification of the operating characteristic

B.8.2.1 Test circuit

The CBR is installed as in normal use.

The test circuit shall be in accordance with Figure B.1.

B.8.2.2 Test voltage for CBRs functionally independent of line voltage

Tests may be made at any convenient voltage.

B.8.2.3 Test voltage for CBRs functionally dependent on line voltage

Tests shall be made at the following values of voltage applied to the relevant terminals:

– 0,85 times the minimum rated voltage for the tests specified in B.8.2.4 and B.8.2.5.2;

– 1,1 times the maximum rated voltage for the tests specified in B.8.2.5.3.

CBRs with more than one rated frequency or a range of rated frequencies shall be tested in each case at the highest and lowest rated frequency. However, for CBRs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover the requirements.

B.8.2.4 Off-load test at 20 °C ± 5 °C

B.8.2.4.1 General

The connections being as in Figure B.1, the CBR shall perform the tests of B.8.2.4.2, B.8.2.4.3 and B.8.2.4.4 and also, where applicable, B.8.2.4.5, all made on one pole only chosen at random. Each test shall comprise three measurements or verifications, as applicable.

Unless otherwise specified, for CBR’s with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the lowest and highest settings, and at one intermediate setting.

B.8.2.4.2 Verification of the correct operation in the case of a steady increase of the residual current

For CBR’s with adjustable time-delay, the tests shall be performed at the lowest setting. The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$ so as to attain the value $I_{\Delta n}$ in approximately 30 s, the tripping current being measured each time. The three measured values shall be greater than $I_{\Delta no}$ and less than or equal to $I_{\Delta n}$.

B.8.2.4.3 Verification of the correct operation in the case of closing on residual current

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or the specific settings of the residual operating current if applicable, see B.8.2.4), and the switches S_1 and S_2 being closed, the CBR is closed onto the circuit so as to simulate service conditions as closely as possible. The break time is measured three times.

No measurement shall exceed the limiting value specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2.2, as applicable.

B.8.2.4.4 Verification of the correct operation in the case of sudden appearance of residual current

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in B.4.2.4.1 or B.4.2.4.2.2, as applicable, and the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing switch S_2.

The CBR shall trip during each test.

Three measurements of the break time are made at each value of I_{Δ}. No value shall exceed the relevant limiting value.

B.8.2.4.5 Verification of the limiting non-actuating time of CBRs of the time-delayed type

The test circuit being calibrated at the value of 2 $I_{\Delta n}$, the test switch S_1 and the CBR being in the closed position, the residual current is established by closing the switch S_2 and applied for a time equal to the limiting non-actuating time declared by the manufacturer, in accordance with B.4.2.4.2.1.

During each of the three verifications the CBR shall not trip. If the CBR has an adjustable residual operating current setting and/or an adjustable time-delay, the test is made, as applicable, at the lowest setting of residual operating current and at the maximum setting of time delay.

B.8.2.5 Tests at the temperature limits

B.8.2.5.1 General

NOTE The upper temperature limit ~~may~~ can be the reference temperature.

The temperature limits of this subclause may be extended by agreement between manufacturer and user, in which case tests shall be performed at the agreed temperature limits.

B.8.2.5.2 Off-load test at –5 °C

The CBR is placed in a chamber having a stabilized ambient temperature within the limits of –7 °C and –5 °C. After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, if applicable, B.8.2.4.5.

B.8.2.5.3 On-load test at the reference temperature or at +40 °C

The CBR, connected in accordance with Figure B.1, is placed in a chamber having a stabilized ambient temperature equal to the reference temperature (see 4.7.3) or, in the absence of a reference temperature, equal to 40 °C ± 2 °C. A load current equal to I_n (not indicated on Figure B.1) is applied on all phase poles.

After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, where applicable, B.8.2.4.5.

B.8.3 Verification of dielectric properties

CBRs shall comply with 8.3.3.3.

B.8.4 Verification of the operation of the test device at the limits of rated voltage

The verification consists of the following tests:

a) The CBR being supplied with a voltage equal to 1,1 times the highest rated voltage, the test device is momentarily actuated 25 times at intervals of 5 s, the CBR being closed again before each operation.

b) Test a) is then repeated at 0,85 times the lowest rated voltage, the device being actuated three times.

c) Test a) is then repeated, but only once, the operating means of the test device being held in the closed position for 5 s.

For these tests:

– in the case of CBRs with identified line and load terminals, the supply connections shall be in accordance with the marking;

– in the case of CBRs 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.

At each test the CBR shall operate.

For CBRs having an adjustable residual operating current:

– the lowest setting shall be used for tests a) and c);

– the highest setting shall be used for test b).

For CBRs having an adjustable time-delay the test is made at the maximum setting of time-delay.

NOTE The verification of the endurance of the test device is considered to be covered by the tests of B.8.1.1.1.

B.8.5 Verification of the limiting value of the non-operating current under over-current conditions

The test shall be made with a single phase load, the connections being made according to Figure B.2.

The impedance *Z* is adjusted so as to let a current equal to the lower of the following two values flow in the circuit:

– 6 I_n;

– 80 % of the maximum short-circuit release current setting.

NOTE 1 For the purpose of this current adjustment, the CBR D (see Figure B.2) ~~may~~ can be replaced by connections of negligible impedance.

For CBRs with an adjustable residual current setting the test is made at the lowest setting.

CBRs functionally independent of line voltage are tested at any convenient voltage.

CBRs functionally dependent on line voltage are supplied on the line side with their rated voltage (or, if relevant, with a voltage having any value within the range of rated voltages).

The test is made at a power factor of 0,5.

The switch S_1, being open, is closed and reopened after 2 s. The test is repeated three times for each possible combination of the current paths, the interval between successive closing operations being at least 1 min.

The CBR shall not trip.

NOTE 2 The time of 2 s ~~may~~ can be reduced (but to not less than the minimum break time) to avoid the risk of tripping by action of the overload release(s) of the CBR.

B.8.6 Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages

B.8.6.1 General

For CBRs with adjustable time delay (see B.3.3.2.2) the time-delay shall be set at minimum.

B.8.6.2 Verification of resistance to unwanted tripping in case of loading of the network capacitance

The CBR is tested using a surge current generator capable of delivering a damped oscillatory current as shown in Figure B.4.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.5.

One pole of the CBR chosen at random shall be subjected 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 approximately 30 s. The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 200 A $^{+10}_{0}$ %;

– virtual front time: 0,5 μs ± 30 %;

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

– each successive peak: about 60 % of the preceding peak.

During the tests the CBR shall not trip.

B.8.6.3 Verification of resistance to unwanted tripping in case of flashover without follow-on current

The CBR is tested using a surge current generator capable of delivering an 8/20 μs surge current wave, without reverse polarity, as shown in Figure B.6.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.7.

One pole of the CBR, 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 operations shall be approximately 30 s.

The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 250 A $^{+10}_{0}$ %;

– virtual front time (T_1): 8 μs ± 10 %;

– virtual time to half value (T_2): 20 μs ± 10 %.

During the tests the CBR shall not trip.

B.8.7 Verification of the behaviour of CBRs of type A in the case of an earth fault current comprising a d.c. component

B.8.7.1 Test conditions

The test conditions of B.8 and B.8.2.1, B.8.2.2 and B.8.2.3 apply, except that the test circuits shall be those shown in Figure B.8 and Figure B.9, as applicable.

B.8.7.2 Verifications

B.8.7.2.1 Verification of the correct operation in case of a continuous rise of residual pulsating direct current

The test circuit shall be according to Figure B.8. In the case of a CBR with adjustable time delay (see B.3.3.2.2), the time-delay shall be set to minimum.

The auxiliary switches S_1 and S_2 and the CBR D shall be closed. The relevant thyristor shall be controlled in such a manner that current delay angles α of 0°, 90° and 135° are obtained. Each pole of the CBR shall be tested at each of the current delay angles, twice in position I and twice in position II of the auxiliary switch S_3.

At every test, the current, starting from zero, shall be steadily increased at an approximate rate of:

$\frac{1,4\ I_{\Delta n}}{30}$ A/s for CBRs of $I_{\Delta n} > 0,015$ A;

$\frac{2\ I_{\Delta n}}{30}$ A/s for CBRs of $I_{\Delta n} \leq 0,015$ A.

The tripping current shall be in accordance with Table B.5.

Table B.2 – Tripping current range for CBRs in case of an earth fault comprising a d.c. component

Angle α	**Tripping current** A	
	Lower limit	**Upper limit**
0°	0,35 $I_{\Delta n}$	0,03 A for $I_{\Delta n} \leq 0,015$ A or 1,4$I_{\Delta n}$ for $I_{\Delta n} > 0,015$ A
90°	0,25 $I_{\Delta n}$	
135°	0,11 $I_{\Delta n}$	

B.8.7.2.2 Verification of the correct operation in case of a suddenly appearing residual pulsating direct current

The test shall be performed according to Figure B.8.

The circuit being successively calibrated at the values specified hereafter and the auxiliary switch S_1 and the CBR being in the closed position, the residual current is suddenly established by the closing switch S_2.

NOTE In the case of CBR's functionally dependent on line voltage, classified according to B.3.1.2.2, the control circuit of which is supplied from the line side of the main circuit, this verification does not take into account the time necessary to energize the CBR. In this case, therefore, the verification is considered as made by establishing the residual current by closing S_1, the CBR under test and S_2 being previously closed.

Four measurements are made at each value of test current at a current delay angle α = 0°, two with the auxiliary switch in position I and two in position II.

For CBRs with $I_{\Delta n} > 0{,}015$ A, the test shall be made at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 1,4.

For CBRs with $I_{\Delta n} \leq 0{,}015$ A, the test shall be made at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 2 (or at 0,03 A, whichever is the higher).

No value shall exceed the specified limiting values (see B.7.2.9).

B.8.7.2.3 Verification of the correct operation with load at the reference temperature

The tests of B.8.7.2.1 and B.8.7.2.2 are repeated, the pole under test and one other pole of the CBR being loaded with the rated current, this current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure B.8.

B.8.7.2.4 Verification of the correct operation in case of residual pulsating direct currents superimposed by a smooth direct current of 0,006 A

The CBR shall be tested according to Figure B.9, with a half-wave rectified residual current (current delay angle $\alpha = 0°$) superimposed by a smooth direct current of 0,006 A.

Each pole of the CBR is tested in turn, twice at each of positions I and II.

For CBRs of $I_{\Delta n} > 0{,}015$ A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 1,4 $I_{\Delta n}$ / 30 A/s, tripping shall occur before the current reaches a value not exceeding 1,4 $I_{\Delta n} + 0{,}006$ A.

For CBRs of $I_{\Delta n} \leq 0{,}015$ A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 2 $I_{\Delta n}$ / 30 A/s, tripping shall occur before the current reaches a value not exceeding 0,03 A + 0,006 A.

B.8.8 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1

B.8.8.1 General

For CBRs having an adjustable residual operating current, the test is made at the lowest setting.

For CBRs with an adjustable time-delay, the test is made at any one of the time-delay settings.

B.8.8.2 Determination of the limiting value of the line voltage

A voltage equal to the rated voltage is applied to the line terminals of the CBR and is then progressively lowered to zero over a time period corresponding to the longer of the two values given hereinafter until automatic opening occurs:

– about 30 s;
– a period long enough with respect to the delayed opening of the CBR, if any (see B.7.2.11).

The corresponding voltage is measured.

Three measurements are made. All the values shall be less than 0,85 times the minimum rated voltage of the CBR.

Following these measurements it shall be verified that the CBR trips when a residual current equal to $I_{\Delta n}$ is applied, the applied voltage being just above the highest value measured.

It shall then be verified that, for any value of voltage less than the lowest value measured, it is not be possible to close the CBR by manual operating means.

B.8.8.3 Verification of the automatic opening in the case of failure of the line voltage

The CBR being closed, a voltage equal to its rated voltage, or, in the case of a range of rated voltages, any one of the rated voltages is applied to its line terminals. The voltage is then switched off. The CBR shall trip. The time interval between the switching off and the opening of the main contacts is measured.

Three measurements are made:

a) for CBRs opening without delay (see B.7.2.11), no value shall exceed 0,2 s;

b) for CBRs opening with delay the maximum and minimum values shall be situated within the range indicated by the manufacturer.

B.8.9 Verification of the behaviour of CBRs functionally dependent on line voltage as classified under B.3.1.2.2 in the case of failure of line voltage

B.8.9.1 General

For CBRs having an adjustable residual operating current, the test is made at the lowest setting.

For CBRs having an adjustable time-delay the test is made at any one of the time-delay settings.

B.8.9.2 Case of loss of one phase in a 3-phase system (for 3-pole and 4-pole CBRs)

The CBR is connected according to Figure B.3 and is supplied on the line side at 0,85 times the rated voltage, or, in the case of a range of rated voltages, at 0,85 times the lowest value of rated voltage.

One phase is then switched off by opening switch S_4; the CBR is then submitted to the test of B.8.2.4.4. The switch S_4 being closed again, a further test is made by opening switch S_5; the CBR is then submitted to the test of B.8.2.4.4.

This test procedure is repeated by connecting the adjustable resistor *R* to each of the other two phases in turn.

B.8.9.3 Case of voltage drop due to an overcurrent resulting from a low impedance fault to earth

The CBR is connected according to Figure B.3 and is supplied on the line side with the rated voltage or, in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_1. The CBR shall not trip.

S_1 is then reclosed and the voltage is reduced as follows:

a) for CBRs for use with a three-phase supply: to 70 % of the lowest rated voltage;

b) for CBRs for use with a single phase supply: to 85 V applied as follows:

  – for single-pole and two-pole CBRs: between poles;

  – for three-pole and four-pole CBRs, declared as suitable for use with a single-phase supply (see B.5 e)): between each combination of two poles, connected according to the manufacturer's specification.

NOTE For the purpose of this annex, a single-pole CBR is a device with one overcurrent protected pole and an uninterrupted neutral (two current paths).

A current of value $I_{\Delta n}$ is then applied to a) and/or b), as applicable. The CBR shall trip.

Test sequence B II

B.8.10 Verification of the residual short-circuit making and breaking capacity

B.8.10.1 General

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

B.8.10.2 Test conditions

The CBR shall be tested according to the general test conditions specified in 8.3.2.6, using Figure 9 of IEC 60947-1:2007/AMD1:2010, but connected in such a manner that the short-circuit current is a residual current.

The test is carried out at phase to neutral voltage on one pole only which shall not be the neutral pole. The current paths which do not have to carry the residual short-circuit current are connected to the supply voltage at their line terminals.

Where applicable, the CBR is adjusted at the lowest setting of residual operating current and at the maximum setting of time-delay.

If the CBR has more than one value of I_{cu}, each one having a corresponding value of $I_{\Delta m}$, the test is made at the maximum value of $I_{\Delta m}$, at the corresponding phase-to-neutral voltage.

B.8.10.3 Test procedure

The sequence of operations to be performed is

$$O – t – CO$$

B.8.10.4 Conditions of the CBR after test

B.8.10.4.1 Following the test of B.8.10.3 the CBR shall show no damage likely to impair its further use and shall be capable, without maintenance, of:

– withstanding a voltage equal to twice its maximum rated operational voltage, under the conditions of 8.3.3.4.1 item 4) of IEC 60947-1:2007. For the purposes of this standard, circuits incorporating solid-state devices shall be disconnected for the tests;
– making and breaking its rated current at its maximum rated operational voltage.

B.8.10.4.2 The CBR shall be capable of performing satisfactorily the tests specified in B.8.2.4.4, but at a value of 1,25 $I_{\Delta n}$ and without measurement of break time. The test is made on any one pole, taken at random.

If the CBR has an adjustable residual operating current, the test is made at the lowest setting, at a current of a value of 1,25 times that setting.

B.8.10.4.3 Where applicable the CBR shall also be submitted to the test of B.8.2.4.5.

B.8.10.4.4 CBRs functionally dependent on line voltage shall also satisfy the tests of B.8.8 or B.8.9, as applicable.

Test sequence B III

B.8.11 Verification of the effects of environmental conditions

The test is carried out according to IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be

- 6 for $I_{\Delta n} > 1$ A,
- 28 for $I_{\Delta n} \leq 1$ A.

~~NOTE~~ The 28 cycle test ~~should~~ shall be applied to CBRs having multiple settings of residual operating current when one of the possible settings is ≤ 1 A.

At the end of the cycles the CBR shall be capable of complying with the tests of B.8.2.4.4, but with a residual operating current of 1,25 $I_{\Delta n}$ and without measurement of break time. Only one verification need to be made.

Where applicable the CBR shall also comply with the test of B.8.2.4.5. Only one verification need to be made.

B.8.12 Verification of electromagnetic compatibility

B.8.12.1 Immunity tests

B.8.12.1.1 General

Annex J applies with the following additional requirements.

For CBRs with adjustable settings of residual operating current and/or time-delay, the tests shall be made at the lowest of these settings.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

The tests are performed without load current but with the residual current, when specified.

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1, with the following specifications:

Performance criterion A:

For step 1, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, shall correctly indicate the status.

For step 2, the CBR shall trip at each test frequency, when loaded at 1,25 $I_{\Delta n}$; the dwell time at each frequency shall be not less than the maximum break time specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2, as applicable.

Following these tests, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

Performance criterion B:

During the test, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, may be temporarily affected. Following the test, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

B.8.12.1.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

The test set-up shall be in accordance with Figure J.1 and Figure J.3.

Performance criterion B of B.8.12.1.1 applies except that during the test the CBR may trip. If this is the case a further test shall be made at the immediate lower level, and the CBR shall not trip.

B.8.12.1.3 Radiated ~~radio-frequency~~ RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test set-up shall be in accordance with Figure J.4.

The test connections shall be in accordance with Figure 5 or Figure 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer's instructions for installation. The type of cable used shall be stated in the test report.

Performance criterion A of B.8.12.1.1 applies.

B.8.12.1.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figure 4 of IEC 61000-4-4:2012.

The test set-up shall be in accordance with Figure J.5 for testing power lines and with Figure J.6 for testing signal lines, taking into consideration the manufacturer's instructions for installation.

Performance criterion B of B.8.12.1.1 applies.

B.8.12.1.5 Surges

Annex J applies, in particular J.2.5.

The test conditions of 7.2 of IEC 61000-4-5:2014 apply.

For convenience, the mounting specified in B.8.12.1.4 may be used but the use of the ground reference plane is optional.

The test connections shall be in accordance with Figures 6, 7, 8 or 9 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B of B.8.12.1.1 applies.

B.8.12.1.6 Conducted disturbances induced by ~~radio-frequency~~ RF fields (common mode)

Annex J applies, in particular J.2.6.

Performance criterion A of B.8.12.1.1 applies.

B.8.12.2 Emission tests

B.8.12.2.1 General

Annex J applies with the following additional requirements.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

Tests shall be made without load current and without residual current.

B.8.12.2.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

B.8.12.2.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

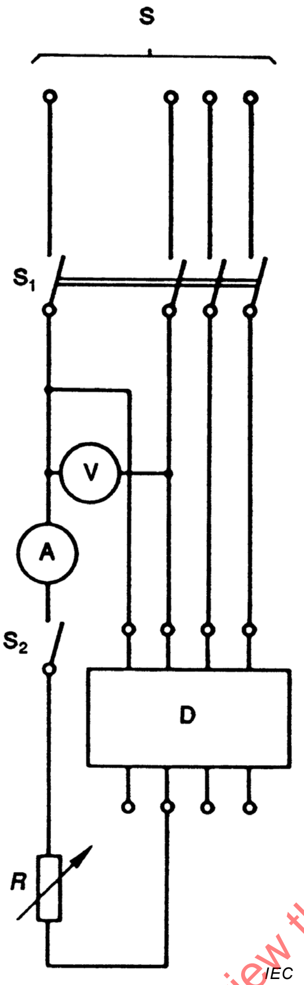
Annex J applies, in particular J.3.3.

B.8.13 Test for variations or interruptions of voltage and for voltage dips

NOTE For definition of voltage dips, see IEC 61000-4-11.

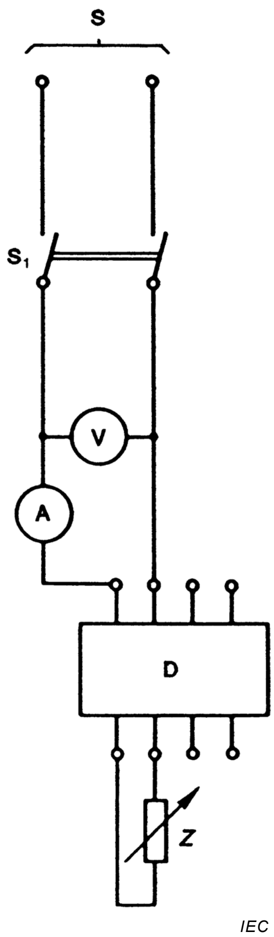
The relevant tests of B.8.8 and B.8.9 are considered adequate to cover the EMC requirements.

No additional tests are therefore required.



S = Supply
V = Voltmeter
A = Ammeter
S_1 = All-pole switch
S_2 = Single-pole switch
D = CBR under test
R = Adjustable resistor

Figure B.1 – Test circuit for the verification of the operating characteristic (see B.8.2)



S = Supply

S_1 = Two-pole switch

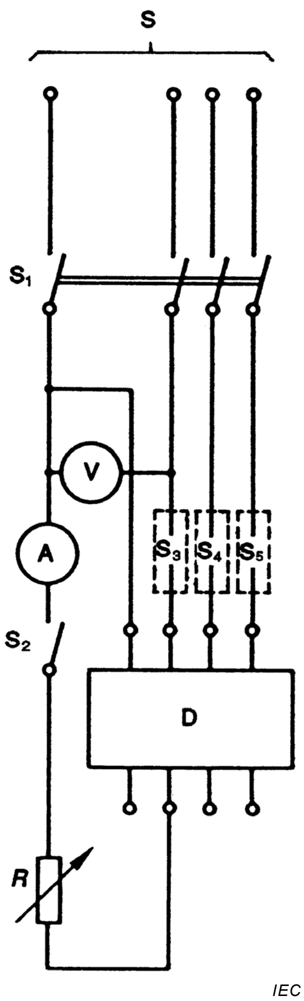
V = Voltmeter

A = Ammeter

D = CBR under test

Z = Adjustable impedance

Figure B.2 – Test circuit for the verification of the limiting value of the non-operating current under over-current conditions (see B.8.5)



S = Supply
V = Voltmeter
A = Ammeter
S_1 = All-pole switch
S_2 = Single-pole switch
S_3, S_4, S_5 = Single-pole switches opening one phase in turn
D = CBR under test
R = Adjustable resistor

Figure B.3 – Test circuit for the verification of the behaviour of CBRs classified under B.3.1.2.2 (see B.8.9)

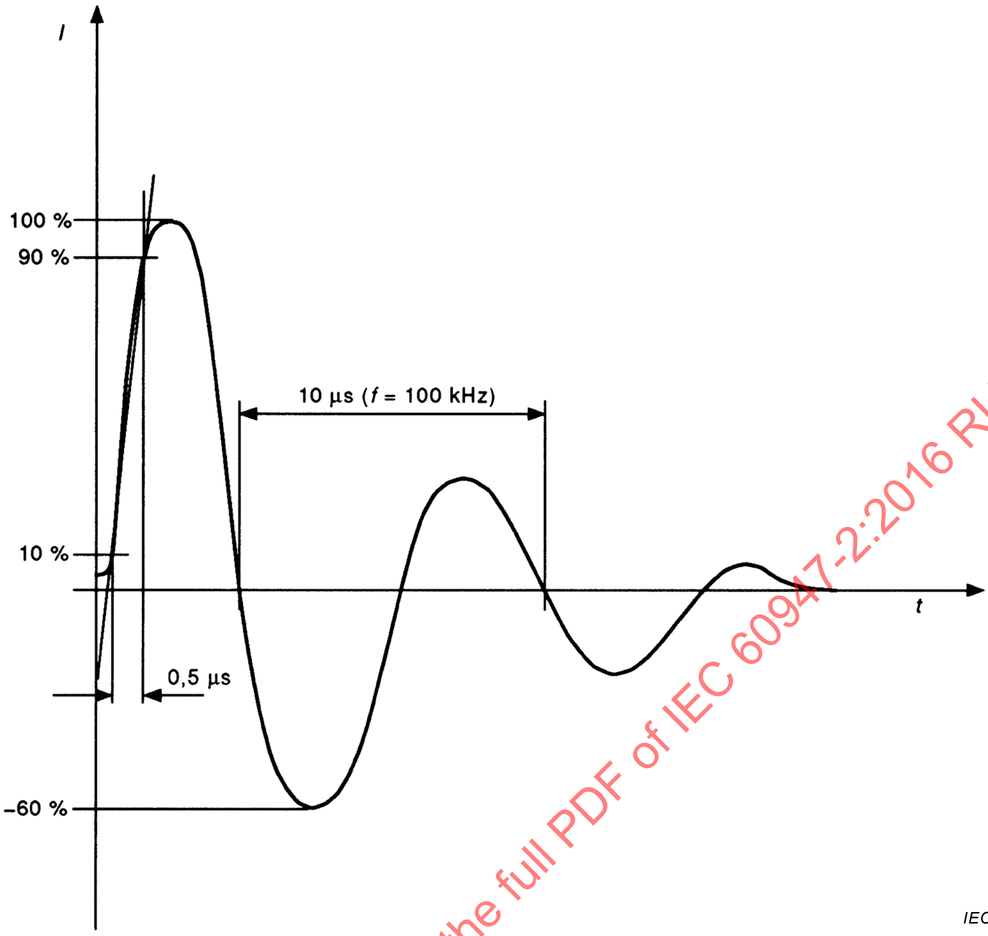
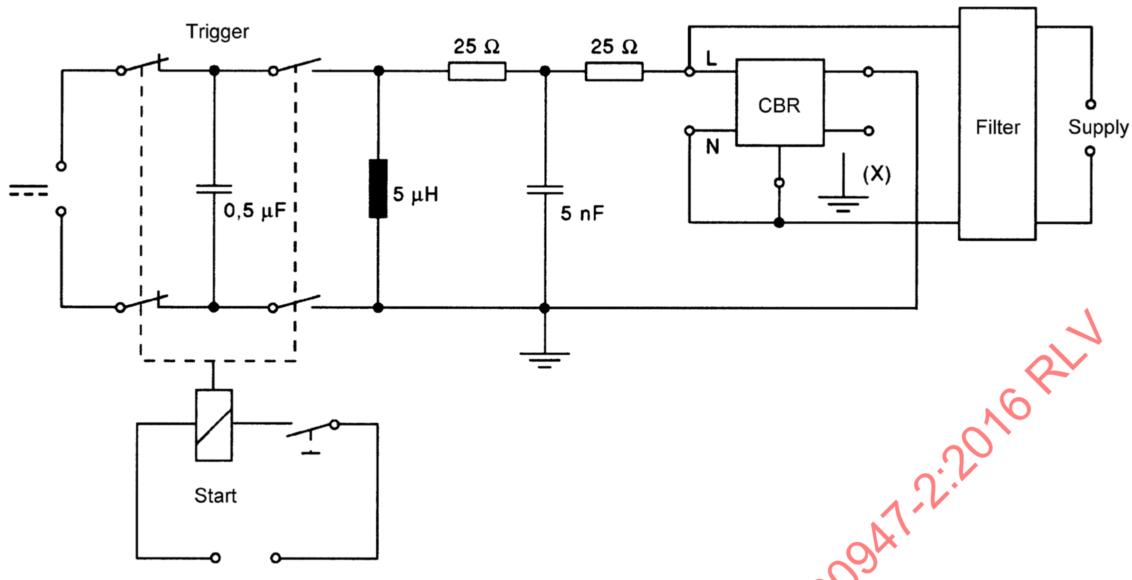


Figure B.4 – Current ring wave 0,5 µs/100 kHz



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

NOTE The circuit component values are given for guidance only and may require adjustment to comply with the wave shape requirements of Figure B.4.

Figure B.5 – Example of test circuit for the verification of resistance to unwanted tripping

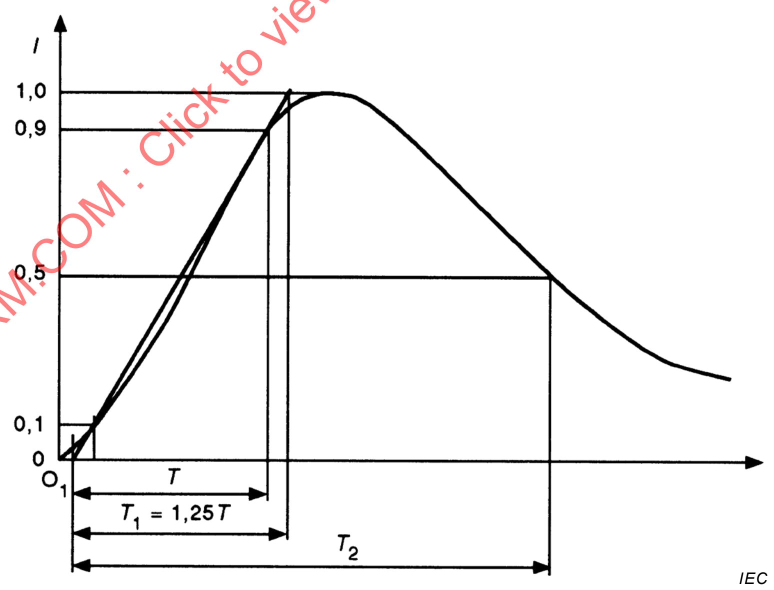
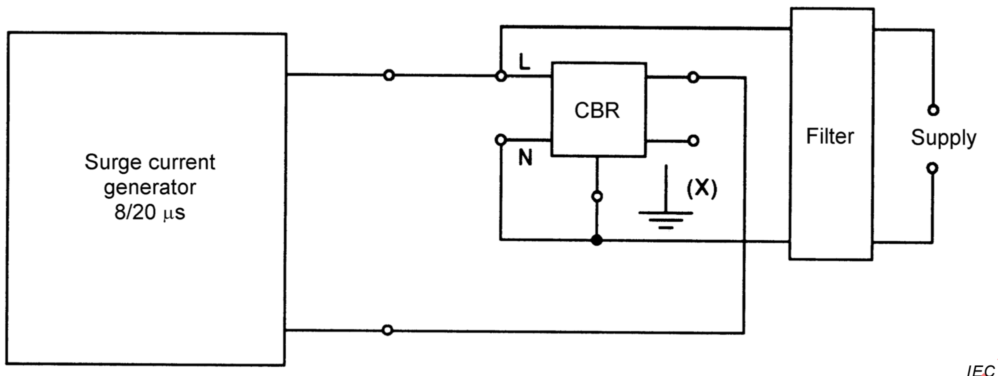
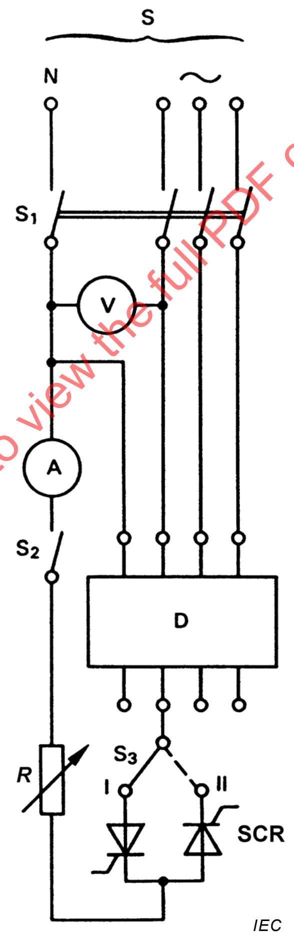


Figure B.6 – Surge current wave 8/20 µs



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

Figure B.7 – Test circuit for the verification of resistance to unwanted tripping in case of flashover without follow-on current (B.8.6.3)



S = Supply

V = Voltmeter

A = Ammeter (measuring r.m.s values)

D = CBR under test

SCR = Thyristors

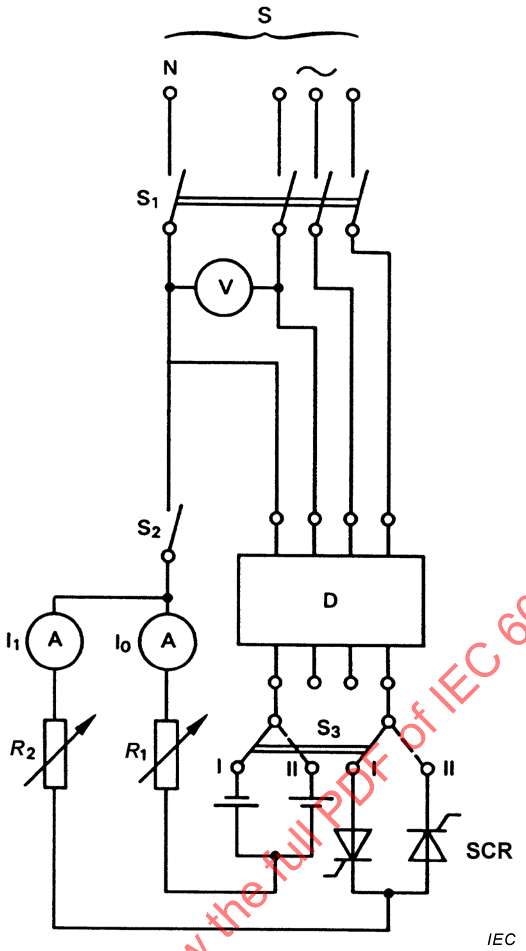
R = Variable resistor

S_1 = All-pole switch

S_2 = Single pole switch

S_3 = Two-way switch

Figure B.8 – Test circuit for the verification of the correct operation of CBRs, in the case of residual pulsating direct currents (see B.8.7.2.1, B.8.7.2.2 and B.8.7.2.3)



S = Supply

V = Voltmeter

A = Ammeter (measuring r.m.s values)

D = CBR under test

SCR = Thyristors

R_1, R_2 = Variable resistor

S_1 = All-pole switch

S_2 = Single pole switch

S_3 = Two-way switch

Figure B.9 – Test circuit for the verification of the correct operation of CBRs, in the case of a residual pulsating direct current superimposed by a smooth direct residual current (see B.8.7.2.4)

Annex C
(normative)

Individual pole short-circuit test sequence

C.1 General

This test sequence applies to multipole circuit-breakers intended for use on phase-earthed systems and identified in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit breaking capacity (I_{su})	C.2
Verification of dielectric withstand	C.3
Verification of overload releases	C.4

C.2 Test of individual pole short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{su} equal to 25 % of the ultimate rated short-circuit breaking capacity I_{cu}.

NOTE Values higher than 25 % of I_{cu} ~~may~~ can be tested and declared by the manufacturer.

The ~~applied~~ test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on phase-earthed systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with
Table 10. The power factor shall be according to Table 11, appropriate to the test current.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

$$O - t - CO$$

and shall be made on each pole separately, in turn.

C.3 Verification of dielectric withstand

Following the test according to Clause C.2, the dielectric withstand shall be verified according to 8.3.5.4.

C.4 Verification of overload releases

Following the test according to Clause C.3, the operation of the overload releases shall be verified in accordance with 8.3.5.5.

Annex D

Vacant

Annex E
(informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex

– "agreement" is used in a very wide sense;

– "user" includes testing stations.

Annex J of IEC 60947-1:2007 applies with regard to clauses and subclauses of this standard, with the following additions:

Clause or subclause number of this standard	Item
4.3.6.3	Circuit-breakers for higher short-circuit making capacity than given in Table 2
7.2.1.2.1	Automatic opening operation other than trip-free operation and by stored energy
Table 10	Setting of overload releases at intermediate values for short-circuit tests
8.3.3.5	Method of temperature-rise tests for four-pole circuit-breakers having a conventional thermal current higher than 63 A
8.3.2.6.4.3	Value of test current for short-circuit tests on the fourth pole of four-pole circuit-breakers
8.3.3.2.3, item b)	Test current value for the verification of inverse time/current characteristics
8.3.3.5	To increase the severity of the conditions for testing overload performance
8.3.3.8 8.3.4.6	Permissible delay between the verification of temperature-rise and that of overload relays in test sequences I and II
8.4.3	Calibration of releases other than over-current releases, shunt releases and undervoltage releases
8.5	Special tests – Damp heat, salt mist, vibration and shock
B.8	Applicability of tests when $I_{\Delta n}$ > 30 A
B.8.2.5	Extension of the test ambient temperature limits
~~F.4.1.3~~	~~Test at a current lower than twice the current setting~~

Annex F
(normative)

Additional tests for circuit-breakers with electronic over-current protection

F.1 ~~Scope~~ General

This annex applies to circuit-breakers intended to be installed on a.c. circuits and providing over-current protection by electronic means, incorporated in the circuit-breaker and independent of the line voltage or any auxiliary supply.

The tests verify the performance of the circuit-breaker under the environmental conditions stated in this annex.

Specific tests for electronic means intended for functions other than over-current protection are not covered by this annex. However, the tests of this annex shall be performed to ensure that these electronic means do not impair the performance of the over-current protective functions.

F.2 List of tests

F.2.1 General

Tests specified in this annex are type tests and are supplementary to the tests of Clause 8.

NOTE Where a standard for specific environmental conditions exists, reference is systematically made to this standard, if relevant.

F.2.2 Electromagnetic compatibility (EMC) tests

F.2.2.1 General

Circuit-breakers with electronic overcurrent protection shall be tested according to Table J.1 and Figure J.3.

F.2.2.2 Performance criteria

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1 with the following specifications:

Performance criterion A:

For step 1, the circuit-breaker when loaded at 0,9 times the current setting shall not trip and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

For step 2, when loaded at 2,0 times the current setting, the circuit-breaker shall trip within 0,9 times the minimum value and 1,1 times the maximum value of the manufacturer's time current characteristic, and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

Performance criterion B:

During the test, the circuit-breaker when loaded at 0,9 times the current setting shall not trip. After the test, the circuit-breaker shall comply with the manufacturer's time current characteristic when loaded at 2,0 times the current setting and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

F.2.3 Suitability for multiple frequencies

The test shall be performed in accordance with F.6.

F.2.4 Dry heat test

The test shall be performed in accordance with F.7.

F.2.5 Damp heat test

The test shall be performed in accordance with F.8.

F.2.6 Temperature variation cycles at a specified rate of change

The test shall be performed in accordance with F.9.

F.3 General test conditions

F.3.1 General

Tests according to this annex may be performed separately from the tests of Clause 8.

In the case of the EMC tests, Annex J applies with the additional requirements specified in F.4 and F.5.

F.3.2 Electromagnetic compatibility tests

For immunity tests (F.4) one circuit-breaker per frame size and per type of current sensor design shall be tested; a change of winding turns is not considered as a different design in this context. In the case of withdrawable circuit-breaker, the device shall be mounted inside the enclosure in accordance with the manufacturer's instructions, the test set-up being modified accordingly.

The current setting I_r shall be adjusted to the minimum value.

Short-time and instantaneous release settings shall each, if applicable, be adjusted to the minimum value but to not less than 2,5 times I_r.

The tests shall be performed with the appropriate test circuit, as specified in the following subclauses, taking into account any phase-loss sensitive features.

For circuit-breakers having electronic overcurrent protection, it may be assumed that the tripping characteristics are the same, whether tests are performed:

– on individual poles of multipole circuit-breakers;

– on two or three phase poles in series;

– by three-phase connection.

NOTE This enables comparisons to be made between test results obtained on different phase pole combinations as required by the different test sequences.

For circuit-breakers incorporating a residual current function (see also Annex B and Annex M):

– in the cases of F.4.4, F.4.5 and F.4.6, tests are made on pairs of phase poles for multipole circuit-breakers, to avoid unintentional tripping by residual current;

– in the cases of F.4.1 and F.4.7, tests may be made on any combination of phase poles, as long as unintentional tripping by residual current is avoided.

F.4 Immunity tests

F.4.1 Harmonic currents

F.4.1.1 General

These tests apply to circuit-breakers for which the electronic current sensing means are stated by the manufacturer to be r.m.s. responsive.

This shall be indicated either by marking "r.m.s." on the circuit-breaker or given in the manufacturer's literature, or both.

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details including the dimensions of the enclosure shall be stated in the test report.

Where applicable, the tests shall be performed at the rated frequency.

NOTE The test currents ~~may~~ can be generated by a source of power based on the use of thyristors (see Figure F.1), saturated cores, programmable power supplies, or other appropriate sources.

F.4.1.2 Test currents

The test current waveform shall consist of one of the following two options:

– option a): two waveforms applied successively:
  - a waveform consisting of a fundamental and a third harmonic component;
  - a waveform consisting of a fundamental and a fifth harmonic component.
– option b): a waveform consisting of a fundamental and a third, fifth and seventh harmonic component.

Test currents shall be

– for option a):

  test of the third harmonic and peak factor
  - 72 % of fundamental component ≤ third harmonic ≤ 88 % of fundamental component;
  - peak factor: 2,0 ± 0,2;

  test of the fifth harmonic and peak factor
  - 45 % of fundamental component ≤ fifth harmonic ≤ 55 % of fundamental component;
  - peak factor: 1,9 ± 0,2;
– for option b):

  the test current, for each period, consists of two equal opposite half-waves defined as follows:
  - current conduction time, for each half-wave is ≤ 21 % of the period;
  - peak factor: ≥ 2,1.

NOTE 1 The peak factor is the peak value of the current divided by the r.m.s. value of the current wave. For the relevant formula, see Figure F.1.

NOTE 2 This test current for option b) has at least the following harmonic content of the fundamental component:

– third harmonic > 60 %;
– fifth harmonic > 14 %;
– seventh harmonic > 7 %;
– twenty-first harmonic > 1 %.

Higher Other harmonics may can also be present.

NOTE 3 The test current waveform for option b) may can be produced by, for example, two back-to-back thyristors (see Figure F.1).

NOTE 4 The test currents 0,9 I_r and 2,0 I_r (see performance criterion A of F.2.2.2) are the r.m.s. values of the composite waveforms.

F.4.1.3 Test procedure

The tests shall be performed on two-phase poles, chosen at random in accordance with item b) of 7.2.1.2.4 carrying the test current at any convenient voltage, connections being in accordance with Figure F.2. For releases with a phase loss sensitive feature, connections shall be made in accordance with Figure F.3 or Figure F.4, as applicable.

Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The duration of the test to verify the immunity to unwanted tripping (at 0,9 times the current setting) shall be 10 times the tripping time, which corresponds to twice the current setting.

F.4.1.4 Test results

Performance criterion A of F.2.2.2 shall apply.

F.4.2 Electrostatic discharges

Annex J, in particular J.2.2, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure J.3.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

The busbar routing shown in Figure F.2, Figure F.3 and Figure F.4 may be varied providing the 0,1 m distances, with a tolerance of $^{+10}_{0}$ %, to the enclosure are maintained. The actual configuration used shall be shown in the test report.

Performance criterion B of F.2.2.2 applies.

F.4.3 Radiated radio-frequency RF electromagnetic fields

Annex J, in particular J.2.3, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure F.17.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.4 Electrical fast transient/burst (EFT/B)

Annex J, in particular J.2.4, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure F.18 for testing power lines and with Figure F.16 and Figure F.19 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.6.

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.7 for the three phase poles in series connection or as shown in Figure F.8 on a phase pole chosen at random for the three-phase connection.

Performance criterion A of F.2.2.2 applies. However, temporary changes to the monitoring functions (e.g. unwanted LED illumination) during the tests are acceptable, in which case the correct functioning of the monitoring shall be verified after the tests. For step 2, the disturbance shall be applied until the circuit-breaker trips.

F.4.5 Surges

Annex J, in particular J.2.5, applies with the following additions.

On a.c. mains ports, the disturbance shall be applied on one phase pole chosen at random, the EUT being supplied from the other two phase poles, in accordance with Figure F.9 (line-to-earth) and Figure F.12 (line-to-line).

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.10 (line-to-earth) and Figure F.13 (line-to-line) for the three phase poles in series connection or as shown in Figure F.11 (line-to-earth) and Figure F.14 (line-to-line) on a phase pole chosen at random for the three-phase connection.

Performance criterion B of F.2.2.2 applies.

F.4.6 Conducted disturbances induced by ~~radio-frequency~~ RF fields (common mode)

Annex J, in particular J.2.6, applies with the following additions.

The test set-up shall be in accordance with Figure F.16, Figure F.20 and Figure F.21, Figure F.22 or Figure F.23 for testing power lines and with Figure F.16 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.2.

For releases which have a phase-loss sensitive feature the test circuit shall be in accordance with Figure F.3 or Figure F.4 as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.7 Current dips

F.4.7.1 Test procedure

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details including the dimensions of the enclosure shall be stated in the test report.

The test circuit shall be in accordance with Figure F.2 on two-phase poles chosen at random. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

The tests shall be performed with a sinusoidal current at any convenient voltage. The current applied shall be according to Figure F.5 and to Table F.1 below where I_r is the setting current, I_D is the dip test current and T is the period of the sinusoidal current.

The duration of each test shall be between three and four times the maximum tripping time corresponding to twice the current setting or 10 min, whichever is the lower.

Table F.1 – Test parameters for current dips and interruptions

Test No.	I_D	Δt
1		0,5 T
2		1 T
3	0	5 T
4		25 T
5		50 T
6		10 T
7	0,4 I_r	25 T
8		50 T
9		10 T
10	0,7 I_r	25 T
11		50 T

F.4.7.2 Test results

Performance criterion B of F.2.2.2 shall apply, except that the after-test verification is not required.

F.5 Emission tests

F.5.1 Harmonics

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.2 Voltage fluctuations

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.3 Conducted RF disturbances (150 kHz to 30 MHz)

Circuit-breakers covered by this annex are independent of line voltage or of any auxiliary supply. Electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

F.5.4 Radiated RF disturbances (30 MHz to 1 GHz)

Annex J, in particular J.3.3, applies with the following additions.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The limits of Table J.3 apply.

F.6 Suitability for multiple frequencies

F.6.1 General

The test verifies the tripping characteristics of circuit-breakers declared as suitable for multiple frequencies. It does not apply to circuit-breakers rated at 50 Hz to 60 Hz only.

F.6.2 Test conditions

The tests shall be performed at each rated frequency or, when a range of rated frequencies is declared, at the lowest and the highest rated frequencies.

F.6.3 Test procedure

Tests shall be performed on any pair of phase-poles chosen at random at any convenient voltage.

The test circuit shall be in accordance with Figure F.2. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Under-voltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The short-time and instantaneous trip current settings shall each, if relevant, be adjusted to 2,5 times the current setting. If this setting is not available, the next closest higher setting shall be used.

Tests shall be performed as follows:

a) A current of 0,95 times the conventional non-tripping current (see Table 6) is applied for a time equal to 10 times the tripping time which corresponds to 2,0 times the current setting.
b) Immediately following the test of a), a current of 1,05 times the conventional tripping current (see Table 6) is applied.
c) A further test starting from the cold state is made at 2,0 times the current setting.

F.6.4 Test results

For each test frequency, the overload tripping characteristics shall comply with the following requirements:

– for test a) no tripping shall occur;
– for test b) tripping shall occur within the conventional time (see Table 6);
– for test c) tripping shall occur within 1,1 times the maximum and 0,9 times the minimum values of the manufacturer's stated time-current characteristic.

F.7 Dry heat test

F.7.1 Test procedure

The test shall be performed on the circuit-breaker in accordance with 7.2.2 at the maximum rated current for a given frame size, on all phase poles, at an ambient temperature of 40 °C. The duration of the test, once temperature equilibrium is reached, shall be 168 h.

The tightening torques to be applied to the terminals screws shall be in accordance with the manufacturer's instructions (see 5.2 e)). ~~In the absence of such instructions, Table 4 of IEC 60947-1 shall apply.~~

As an alternative, the test may be performed as follows:

– measure and record the highest temperature rise of the air surrounding the electronic components, during the temperature rise verification of test sequence I;
– install the electronic controls in the test chamber;
– supply the electronic controls with their input energizing value;
– adjust the temperature of the test chamber to a value of 40 K above the temperature rise recorded for the air surrounding the electronic components and maintain this temperature for 168 h.

F.7.2 Test results

The circuit-breaker and the electronic controls shall meet the following requirements:

– no tripping of the circuit-breaker shall occur;
– no operation of the electronic controls which would cause the circuit-breaker to trip shall occur.

F.7.3 Verification of overload releases

Following the test of F.7.1, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.8 Damp heat test

F.8.1 Test procedure

The test shall be performed according to IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be six.

The test may be performed with only the electronic controls in the test chamber.

F.8.2 Verification of overload releases

Following the test of F.8.1 the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.9 Temperature variation cycles at a specified rate of change

F.9.1 Test conditions

Each design of electronic controls shall be submitted to temperature variation cycles in accordance with Figure F.15.

The rise and fall of temperature during the rate of variation shall be 1 K/min ± 0,2 K/min. The temperature, once reached, shall be maintained for at least 2 h.

The number of cycles shall be 28.

F.9.2 Test procedure

The test shall be carried out according to IEC 60068-2-14.

For these tests, the electronic controls may be mounted inside the circuit-breaker or separately.

The electronic controls shall be energized to simulate service conditions.

Where the electronic controls are mounted inside the circuit-breaker, the main circuit shall not be energized.

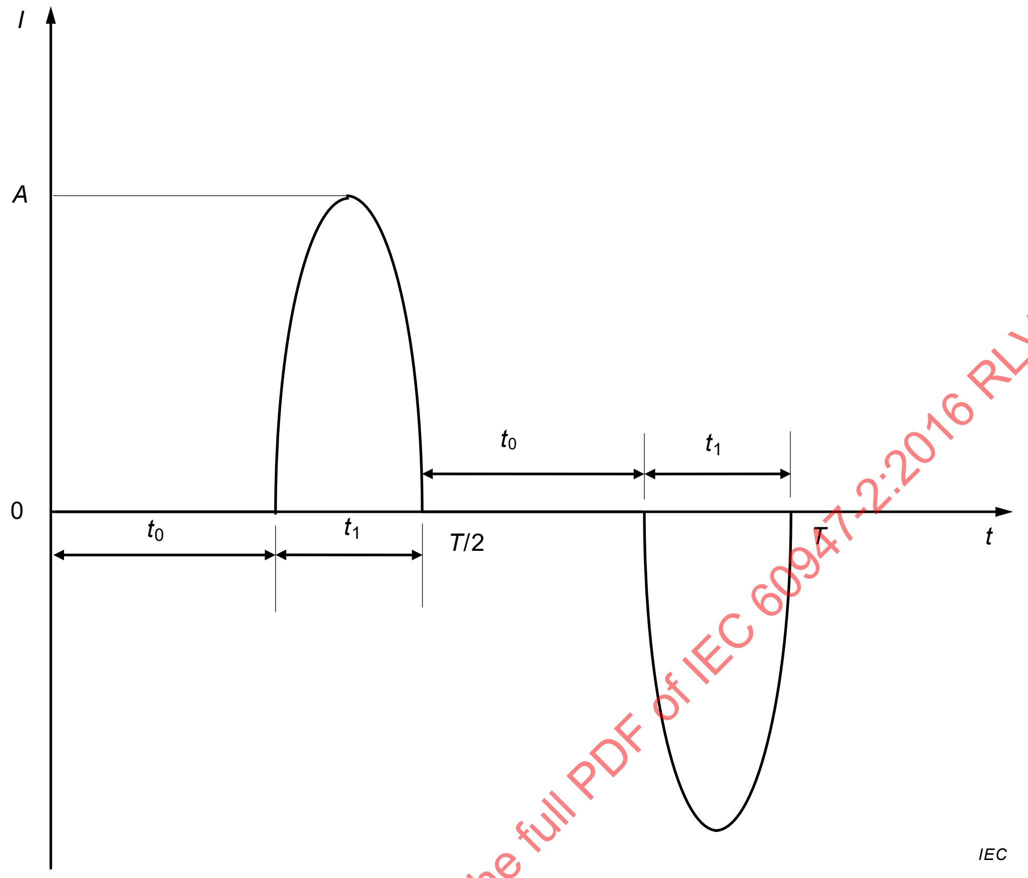
F.9.3 Test results

The electronic controls shall meet the following requirement.

No operation of the electronic controls which would cause the circuit-breaker to trip during the 28 cycles shall occur.

F.9.4 Verification of overload releases

Following the test of F.9.2, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).



Key

A peak current

T period

t_1 conducting time during each half-cycle

t_0 delay time

$$\text{Peak factor} = \frac{A}{\sqrt{\frac{2}{T}\int_{0}^{T/2} i^2(t)\,\mathrm{d}t}}$$

Figure F.1 – Representation of test current produced by back-to-back thyristors in accordance with F.4.1

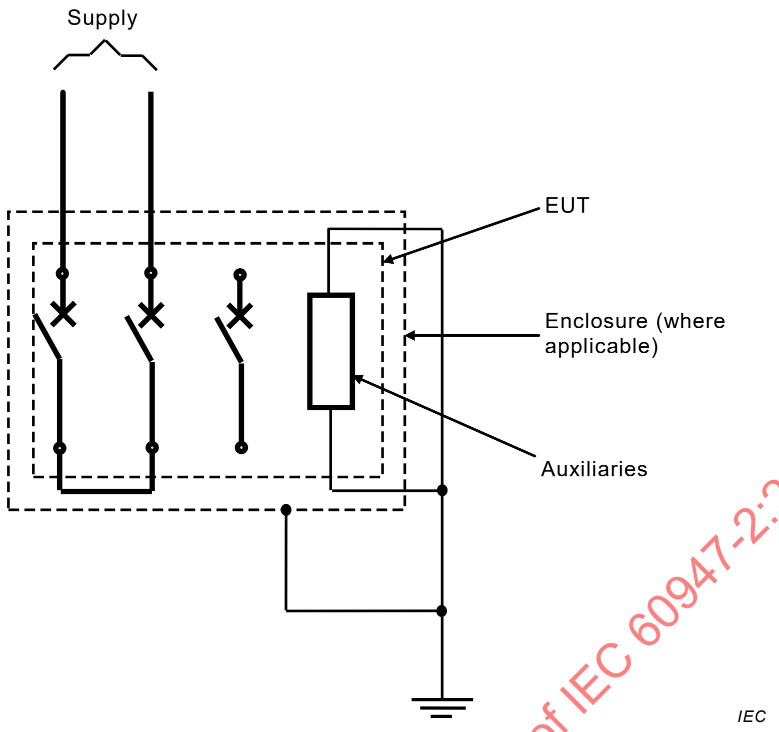


Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series

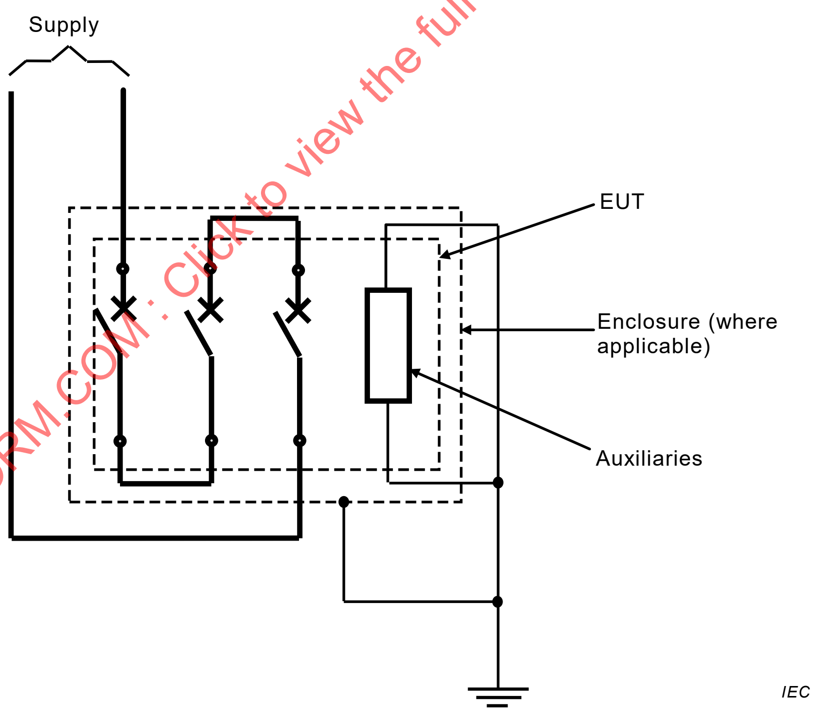
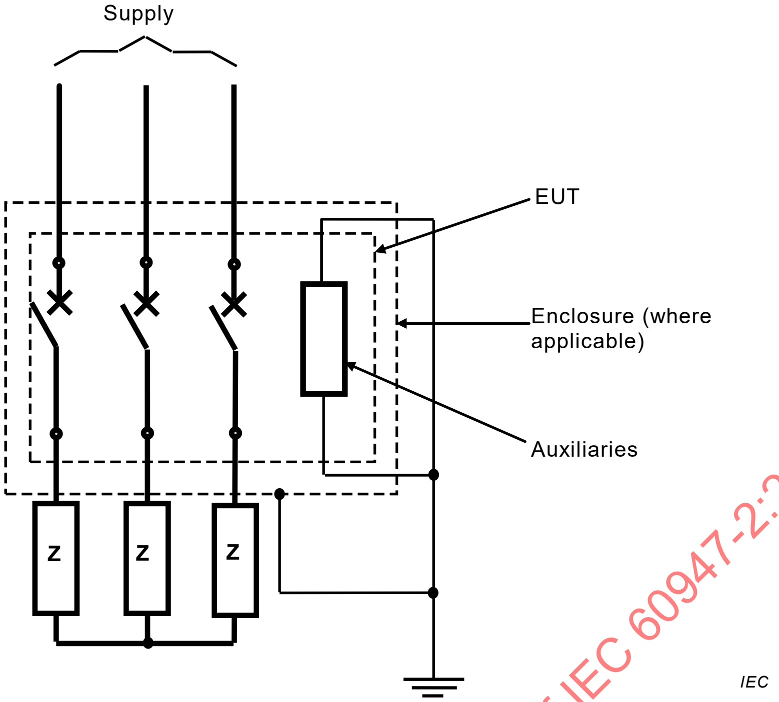


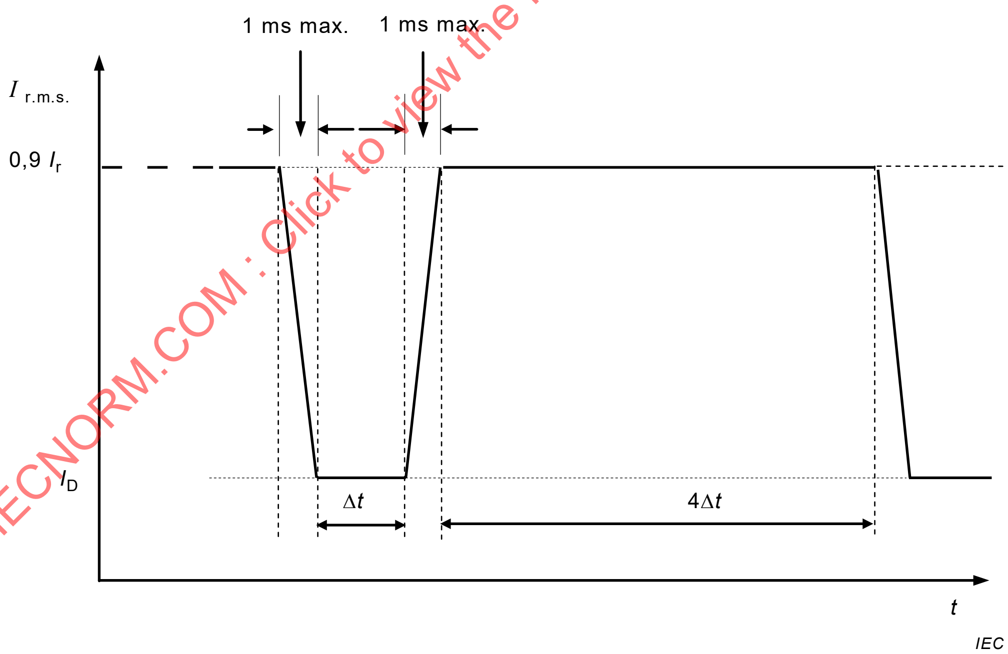
Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.4 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three-phase connection



Key

I_r setting current

I_D dip test current

Δt dip time

$4\Delta t$ dwell time

Figure F.5 – Test current for the verification of the influence of the current dips and interruptions in accordance with F.4.7.1

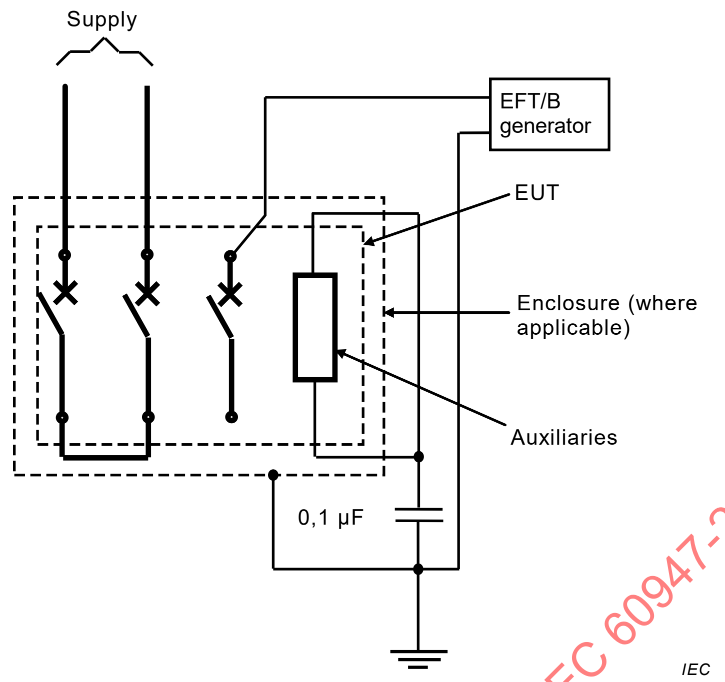


Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Two phase poles in series

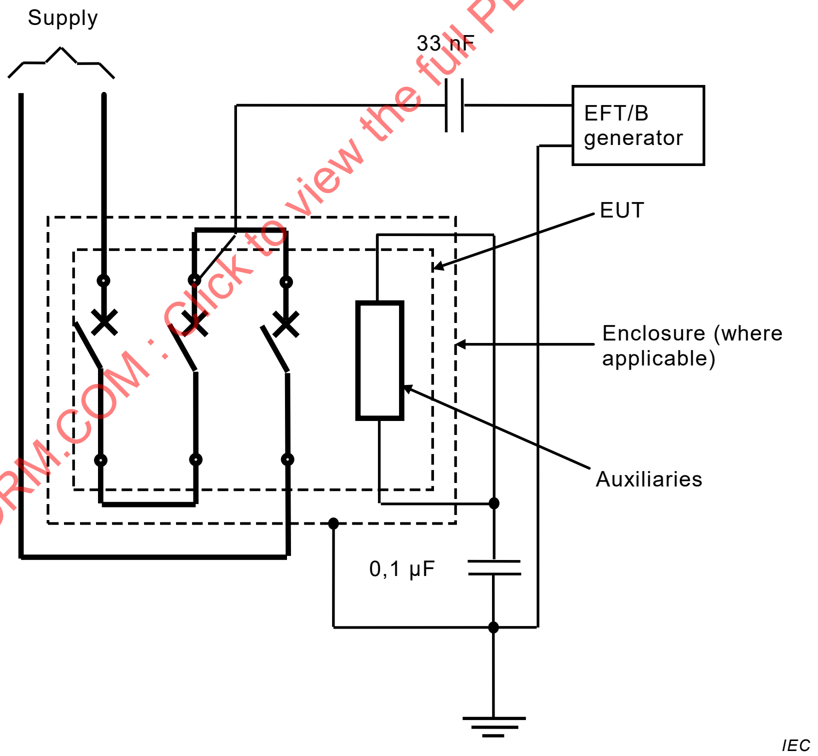
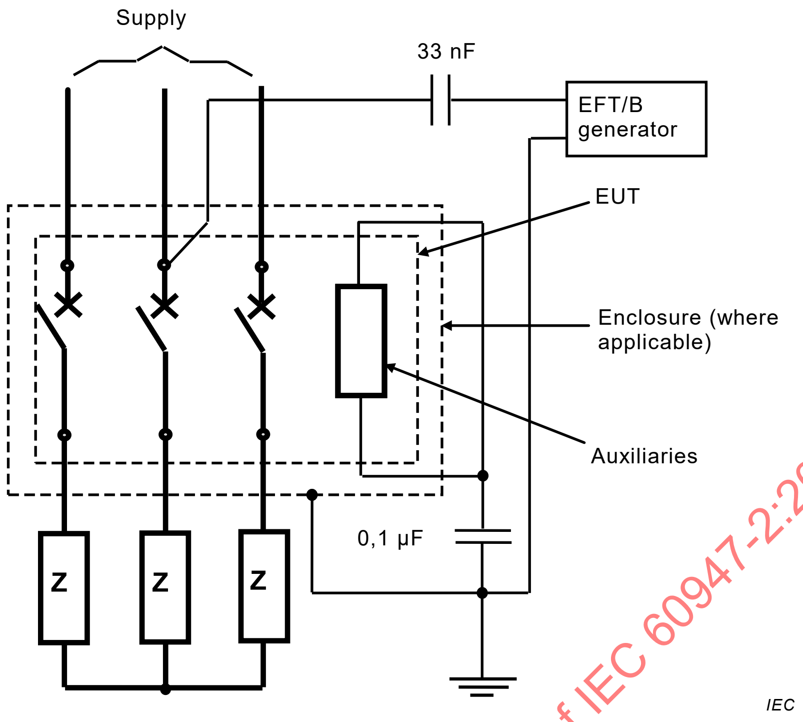


Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three-phase connection

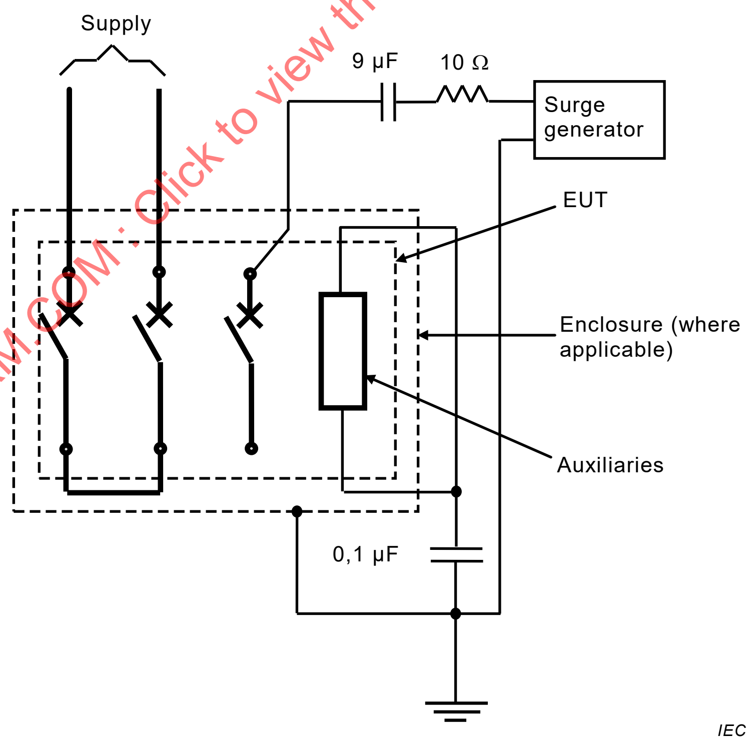


Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Two phase poles in series

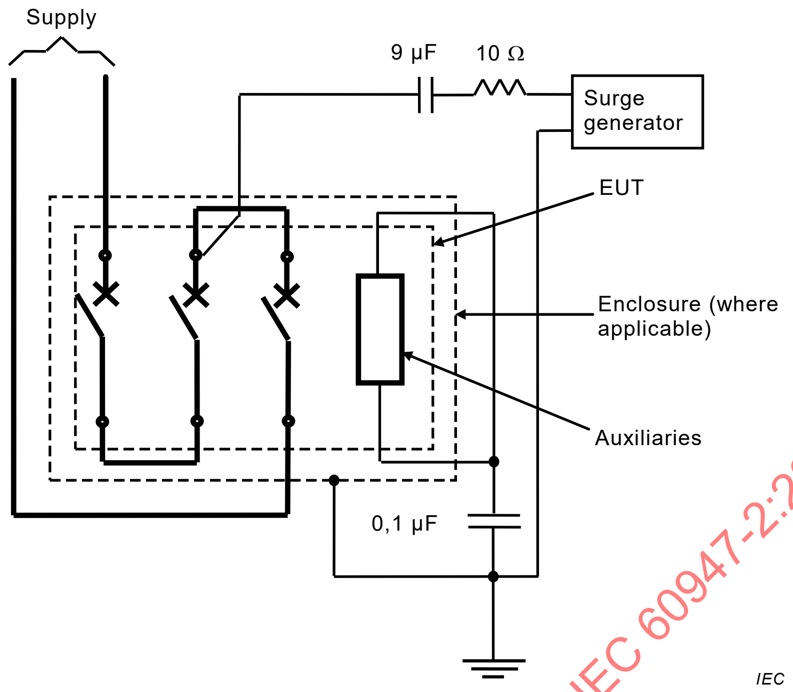
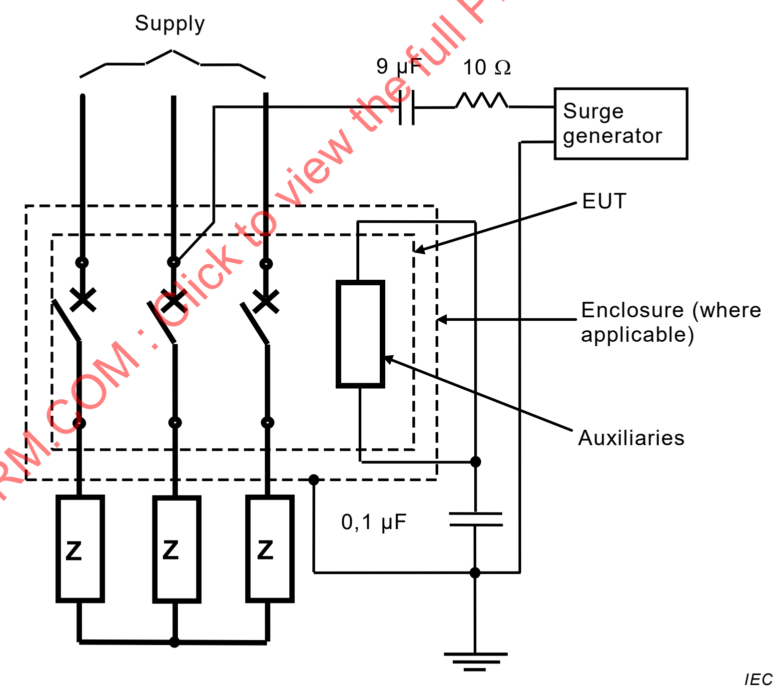


Figure F.10 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.11 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three-phase connection

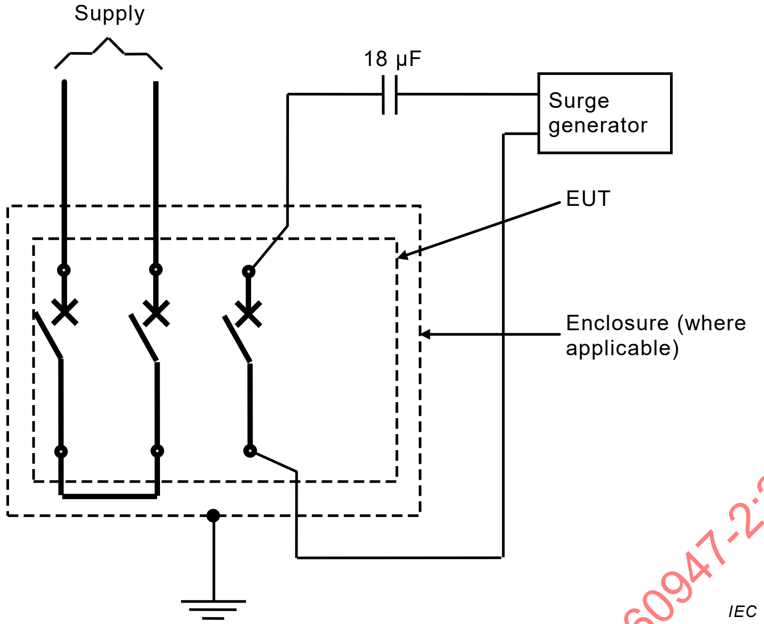


Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Two phase poles in series

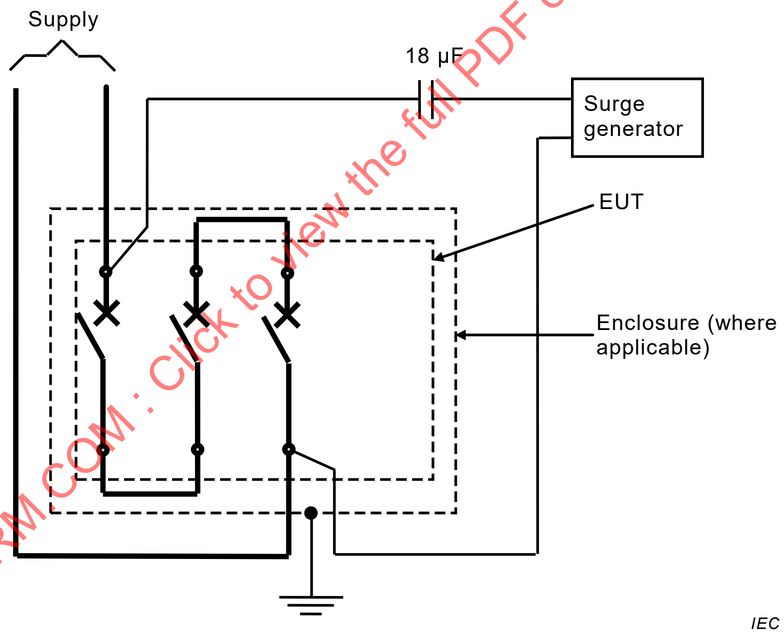
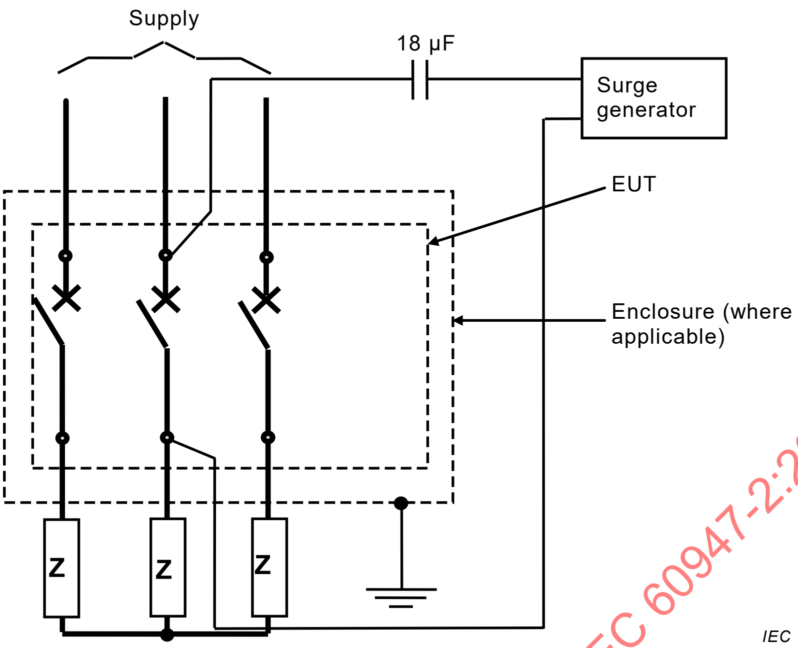


Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.14 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three-phase connection

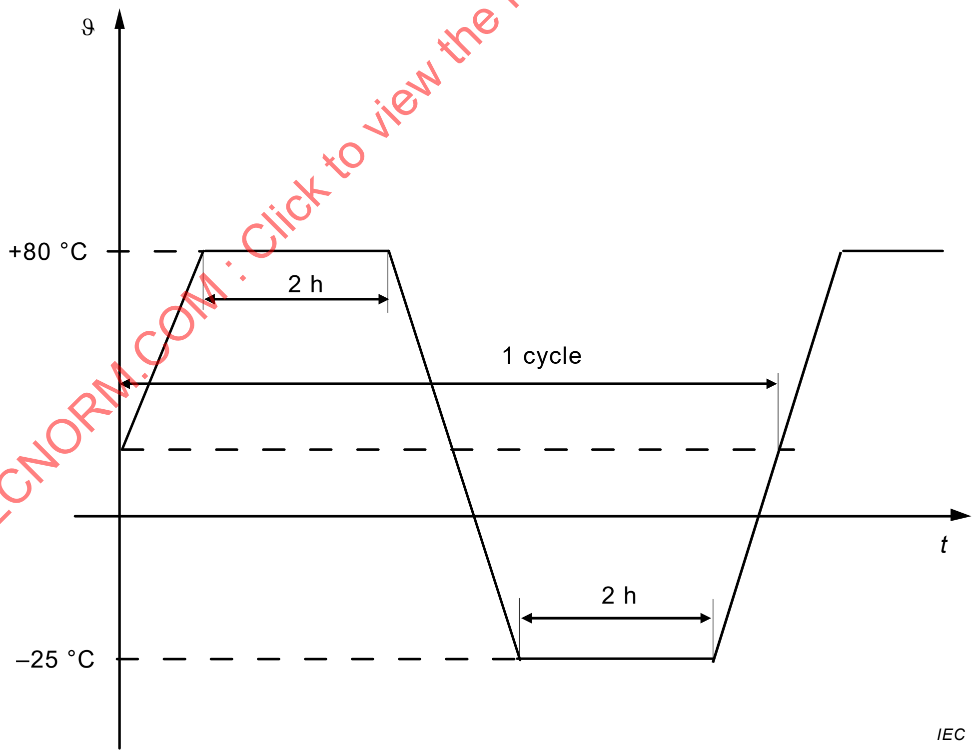
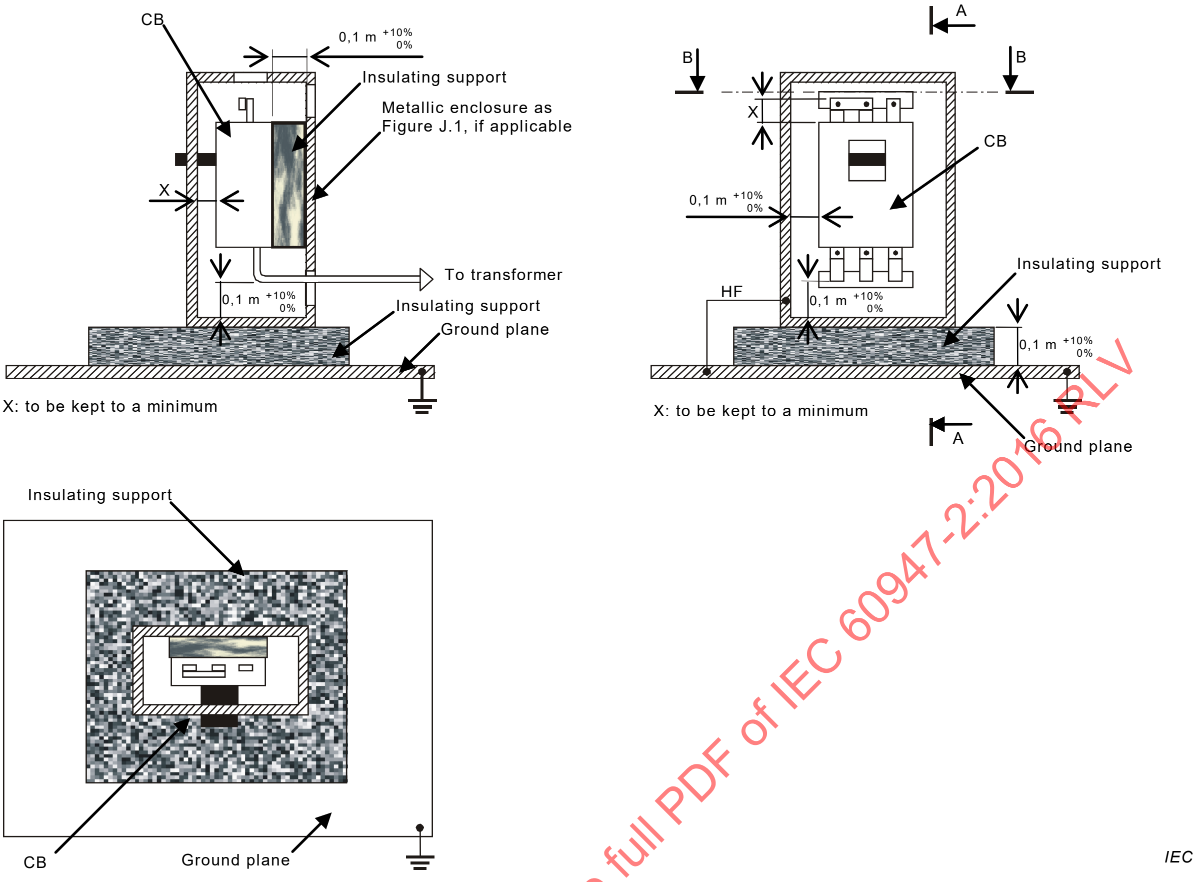


Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.4.5



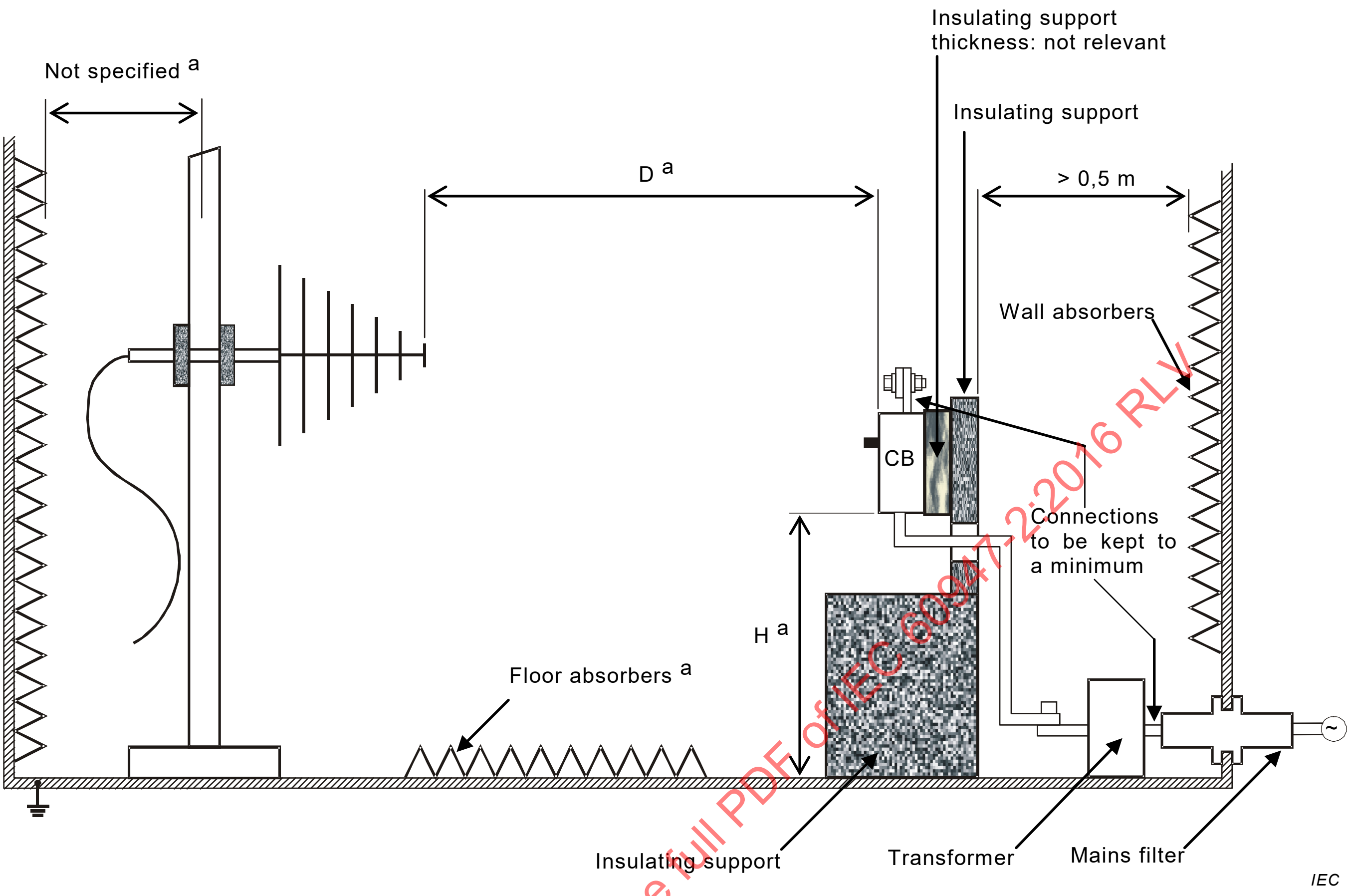
Key

CB circuit-breaker

NOTE ~~1~~ The terminal arrangement ~~may~~ can vary according to the type of circuit-breaker tested.

~~NOTE 2 In the case of withdrawable circuit-breaker, the device should be mounted inside the enclosure in accordance with the manufacturer's instructions, the test set up being modified accordingly.~~

Figure F.16 – General test set-up for immunity tests

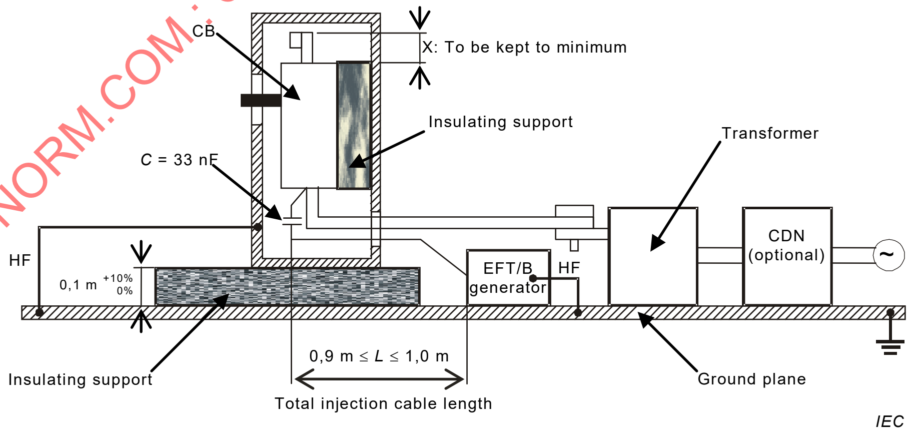


Key

CB circuit-breaker

a See IEC 61000-4-3

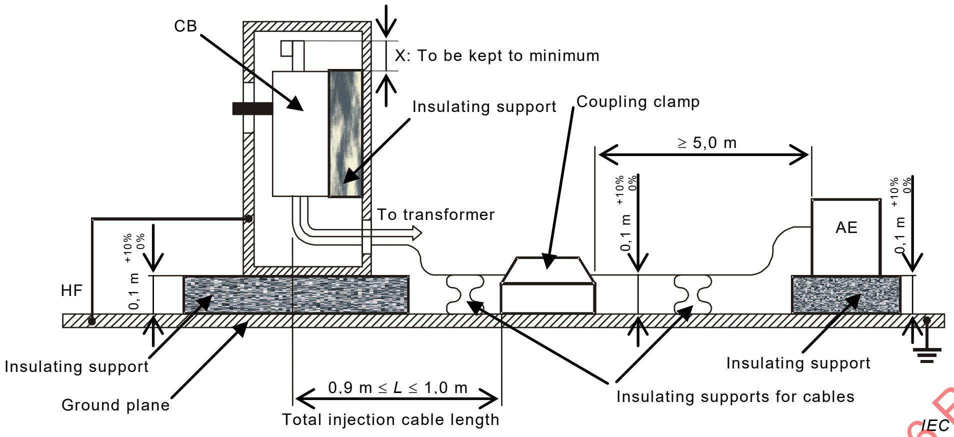
Figure F.17 – Test set-up for the verification of immunity to radiated RF electromagnetic fields



Key

CB	circuit-breaker	HF	high frequency connection
CDN	coupling-decoupling network		

Figure F.18 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines



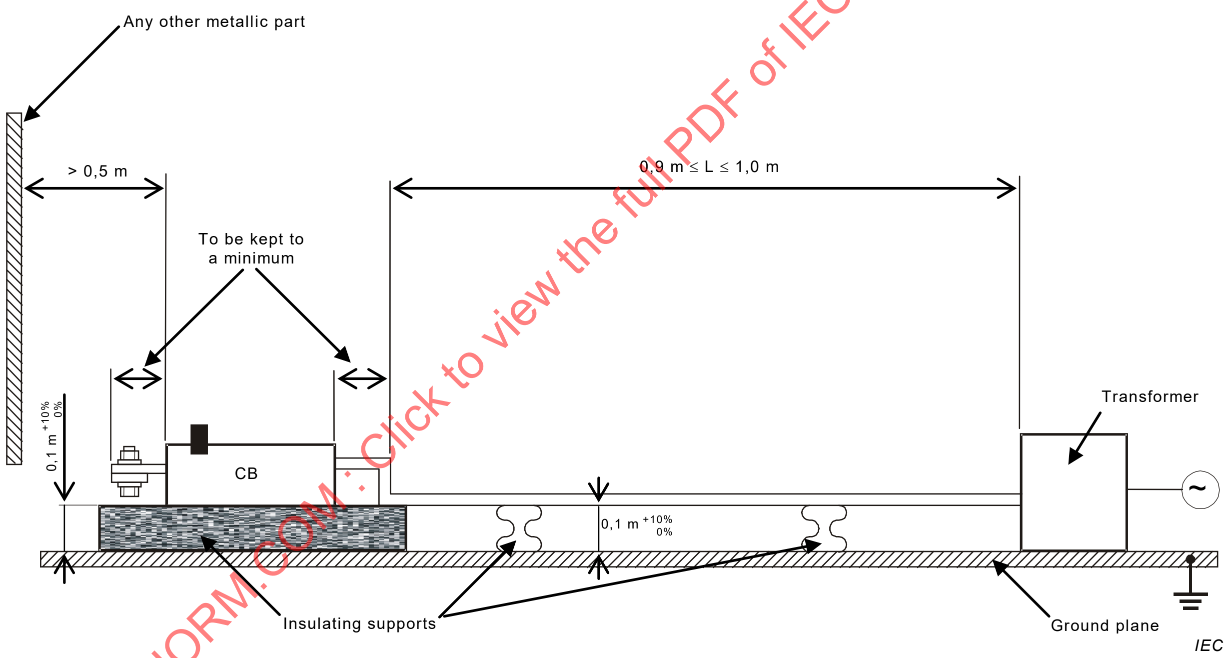
Key

AE auxiliary equipment

CB circuit-breaker

HF high frequency connection

Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

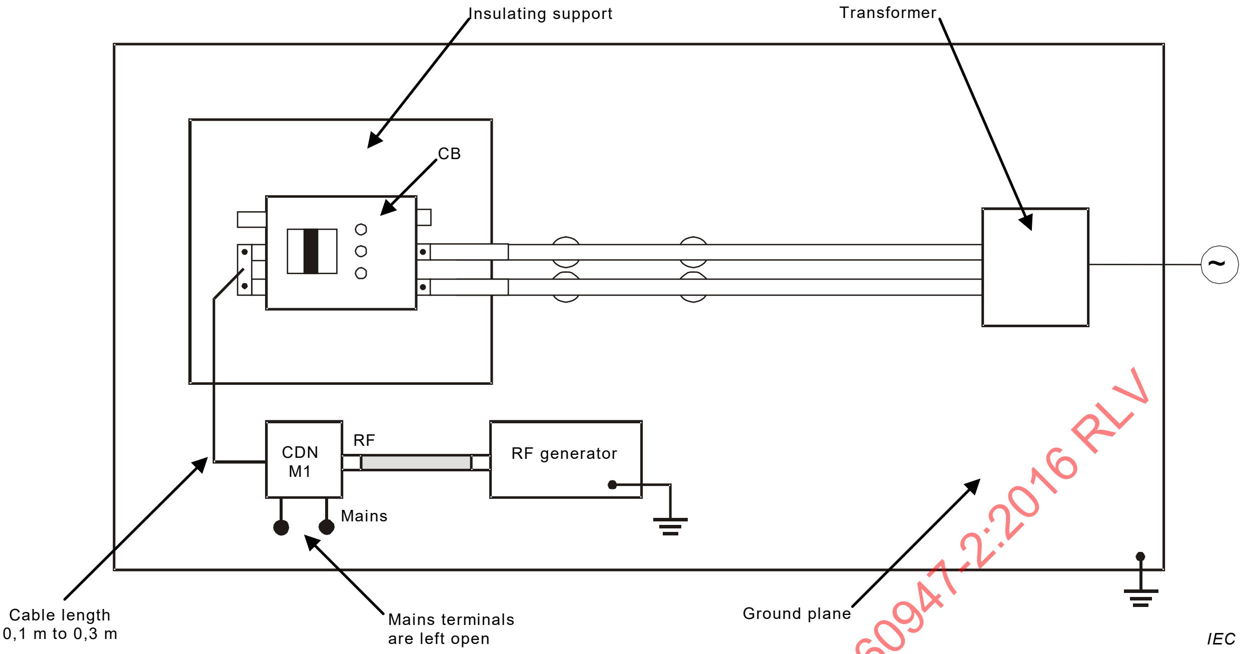


Key

CB circuit-breaker

NOTE The dimension *L* is the length of the conductor coupled at 0,1 m to the ground plane.

Figure F.20 – General test set-up for the verification of immunity to conducted disturbances induced by RF fields (common mode)



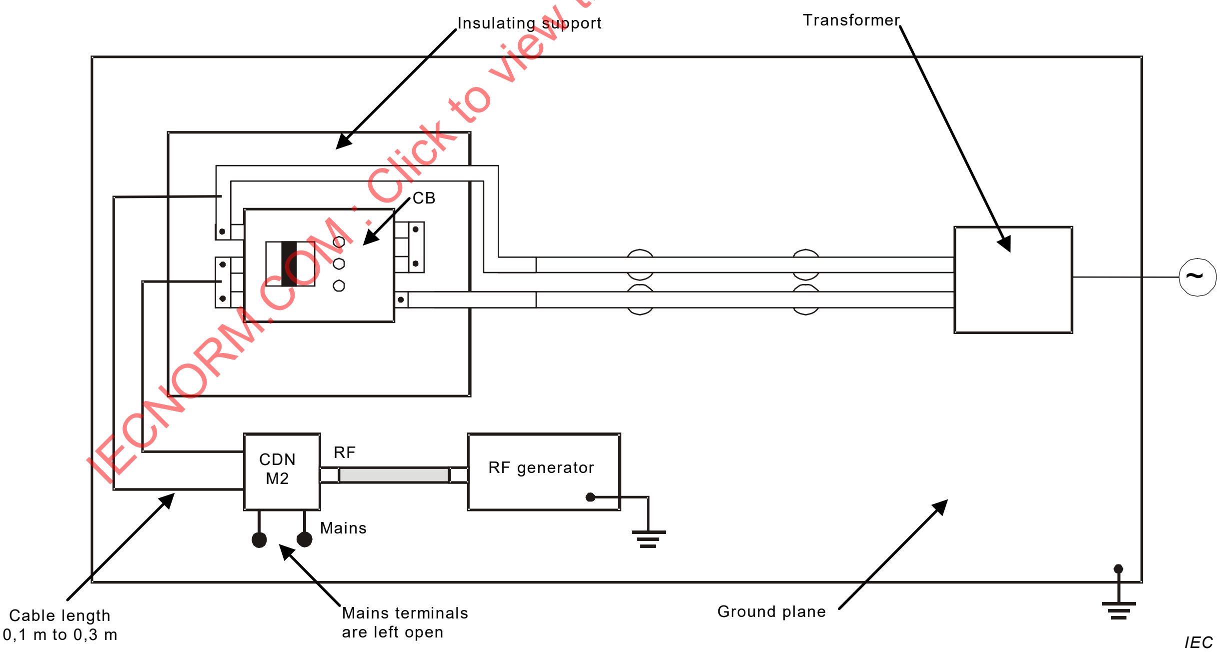
Key

CB circuit-breaker

CDN M1 coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, the coupling-decoupling network M2 or M3 ~~may~~ can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.21 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Two phase poles in series configuration



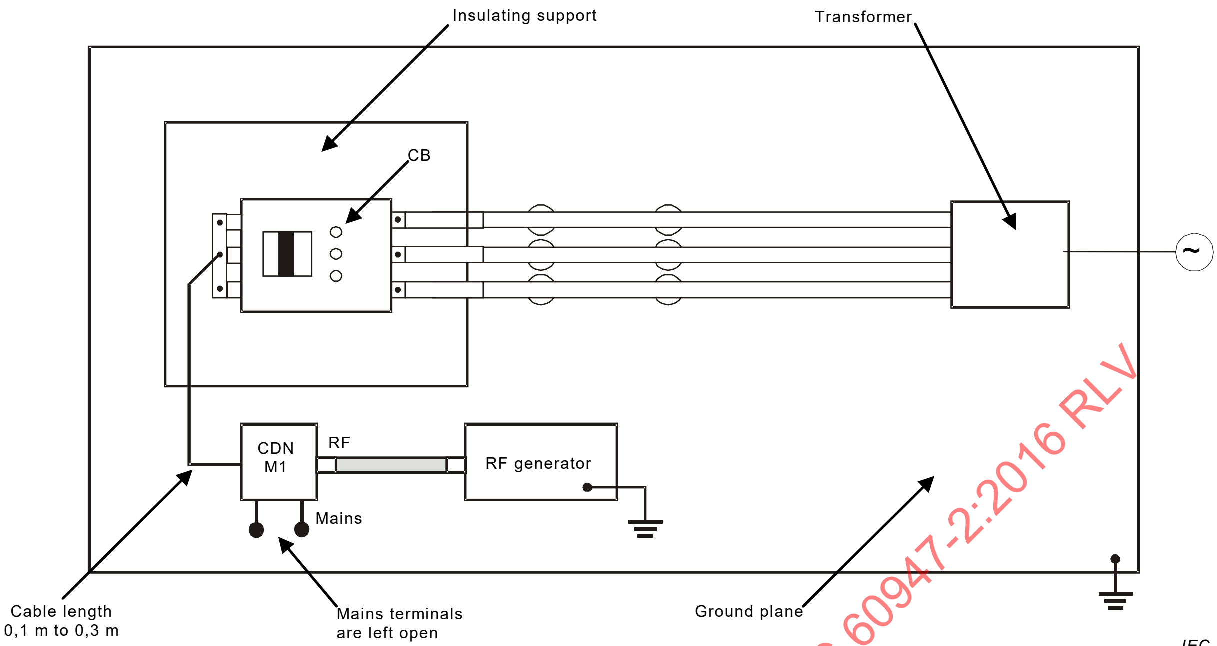
Key

CB circuit-breaker

CDN M2 coupling-decoupling network M2

NOTE As an alternative to the coupling-decoupling network M2, coupling-decoupling network M3 ~~may~~ can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.22 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three phase poles in series configuration



Key

CB circuit-breaker

CDN M1 coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, coupling-decoupling network M2 or M3 ~~may~~ can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.23 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three-phase configuration

Annex G
(normative)

Power loss

G.1 General

Power loss is not a fundamental characteristic of a circuit-breaker and need not be marked on the product.

It gives some indication of the heat generated under specified conditions.

Measurement of power loss shall be made in free air, on new samples, and shall be stated in watts.

G.2 Test methods

G.2.1 General case

Power loss is evaluated as follows, connections being in accordance with Figure G.1.

$$\sum_{k=1}^{k=p} \Delta U_k \, I_k \, \cos \varphi_k$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I is the test current which shall be equal to I_n within the tolerances according to 8.3.2.2.2;

$\cos \varphi$ is the power factor.

The use of a wattmeter on each pole is recommended.

G.2.2 AC circuit-breakers of rated current not exceeding 400 A

For a.c. circuit-breakers of rated current not exceeding 400 A, it is acceptable to use single-phase a.c. measurement without power factor measurement.

The power loss is evaluated as follows, connections being in accordance with Figure G.2.

$$\sum_{k=1}^{k=p} \Delta U_k \, I_n$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I_n is the rated current.

G.2.3 DC circuit-breakers

For d.c. circuit-breakers, the power loss shall be measured with d.c. current.

It is evaluated as in G.2.2.

G.3 Test procedure

The power loss evaluation shall be made under rated current steady-state temperature conditions.

The voltage drop shall be measured between incoming and outgoing terminals on each pole.

The connecting leads to measuring instruments (e.g. voltmeter, wattmeter) shall be twisted together. The measuring loop shall be as small as practicable and shall be positioned similarly for each pole.

For evaluating the power loss of three-pole and four-pole a.c. circuit breakers according to G.2.1, the test is performed under three-phase current conditions (see Figure G.1), without current in the fourth pole in the case of four-pole circuit-breakers.

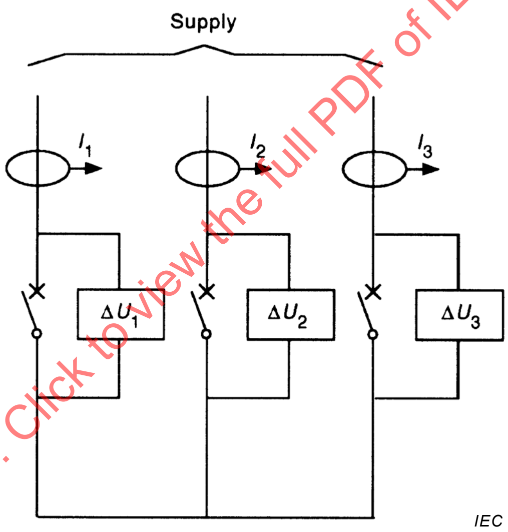


Figure G.1 – Example of power loss measurement according to G.2.1

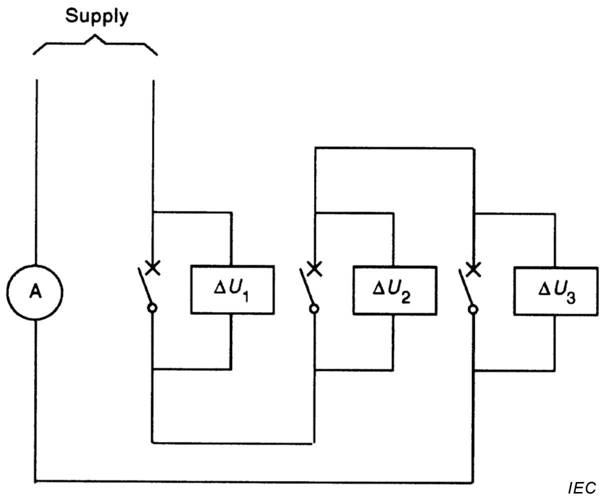


Figure G.2 – Example of power loss measurement according to G.2.2 and G.2.3

Annex H
(normative)

Test sequence for circuit-breakers for IT systems

NOTE This test sequence is intended to cover the case of a second fault to earth in presence of a first fault on the opposite side of a circuit-breaker when installed in IT systems (see 4.3.2.1).

H.1 General

This test sequence applies to multipole circuit-breakers for application on IT systems, in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit (I_{IT})	H.2
Verification of dielectric withstand	H.3
Verification of overload releases	H.4

H.2 Individual pole short-circuit

A short-circuit test is made on the individual poles of a multipole circuit-breaker under the general conditions of 8.3.2, at a value of current I_{IT} equal to

– 1,2 times the maximum setting of the short-time delay release tripping current or, in the absence of such a release, 1,2 times the maximum setting of the tripping current of the instantaneous release,

or, where relevant

– 1,2 times the maximum setting of the definite time delay release tripping current,

but not less than 500 A nor exceeding 50 kA.

NOTE 1 The prospective current of the test circuit ~~may~~ can have to be increased to ensure that the test current exceeds the actual short-time or instantaneous pick-up current, allowing for the impedance of the circuit-breaker and its connections.

NOTE 2 Values higher than I_{IT} ~~may~~ can be required, tested instead and declared by the manufacturer.

The ~~applied~~ test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on IT systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10. The power factor shall be according to Table 11, appropriate to the test current. When I_{IT} = 50 kA, the short-time or instantaneous pick-up setting shall be adjusted to the nearest setting lower than (50/1,2) kA.

For 4-pole circuit-breakers with a protected neutral pole, the test voltage for that pole shall be phase-to-phase voltage divided by √3. This test is applicable only where the construction of the protected neutral pole differs from that of the phase poles.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

$$O - t - CO$$

and shall be made on each pole separately, in turn.

H.3 Verification of dielectric withstand

Following the test according to H.2, the dielectric withstand shall be verified according to 8.3.5.4.

H.4 Verification of overload releases

Following the test according to H.3, the operation of the overload releases shall be verified according to 8.3.5.5.

H.5 Marking

Circuit-breakers for which all values of rated voltage have been tested according to this annex or are covered by such testing require no additional marking.

Circuit-breakers for which all values of rated voltage have not been tested according to this annex or are not covered by such testing shall be identified by the symbol  which shall be marked on the circuit-breaker immediately following these values of rated voltage, e.g., 690 V  in accordance with 5.2, item b).

~~NOTE~~ Where a circuit-breaker has not been tested according to this annex, a single marking by the symbol  may be used provided it is so placed that it unmistakably covers all voltage ratings.

Annex J
(normative)

Electromagnetic compatibility (EMC) – Requirements and test methods for circuit-breakers

J.1 General

Two sets of environmental conditions are considered and are referred to as follows:

– environment A;

– environment B.

Environment A: relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources.

NOTE 1 Environment A corresponds to equipment class A in CISPR 11 and CISPR 22.

NOTE 2 Environment A equipment can cause electromagnetic interferences when installed in environment B.

Environment B: relates to low-voltage public networks such as domestic, commercial and light industrial locations/installations. Highly disturbing sources such as arc welders are not covered by this environment.

NOTE 3 Environment B corresponds to equipment class B in CISPR 11 and CISPR 22.

NOTE 4 Environment B equipment will not cause electromagnetic interferences when installed in environment A.

For the purposes of this annex the term "EUT" means “equipment under test”.

NOTE 5 The EMC requirements for CBI (Annex L) and ICB (Annex O) are deemed to be covered by the relevant tests on the equivalent circuit-breaker (see L.2.1 and O.2.1).

The tests of J.2 and J.3 are applicable to devices incorporating electronic circuits except where specified otherwise in this standard.

The test methods in J.2 and J.3 are supplemented by specific procedures in the relevant parts of this standard to verify the performance based on the acceptance criteria.

Supplementary requirements and test details are given in the relevant parts of this standard, i.e., Annex B for circuit-breakers incorporating residual current protection (CBR), Annex F for circuit-breakers with electronic overcurrent protection, Annex M for modular residual current devices (MRCD) and Annex N for circuit-breaker auxiliaries.

A new device may be used for each test or one device may be used for several tests, at the manufacturer’s discretion. Devices rated 50 Hz/60 Hz shall be tested at either one of the rated frequencies.

In the case of a range of devices with identical electronic controls (including dimensions, components, printed circuit board assemblies and enclosure, if any) and the same design of current sensors, it is sufficient to test only one device in the range.

The tests shall be performed with a specific mounting; free air or within an enclosure, as specified in J.2 and J.3.

J.2 Immunity

J.2.1 General

Subclause 7.3.2.2 of IEC 60947-1:2007/AMD1:2010 applies with the following additions.

Immunity tests shall be performed according to Table J.1.

The reference data for the additional test specifications is given in Table J.2.

For the purposes of this clause (J.2), the term "power port" covers the main circuit, auxiliary power supply port(s) and any auxiliary connected to the main circuit.

For the immunity tests, the following performance criteria shall be defined:

Performance criterion A: during the test, the resistance against unwanted operation (step 1) and the functional characteristics (step 2) are verified. Any monitoring function shall correctly indicate the status.

Performance criterion B: during the test, the resistance against unwanted operation is verified. Monitoring functions may indicate a false status. After the test the functional characteristics are verified.

Details of the verification of performance are given in the respective annex (Annex B, Annex F, Annex M or Annex N).

For all immunity tests, the EUT shall be tested as floor-standing equipment (see IEC 61000-4 series).

Table J.1 – EMC – Immunity tests

Description	Reference standard	Test level [a]	Performance criterion	Mounting
Electrostatic discharges	IEC 61000-4-2	8 kV contact 8 kV air	B	Enclosure Figure J.1
Radiated radio-frequency electromagnetic fields	IEC 61000-4-3	10 V/m (up to 2 GHz) 3 V/m (from 2 GHz to 2,7 GHz)	A	Free air [c]
Electrical fast transients/bursts	IEC 61000-4-4	Power port: $U_e \geq 100$ V, a.c. or d.c.: 4 kV $U_e < 100$ V, a.c. or d.c.: 2 kV [f] Signal port: 2 kV [g]	B	Enclosure Figure J.1
Surges	IEC 61000-4-5	Power port, $U_e \geq 100$ V a.c.: 4 kV line-to-earth 2 kV line-to-line (Annex F and Annex N) 4 kV line-to-line (Annex B and Annex M) [e] Power port, $U_e < 100$ V a.c.: 2 kV line-to-earth 1 kV line-to-line Power port, d.c. [f]: 0,5 kV line-to-earth 0,5 kV line-to-line Signal port [h]: 2 kV line-to-earth 1 kV line-to-line	B	Enclosure Figure J.1
Conducted disturbances induced by radio-frequency fields	IEC 61000-4-6	Power port: 10 V Signal port: 10 V [g]	A	Free air [c]
Power frequency magnetic fields	Not applicable	Not applicable	Not applicable	Not applicable
Voltage dips and interruptions	IEC 61000-4-11 [d]	[d]	[d]	Free air
Harmonics	IEC 61000-4-13 [b]	[b]	[b]	Free air
Current dips	[b]	[b]	[b]	Free air

[a] The immunity levels specified are generally higher than the requirements of IEC 60947-1 in order to provide greater security for the circuit protection functions of the device.

[b] A specific test procedure is defined in the case of electronic overcurrent devices in Annex F, in the absence of an appropriate basic standard.

[c] Unless the circuit-breaker is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report. The enclosure shall be connected to the ground plane in accordance with the manufacturer's instructions.

[d] A specific test procedure and a performance criterion are defined in Annex B in the case of CBRs functionally dependent on line voltage and in Annex M in the case of MRCDs functionally dependent on a voltage source, in the absence of an appropriate basic standard. These tests are not applicable to circuit-breakers with electronic overcurrent protection as described in Annex F (see F.1), but are replaced by tests for current dips and interruptions (see F.4.7).

[e] The immunity level is higher for residual current devices because they perform safety functions.

[f] Not applicable to input ports intended for connection to a battery or a rechargeable battery which shall be removed or disconnected from the apparatus for recharging. Apparatus with a d.c. power input port intended for use with an a.c.-d.c. power adapter shall be tested on the a.c. power input of the a.c.-d.c. power adapter specified by the manufacturer or, where none is so specified, using a typical a.c.-d.c. power adapter. The test is not applicable to d.c. power input ports intended to be permanently connected to cables less than 3 m in length.

[g] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.

[h] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 10 m. When shielded cables are used, this test is applied only to the shield.

The appropriate test set-up and circuit diagram for each immunity test are as shown in Table J.2.

Table J.2 – Reference data for immunity test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Electrostatic discharges	CBR	J.2.2, B.8.12.1.2	Figure J.1, Figure J.3	Figure B.1
	CB	J.2.2, F.4.2	Figure J.3, Figure F.16	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.2, M.8.16.1.2	Figure J.1, Figure J.3	Figure M.3
	Other devices [a]	J.2.2, N.2.2	[b]	[b]
Radiated radio-frequency electromagnetic fields	CBR	J.2.3, B.8.12.1.3	Figure J.4	Figure B.1
	CB	J.2.3, F.4.3	Figure F.16, Figure F.17	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.3, M.8.16.1.3	Figure J.4, Figure M.20	Figure M.3
	Other devices [a]	J.2.3, N.2.3	[b]	[b]
Electrical fast transients/bursts	CBR	J.2.4, B.8.12.1.4	Figure J.5, Figure J.6	Figure B.1
	CB	J.2.4, F.4.4	Figure F.16, Figure F.18, Figure F.19	Figure F.6, Figure F.7 or Figure F.8
	MRCD	J.2.4, M.8.16.1.4	Figure J.5, Figure J.6, Figure M.21	Figure M.3
	Other devices [a]	J.2.4, N.2.4	[b]	[b]
Surges	CBR	J.2.5, B.8.12.1.5	[b]	Figure B.1
	CB	J.2.5, F.4.5	Line-to-earth: Figure F.16 Line-to-line: Figure F.16	Line-to-earth: Figure F.9, Figure F.10 or Figure F.11 Line-to-line: Figure F.12, Figure F.13 or Figure F.14
	MRCD	J.2.5, M.8.16.1.5	[b]	Figure M.3
	Other devices [a]	J.2.5, N.2.5	[b]	[b]
Conducted disturbances induced by radio-frequency fields	CBR	J.2.6, B.8.12.1.6	[b]	Figure B.1
	CB	J.2.6, F.4.6	Figure F.16, Figure F.20, Figure F.21, Figure F.22, Figure F.23	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.6, M.8.16.1.6	Figure M.22	Figure M.3
	Other devices [a]	J.2.6, N.2.6	[b]	[b]

[a] Devices in the scope of Annex N.

[b] No additional figure necessary.

J.2.2 Electrostatic discharges

The EUT shall be tested in a specific enclosure (see Table J.1). The test set-up and additional test requirements are given in Table J.2. Direct and indirect discharges shall be applied in accordance with IEC 61000-4-2.

The direct discharge tests shall be performed only on parts of the EUT normally accessible to the user, such as setting means, keyboards, displays, pushbuttons etc. The application points shall be stated in the test report.

Direct discharges are made 10 times for each polarity, at intervals of ≥ 1 s.

Indirect discharges shall be applied at selected points on the surface of the enclosure; the test at such points is made 10 times, for each polarity, at intervals of ≥ 1 s.

J.2.3 Radiated ~~radio-frequency~~ RF electromagnetic fields

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The EUT shall be tested on the front face only.

To enable repeatability, the actual test set-up shall be detailed in the test report.

Tests shall be performed with both horizontal and vertical antenna polarization.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the ranges of 80 MHz to 1 000 MHz, 1 400 MHz to 2 000 MHz, and 2 110 MHz to 2 700 MHz, in accordance with Clause 8 of IEC 61000-4-3:2006. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 80 MHz; 100 MHz; 120 MHz; 180 MHz; 240 MHz; 320 MHz; 480 MHz; 640 MHz; 960 MHz; 1 400 MHz; 1 920 MHz; 2 150 MHz and 2 450 MHz, the operation being verified after the field at each frequency has stabilized.

J.2.4 Electrical fast transients/bursts (EFT/B)

The test shall be performed with the EUT in a specific enclosure (see Table J.1).

The test set-up is given in Table J.2.

For power and auxiliary supply ports, the coupling-decoupling network shall be used, except for Annex F where the direct injection method shall be used (see Figure F.18).

For signal ports the coupling-decoupling network or the clamp injection method shall be used, as applicable.

The disturbance shall be applied for 1 min, except where otherwise specified.

J.2.5 Surges

The test shall be carried out with the EUT in a specific enclosure (see Table J.1). The test levels and test set-up are given in Table J.1 and Table J.2, depending upon the EUT.

Pulses with both positive and negative polarity shall be applied, the phase angles being 0° and 90°.

A series of five pulses is applied for each polarity and each phase angle (total number of pulses: 20), the interval between two pulses being approximately 1 min. A shorter interval may be used by agreement with the manufacturer.

J.2.6 Conducted disturbances induced by ~~radio-frequency~~ RF fields (common mode)

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The disturbances shall be injected, on power lines, by means of a coupling-decoupling network M1, M2 or M3 as applicable.

On signal lines, the disturbances shall be injected by means of a coupling-decoupling network. If not feasible, an E.M. clamp may be used.

The particular test set-up shall be detailed in the test report.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the range of 150 kHz to 80 MHz in accordance with Clause 8 of IEC 61000-4-6:2013. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 0,150 MHZ; 0,300 MHZ; 0,450 MHZ; 0,600 MHZ; 0,900 MHZ; 1,20 MHZ; 1,80 MHZ; 2,40 MHZ; 3,60 MHZ; 4,80 MHZ; 7,20 MHZ; 9,60 MHZ; 12,0 MHZ; 19,2 MHZ; 27,0 MHZ; 49,4 MHZ; 72,0 MHZ and 80,0 MHz, the operation being verified after the level of the disturbing voltage at each frequency has stabilized.

J.3 Emission

J.3.1 General

Subclause 7.3.3.2 of IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Emission tests are performed according to Table J.3.

The reference data for the application of the figures for emission tests is given in Table J.4.

Table J.3 – EMC – Emission tests

Description	Reference standard	Limits	Mounting
Harmonics	IEC 61000-3-2	[c]	[c]
Voltage fluctuations	IEC 61000-3-3	[c]	[c]
Conducted RF disturbances 150 kHz to 30 MHz[e]	CISPR 11 / CISPR 22	Class A or class B, group 1[b, e]	Free air[d]
Radiated RF disturbances 30 MHz to 1 000 MHz[a]	CISPR 11 / CISPR 22	Class A or class B, group 1[b]	Free air[d]

[a] Applicable only for EUT containing processing devices (e.g. microprocessors) or switched-mode power supplies operating at frequencies greater than 9 kHz.

[b] Equipment class A in CISPR 11 and CISPR 22 corresponds to environment A in IEC 60947-1. Environment A equipment can cause electromagnetic interferences when installed in environment B. The manufacturer of environment A equipment shall declare the risk of electromagnetic interference in the product documentation.

Equipment class B in CISPR 11 and CISPR 22 corresponds to environment B in IEC 60947-1. Environment B equipment will not cause electromagnetic interference when installed in environment A.

[c] No test required since the electronic control circuits operate at very low power and hence create negligible disturbances.

[d] Unless the EUT is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report.

[e] Circuit-breakers covered by Annex F are independent of line voltage or of any auxiliary supply. The electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

Table J.4 – Reference data for emission test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Conducted RF disturbances	CBR	J.3.2, B.8.12.2.1	[a]	[a]
	CB	J.3.2, F.5.3	No test	No test
	MRCD	J.3.2, B.8.12.2.1	[a]	[a]
	Other devices	J.3.2, N.3.2	[a]	[a]
Radiated RF disturbances	CBR	J.3.3, B.8.12.2.1	Figure J.2	[a]
	CB	J.3.3, F.5.4	Figure J.2	Figure F.2, Figure F.3 Figure F.4
	MRCD	J.3.3, B.8.12.2.1	Figure J.2	[a]
	Other devices	J.3.3, N.3.3	[a]	[a]

[a] No additional figure necessary.

J.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

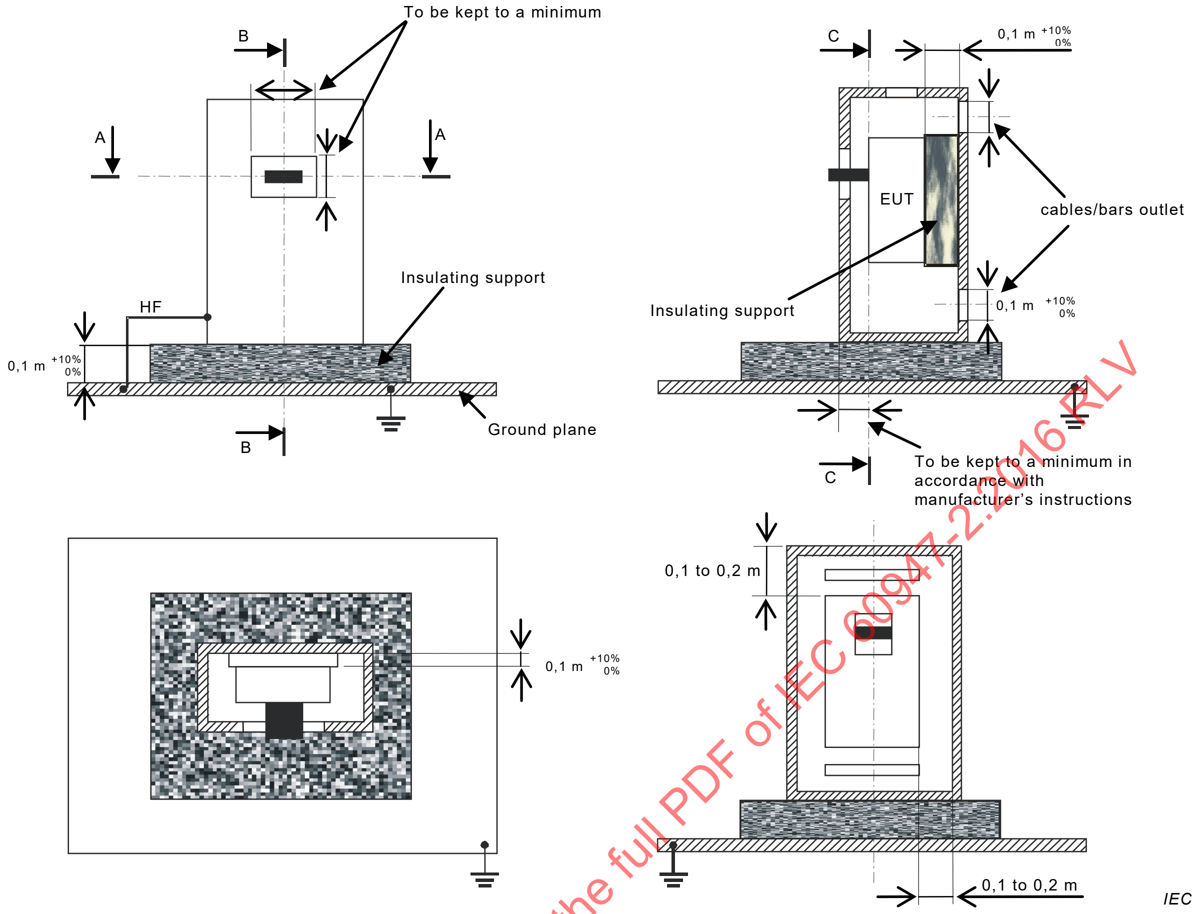
~~Descriptions of~~ The test method and test arrangement ~~are given~~ shall be as in CISPR 11 or CISPR 22, as relevant.

The particular test set-up, including the type of cable, shall be detailed in the test report.

J.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

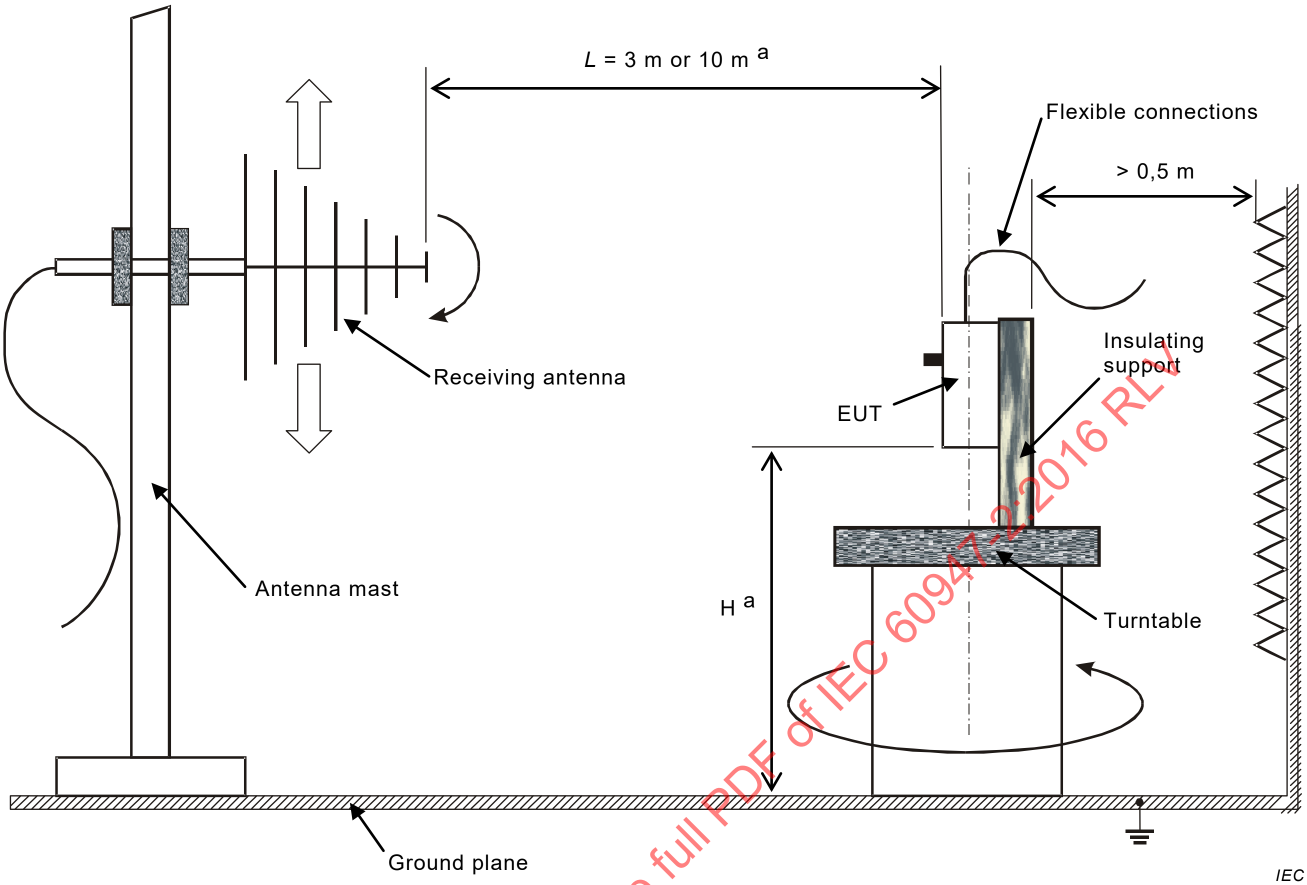
The test set-up is shown in Figure J.2.

The particular test set-up including supply bars, transformer, etc. shall be detailed in the test report.



NOTE In the case of a withdrawable circuit-breaker, the EUT includes the draw-out cradle.

Figure J.1 – EUT mounted in a metallic enclosure



[a] See CISPR 11/CISPR 22.

Figure J.2 – Test set up for the measurement of radiated RF emissions

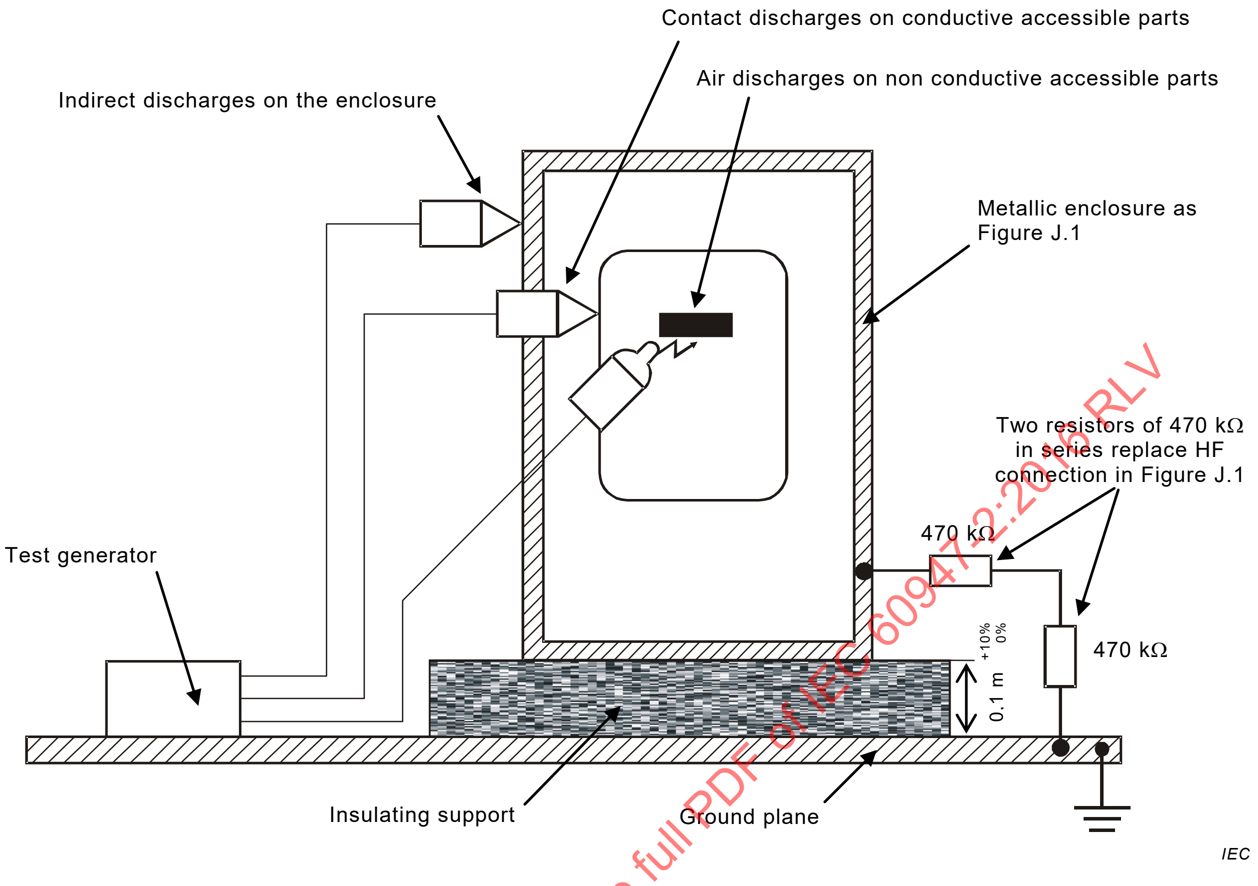
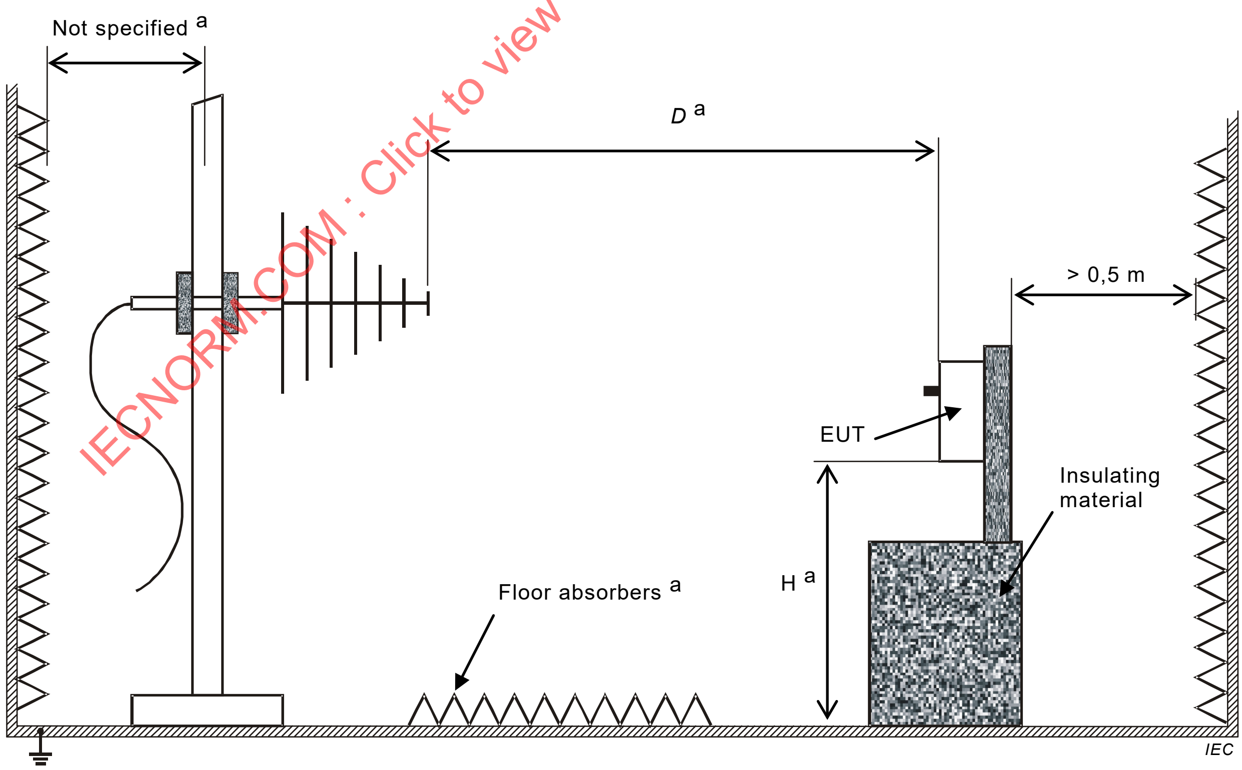
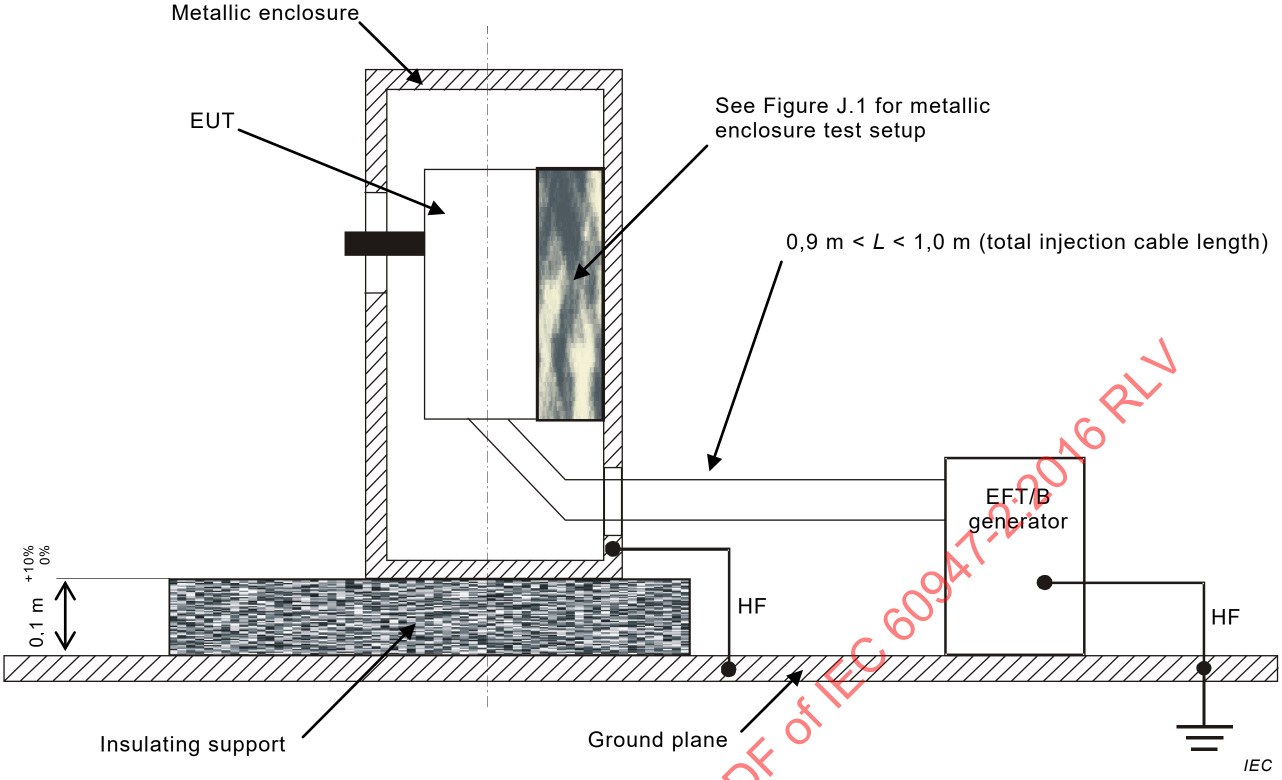


Figure J.3 – Test set up for the verification of immunity to electrostatic discharges



[a] See IEC 61000-4-3.

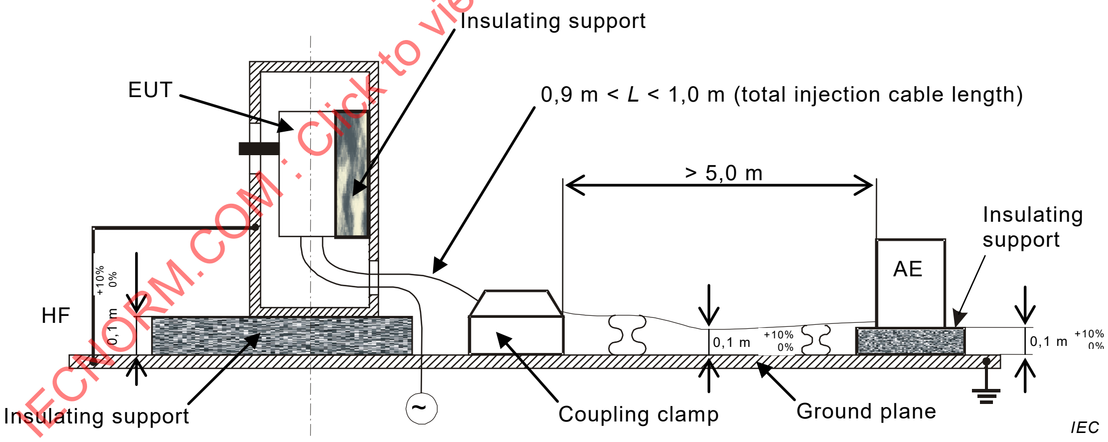
Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic fields



Key

HF high frequency connection

Figure J.5 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines



Key

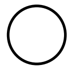
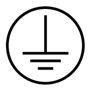
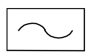
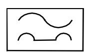
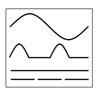
AE auxiliary equipment

HF high frequency connection

Figure J.6 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

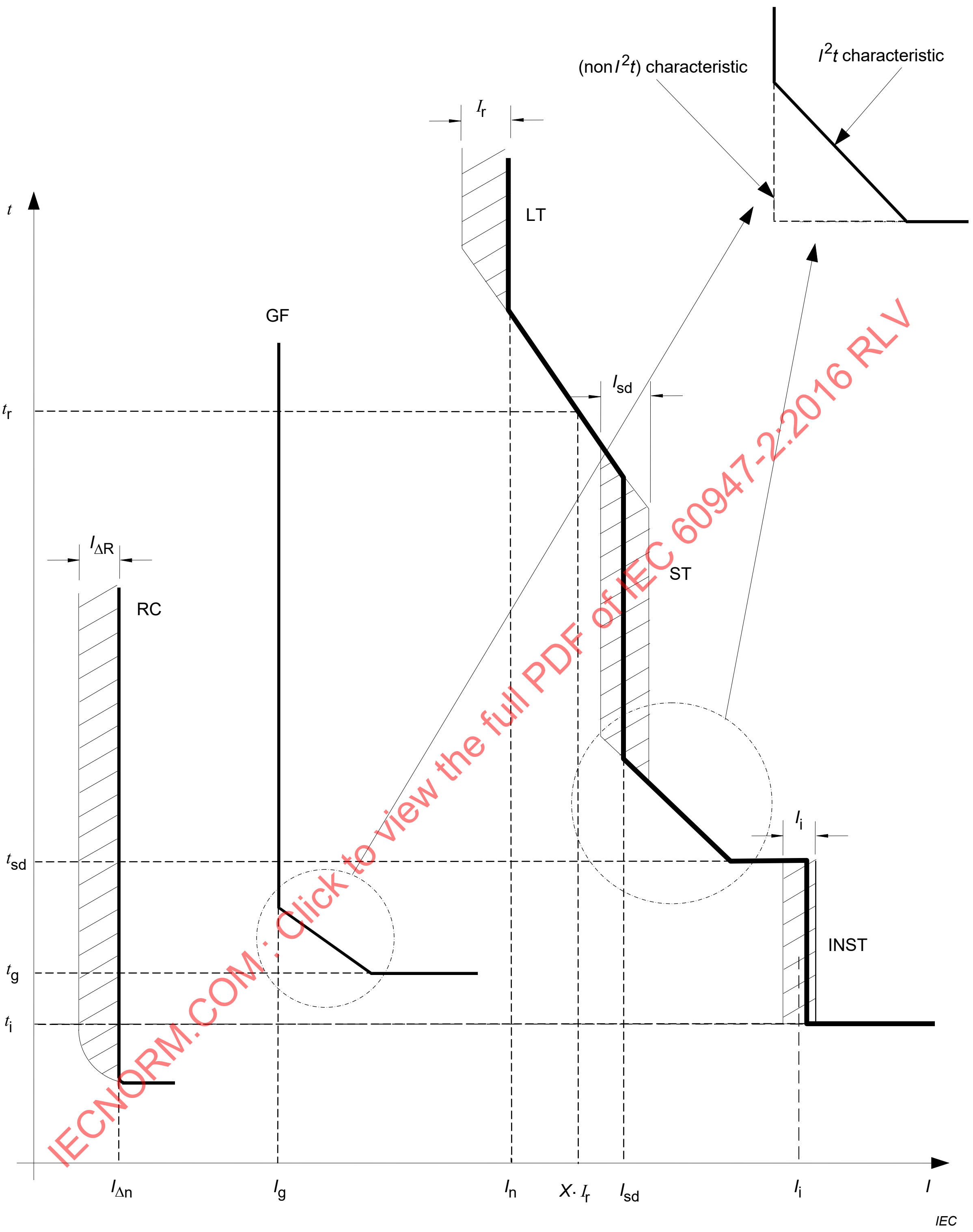
Annex K
(informative)

Glossary of symbols ~~related to products covered by this standard~~ and graphical representation of characteristics

Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Subclause of this standard
Circuit-breaker, closed position		IEC 60417-5007 (2002-10)	5.2
Circuit-breaker, open position		IEC 60417-5008 (2002-10)	5.2
Isolation suitability – circuit-breaker and ICB		IEC 60617-S00287 combined with IEC 60617- S00220 (2007-01)	5.2 O.4
Isolation suitability – CBI		IEC 60617-S00288 (2007-01)	L.5
Neutral pole terminal	N		5.2
Protective earth terminal		IEC 60417-5019 (2006-08)	5.2
Rated control circuit voltage	U_c		4.7.2
Rated voltage of the voltage source of an MRCD	U_s		M.4.1.2.1
Rated voltage of the monitored circuit for an MRCD	U_n		Annex M
Rated current	I_n		4.3.3.3
Rated impulse withstand voltage	U_{imp}		4.3.3.2
Rated insulation voltage	U_i		4.3.2.2
Rated operational voltage	U_e		4.3.2.1
Rated service short-circuit breaking capacity	I_{cs}		4.3.6.2.3
Rated short-circuit making capacity	I_{cm}		4.3.6.1
Rated short time withstand current	I_{cw}		4.3.6.4
Rated residual short time withstand current of an MRCD	$I_{\Delta w}$		M.4.3.5
Rated conditional short-circuit current	I_{cc}		Annex L Annex M
Rated conditional residual short-circuit current of an MRCD	$I_{\Delta c}$		M.4.3.2
Rated ultimate short-circuit breaking capacity	I_{cu}		4.3.6.2.2
Selectivity limit current	I_s		2.17.4
Take-over current	I_B		2.17.5
Conventional enclosed thermal current	I_{the}		4.3.3.2
Conventional free air thermal current	I_{th}		4.3.3.1
CBRs and MRCDs of type AC		IEC 60417-6148 (2012-01)	B.4.4.1 M.4.2.2.1
CBRs and MRCDs of type A		IEC 60417-6149 (2012-01)	B.4.4.2 M.4.2.2.2
MRCDs of type B			M.4.2.2.3

Characteristics list	**Symbol**	**IEC 60417 or IEC 60617 reference**	**Subclause of this standard**
Test device CBR or MRCD	T		B.7.2.6 M.7.2.6
Current setting of adjustable overload release	I_r		4.7.3
Corresponding tripping time	t_r		Figure K.1
Ground fault current setting	I_g		Figure K.1
Corresponding tripping time	t_g		Figure K.1
Individual pole short-circuit breaking capacity (phase/earthed systems)	I_{su}		Annex C
Individual pole short-circuit test current (IT systems)	I_{IT}		Annex H
Rated instantaneous short-circuit current setting	I_i		2.20 Figure K.1 ~~Figure K.1~~ Annex L Annex O
Maximum corresponding tripping time	t_i		Figure K.1
Not suitable for use in IT systems			Annex H
Rated residual short-circuit making and breaking capacity	$I_{\Delta m}$		Annex B Annex M
Rated residual non-operating current	$I_{\Delta no}$		Annex B Annex M
Rated residual operating current	$I_{\Delta n}$		Annex B Annex M
Residual operating current	$I_{\Delta R}$		Figure K.1
Short time pick-up current	I_{sd}		Figure K.1
Corresponding tripping time	t_{sd}		Figure K.1
Suitability for phase earthed systems	C		4.3.2.1
Limiting non-actuating time at 2 $I_{\Delta n}$	Δt		Annex B
Time delay CBR or MRCD with limiting non-actuating time of 0,06 s			B.5 a) M.3.4
CBRs for use with 3-phase supply only			B.8.9.3
Rated automatic re-closing operating residual current	$I_{\Delta ar}$		R.2.2

~~*These terms are not used in this standard. For their identification, see Figure K.1.~~



RC residual current

GF ground fault

LT long time

ST short time

INST instantaneous

Figure K.1 – Relationship between symbols and tripping characteristics

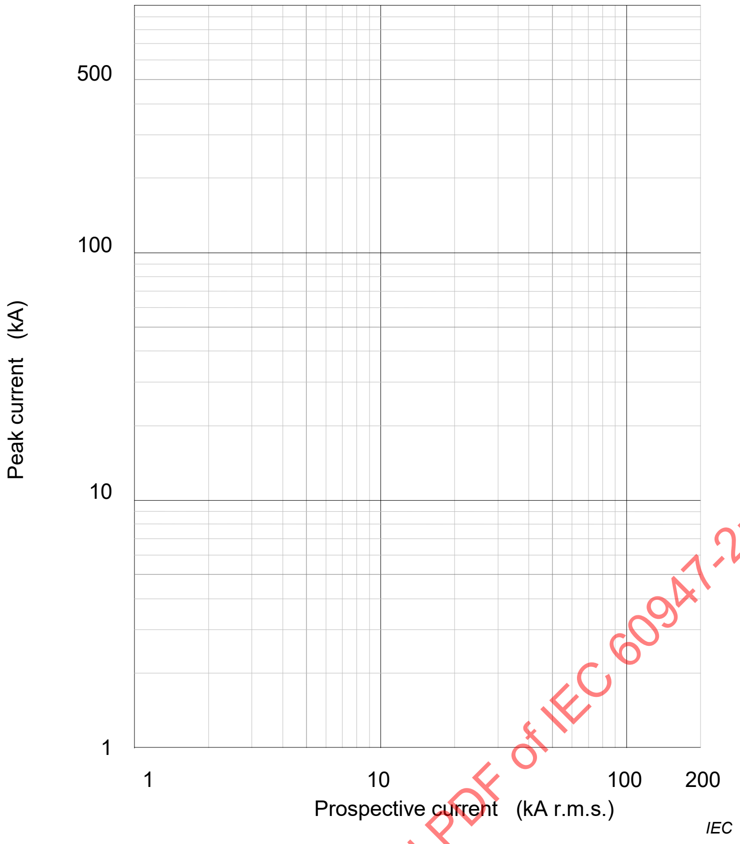


Figure K.2 – Template for characteristics of cut-off current versus prospective current from 1 kA to 200 kA

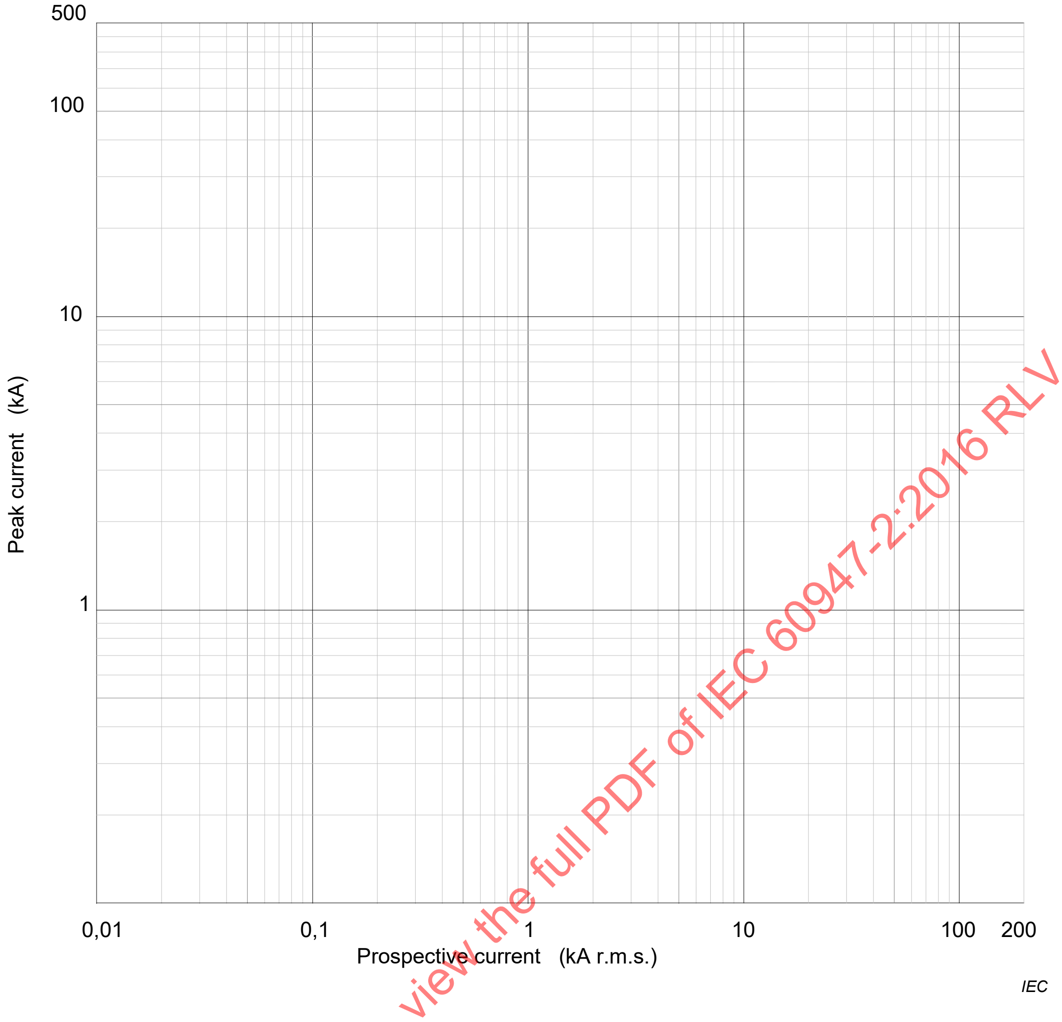


Figure K.3 – Template for characteristics of cut-off current versus prospective current from 0,01 kA to 200 kA

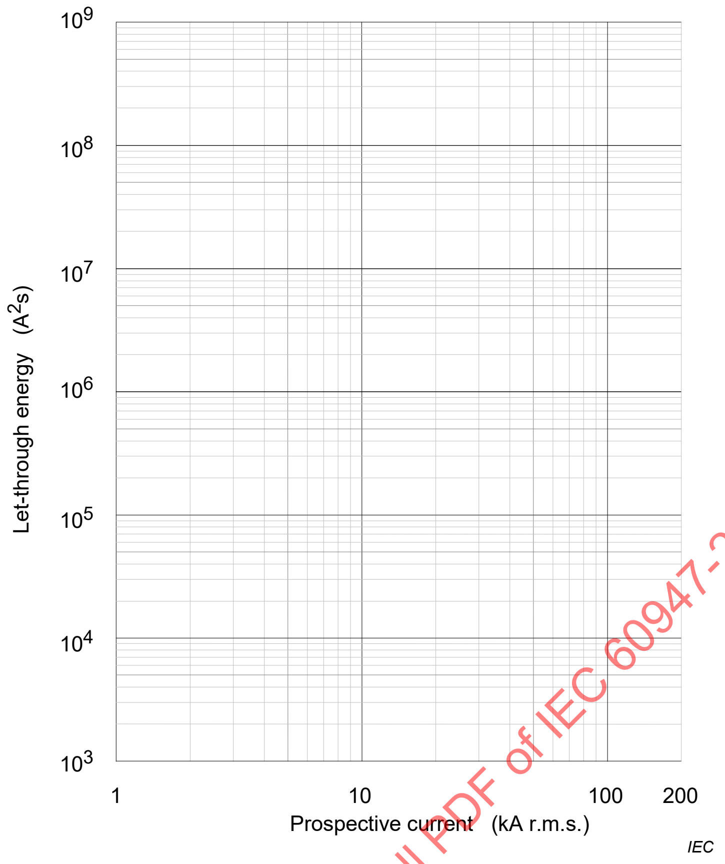


Figure K.4 – Template for characteristics of let-through energy versus prospective current from 1 kA to 200 kA

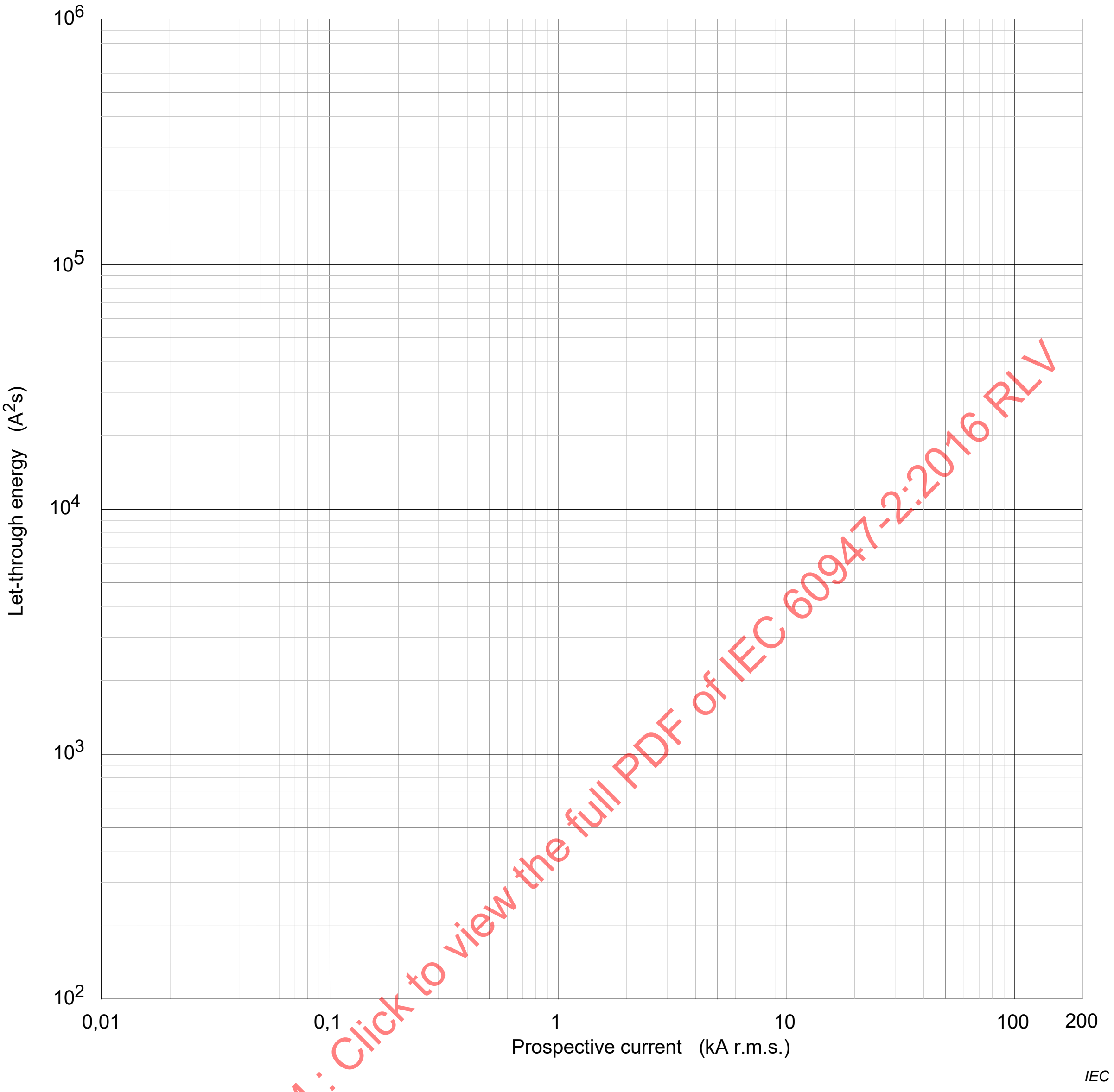
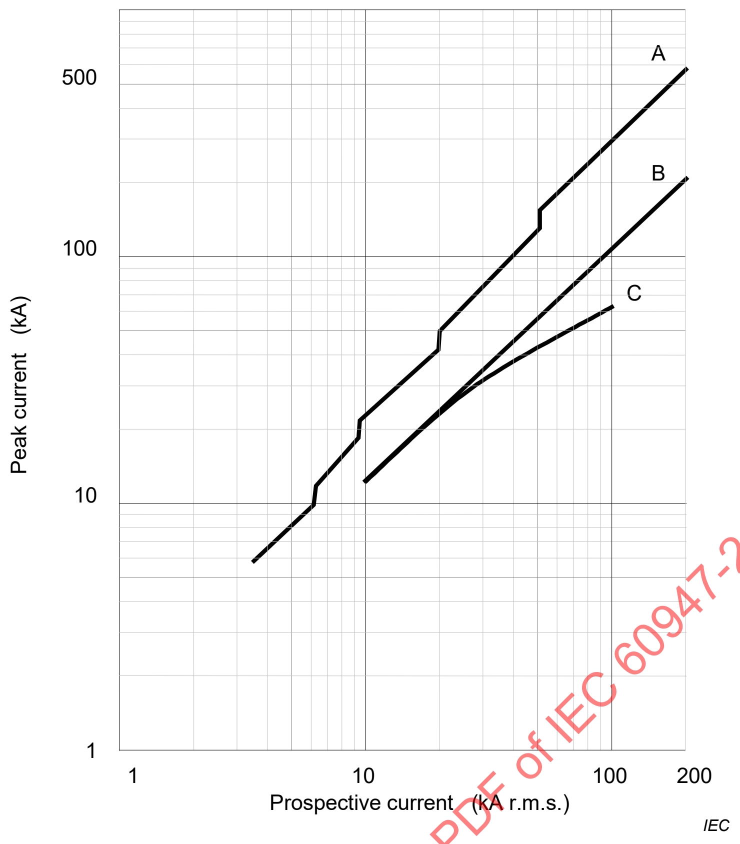


Figure K.5 – Template for characteristics of let-through energy versus prospective current from 0,01 kA to 200 kA



A Prospective asymmetric peak current under the test conditions of this standard

B Prospective symmetrical peak current

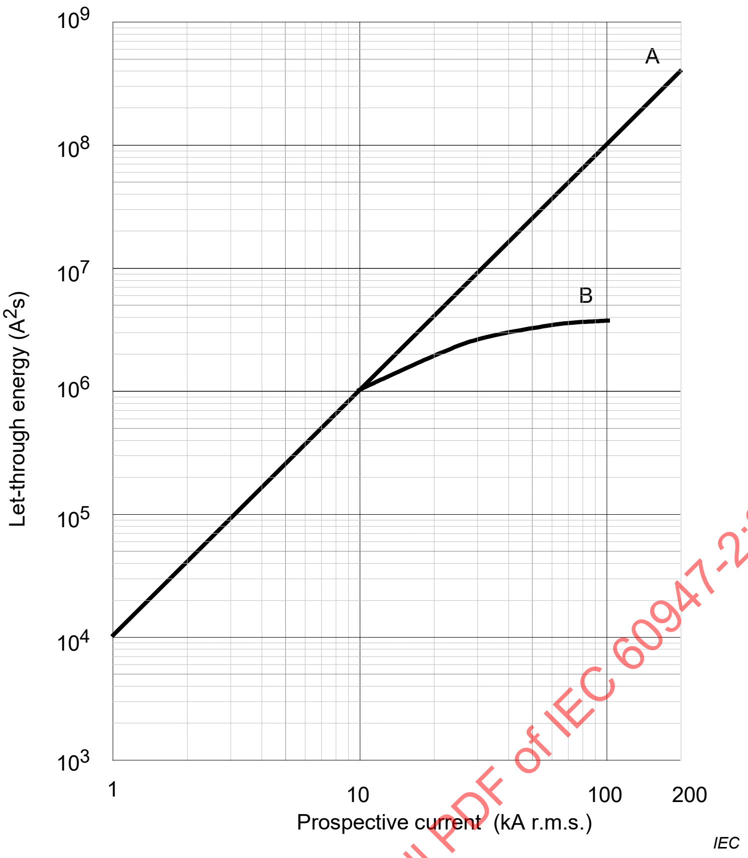
C Typical cut-off current characteristic

The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of cut-off current the effect of current limiting is shown by comparison with the current that would be let through (prospective current) if the circuit-breaker were not present. The comparison is made with the asymmetric (inrush) peak current or the symmetrical peak current (see 2.3).

The typical curve does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.6 – Example of the use of template to Figure K.2



A Let-through energy of one half cycle of prospective current at 50 Hz

B Typical let-through energy characteristic of a 250 A MCCB at 400 V 50 Hz

The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of let-through energy the effect of current limiting is shown by comparison with the energy that would be let through in one half-cycle of the symmetrical prospective current if the circuit-breaker were not present (see 2.3).

The typical curve for the 250 A MCCB does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.7 – Example of the use of template to Figure K.4

Annex L
(normative)

Circuit-breakers not fulfilling the requirements for overcurrent protection

L.1 ~~Scope~~ General

This annex covers circuit-breakers which do not fulfil the requirements for overcurrent protection specified in the main part of this standard, hereinafter referred as CBIs. They are capable of being tripped by an auxiliary device, e.g. shunt or undervoltage release. They do not provide circuit protection[2)] but may trip under short-circuit conditions for self-protection. They have a conditional short-circuit rating and may be used for isolation. They may incorporate accessories such as auxiliary and alarm switches for control purposes, and/or remote operators.

A CBI forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (L.2.1) by omitting the overcurrent releases (class Y) or the overload releases only (class X), see L.3.

L.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

L.2.1
equivalent circuit-breaker
circuit-breaker from which the CBI has been derived, which has been tested according to this standard and which has the same frame size as the CBI

L.2.2
overcurrent protective device
OCPD
device intended to protect a CBI against overcurrents by interrupting them, and incorporating overload protection no less effective than that of the equivalent circuit-breaker and an I_{cu} (for a circuit-breaker) or a breaking capacity (for a fuse) equal to or higher than that of the equivalent circuit-breaker

Note 1 to entry: The OCPD may be the equivalent circuit-breaker.

L.3 Classification

CBIs are classified as follows:

- class X: with integral non-adjustable instantaneous short-circuit releases for self-protection;
- class Y: without integral short-circuit releases.

L.4 Rated values

L.4.1 Rated current (I_n)

The rated current of a CBI shall not exceed the rated current of the equivalent circuit-breaker.

~~[2)] This applies in particular to overload protection.~~

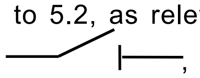
NOTE The rated current of a CBI ~~may~~ can be correlated to the rated current corresponding to utilization category AC-22 (see Annex A of IEC 60947-1:2007/AMD2:2014).

L.4.2 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

A CBI may have a value of I_{cc} equal to or higher than that of the I_{cu} of the equivalent circuit-breaker.

L.5 Product information

A CBI shall be marked according to 5.2, as relevant, except that the symbol of suitability for isolation, if applicable, shall be , replacing the symbol shown in the second dashed item of 5.2 a).

In addition it shall be marked as follows:

– for 5.2, item a): with the symbol according to the classification:

CBI-X I_i = …	or	CBI-Y	as applicable.

where I_i is the rated instantaneous short-circuit current setting (see 2.20).

– for 5.2, item c): with the following items:
  - rated conditional short-circuit-current (I_{cc});
  - the OCPD, if specified.

Manufacturer's instructions should draw attention to the fact that CBIs do not provide overcurrent protection.

L.6 Constructional and performance requirements

A CBI, being derived from the equivalent circuit-breaker (see L.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4.

NOTE A CBI ~~may~~ can additionally comply with IEC 60947-3 and be marked accordingly.

L.7 Tests

L.7.1 General

L.7.1.1 CBI of class X

The OCPD is specified.

Case 1:

I_{cc} = I_{cu} of the equivalent circuit-breaker.

No additional tests are required.

NOTE The specified OCPD ~~may~~ can be

– the equivalent circuit-breaker (see L.2.1);

– another circuit-breaker (see L.2.2);

– a fuse of conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and of a breaking capacity ≥ I_{cc} of the CBI.

Case 2:

$I_{cc} > I_{cu}$ of the equivalent circuit-breaker.

Tests shall be made according to L.7.2.1 and L.7.2.2, with the specified OCPD.

This applies when

– the specified OCPD is a circuit-breaker of the same frame size as the equivalent circuit-breaker and of $I_{cu} \geq I_{cc}$ of the CBI,

or

– the specified OCPD is a fuse having a conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and a breaking capacity ≥ I_{cc} of the CBI.

L.7.1.2 CBI of class Y

No tests are required, provided that one of the following two conditions are fulfilled:

– condition 1: $I_{cc} \leq I_{cw}$ of the equivalent circuit-breaker;
– condition 2: $I_{cc} \leq$ maximum setting of the rated instantaneous short-circuit current setting of the equivalent circuit-breaker.

If neither of the above conditions are fulfilled, tests are required as follows:

Case 1:

The OCPD is specified by the manufacturer.

Tests shall be made according to L.7.2.1 and L.7.2.2.

Case 2:

The OCPD is not specified.

Tests shall be made according to L.7.2.1 and L.7.2.3.

L.7.2 Rated conditional short-circuit tests

L.7.2.1 General

L.7.2.1.1 Applicability

These tests shall be made when required by L.7.1.1 case 2, or by L.7.1.2 case 1 or case 2, as applicable.

For CBIs having variants with different number of poles, tests shall be carried out on each variant.

L.7.2.1.2 Test conditions

Subclause 8.3.2.6 applies.

The test circuit shall be according to Figure A.4, SCPD being replaced by OCPD. If the OCPD is a circuit-breaker with adjustable overcurrent settings, these shall be set at maximum.

If the OCPD consists of a set of fuses, each test shall be made with a set of new fuses.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the OCPD is a circuit-breaker, the full length of cable (0,75 m) associated with the circuit-breaker may be on the supply side (see Figure A.4).

L.7.2.1.3 Behaviour during tests

Subclause 8.3.2.6.5 applies.

L.7.2.2 OCPD specified

~~Tests shall be made in accordance with L.7.2.2.1, L.7.2.2.2 and L.7.2.2.3.~~

L.7.2.2.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.2.2
Verification of dielectric withstand	L.7.2.2.3

L.7.2.2.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – *t* – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

After each operation, the CBI shall be manually closed and opened three times.

L.7.2.2.3 Verification of dielectric withstand

Following the test of L.7.2.2.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

L.7.2.3 OCPD not specified

~~Tests shall be made in accordance with L.7.2.3.1, L.7.2.3.2 and L.7.2.3.3.~~

L.7.2.3.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.3.2
Verification of dielectric withstand	L.7.2.3.3

L.7.2.3.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – *t* – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

During the test, the current shall be maintained for three cycles and then disconnected at the power supply.

After each operation, the CBI shall be manually closed and opened three times.

L.7.2.3.3 Verification of dielectric withstand

Following the test of L.7.2.3.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

Annex M
(normative)

Modular residual current devices (without integral current breaking device)

~~INTRODUCTION~~

M.1 ~~Scope and object~~ General

M.1.1 Field of application

The provisions of Annex B apply to this Annex M, adapting, amending or supplementing Annex B as necessary to cover its applicability to equipment where the current sensing means and/or the processing device are mounted separately from the current breaking device.

Throughout this annex, "CBR" as used in Annex B (see B.2.3.1), is replaced by "MRCD" (see M.2.2.1).

Wherever relevant, reference is made to the corresponding subclause of Annex B. In other cases, reference is made to the relevant subclause of the main body of this standard, or, where applicable, of IEC 60947-1.

This annex contains also additional definitions and characteristics not contained in Annex B, e.g. "type B" MRCDs (in the context of d.c. residual current), with consequent requirements and tests.

Since the equipment covered by this annex does not include a current breaking device, certain conventional phrases used in Annex B have been adapted accordingly in this annex, e.g. "ON position" is replaced by "ready condition", meaning "ready to operate".

M.1.2 Field of application

This annex applies to residual current operated devices which do not incorporate a current breaking device, hereinafter called "Modular Residual Current Device (MRCD)". They are primarily intended to be used in conjunction with circuit-breakers in accordance with this standard.

NOTE They ~~may~~ can also be declared suitable for use in conjunction with other current breaking devices.

They may or may not be functionally dependent on a voltage source.

The object of this annex is to state the specific requirements which shall be complied with by the MRCD.

M.2 Terms and definitions

The terms and definitions of Annex B apply.

The following additional terms and definitions apply to this annex.

M.2.1 Terms and definitions relating to the energization of an MRCD

M.2.1.1
voltage source
source intended to supply the energizing quantity; it may consist of:

– the line voltage
– a voltage other than the line voltage

M.2.2 Terms and definitions relating to the operation and the functions of an MRCD

M.2.2.1
Modular Residual Current Device
MRCD
device or an association of devices comprising a current sensing means and a processing device designed to detect and to evaluate the residual current and to control the opening of the contacts of a current breaking device

M.2.2.2 Operating time

M.2.2.2.1
operating time of an MRCD
time which elapses between the instant when the residual operating current is suddenly applied and the instant when the MRCD output changes status

M.2.2.2.2
total operating time of an MRCD and associated current breaking device (combination time)
time which elapses between the instant when the residual operating current is suddenly applied and the instant of the arc extinction of the associated current breaking device

M.2.2.2.3
limiting non-operating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the MRCD without bringing it actually to operate

M.2.3
conditional residual short-circuit current
~~definition 2.5.29 of IEC 60947-1 applies except that the prospective current is a residual current~~
prospective residual current that a CBR, protected by a specified short-circuit protective device, can satisfactorily withstand for the total operating time of that device under specified conditions

M.2.4
residual short-time withstand current
~~definition 2.5.27 of IEC 60947-1 applies except that the short -time withstand current is a residual current~~
residual current that a CBR in the closed position can carry during a specified short time under specified conditions

M.3 Classification

M.3.1 Classification according to the configuration of the primary conductors

M.3.1.1 Terminal type: MRCD with incoming and outgoing terminals and integral primary conductors

M.3.1.2 Through-conductor type

M.3.1.2.1 MRCD with sensing means and processing device combined.

M.3.1.2.2 MRCD with sensing means and processing device separate.

M.3.2 Classification according to the method of operation

M.3.2.1 MRCD without voltage source (see M.2.1.1)

M.3.2.2 MRCD with voltage source

M.3.2.2.1 Operating automatically in case of failure of the voltage source.

M.3.2.2.2 Not operating automatically after failure of the voltage source but able to operate as intended in case of a residual current fault.

M.3.3 Classification according to the possibility of adjusting the residual operating current

Subclause B.3.2 applies.

M.3.4 Classification according to time-delay of the residual current function

Subclause B.3.3 applies.

M.3.5 Classification according to behaviour in presence of a d.c. component

M.3.5.1 MRCD of type AC (see M.4.2.2.1)

M.3.5.2 MRCD of type A (see M.4.2.2.2)

M.3.5.3 MRCD of type B (see M.4.2.2.3)

M.4 Characteristics of MRCDs

M.4.1 General characteristics

M.4.1.1 Characteristics of the monitored circuit

M.4.1.1.1 Rated frequency range

Range of frequency values of the monitored circuit for which the MRCD is designed and for which it operates correctly under specified conditions.

M.4.1.1.2 Rated voltage (U_n)

Value of the voltage assigned by the manufacturer to the MRCD.

M.4.1.1.3 Rated current (I_n)

M.4.1.1.3.1 Terminal type

Subclause 4.3.3.3 applies.

M.4.1.1.3.2 Through-conductor type

Value of current, assigned to the MRCD by the manufacturer and marked in accordance with Table M.1, item g), which the MRCD can monitor in uninterrupted duty under specified conditions (see M.8.6).

M.4.1.1.4 Rated insulation voltage (U_i)

Voltage, assigned by the manufacturer, to which the dielectric tests and the MRCD creepage distances are referred with respect to the monitored circuit.

M.4.1.1.5 Rated impulse withstand voltage (U_{imp})

Peak value of the impulse voltage that the MRCD can withstand without failure and to which the values of the clearances are referred with regard to the monitored circuit.

M.4.1.2 Characteristics of the voltage source of MRCDs

M.4.1.2.1 Rated values of the voltage source of MRCDs (U_s)

Values of the voltage source to which the operating functions of the MRCD are referred.

M.4.1.2.2 Rated values of the frequencies of the voltage source of MRCDs

Values of the frequencies of the voltage source to which the operating functions of the MRCD are referred.

M.4.1.2.3 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

M.4.1.2.4 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

NOTE In the case of a specified power supply the requirement applies to the incoming connections.

M.4.1.3 Characteristics of auxiliary contacts

Subclause 4.6 of IEC 60947-1:2007 applies.

M.4.2 Characteristics of MRCDs concerning their residual current function

M.4.2.1 General

Subclause B.4.2.4 applies, replacing "non-actuating time" by "non-operating time", and with the following additions.

The maximum values of the MRCD operating time shall be stated by the manufacturer for residual current values equal to $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ (or 0,25 A for $I_{\Delta n} \leq 30$ mA), 10 $I_{\Delta n}$ (or 0,5 A for $I_{\Delta n} \leq 30$ mA).

The maximum combination time shall comply with Table B.1 for a non-time-delay type MRCD and with Table B.2 for a time-delay type MRCD having a limiting non-operating time of 0,06 s.

MRCDs having $I_{\Delta n} \leq 30$ mA shall be of the non-time-delay type. They shall be used only with a specified current breaking device.

M.4.2.2 Operating characteristic in case of residual current with d.c. component

M.4.2.2.1 Type AC MRCD

Subclause B.4.4.1 applies.

M.4.2.2.2 Type A MRCD

Subclause B.4.4.2 applies.

M.4.2.2.3 Type B MRCD

MRCD for which operation is ensured:

- for residual sinusoidal alternating currents,
- for residual pulsating direct currents,
- for residual pulsating direct currents superimposed by a smooth direct current of 6 mA,
- for residual currents which may result from rectifying circuits, i.e.:
  - single-phase connection with capacitive load causing smooth direct current,
  - two-pulse bridge connection line-line,
  - three-pulse star connection or six-pulse bridge connection,

  with or without phase angle control, independent of polarity, whether suddenly applied or slowly rising.

M.4.3 Behaviour under short-circuit conditions

M.4.3.1 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.2 Rated conditional residual short-circuit current ($I_{\Delta c}$)

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.3 Rated short-time withstand current (I_{cw})

Subclause 4.3.6.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.4 Peak withstand current

Subclause 2.5.28 of IEC 60947-1:2007 applies to the primary circuit of the MRCD.

M.4.3.5 Rated residual short-time withstand current ($I_{\Delta w}$)

The rated residual short-time withstand current of an equipment is the value of residual short-time withstand current, assigned to the equipment by the manufacturer, that the equipment can carry without damage, under the test conditions specified in this standard.

M.4.4 Preferred and limiting values

M.4.4.1 Preferred values of the rated residual operating current ($I_{\Delta n}$)

Subclause B.4.2.1 applies.

M.4.4.2 Minimum value of the rated residual non-operating current ($I_{\Delta no}$)

Subclause B.4.2.3 applies.

M.4.4.3 Limiting value of the non-operating overcurrent in the case of a single-phase load in a multiphase circuit

Subclause B.4.2.4 applies.

M.4.4.4 Preferred values of rated voltage of the voltage source of MRCDs

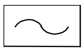
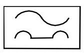
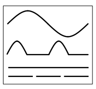
Subclause 4.5.1 applies.

M.5 Product information

The MRCD, processing device or sensing means, as applicable, shall be provided with the information as given in Table M.1. Any marking shall be durable. The marking shall be on the MRCD itself or on one or more nameplates. The manufacturer shall state:

- for a separate sensing means, the details of the sensing means including the conditions for connection to the processing device (cable type, length etc.);
- for a through-conductor type MRCD, the dimensions of the conductor aperture(s) and the position of the through-conductors relative to the sensing means;
- for a terminal type MRCD, the maximum cross sectional area of the conductors to be connected;
- for all types, distances to be respected with regard to nearby conductors;
- for all types, the conditions to be observed for the connection between the processing device and the current breaking device;
- for all types, the SCPDs to be associated with the MRCD to achieve the rated conditional (residual or not) short-circuit current;
- for a non-time-delay type, the current breaking devices to be associated with the MRCD to meet the maximum combination times of Table B.1;
- for a time-delay type having a limiting non-operating time of 0,06 s, the current breaking device(s) to be associated with the MRCD to meet the combination times of Table B.2.

Table M.1 – Product information

Information	Symbol	Location (see Note 1)	Single device	Separate devices	
				Sensing means	Processing device
a) manufacturer's name or trade mark		Marked	a	a	a
b) type designation or serial number		Marked	a	a	a
c) IEC 60947-2		Marked	a		a
d) rated voltage of the voltage source	U_s	Marked	a		a
e) rated voltage of the monitored circuit	U_n	Marked	a	a	
f) rated frequency of the voltage source		Literature			
g) rated frequency of the monitored circuit		Literature			
h) maximum rated current of the monitored circuit	I_n	Visible	a	a	a (see Note 2)
i) rated residual operating current (value(s) or range, as applicable)	$I_{\Delta n}$	Visible	a		a)
j) rated residual non-operating current if it differs from 0,5 $I_{\Delta n}$	$I_{\Delta no}$	Literature			
k) lowest residual current setting at 6 I_n for MRCDs with separate sensing means		Literature			
l) rated conditional short-circuit current and/or rated short-time withstand current, and rated conditional residual short-circuit current	I_{cc} I_{cw} $I_{\Delta c}$	Literature			
m) U_{imp} of the voltage source	U_{imp}	Literature			
n) U_{imp} of the monitored circuit	U_{imp}	Marked	a	a	
o) IP code, where applicable (see Annex C of IEC 60947-1:2007)	IP--	Literature			
p) position of use and mounting precautions		Literature			
q) output characteristics and/or specified current breaking device(s)		Literature			
r) operating characteristic in case of residual currents in the presence or absence of a d.c. component	Type AC  Type A  Type B 	Visible	a		a
s) limiting non-operating time (value or range) at 2 $I_{\Delta n}$ for time-delay type, as applicable	Δt or S	Visible	a		a
t) test device	T	Visible	a		a
u) wiring diagram		Literature			
a Information/marking applies.					

NOTE 1 Visible = marked on the device and visible after installation.
Literature = given in the manufacturer's catalogue or instructions.
Marked = marked on the device but not necessarily visible after installation.

NOTE 2 Only ~~necessary~~ applicable if the residual current is marked as a percentage of I_n.

M.6 Normal service, mounting and transport conditions

Clause 6 applies.

M.7 Design and operating requirements

M.7.1 Design requirements

It shall not be possible to modify the operating characteristic of an MRCD except by means which are specifically provided for setting the rated residual operating current or the definite time-delay.

NOTE MRCDs ~~may~~ can be provided with means indicating the status of the outputs.

M.7.2 Operating requirements

M.7.2.1 Operation in case of a residual current

Subclause B.7.2.1 applies.

Compliance shall be checked by the tests of M.8.3.

M.7.2.2 Operation under short-circuit conditions

MRCDs shall have a rated conditional short-circuit current (I_{cc}) or a rated short-time withstand current (I_{cw}), but may have both. They shall also have a rated conditional residual short-circuit current ($I_{\Delta c}$) or a rated residual short-time withstand current ($I_{\Delta w}$), but may have both.

MRCDs shall comply with the relevant tests of M.8.14.

M.7.2.3 Mechanical and electrical endurance

MRCDs shall comply with the tests of M.8.11.

M.7.2.4 Effects of environmental conditions

MRCDs shall comply with the test of M.8.15.

M.7.2.5 Dielectric properties

MRCDs shall be capable of withstanding the impulse withstand voltage declared by the manufacturer in accordance with 7.2.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

MRCDs shall comply with the tests of M.8.4.

Clearances from the live parts of the monitored circuit to:

– the live parts of the MRCD,
– the parts intended to be grounded,
– the clearances between the current paths, for terminal type MRCDs,

shall withstand the test voltage given in Table 12 of IEC 60947-1:2007 according to the rated impulse withstand voltage.

M.7.2.6 Test device

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

The test device shall satisfy the tests of M.8.5.

The protective conductor, if any, shall not become live when the test device is operated.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; the use of a light colour is recommended.

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

M.7.2.7 Value of the non-operating overcurrent in case of a single phase load

MRCDs shall comply with the test of M.8.6.

M.7.2.8 Resistance of MRCDs to unwanted tripping due to surge currents resulting from impulse voltages

MRCDs shall withstand the test of M.8.7.

M.7.2.9 Behaviour of MRCDs of type A and B in case of an earth fault current comprising a d.c. component

MRCDs of type A and type B shall comply with the tests of M.8.8, as applicable.

M.7.2.10 Requirements for MRCDs with voltage source

MRCDs functionally dependent on a voltage source shall operate correctly at any value of the voltage between 0,85 and 1,1 times the rated value U_s (see M.2.1.1 and M.4.1.2.1).

According to their classification, MRCDs functionally dependent on a voltage source shall comply with the requirements given in Table M.2.

Table M.2 – Requirements for MRCDs with voltage source

Classification of the device according to M.3.2.2	Behaviour in case of failure of the voltage source
MRCD operating automatically without delay in case of voltage source failure (M.3.2.2.1)	Operating without delay according to M.8.12
MRCD operating automatically with delay in case of voltage source failure (M.3.2.2.1)	Operating with delay according to M.8.12
MRCD not operating automatically after failure of the voltage source but able to operate as intended in case of a residual current fault arising (M.3.2.2.2)	Operating according to M.8.13

M.7.2.11 Temperature-rise of terminal type MRCDs

M.7.2.11.1 General

The temperature-rise of the parts of terminal type MRCDs shall not exceed the values specified in 7.2.2 of IEC 60947-1:2007/AMD2:2014.

M.7.2.11.2 Ambient air temperature

The temperature-rise limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014 are only applicable if the ambient air temperature remains between the limits given in M.6.

M.7.2.11.3 Main circuit of terminal type MRCDs

The main circuit of the MRCD, to which the monitored circuit is connected, shall withstand the rated current as defined in M.4.1.2.3, without the temperature-rises exceeding the limits given in Table~~s~~ 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014.

M.7.2.12 Electromagnetic compatibility

Requirements of Annex J apply to the sensing means and the processing device of the MRCD, connected in accordance with the manufacturer's instructions.

Tests shall be made in accordance with M.8.16.

Immunity to voltage variations is covered by the requirements of M.7.2.10.

M.7.2.13 Behaviour of MRCDs in case of failure of the sensing means connection

For MRCDs with separate sensing means, if the sensing means are disconnected, then:

– the MRCD shall operate, or
– the MRCD shall provide a signal to indicate such disconnection, or
– it shall be possible to verify the disconnection by operating the test device.

Compliance is verified by the tests of M.8.9.

M.7.2.14 Behaviour of MRCDs according to the rated frequency

The MRCD shall operate correctly within its rated frequency range.

Compliance is verified by the tests of M.8.3.3 and M.8.5.

M.8 Tests

M.8.1 General

~~Tests specified in this annex are:~~

~~– type tests: see M.8.1.1;~~
~~– routine tests: see M.8.1.2.~~

M.8.1.1 Type tests

Type tests are grouped together in a number of sequences, as shown in Table M.3.

In the case of MRCDs with multiple settings of residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.

In the case of MRCDs with adjustable time-delay (see B.3.3.2.2), the tests shall be made at the highest setting, unless otherwise stated.

The release of the associated breaking device, when applicable, shall be energized at its lowest rated voltage.

Table M.3 – Test sequences

Sequences		
M I	Operating characteristics	M.8.3
	Dielectric properties	M.8.4
	Operation of the test device at the limits of rated voltage	M.8.5
	Limiting value of the non-operating current under overcurrent conditions	M.8.6
	Resistance against unwanted tripping due to surge currents resulting from impulse voltages	M.8.7
	Behaviour in case of an earth fault current comprising a d.c. component	M.8.8
	Behaviour in case of failure of the connection to the sensing means	M.8.9
	Temperature-rise	M.8.10
	Mechanical and electrical endurance	M.8.11
	Behaviour in the case of failure of the voltage source for MRCDs classified under M.3.2.2.1	M.8.12
	Behaviour of MRCDs classified under M.3.2.2.2. in the case of failure of the voltage source	M.8.13
M II	Behaviour of MRCDs under short-circuit conditions	M.8.14
M III	Effects of environmental conditions	M.8.15
M IV	Electromagnetic compatibility	M.8.16

For terminal-type MRCDs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants construction is not identical to the variant tested then those variants shall also be tested.

One sample shall be tested for each of the test sequences M I, M II and M III.

For test sequence M IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Unless otherwise specified, each type test (or sequence of type tests) is carried out on the MRCD in new and clean condition, the influencing quantities having their normal reference values.

The MRCD shall be installed individually, according to the manufacturer's instructions, in free air, unless otherwise specified. Ambient temperature shall be between 15 °C and 30 °C unless otherwise specified. Connections and mounting shall comply with the manufacturer's instructions.

M.8.1.2 Routine tests

Subclause 8.4.5 applies.

M.8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except in so far as 7.1 applies.

Test sequence M I

M.8.3 Verification of the operating characteristics

M.8.3.1 General

The MRCD shall be installed, mounted and wired according to the manufacturer's instructions. Unless otherwise specified, it is connected to a test equipment, as specified by the manufacturer, representing normal service conditions for the output circuit (e.g. connection to a circuit-breaker) in order to verify the change in the status of the output and the combination time (see M.2.2.2.2).

M.8.3.2 Test conditions for MRCDs without voltage source

Subclause B.8.2.2 applies.

M.8.3.3 Test conditions for MRCDs with voltage source

The tests shall be carried out at the following values:

– 0,85 times the minimum rated value of the source voltage for tests specified in M.8.3.4 and M.8.3.5.2;

– 1,1 times the maximum rated value of the source voltage for tests specified in M.8.3.5.3.

MRCDs with a range of rated frequencies shall be tested at the highest and lowest frequencies. However, for MRCDs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover both frequencies.

M.8.3.4 Off-load tests at 20 °C ± 5 °C

M.8.3.4.1 General

With the connections as shown in Figure M.1, Figure M.2 or Figure M.3, the MRCD shall comply with the tests of M.8.3.4.2, M.8.3.4.3 and M.8.3.4.4 as well as with the test of M.8.3.4.5 where applicable; all these tests are carried out on a single current path. Each verification shall comprise three measurements, as applicable.

Unless otherwise specified:

– for MRCDs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the highest and at the lowest settings, as well as at an intermediate setting;

– for MRCDs of the adjustable time-delay type, the time-delay shall be set to its minimum value.

M.8.3.4.2 Verification of operation in case of a steady increase of the residual current (Figure M.1)

The test switches S_1 and S_2, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, up to $I_{\Delta n}$ in approximately 30 s. Three current measurements causing change in status of the output are carried out.

The three values measured shall be situated between the rated residual non-operating current $I_{\Delta no}$ and $I_{\Delta n}$.

M.8.3.4.3 Verification of operation in case of closing on residual current (Figure M.2)

The MRCD is connected to a breaking device, specified by the manufacturer, and installed on the monitored circuit. The characteristics of this device shall be given in the test report.

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or at each specific setting of the residual operating current if applicable), the test switch S_2 and the breaking device being closed, switches S_1 and S_a (if applicable) are closed simultaneously. The combination time is measured three times.

No measurements shall exceed the limiting value specified for $I_{\Delta n}$ in M.4.2.

M.8.3.4.4 Verification of operation in case of a sudden appearance of residual current (Figure M.2 and Figure M.3)

The MRCD is connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in M.4.2, the test switches S_1, and S_a if applicable, and the test equipment being in the closed position, and the MRCD being ready to operate, the residual current is suddenly established by closing the test switch S_2.

Three measurements of operating time and of combination time (if applicable) are made at each value of I_{Δ}:

- none of the values of operating time shall exceed the values indicated by the manufacturer,
- none of the values of combination time shall exceed the limits specified in M.4.2.

M.8.3.4.5 Verification of the limiting non-operating time of time delayed type MRCDs (Figure M.3)

The MRCD is connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at the value 2 $I_{\Delta n}$, the test switches S_1, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is established by closing the switch S_2 for a time equal to the limiting non-operating time declared by the manufacturer in accordance with M.4.2.

The test is made 3 times. The MRCD shall not operate.

If the MRCD has an adjustable current setting and/or an adjustable time-delay, the test is made, as applicable, at the lowest setting of the residual operating current and at the maximum and minimum settings of the time-delay.

M.8.3.5 Tests at the temperature limits

M.8.3.5.1 General

Subclause B.8.2.5 applies.

M.8.3.5.2 Off-load test at –5 °C

Subclause B.8.2.5.2 applies, but in accordance with M.8.3.4.4 and M.8.3.4.5 if applicable.

M.8.3.5.3 On-load test at +40 °C

Subclause B.8.2.5.3. applies.

After reaching thermal steady-state conditions, the MRCD is submitted to the tests described in M.8.3.4.4 and in M.8.3.4.5 if applicable.

M.8.4 Verification of dielectric properties

M.8.4.1 Verification of rated impulse withstand voltage

M.8.4.1.1 General

The MRCD shall comply with the requirements stated in M.7.2.5. The tests shall be carried out in all the auxiliary contact positions.

The tests are made in accordance with 8.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 with the following additions.

M.8.4.1.2 Verification of rated impulse withstand voltage with respect to the monitored circuit

M.8.4.1.2.1 Tests for terminal type MRCD

The test voltage, defined in M.7.2.5, is applied as indicated in 8.3.3.4.1 item 2), of IEC 60947-1:2007/AMD1:2010.

M.8.4.1.2.2 Tests for MRCDs of through-conductor type

The test is carried out on a sensing means through which runs an uninsulated busbar, installed according to the manufacturer's instructions.

The test voltage, defined in M.7.2.5, is applied as follows:

a) between all the conductors of the monitored circuit connected together and the mounting plate if the sensing means are separate;
b) between all the conductors of the monitored circuit connected together and the processing device enclosure or its mounting plate if the sensing means are combined;
c) between each auxiliary circuit and
   – the monitored circuit;
   – the enclosure or mounting plate of the MRCD.

M.8.4.1.3 Verification of rated impulse withstand voltage of the voltage source circuit (if applicable)

If the voltage source circuit is supplied directly from the monitored circuit, the tests are carried out in accordance with M.8.4.1.2.1.

If the voltage source circuit is not supplied by the monitored circuit, the test voltage defined in Table 12 of IEC 60947-1:2007 is applied as follows:

a) between all the supply terminals of the voltage source circuit connected together and the enclosure or mounting plate of the MRCD;
b) between each supply terminal of the voltage source circuit and the other supply terminals connected together and connected to the enclosure or mounting plate of the MRCD.

M.8.4.2 Capability of any circuits connected to the monitored circuit in respect of withstanding d.c. voltages due to insulation measurements

The need for this verification of MRCDs which cannot be disconnected in service is under consideration.

M.8.5 Verification of the operation of the test device at the limits of the rated voltage

Subclause B.8.4 applies, replacing the rated voltage by the rated voltage of the voltage source. The MRCD shall be tested in association with the test equipment specified in M.8.3.1.

M.8.6 Verification of the limiting value of non-operating current under overcurrent conditions, in case of a single phase load

The MRCD is connected according to Figure M.4 a), b) or c), as applicable, paying particular attention to the positioning of the conductors in case of a through-conductor type according to the manufacturer's instructions, the switch S_1 being open. The switch S_a, where applicable, is then closed and the voltage U_s is applied.

The test is made in accordance with B.8.5 at a current of 6 I_n. For MRCDs with separate sensing means, the test shall be made at the lowest residual current setting value declared by the manufacturer.

No change of state of the MRCD shall occur.

M.8.7 Resistance against unwanted tripping due to surge currents resulting from impulse voltages

M.8.7.1 General

For MRCDs with adjustable time-delay, the time-delay shall be set at its minimum.

M.8.7.2 Verification of the resistance to unwanted tripping in case of loading of the network capacitance

Subclause B.8.6.2 applies, replacing Figure B.5 by Figure M.5.

No change of state of the MRCD shall occur.

M.8.7.3 Verification of the resistance to unwanted tripping in case of flashover without follow-on current

Subclause B.8.6.3 applies, replacing Figure B.7 by Figure M.6.

No change of state of the MRCD shall occur.

M.8.8 Verification of the behaviour in case of an earth fault current comprising a d.c. component

M.8.8.1 General

The test conditions of M.8.3.1, M.8.3.2 and M.8.3.3 apply.

M.8.8.2 Type A MRCD

M.8.8.2.1 General

Type A MRCDs shall satisfy the tests from M.8.8.2.2 to M.8.8.2.5.

For MRCDs the operation of which depends on a voltage source the tests are made at 1,1 and 0,85 times the rated voltage of the voltage source (U_s).

M.8.8.2.2 Verification of operation in case of a continuous rise of a residual pulsating direct current

Subclause B.8.7.2.1 applies, replacing Figure B.8 by Figure M.7.

The switches S_1 and S_2, and S_a if applicable, are closed, the MRCD being ready to operate.

M.8.8.2.3 Verification of operation in case of a suddenly appearing residual pulsating direct current

Tests of B.8.7.2.2 apply with the following modifications.

The test circuit shall be in accordance with Figure M.8 or Figure M.9, as applicable.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement instrument indicating the change in status of the output;
– for the second step, the MRCD is connected to a breaking device, specified by the manufacturer, and installed on the monitored circuit. The characteristics of this breaking device shall be given in the test report.

The switches S_1, and S_a if applicable, are in the closed position and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S_2.

The test is carried out at each value of the residual current specified:

– for the first step, none of the operating times measured shall exceed the values indicated by the manufacturer for the response time of the MRCD only;
– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.2.4 Verification of operation with load at the reference temperature

The tests of M.8.8.2.2 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current, the current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure M.7c).

M.8.8.2.5 Verification of operation in case of a residual pulsating direct current superimposed by a smooth direct current of 6 mA

Tests of B.8.7.2.4 apply with the following modifications.

The test circuit shall be in accordance with Figure M.10 a), b) or c), as applicable.

M.8.8.3 Type B MRCD

M.8.8.3.1 General

Additionally to the tests specified in M.8.3.4 and M.8.3.5, type B MRCDs shall comply with the tests from M.8.8.3.2 to M.8.8.3.6. For MRCDs with voltage source, these tests are carried out at 1,1 and 0,85 times the rated voltage of the source voltage.

M.8.8.3.2 Verification of operation in case of a slowly rising residual smooth direct current

The test circuit shall be in accordance with Figure M.11, switches S_1 and S_2, and S_a if applicable, being closed. Each current path is tested twice in position I and twice in position II of switch S_3.

The residual current, starting from zero, shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 2 $I_{\Delta n}$.

M.8.8.3.3 Verification of operation in case of a suddenly appearing residual smooth direct current

The test circuits shall be in accordance with Figure M.12 and Figure M.13.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement apparatus giving the status of the output;
– for the second step, the MRCD is connected to a current breaking device, specified by the manufacturer and installed on the monitored circuit. The characteristics of this breaking device shall be given in the test report.

The circuit being successively calibrated at the values specified hereafter, the auxiliary switch S_1 or S_a, as applicable, being closed and the MRCD being ready to operate, the residual current is suddenly established by closing switch S_2.

The test is carried out at each value of residual current specified in Table B.1, multiplied by two.

Two operating time measurements are performed for each value, the auxiliary switch S_3 being in position I for the first measurement and in position II for the second measurement:

– for the first step, none of the values obtained shall exceed the values indicated by the manufacturer for the actuating time of the MRCD alone,
– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.4 Verification of operation in case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection

The test circuit shall be in accordance with Figure M.14, the switches S_1 and S_2, and S_a if applicable, being in the closed position. The test shall be carried out twice.

For each test, starting from zero, the current shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 2 $I_{\Delta n}$.

M.8.8.3.5 Verification of operation in case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line

The test circuit shall be in accordance with Figure M.15, with switches S_1 and S_2, and S_a if applicable, being in the closed position. The test shall be carried out on all possible combinations of pairs of current paths for the MRCD sensing means.

For each test, starting from zero, the current shall be steadily increased to 1,4 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 1,4 $I_{\Delta n}$.

NOTE 1 To simplify tests for residual currents caused by a fault in a circuit supplied by a two-pulse bridge connection line-to-line or a three-pulse star connection or six-pulse bridge connection, the verification of the operation is carried out only with a residual current slowly rising and a phase control angle of α = 0°.

NOTE 2 To simplify tests for residual currents caused by a fault in a three-phase rectified circuit, the verification of the operation is carried out only for a three-pulse star connection.

M.8.8.3.6 Verification of operation with load at the reference temperature

The tests of M.8.8.3.2, M.8.8.3.4 and M.8.8.3.5 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current.

M.8.9 Verification of the behaviour of MRCDs with separate sensing means in case of a failure of the sensing means connection

M.8.9.1 General

For MRCDs with a range of rated values of the voltage source, tests shall be made for each rated value, according to M.8.9.2 or M.8.9.3, as applicable, according to the manufacturer's instructions.

M.8.9.2 Test method 1

The MRCD shall be connected to the external sensing means and is supplied successively with each rated voltage, as shown in Figure M.16. There shall be no fault current flowing in the sensing means and the test circuit shall not be activated.

The sensing means are disconnected and the MRCD shall operate or provide a signal to indicate such disconnection.

The time interval between the disconnection and the output status change is measured.

Three measurements are carried out; no value shall exceed 5 s.

M.8.9.3 Test method 2

Tests shall be carried out as follows:

a) The test device is activated. The MRCD shall operate.

b) The sensing means are disconnected and the test device is activated. The MRCD shall not operate.

M.8.10 Verification of temperature-rise of terminal type MRCDs

M.8.10.1 General

Unless otherwise specified, the MRCD is connected with the appropriate conductors whose cross-sections are specified in Tables 9, 10 and 11 of IEC 60947-1:2007, and is fixed on a mat black painted plywood board of about 20 mm thickness.

The test shall be carried out in an atmosphere protected against abnormal external heating or cooling.

M.8.10.2 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.8.10.3 Test procedure

The test shall be carried out in accordance with 8.3.3.3.4 of IEC 60947-1:2007, at the rated current I_n.

During this test, temperature-rise shall not exceed the values listed in Table~~s~~ 2 of IEC 60947-1:2007 and Table 3 of IEC 60947-1:2007/AMD2:2014.

M.8.11 Verification of mechanical and electrical endurance

The MRCD output is submitted to mechanical and electrical endurance tests including:

– 500 off-load operations controlled by the test device;

– 500 off-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path;
– 500 on-load operations controlled by the test device;
– 500 on-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path.

The on-load tests are carried out on a circuit corresponding to the output rating given by the manufacturer.

After the tests, the MRCD shall show no damage impairing its further use. The output shall be able to withstand in the open position a voltage equal to twice its maximum rated value given by the manufacturer.

NOTE 1 This verification is not applicable if the output is designed for a specific load and does not have a rated output voltage.

For MRCDs having more than one output rating, two tests shall be made:

– a test at the highest rated current at the corresponding voltage;
– a test at the highest rated voltage at the corresponding current.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2.

NOTE 2 If the MRCD output has an appropriate AC15 rating, according to IEC 60947-5-1, the tests of this subclause are not necessary.

M.8.12 Verification of the behaviour of MRCDs in case of failure of the voltage source for MRCDs classified under M.3.2.2.1

M.8.12.1 General

For adjustable residual operating current MRCDs, the test shall be carried out at the lowest setting.

For adjustable time-delayed MRCDs, the test is carried out at any one of the time-delay settings.

The voltage applied is the rated voltage of the voltage source (U_s).

For MRCDs having a range of rated voltages of the voltage source, the tests shall be made at the maximum and minimum values of the voltage range.

M.8.12.2 Determination of the limiting value of the voltage source

Tests shall be carried out in accordance with B.8.8.2, replacing “line voltage” by “voltage source” and “line terminals” by “voltage source terminals”.

M.8.12.3 Verification of automatic opening in case of voltage source failure

Tests are carried out in accordance with B.8.8.3, replacing “line voltage” by “voltage source” and “line terminals” by “voltage source terminals”, but in this case the time interval between the switching off and the change in status of the output shall be measured.

Three measurements are carried out:

– for instantaneous MRCDs, no value shall exceed 1 s;
– for time delayed MRCDs, no value shall exceed 1 s plus the set time-delay.

M.8.13 Verification of the behaviour of MRCDs with voltage source as classified under M.3.2.2.2 in case of failure of the voltage source

The provisions of B.8.9 apply in the case where the voltage source is the line voltage of the monitored circuit. In the case where the voltage source is other than the line voltage, a test shall be made as follows.

For MRCDs having an adjustable residual operating current, the test shall be made at the lowest setting.

For MRCDs having an adjustable time-delay, the test is made at any one of the time-delay settings.

The MRCD is connected according to Figure M.3 and is supplied with its rated voltage, or in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_a or S_1, as applicable; the MRCD shall not operate.

The switch S_a or S_1, as applicable, is then reclosed and the voltage is reduced to 70 % of the lowest rated voltage. The rated residual current $I_{\Delta n}$ is then applied by closing S_2; the MRCD shall operate.

Test sequence M II

M.8.14 Verification of the behaviour of the MRCD under short-circuit conditions

M.8.14.1 General

Since an MRCD is not a switching device, where it has been tested with a given SCPD according to M.8.14.3 and M.8.14.5, tests with other SCPDs of a lower peak current and lower I^2t are considered to be also covered.

M.8.14.2 General conditions for the test

M.8.14.2.1 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies, replacing Figures 9, 10, 11 and 12 by Figure M.17, Figure M.18 and Figure M.19.

For short-time withstand tests, the SCPD shall be omitted.

M.8.14.2.2 Tolerances on the test quantities

Table 8 of IEC 60947-1:2007 applies.

M.8.14.2.3 Power factor of test circuit

Table 11 applies.

M.8.14.2.4 Power frequency recovery voltage

Subclause 8.3.2.2.3, item a), of IEC 60947-1:2007/AMD2:2014 applies.

M.8.14.2.5 Calibration of the test circuit

The SCPD and the MRCD, if of the terminal type, are replaced by temporary connections of impedance negligible compared with that of the test circuit. For other MRCDs, the conductors through the sensing means are part of the calibrating circuit.

For the test at rated conditional short-circuit current I_{cc}, the resistors R and the reactors L are adjusted so as to obtain, at the test voltage, a current equal to I_{cc}, at the prescribed power factor. The test circuit is energised simultaneously in all poles.

For the tests at rated residual conditional short-circuit current $I_{\Delta c}$, the additional impedance Z is used so as to obtain the required current values.

M.8.14.2.6 Condition of the MRCD for tests

The wiring and the fixing of the MRCD shall be in accordance with the manufacturer's instructions.

This is particularly the case for MRCDs of the through-conductor type for installing conductors that pass through the sensing means.

The MRCD shall be mounted on a metal plate.

M.8.14.2.7 Condition of the MRCD after tests

After each test of M.8.14.3, M.8.14.4 and M.8.14.5, the MRCD shall show no damage impairing its further use and, in case of a terminal type MRCD, shall be capable of withstanding a voltage equal to twice its rated voltage under the conditions of 8.3.3.6.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2 and M.8.12.3, if applicable, and limited to one measurement.

M.8.14.3 Verification of the rated conditional short-circuit current (I_{cc})

M.8.14.3.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated short-time withstand current I_{cw}.

M.8.14.3.2 Test conditions

The negligible impedance connections are replaced by the SCPD and, if applicable, by the terminal type MRCD.

M.8.14.3.3 Test procedure

The rated voltage of the voltage source, if applicable, is applied.

The following sequence of operations is performed:

$$O - t - O$$

M.8.14.3.4 Behaviour of the MRCD during the tests

During the tests the MRCD may operate.

M.8.14.4 Verification of rated short-time withstand current (I_{cw})

Subclause 8.3.4.3 of IEC 60947-1:2007 applies to the primary circuit.

The test may be carried out at any convenient voltage. The SCPD of Figure M.17, Figure M.18 and Figure M.19 shall be omitted for the test.

M.8.14.5 Verification of the rated conditional residual short-circuit current ($I_{\Delta c}$)

M.8.14.5.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated residual short-time withstand current $I_{\Delta w}$.

M.8.14.5.2 Test conditions

The MRCD shall be tested under the conditions prescribed in M.8.14.2.1 but shall be connected so that the short-circuit current is a residual current. For residual short-circuit tests, the connection B, indicated by the dashed line in Figure M.17, Figure M.18 and Figure M.19, replaces the connection through the sensing means, between X and Y.

The test is carried out on one current path.

The negligible impedance connections are replaced by the SCPD and, where applicable, by the MRCD.

M.8.14.5.3 Test procedure

The following sequence is performed without synchronisation with respect to the voltage wave:

$$O – t – O$$

M.8.14.5.4 Behaviour of the MRCD during the tests

During the tests the MRCD may operate.

M.8.14.6 Verification of rated residual short-time withstand current ($I_{\Delta w}$)

Subclause M.8.14.4 applies except that the MRCD shall be connected so that the short-circuit current is a residual current.

Test sequence M III

M.8.15 Verification of effects of environmental conditions

The tests conditions of B.8.11 apply.

At the end of the tests, the MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2.

Test sequence M IV

M.8.16 Verification of electromagnetic compatibility

M.8.16.1 Immunity tests

M.8.16.1.1 General

Subclause B.8.12.1 applies, replacing "CBR" by "MRCD" where necessary, except that the verifications after the tests shall be a measurement of the operating time (see M.2.2.2.1) at $I_{\Delta n}$, which shall not exceed the value declared by the manufacturer (see M.4.2). The test circuit for the verification shall be in accordance with Figure M.3.

M.8.16.1.2 Electrostatic discharges

Subclause B.8.12.1.2 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.3 Radiated ~~radio-frequency~~ RF electromagnetic fields

Subclause B.8.12.1.3 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.4, and Figure M.20 for MRCDs with separate sensing means.

M.8.16.1.4 Electrical fast transients/bursts (EFT/B)

Subclause B.8.12.1.4 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.5 and Figure J.6, and Figure M.21 for MRCDs with separate sensing means.

M.8.16.1.5 Surges

Subclause B.8.12.1.5 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.6 Conducted disturbances induced by ~~radio-frequency~~ RF fields (common mode)

Subclause B.8.12.1.6 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure M.22 for MRCDs with separate sensing means.

An EM clamp may be used when normal functioning cannot be achieved because of the impact of the CDN on the MRCD.

M.8.16.2 Emission tests

Subclause B.8.12.2 applies.

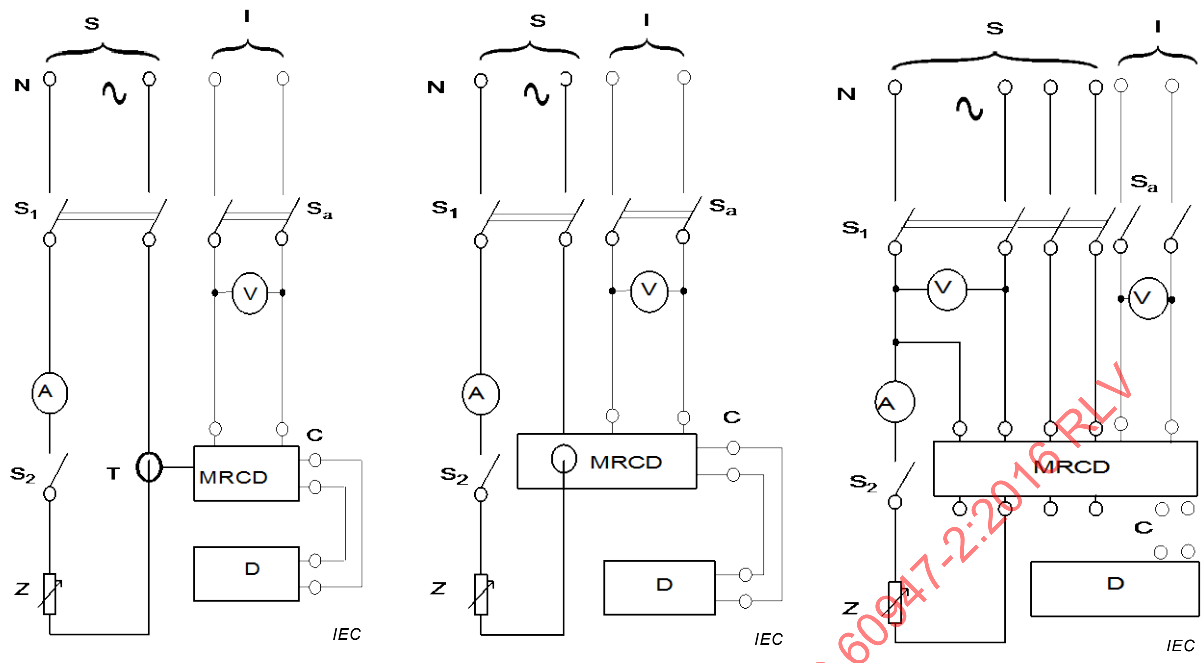


Figure M.1a) – MRCD with separate sensing means **Figure M.1b) – MRCD with integral sensing means** **Figure M.1c) – Terminal type MRCD**

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current

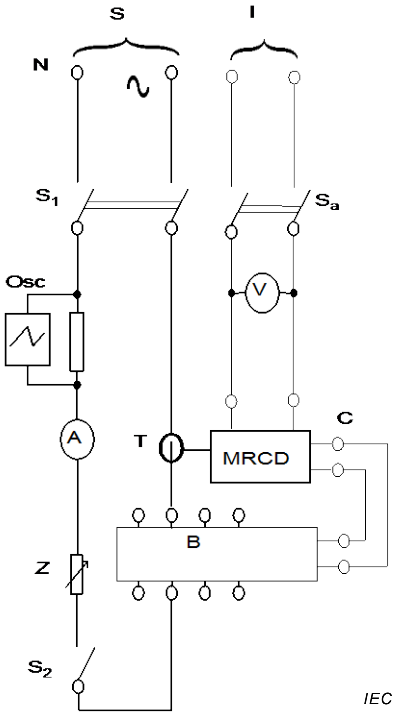


Figure M.2a) – MRCD with separate sensing means

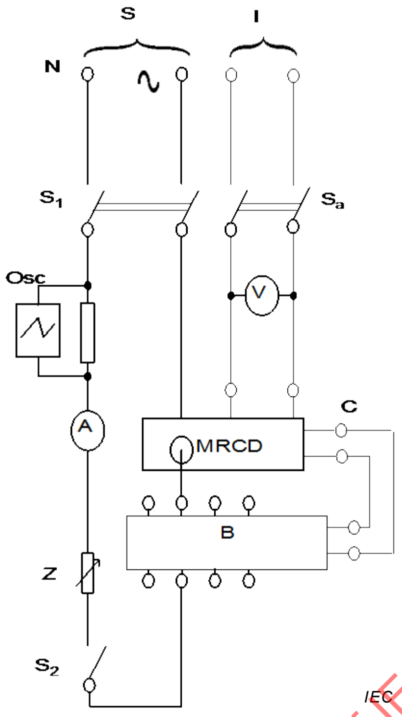


Figure M.2b) – MRCD with integral sensing means

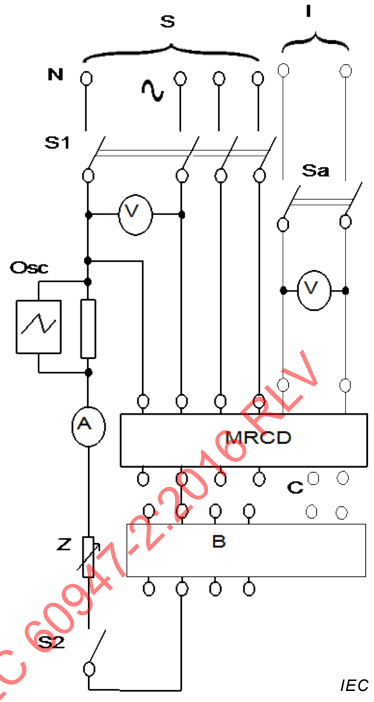


Figure M.2c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

B breaking device

Osc oscilloscope

Figure M.2 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (with breaking device)

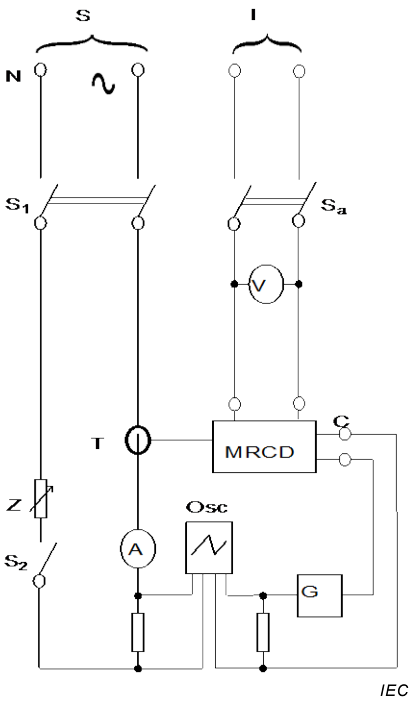


Figure M.3a) – MRCD with separate sensing means

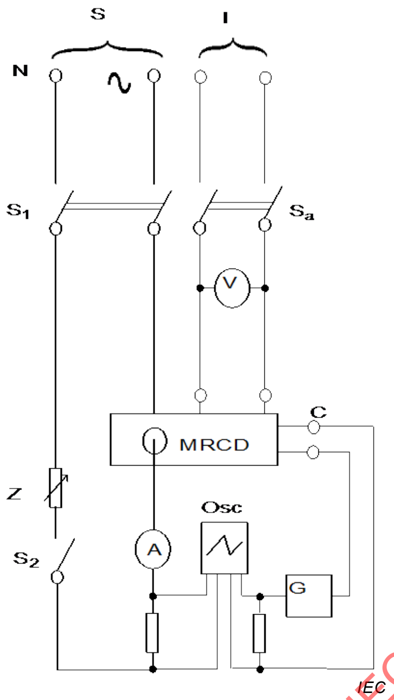


Figure M.3b) – MRCD with integral sensing means

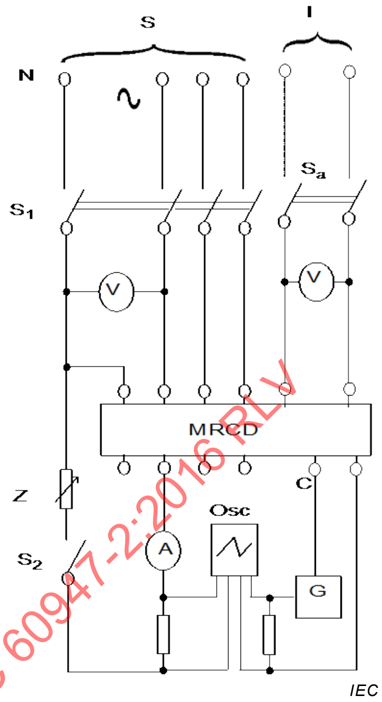


Figure M.3c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope

Figure M.3 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (without breaking device)

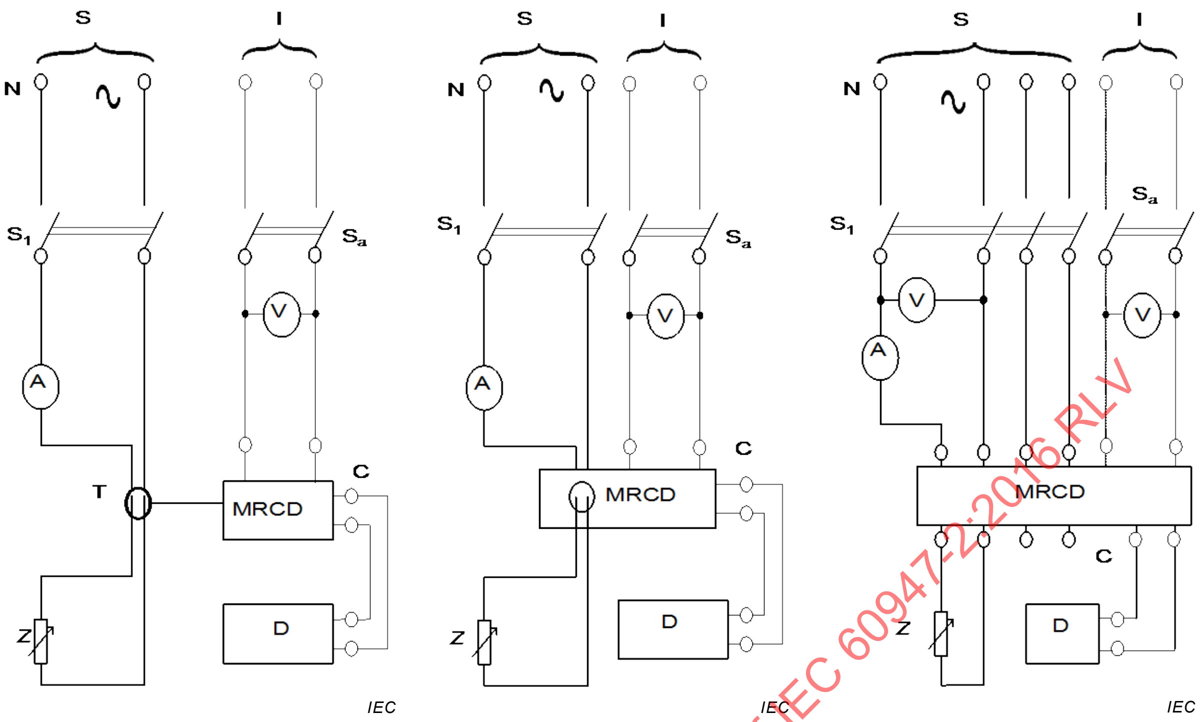


Figure M.4a) – MRCD with separate sensing means

Figure M.4b) – MRCD with integral sensing means

Figure M.4c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.4 – Test circuits for the verification of the limiting value of non-operating current under overcurrent conditions

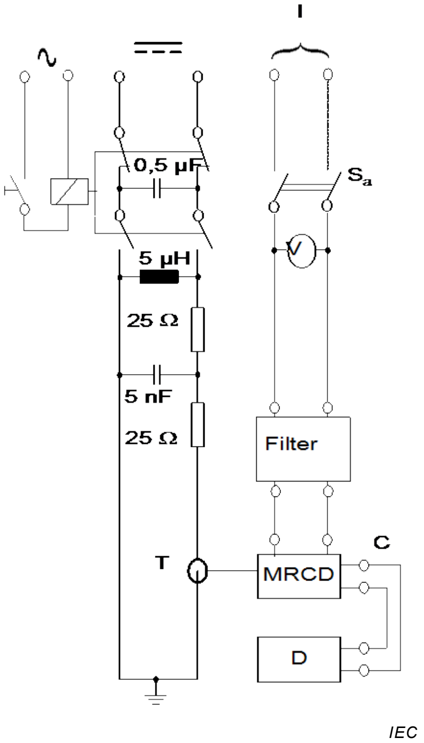


Figure M.5a) – MRCD with separate sensing means

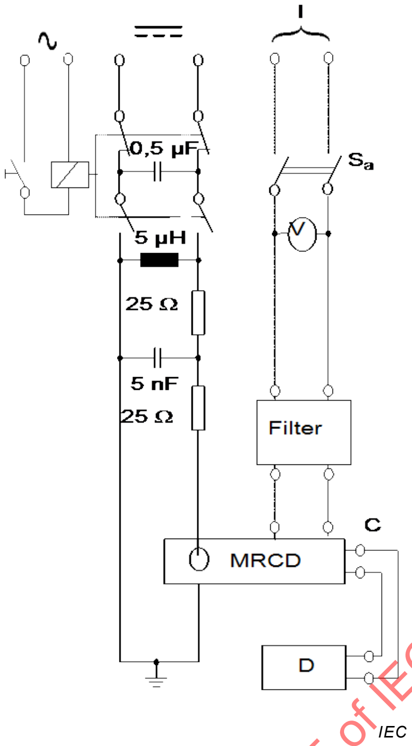


Figure M.5b) – MRCD with integral sensing means

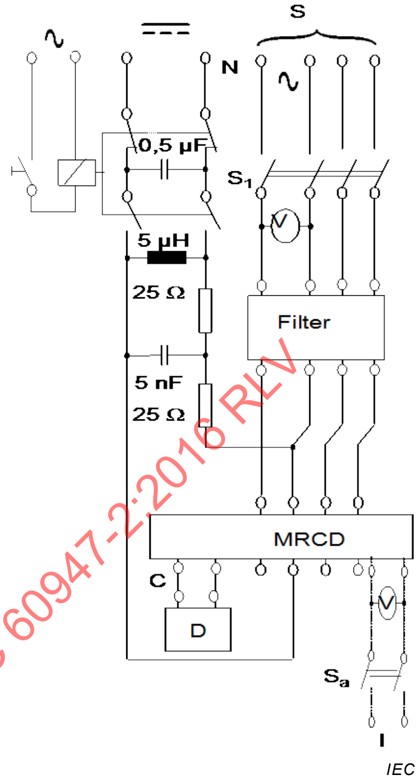


Figure M.5c) – Terminal type MRCD

Key

S power supply

V voltmeter

I separate voltage source, if applicable

S_a auxiliary switch

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance

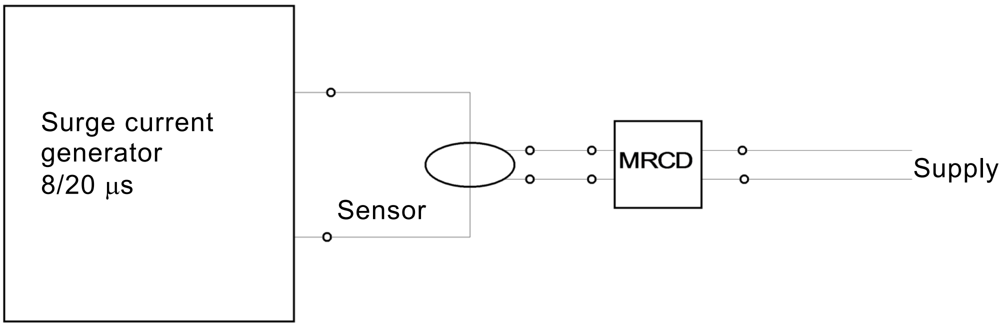


Figure M.6a) MRCD with separate sensing means

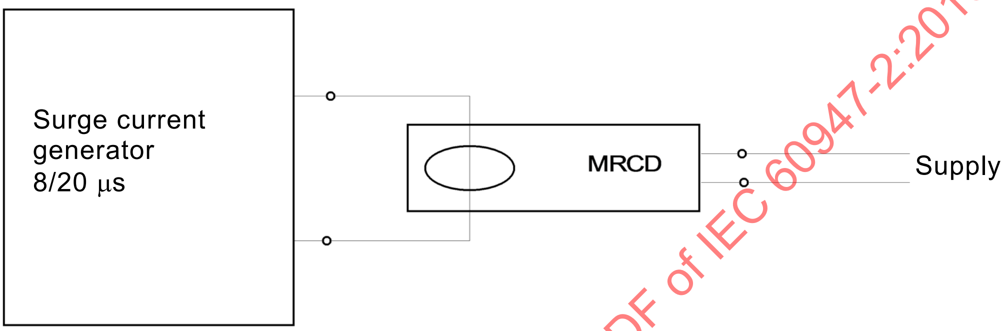


Figure M.6b) MRCD with integral sensing means

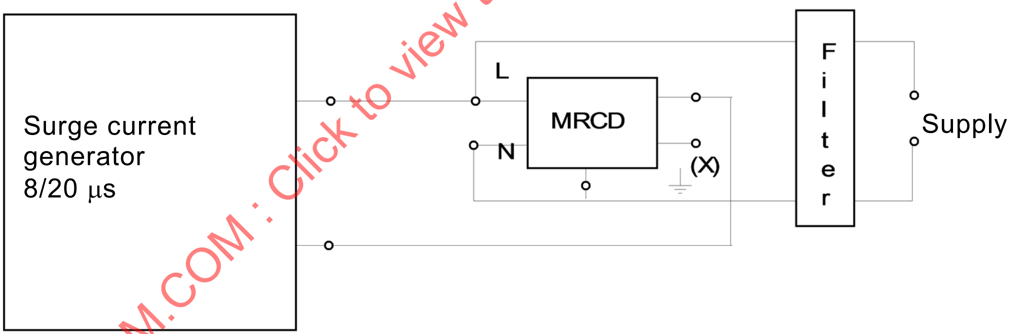


Figure M.6c) Terminals type MRCD

IEC

Figure M.6 – Test circuit for the verification of the resistance to unwanted tripping in the case of flashover without follow-on current

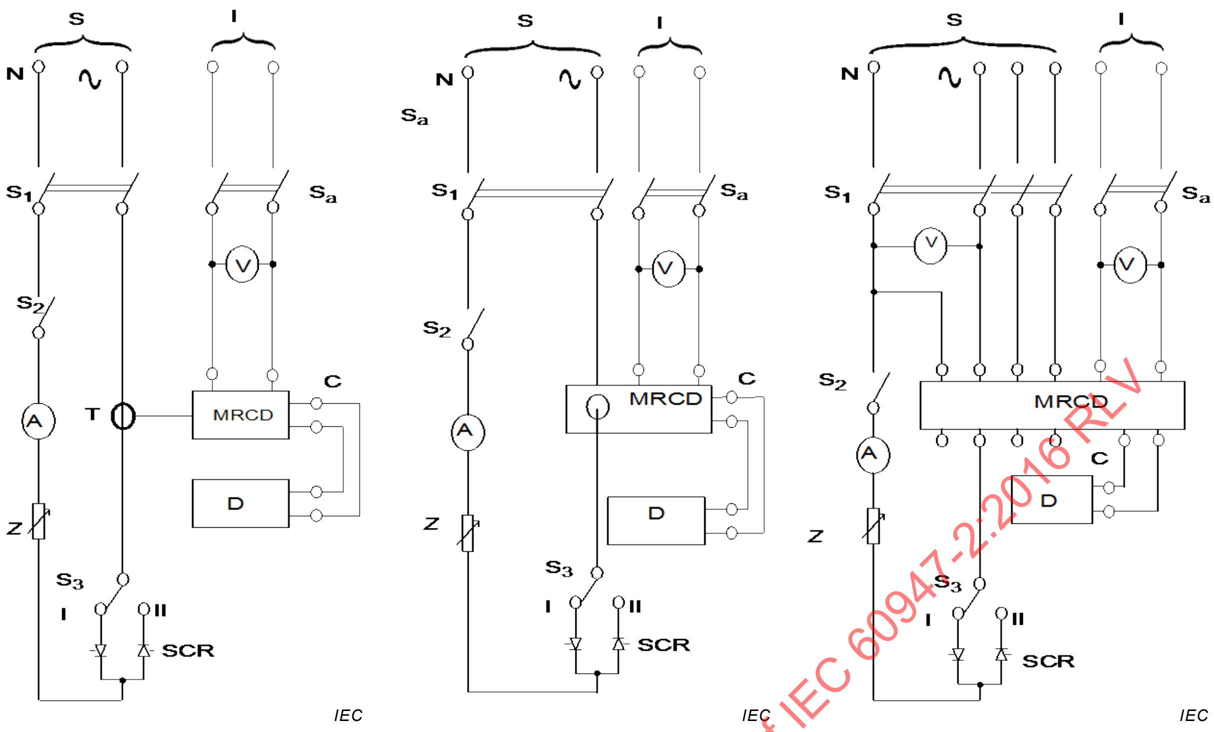


Figure M.7a) – MRCD with separate sensing means

Figure M.7b) – MRCD with integral sensing means

Figure M.7c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	D	instrument indicating the change of status
S_2	single-pole switch	SCR	thyristor
S_3	inverter switch		

Figure M.7 – Test circuits for the verification of operation in the case of a continuous rise of a residual pulsating direct current

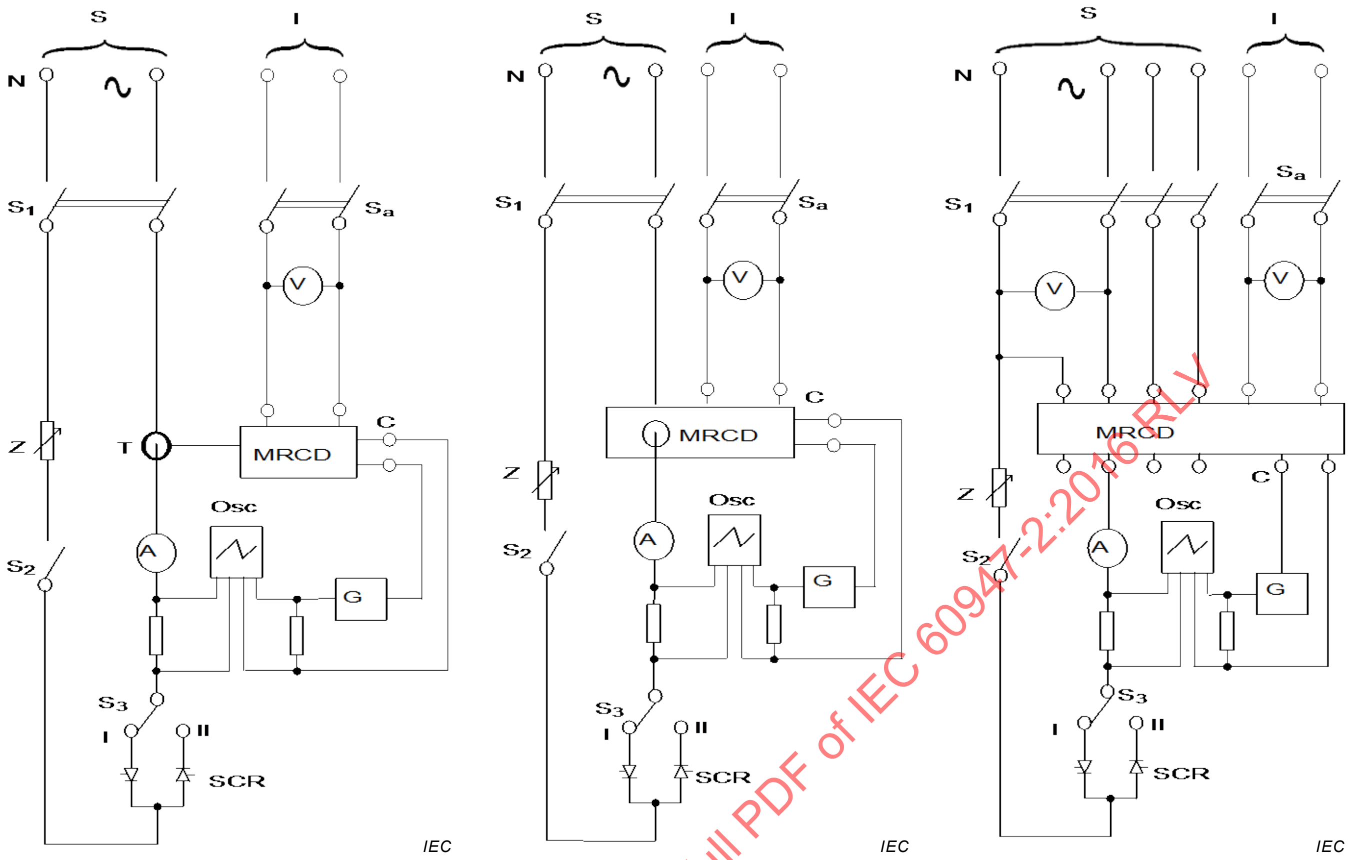


Figure M.8a) – MRCD with separate sensing means

Figure M.8b) – MRCD with integral sensing means

Figure M.8c) – Terminal type MRCD

Key

S	power supply	Sa	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristor

Figure M.8 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (without breaking device)

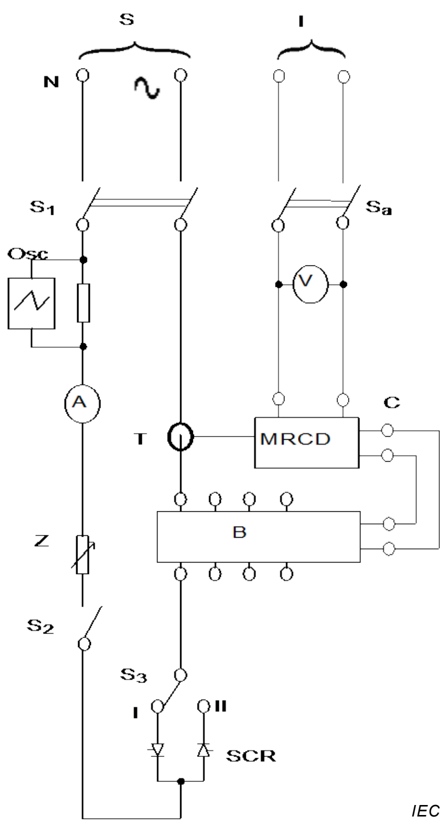


Figure M.9a) – MRCD with separate sensing means

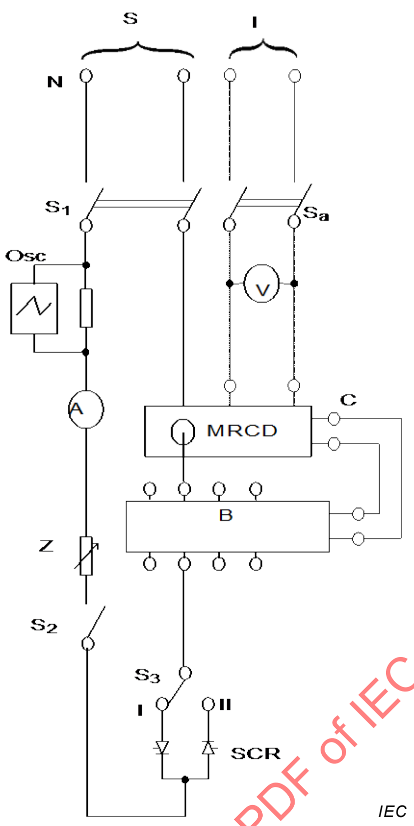


Figure M.9b) – MRCD with integral sensing means

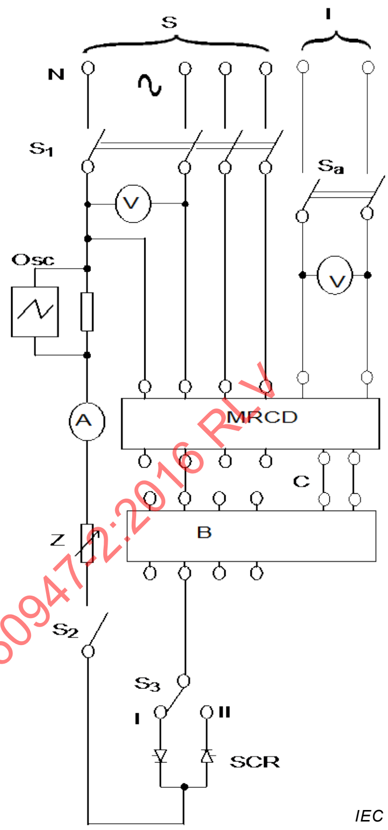


Figure M.9c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	B	breaking device
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristor

Figure M.9 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (with breaking device)

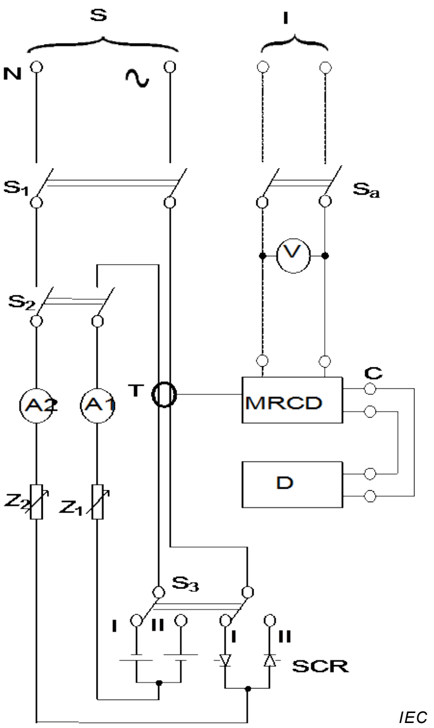


Figure M.10a) – MRCD with separate sensing means

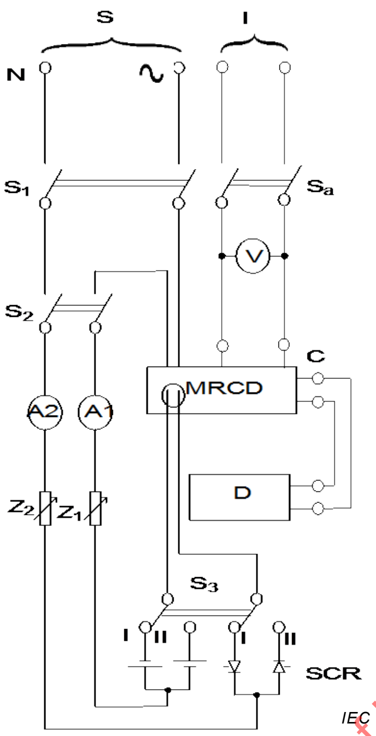


Figure M.10b) – MRCD with integral sensing means

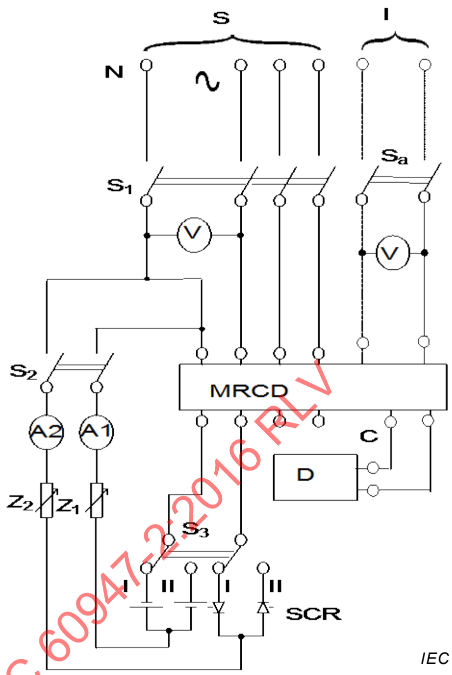


Figure M.10c) – Terminal type MRCD

Key

S	power supply	S_3	double inverter switch
I	separate voltage source if applicable	S_a	auxiliary switch
V	voltmeter	*Z*	variable impedance
A_1	ammeter measuring d.c. current	T	sensing means
A_2	ammeter measuring a.c. r.m.s. current	C	output circuit
S_1	multipole switch	D	instrument indicating the change of status
S_2	two-pole switch	SCR	thyristor

Figure M.10 – Test circuits for the verification of operation in the case of a residual pulsating direct current superimposed by smooth direct current of 6 mA

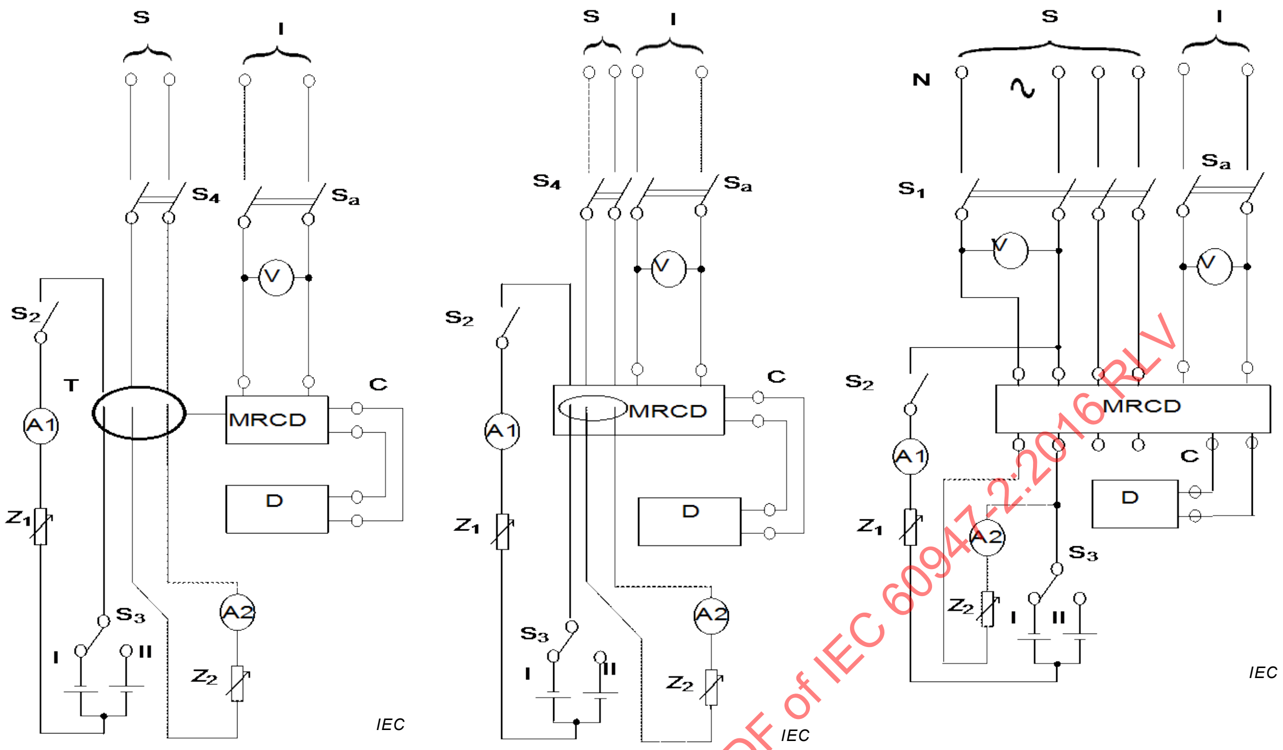


Figure M.11a) – MRCD with separate sensing means

Figure M.11b) – MRCD with integral sensing means

Figure M.11c) – Terminal type MRCD

Key

S	power supply	S_3	double inverter switch
I	separate voltage source, if applicable	S_4	two-pole switch
V	voltmeter	S_a	auxiliary switch
A_1	ammeter measuring d.c. current	Z_1, Z_2	variable impedances
A_2	ammeter measuring a.c. r.m.s. current	T	sensing means
S_1	multipole switch	C	output circuit
S_2	single-pole switch	D	instrument indicating the change of status

Figure M.11 – Test circuits for the verification of operation in the case of a slowly rising residual smooth direct current

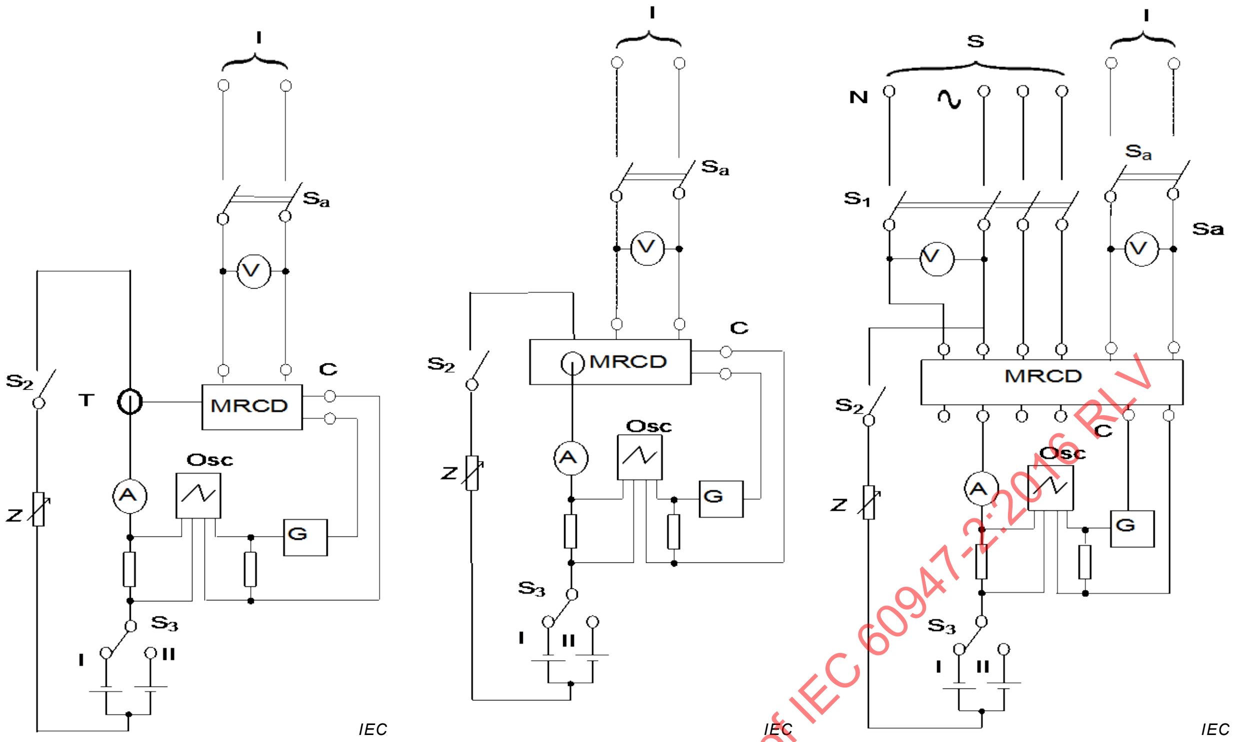


Figure M.12a) – MRCD with separate sensing means

Figure M.12b) – MRCD with integral sensing means

Figure M.12c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter measuring d.c. current	C	output circuit
S_1	multipole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch		

Figure M.12 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (without breaking device)

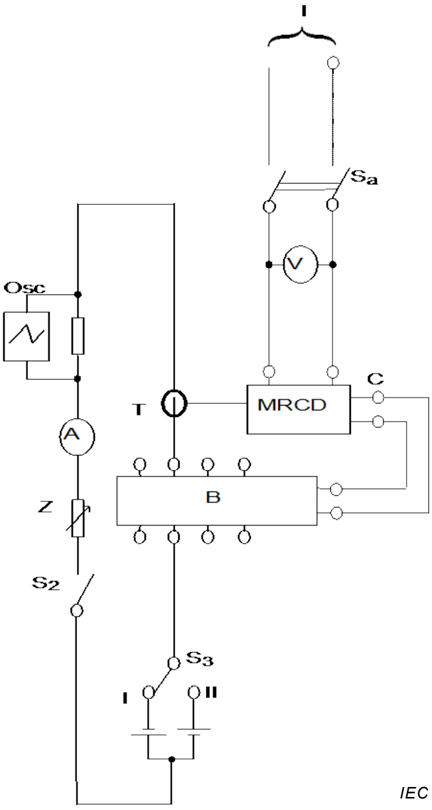


Figure M.13a) – MRCD with separate sensing means

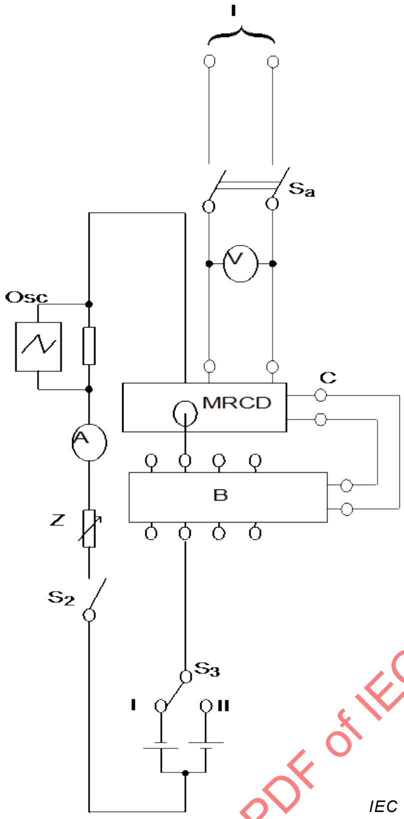


Figure M.13b) – MRCD with integral sensing means

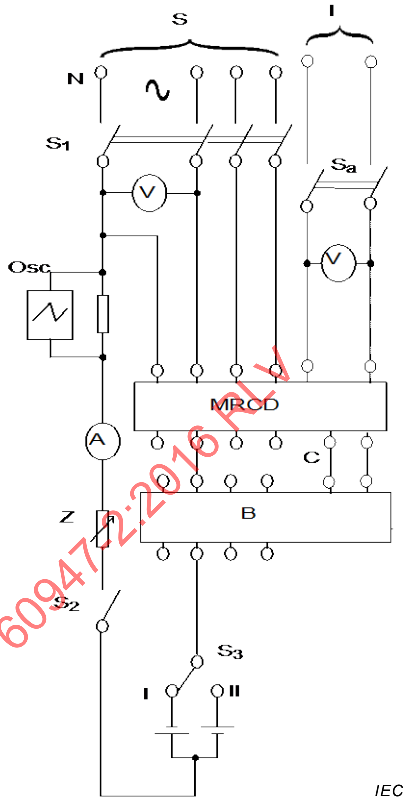


Figure M.13c) – Terminal type MRCD

Key

S power supply

I separate voltage source if applicable

V voltmeter

A ammeter measuring d.c. current

S_1 multipole switch

S_2 single-pole switch

S_3 inverter switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

B breaking device

Osc oscilloscope

Figure M.13 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (with breaking device)

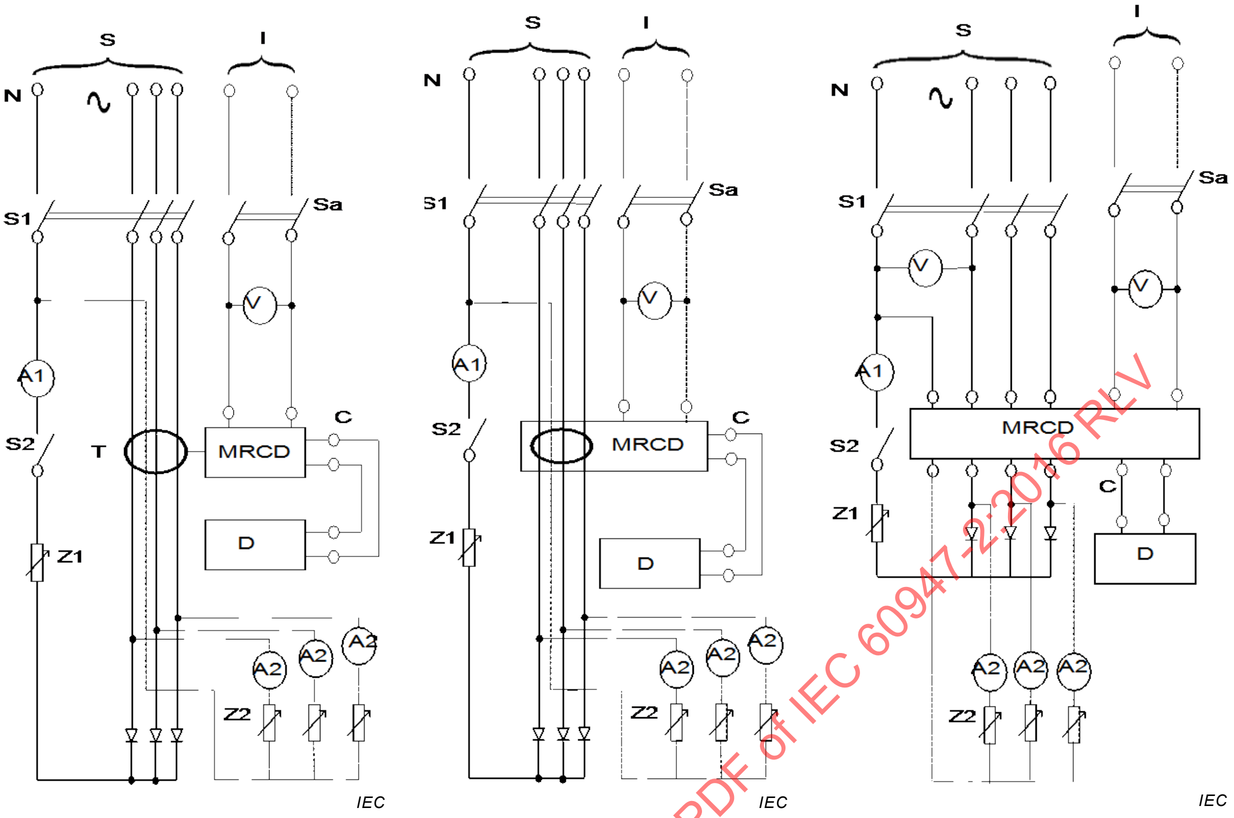


Figure M.14a) – MRCD with separate sensing means

Figure M.14b) – MRCD with integral sensing means

Figure M.14c) – Terminal type MRCD

Key

S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z_1, Z_2	variable impedances
A_1	ammeter measuring r.m.s. current	T	sensing means
A_2	ammeter measuring a.c. current	C	output circuit
S_1	multipole switch	D	instrument indicating the change of status

Figure M.14 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection

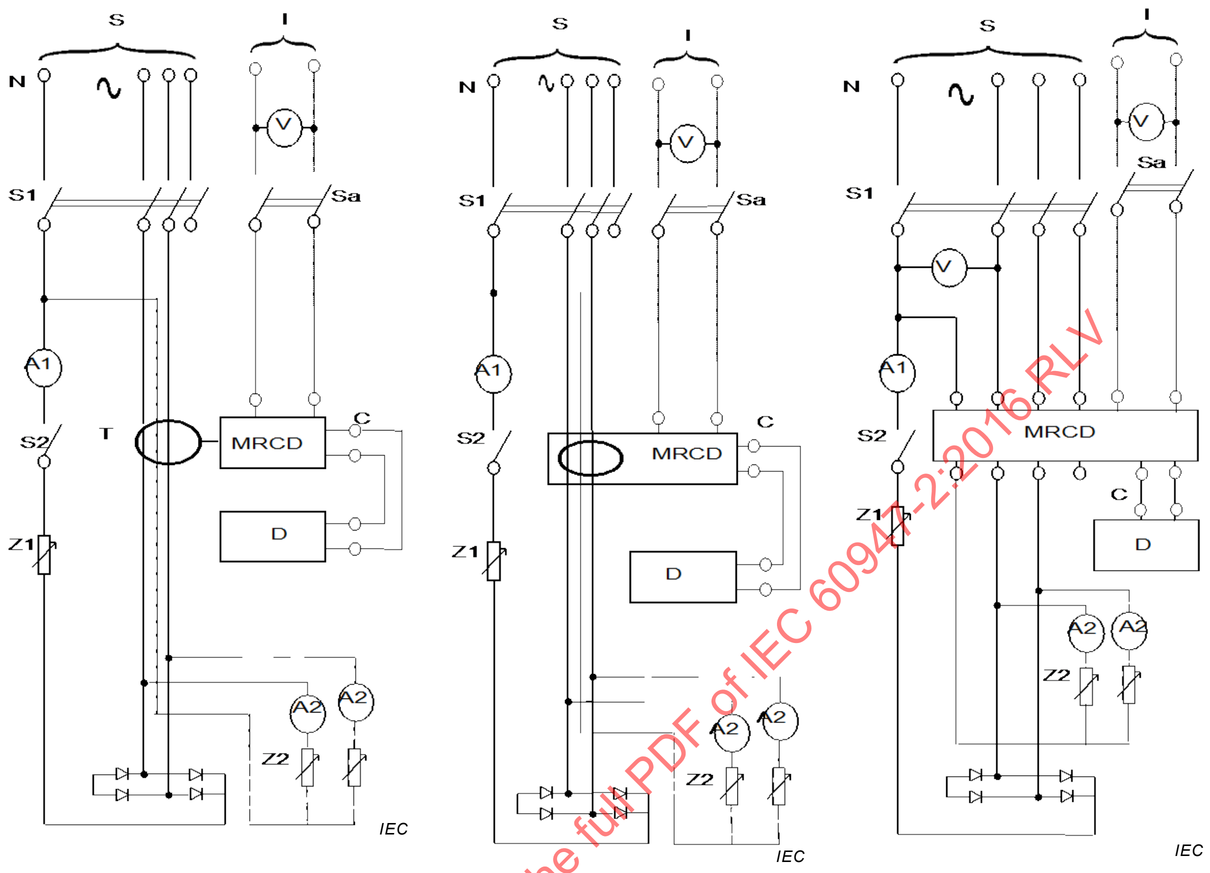


Figure M.15a) – MRCD with separate sensing means

Figure M.15b) – MRCD with integral sensing means

Figure M.15c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A_1 ammeter measuring r.m.s. current

A_2 ammeter measuring a.c. current

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

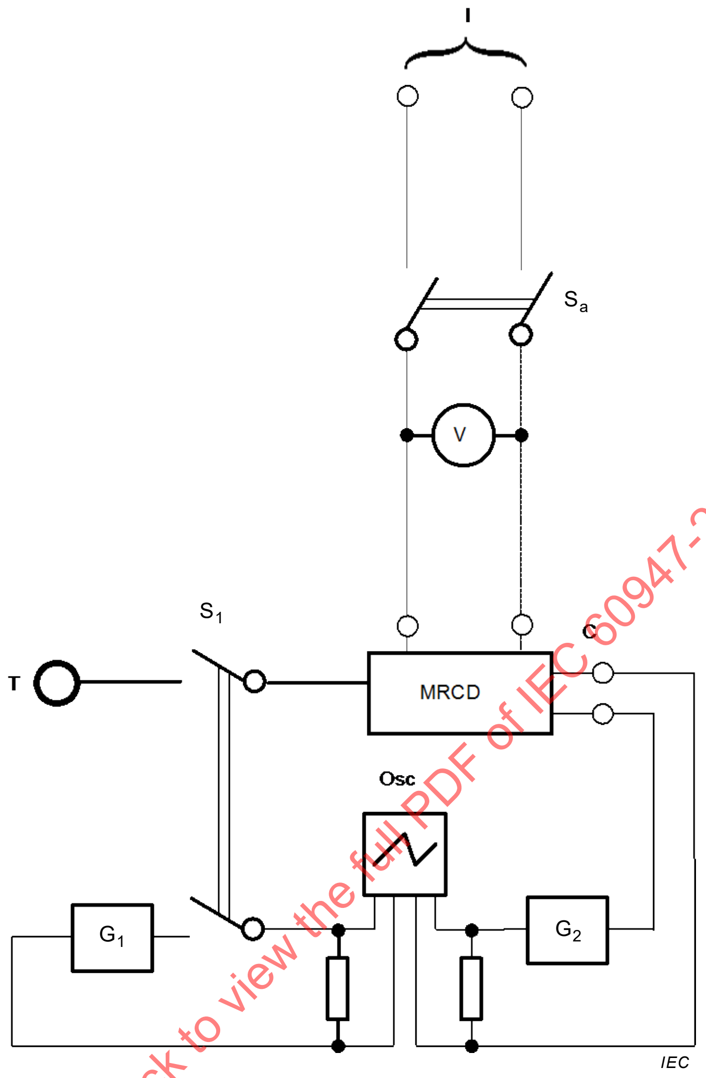
Z_1, Z_2 variable impedances

T sensing means

C output circuit

D instrument indicating the change of status

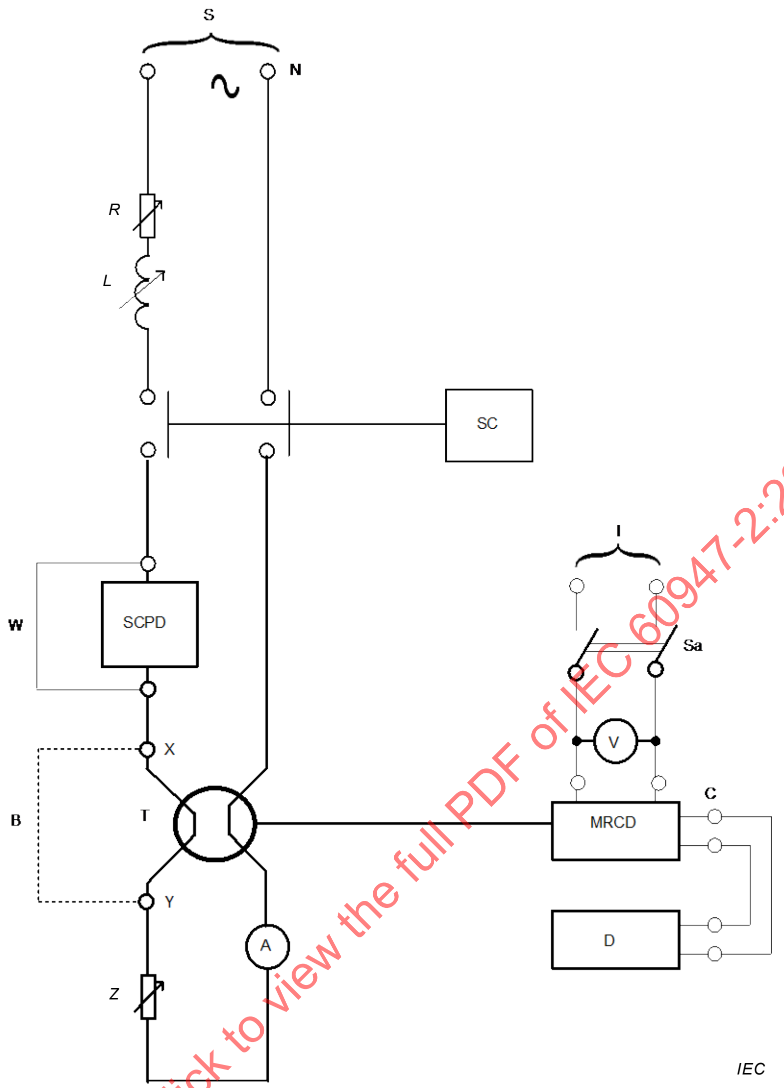
Figure M.15 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line



Key

I	separate voltage source, if applicable	T	sensing means
V	voltmeter	C	output circuit
S_1	multipole switch	G	generator
S_a	auxiliary switch	Osc	oscilloscope

Figure M.16 – Test circuit for the verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensor means connection



Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistance

Z variable impedance

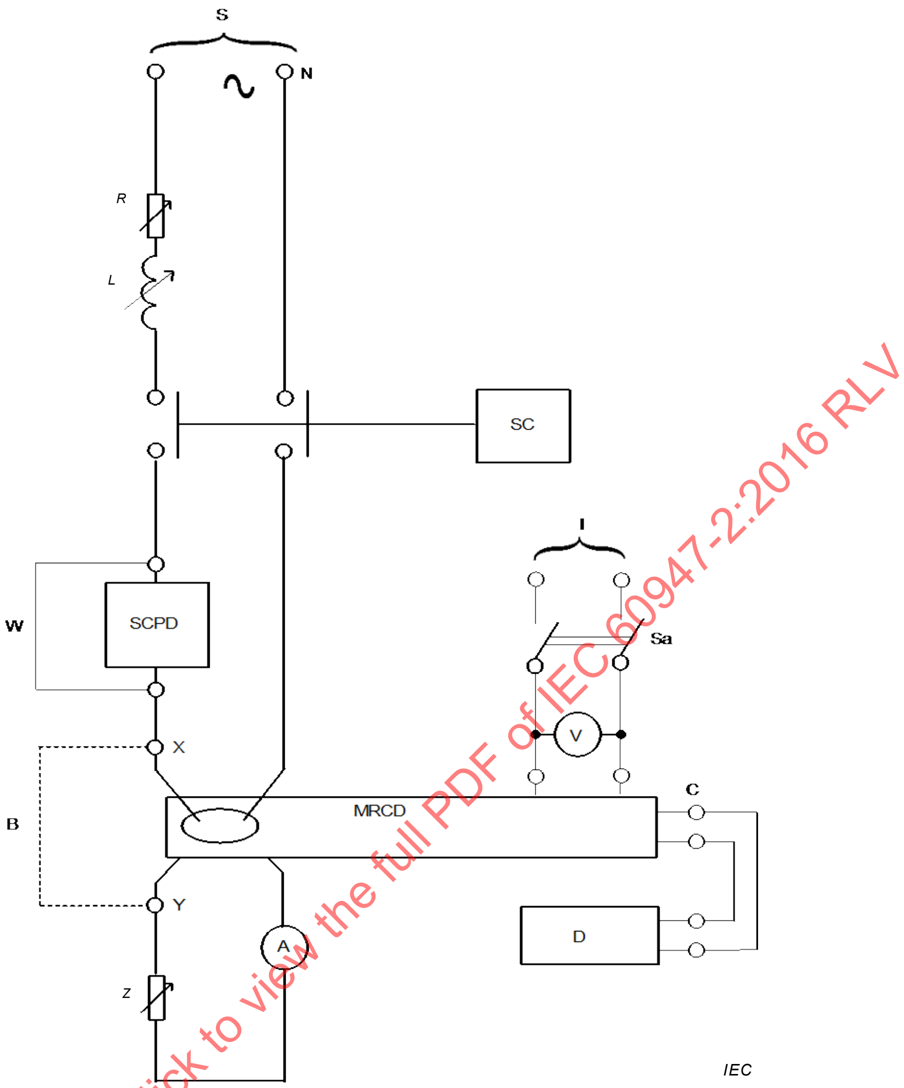
T sensing means

C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.17 – Test circuit for the verification of the behaviour of MRCD with separate sensing means under short-circuit conditions



Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistance

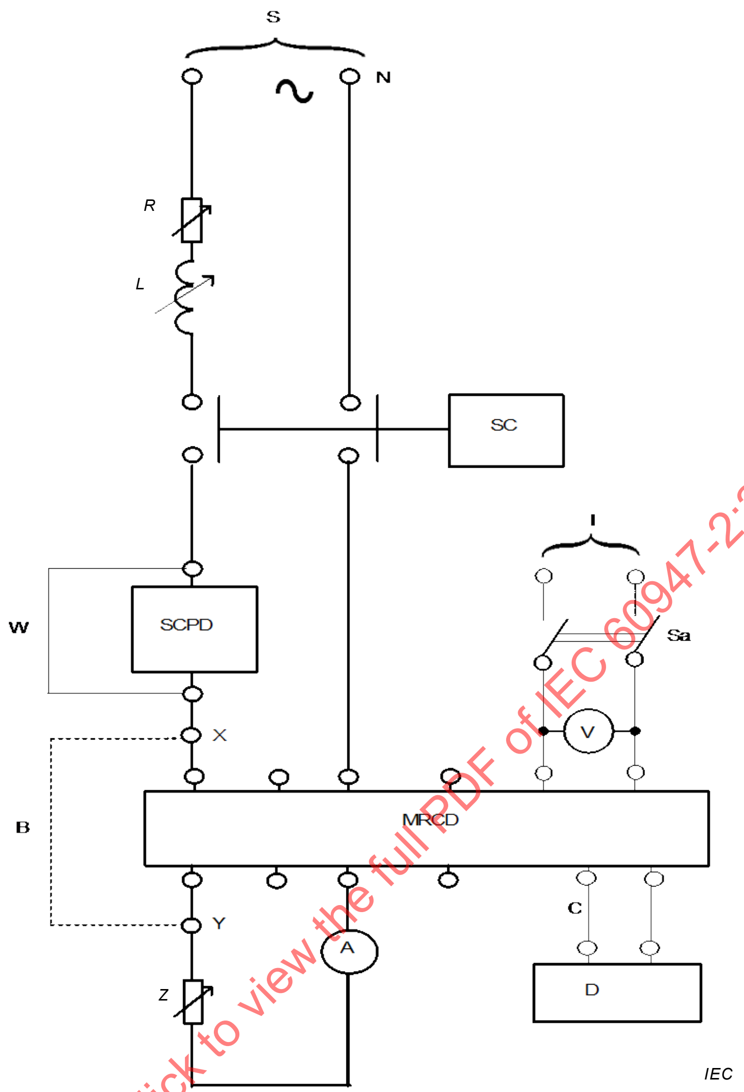
Z variable impedance

C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.18 – Test circuit for the verification of the behaviour of MRCD with integral sensing means under short-circuit conditions



Key

S power supply

A ammeter

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistor

Z variable impedance

C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.19 – Test circuit for the verification of the behaviour of terminal type MRCD under short-circuit conditions

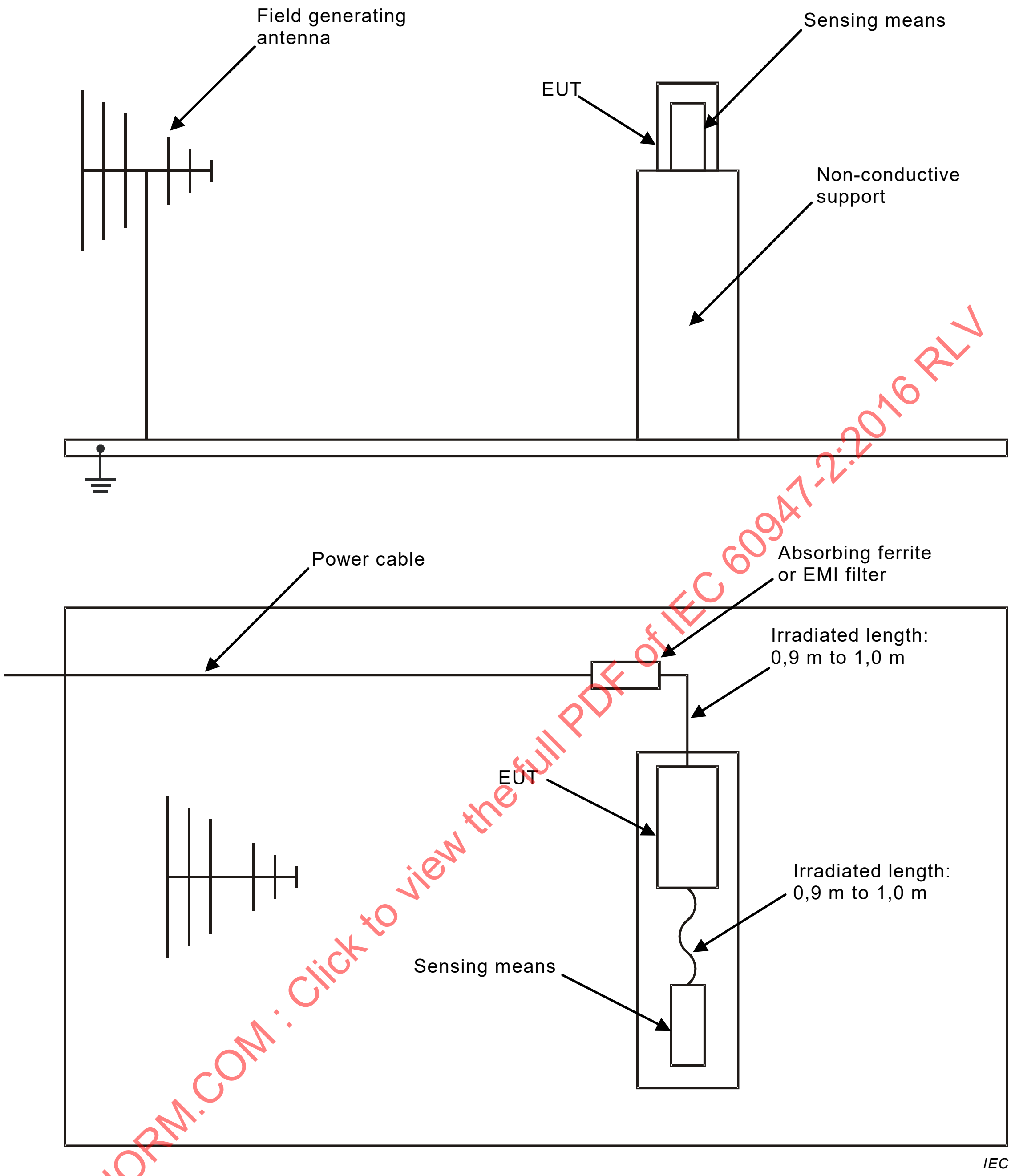


Figure M.20 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCD with separate sensing means (additional to the test of Annex B)

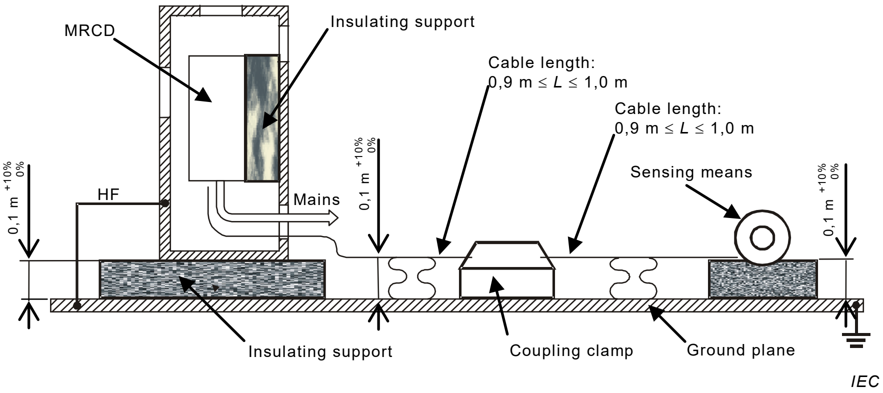


Figure M.21 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (additional to the test of Annex B)

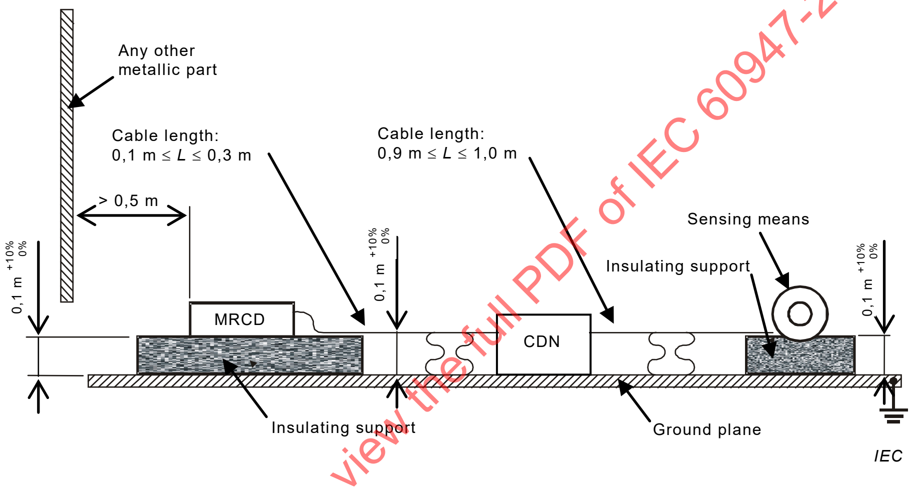


Figure M.22 – Verification of immunity to conducted disturbances induced by RF fields – Test set up for MRCD with separate sensing means (additional to the test of Annex B)

Annex N
(normative)

Electromagnetic compatibility (EMC) – Additional requirements and test methods for devices not covered by Annex B, Annex F and Annex M

N.1 General

N.1.1 ~~Scope~~ General

This annex applies to devices, mounted in or on the circuit-breaker, incorporating electronic circuits (see 7.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014), and not covered by Annex B (circuit-breakers incorporating residual current protection), Annex F (circuit-breakers with electronic overcurrent protection) and Annex M (modular residual current devices).

It covers circuit-breaker auxiliaries such as undervoltage releases, shunt releases, closing coils, motor-operators, remote status indicators, etc. Communication modules are not covered by these requirements.

It supplements Annex J, for test conditions and acceptance criteria specific to these devices.

N.1.2 General test conditions

Tests according to this annex may be performed separately from the test sequences of Clause 8.

A new device may be used for each test, or one device may be used for several tests, at the manufacturer's discretion.

For devices with different voltage supply ratings, one device of each rating shall be tested.

Tests on closing coils are not necessary if their construction (coil and electronic control) is identical to the equivalent shunt trips.

The devices shall be mounted in or on the circuit-breaker, in accordance with the manufacturer's instructions.

Undervoltage releases and power ports intended to be permanently connected to a power supply shall be supplied with the rated voltage. In case of a range of rated voltages, they shall be supplied at any convenient voltage within this range.

Devices rated from 50 Hz to 60 Hz may be tested at either one of the rated frequencies.

N.2 Immunity

N.2.1 General

N.2.1.1 Test conditions

Immunity tests may be performed on a circuit-breaker fitted with different devices, and may be combined with the corresponding tests of Annex B and Annex F, where applicable (e.g. electrostatic discharges, radiated ~~radio-frequency~~ RF electromagnetic fields, etc.).

Devices, except closing coils, shall be tested with the circuit-breaker closed.

Closing coils, if applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

N.2.1.2 Performance criteria

Criterion A: during the test, the status of the circuit-breaker shall not change and the status of the outputs of remote indication modules shall not change.

Criterion B: during the test, the status of the circuit-breaker shall not change while the status of the outputs of remote indication modules may change temporarily, but shall indicate the correct status of the circuit-breaker after the test.

After the tests, the simplified functional verification of N.2.1.3 shall be made.

N.2.1.3 Simplified functional verification

For both criteria, after the test, the operation of the device shall be checked at the rated voltage, or, in the case of a range of rated voltages, at any convenient voltage within this range:

a) An undervoltage release, when energized, shall not prevent the circuit-breaker from being closed; when the voltage is removed, the circuit-breaker shall trip.
b) A shunt trip, when energized, shall trip the circuit-breaker.
c) A closing coil, when energized, shall close the circuit-breaker.
d) A motor-operator, when energized in accordance with the manufacturer's instructions, shall be capable of closing and opening the circuit-breaker.

NOTE This test is intended only to check that the device has not been damaged during the immunity tests. It is not intended to check the full compliance with the requirements of the main body of this standard.

N.2.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

Performance criterion B of N.2.1.2 applies.

N.2.3 Radiated ~~radio-frequency~~ RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test connections shall be in accordance with Figures 5 or 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer's instructions for installation. The type of cable used shall be stated in the test report.

For step 1 (see J.2.3), the performance criterion A applies.

For step 2 (see J.2.3), at each of the frequencies listed in J.2.3, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figures ~~4,~~ 11, 12, 13 and 14 of IEC 61000-4-4:2012, taking into consideration the manufacturer's instructions for installation.

Performance criterion A applies.

N.2.5 Surges

Annex J applies, in particular J.2.5.

The test connections shall be in accordance with Figures 5, 6, 7, 8, 9, 10 or 11 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

N.2.6 Conducted disturbances induced by ~~radio-frequency~~ RF fields (common mode)

Annex J applies, in particular J.2.6.

For step 1 (see J.2.6), the performance criterion A applies.

For step 2 (see J.2.6), at each of the frequencies listed in J.2.6, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.7 Voltage dips and interruptions

These tests are applicable to devices with permanent a.c. power supply only.

Tests shall be performed in accordance with IEC 61000-4-11, at test levels of Table 23 of IEC 60947-1:2007/AMD1:2010.

During the test, the status of the circuit-breaker may change. The status of the outputs of remote indication modules may change, but shall indicate the correct status of the breaker after the test. After the test, the correct operation of the device shall be checked in accordance with N.2.1.3.

N.3 Emission

N.3.1 General

These tests are applicable to devices incorporating electronic circuits with fundamental switching frequencies greater than 9 kHz (see 7.3.3.2.1 of IEC 60947-1:2007/AMD2:2014), and intended for continuous operation (e.g. undervoltage releases).

They are not applicable to shunt trips intended only for use with a clearing switch, either built-in or separate.

They are not applicable to motor-operators not incorporating permanently energized electronic circuits, because these devices are operated at very infrequent intervals and the duration of the operations (closing, opening or resetting) is very short (a few hundreds of milliseconds to a few seconds).

Each device shall be submitted to separate emission tests, these tests shall not be combined with the corresponding tests of Annex B and Annex F.

Closing coils, when applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

Undervoltage releases and closing coils shall be tested with the circuit-breaker closed.

Shunt trips and motor-operators shall be tested with the circuit-breaker open.

Remote status indicators shall be tested with the circuit-breaker closed.

N.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

N.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

Annex J applies, in particular J.3.3.

Annex O
(normative)

Instantaneous trip circuit-breakers (ICB)

O.1 ~~Scope~~ General

This annex covers circuit-breakers which fulfil only the short-circuit portion of overcurrent protection specified in the main part of this standard, hereinafter referred to as ICBs. They comprise instantaneous short-circuit releases which may be adjustable but not overload releases. These devices are generally used in conjunction with other equipment such as motor-starters, overload relays, etc. In combination with specified overload relays, they offer complete overcurrent protection (overload and short-circuit) to both the circuit and specified equipment.

An ICB forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (see O.2.1) by omitting the overload releases and incorporating a short-circuit release, which may be adjustable, designed to provide co-ordinated overcurrent protection when associated with specified motor-starters or overload relays.

O.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

O.2.1
equivalent circuit-breaker
circuit-breaker from which the ICB has been derived, which has been tested according to this standard and which has the same frame size as the ICB

O.3 Rated values

O.3.1 General

The characteristics of Clause 4 apply with the exception of the reference to overload releases and with the following additions.

O.3.2 Rated current (I_n)

The rated current of an ICB shall not exceed the rated current of the equivalent circuit-breaker.

O.3.3 Rated short-circuit making capacity

ICBs may be assigned a rated short-circuit making capacity different to the equivalent circuit-breaker.

NOTE ICBs ~~may~~ can be assigned a rated short-circuit making capacity equal to or greater than that of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.3.4 Rated short-circuit breaking capacities

ICBs may be assigned rated short-circuit breaking capacities different to the equivalent circuit-breaker.

NOTE ICBs ~~may~~ can be assigned a rated short-circuit breaking capacity equal to or greater than I_{cu} of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.4 Product information

An ICB shall be marked according to 5.2 as relevant.

Rated short-circuit making and breaking capacities shall be marked, where applicable (see O.6.1.1). When the ICB is only rated for short-circuit performance in association with a motor-starter or overload relay (see O.6.2), the short-circuit ratings of the association shall not be marked on the ICB.

In addition the ICB shall be marked as follows:

– for 5.2, item a), add the marking “ICB”;

– for 5.2, item b), add the rated instantaneous short-circuit current settings I_i (see 2.20) (actual values or multiples of rated current).

Manufacturers’ instructions shall draw attention to the fact that, below the rated instantaneous short-circuit current settings, an ICB provides no overcurrent protection to itself or to the circuit. Such protection shall be provided separately.

When an ICB is not associated with a specified protected device (see O.6.2), the manufacturer shall provide data to permit the selection of suitable overload protection, e.g. withstand characteristics of the ICB up to its maximum instantaneous setting.

O.5 Constructional and performance requirements

An ICB, being derived from the equivalent circuit-breaker (see O.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4, item b).

O.6 Tests

O.6.1 Test sequence of the ICB alone

O.6.1.1 General

The tests of this subclause are not required if

– the short-circuit characteristics of the short-circuit releases and the main current paths of the ICB are the same as those of the equivalent circuit-breaker, or

– the ICB is only rated and tested as an association (see O.6.2).

A sample of each of the maximum and minimum values of the rated current I_n of each frame size shall be tested.

In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample shall be tested at the maximum rated current corresponding to each construction.

O.6.1.2 Test sequences

Tests shall be made according to sequences II and III of this standard without the verification of overload releases.

For ICBs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. The other variant(s) shall be submitted to the tests of sequence III only (without the verification of overload releases).

O.6.1.3 Verification of short-circuit releases

Following the test of O.6.1.2, a tripping test is made in accordance with 8.3.3.2.2 on each phase pole in turn, at the maximum setting of the rated instantaneous short-circuit current. The test is made at the value of the tripping current declared by the manufacturer for individual poles. The ICB shall trip.

O.6.2 ICB associated with a specified protected device (i.e. motor-starter or overload relay)

The applicable test requirements for these associations are covered in the relevant sections of IEC 60947-4-1, specifically the following clauses:

– co-ordination with short-circuit protective devices;

– additional requirements for combination starters and protected starters suitable for isolation;

– performance under short-circuit conditions;

– co-ordination at the crossover current between the starter and associated SCPD.

NOTE The symbol SCPD in IEC 60947-4-1 applies to various short-circuit protective devices, including the ICB.

Annex P
(normative)

DC circuit-breakers for use in photovoltaic (PV) applications

P.1 Field of application

This annex applies to d.c. circuit-breakers, rated up to 1 500 V d.c., intended for use with photovoltaic (PV) systems, and hereafter referred to as "PV circuit-breakers".

Circuit-breakers used in PV systems are subjected to electrical, environmental and operational conditions which differ from the general conditions taken into account in the body of this standard.

The requirements have thus been adapted to reflect these conditions of use.

The object of this annex is to state:

– the requirements for circuit-breakers to be used on the d.c. side of PV applications;
– the tests intended to verify the product performances and their maintaining after exposure to the PV service environmental conditions.

P.2 Terms and definitions

Clause 2 applies.

P.3 Classification

Clause 3 applies.

P.4 Characteristics of PV circuit-breakers

Clause 4 applies with the following modification:

A PV circuit-breaker rated for use not only in PV applications shall have only one rated current.

The impulse withstand voltage (U_{imp}) of PV circuit-breakers shall comply with Table P.1.

Table P.1 – Rated impulse withstand levels for PV circuit-breakers

Maximum value of rated operational voltage (V)	Value of rated impulse withstand voltage (V)
300	2 500
600	4 000
1 000	6 000
1 500	8 000
NOTE These values are based on requirements in IEC 60364-7-712 for overvoltage category II, as defined in IEC 60664-1 and IEC/TR 60664-2-1:2011, Annex D.	

P.5 Product information

Subclause 5.2 applies with the following additions:

A PV circuit-breaker shall be marked “IEC 60947-2, Annex P” under the conditions of item 5.2 b).

A circuit-breaker rated for use not only in PV applications shall have the ratings U_e and corresponding I_{cu} / I_{cs} according to this annex clearly separated from the ratings according to the body of this standard.

A PV circuit-breaker shall have method and diagram of series connection of poles (as necessary for each rating) marked under the conditions of item 5.2 c).

P.6 Normal service, mounting and transport conditions

Clause 6 applies with the following addition:

Guidance on de-rating for ambient air temperature up to 70 °C may be provided. In addition guidance on operation at temperature lower than -5 °C may also be given.

P.7 Constructional and performance requirements

P.7.1 Constructional requirements

Subclause 7.1 applies.

P.7.2 Performance requirements

Subclause 7.2 applies with the following modifications:

PV circuit-breakers shall be capable of interrupting any current up to their rated short-circuit breaking capacity, including critical load current, if exists, in both forward and reverse directions.

Compliance with these requirements is checked by the tests of P.8.3.

With reference to 7.2.4.1, such overload conditions do not arise in the case of PV applications. Overcurrent conditions can only result from a short-circuit. Therefore, no tests to this clause are required. Tests for short-circuit performance are given from P.8.3.4 to P.8.3.8.

With reference to 7.2.4.2 for operational performance capability, PV circuit-breakers shall be capable of meeting the requirements of Table P.2.

Table P.2 – Number of operating cycles

Rated current [a] (A)	Number of operating cycles per hour [b]	Number of operating cycles		
		Without current	With current [c]	Total
$I_n \leq 100$	120	9 700	300	10 000
$100 < I_n \leq 315$	120	7 800	200	8 000
$315 < I_n \leq 630$	60	4 800	200	5 000
$630 < I_n \leq 2\,500$	20	2 900	100	3 000
$2\,500 < I_n$	10	1 900	100	2 000

[a] This means the maximum rated current for a given frame size.

[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

[c] During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

Due to the installation rules defined in IEC 60364-7-712, the risk of a double fault to earth does not need to be taken in consideration. Therefore, Annex H of this standard is not applicable to PV circuit-breakers.

NOTE The case of a PV circuit-breaker having to interrupt a small fault current on one pole only is under consideration.

P.7.3 Electromagnetic compatibility (EMC)

Subclause 7.3 applies.

P.8 Tests

P.8.1 Kind of tests

Subclause 8.1 applies.

P.8.2 Compliance with constructional requirements

Subclause 8.2 applies.

P.8.3 Type tests

Subclause 8.3 applies with the following modifications:

P.8.3.1 Test sequences

With reference to 8.3.1.2, tests omitted from test sequence I need not be made if the PV circuit-breaker is derived from a circuit-breaker on which identical or more severe tests have already been conducted, except that tripping characteristics conducted in a.c. do not cover d.c. characteristics.

With reference to 8.3.1.4, alternative test programmes do not apply to PV circuit-breakers.

P.8.3.2 General test conditions

For all tests, the series connection of poles of the circuit-breaker shall be in accordance with the manufacturer instructions.

Samples shall be selected and tested according to column "Terminals marked line/load-No" of Table 10.

With reference to 8.3.2.2.5, the time constant for operational performance capability, short-circuit tests and critical d.c. load current test shall be equal to 1 ms. At the discretion of the manufacturer, a higher value may be used. In this case, it shall be stated in the test report.

P.8.3.3 Test sequence I

Subclause 8.3.3 applies with the following modifications:

With reference to 8.3.3.4.3, for operational performance capability without current, the number of operating cycles and the number of cycles per hour are given in Table P.2.

With reference to 8.3.3.4.4, for operational performance capability with current, the number of operating cycles and the number of cycles per hour are given in Table P.2, and the time constant shall comply with P.8.3.2. Half of the operations shall be made with the currents flowing in one direction, the other half with the other direction.

With reference to 8.3.3.5, the overload performance test is not applicable.

P.8.3.4 Test sequence II

Subclause 8.3.4 applies, with the modifications listed in P.8.3.2.

P.8.3.5 Test sequence III

Subclause 8.3.5 applies with the modifications listed in P.8.3.2.

P.8.3.6 Test sequence IV

Subclause 8.3.6 applies with the modifications listed in P.8.3.2.

P.8.3.7 Test sequence V

Subclause 8.3.7 applies with the modifications listed in P.8.3.2.

P.8.3.8 Test sequence VI

Subclause 8.3.8 applies with the modifications listed in P.8.3.2.

P.8.3.9 Critical d.c. load current test

Subclause 8.3.9 applies with the following modifications:

The circuit-breaker shall be closed and opened 10 times on to each of the test currents, 5 times with the current flowing in the forward direction, and 5 times with the current flowing in the reverse direction.

The time constant shall comply with P.8.3.2.

During the operational performance verification, if applicable, the breaker shall be subjected to 100 operations instead of 50.

P.8.3.10 Thermal cycling test

PV circuit-breakers shall be subjected to temperature cycling according to IEC 60068-2-14, test Nb, consisting of 50 cycles, each cycle consisting of 1 h at – 40 °C followed by 1 h at + 85 °C.

Temperature change rate shall be 1 K/min. At the conclusion of the 50 cycles, the devices shall be returned to room temperature of 25 ± 5 °C for a minimum of 3 h.

The device shall then be subjected to:

– a visual inspection to confirm that there is no distortion or damage to parts that will affect normal operation and protection;
– the verification of overload releases according to 8.3.3.2.3;
– a verification of temperature rise at the main terminals in accordance with 8.3.2.5. The temperature rise shall not exceed the values given in Table 7;
– a verification of dielectric withstand according to 8.3.3.6.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I.

P.8.3.11 Climatic test

PV circuit-breakers shall be subjected to the climatic tests of IEC 60947-1:2007/AMD1:2010/AMD2:2014 Annex Q, category B: environment subject to temperature and humidity, except that the dry heat test and the low temperature test are not required, as they are deemed to be covered by the thermal cycling test of P.8.3.10.

Where Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 calls for verification of operational performance capability, this shall be made by carrying out the routine tests to 8.4 of this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I. At the discretion of the manufacturer, this test may be combined with the thermal cycling test and made on the same samples.

P.8.4 Routine tests

Subclause 8.4 applies.

P.8.5 Special tests

Subclause 8.5 applies.

Annex Q

Vacant

Annex R
(normative)

Circuit-breakers incorporating residual current protection with automatic re-closing functions

R.1 General

R.1.1 Preamble

CBRs according to Annex B of this standard are used as protective devices to provide protection against the effects of electric shock hazards.

CBRs according to Annex B need to be manually reset after tripping.

CBRs may be installed at remote, unmanned locations such as telecommunication stations or traffic signaling sites. Where such a CBR is tripped due to a lightning surge or temporary earth leakage there will be a delay and cost in travel to site to effect rectification and restoration of the supply.

The results of this tripping by temporary faults such as the blackout of a mobile telecommunication station or malfunction of a traffic light system could cause inconvenience or danger to life.

CBRs with automatic reclosing functions are intended to improve the efficiency of operating unmanned facilities.

This annex is essentially based on the relevant requirements of Annex B of this standard.

R.1.2 Field of application

This annex applies to CBRs, hereinafter referred to as CBARs, which restore the power supply through automatic reclosing without manual operation, in the case of tripping due to the residual current function.

This annex also applies to automatic reclosing devices supplied separately which, when combined with a CBR, fulfils the requirements of a CBAR. For the purpose of this annex, the term CBAR also covers an automatic reclosing device combined with a CBR.

This annex also covers the requirements for CBARs concerning electromagnetic compatibility (EMC).

This annex applies only to CBARs intended for use in a.c. circuits.

The residual current function of CBARs according to this annex may or may not be functionally dependent on line voltage. CBARs depending on an alternative supply source for the residual current function are not covered by this annex.

The object of this annex is to state:

a) specific features of the automatic reclosing function;
b) specific requirements which shall be complied with by the CBAR:
   – under normal circuit conditions;
   – under abnormal circuit conditions;
   – under temporary fault conditions.

c) tests which shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures;

d) relevant product information.

R.2 Terms and definitions

As a complement to Clause 2 and Clause B.2 of this standard, the following additional terms and definitions apply:

R.2.1
automatic reclosing
operating sequence of a mechanical switching device whereby, following its opening, it closes automatically depending on specific conditions

[SOURCE: IEC 60050-441:1984, 441-16-10, modified – term and supplemented by "depending on specific conditions"]

R.2.2
rated automatic reclosing operating residual current
$I_{\Delta ar}$
maximum value of the residual current at which a type M CBAR recloses automatically under the specified conditions (see R.3.2.1)

R.2.3
selector switch
switch for selecting automatic reclosing or manual reclosing mode

R.2.4
reset time
maximum period of time, declared by the manufacturer, during which consecutive reclosing operations may be made

R.2.5
blocked state
state of the CBAR in which the automatic reclosing function is inhibited and a manual reset is necessary

R.2.6
reclosing time-delay
for type TD CBAR, maximum time between the tripping of the device and the reclosing of the contacts

Note 1 to entry: For definition of type TD CBAR, see R.3.2.2.

R.2.7
reclosing time
for type M CBAR, maximum time between the instant when the reclosing condition is fulfilled and the reclosing of the contacts

Note 1 to entry: For definition of type M CBAR, see R.3.2.1.

R.2.8
monitoring time
for type M CBARs, time during which the monitoring is effective after operation of the residual current tripping function

R.3 Classification

As a complement to Clause 3 and Clause B.3 of this standard, the following additional classifications apply.

R.3.1 According to the method of construction

R.3.1.1 Integral CBAR

CBAR as a single unit comprising an automatic reclosing function integrated by the manufacturer with the circuit-breaker.

R.3.1.2 External automatic reclosing device

An automatic reclosing device externally connected to a CBR without modification of its internal circuits or components.

R.3.2 According to the method of automatic reclosing

R.3.2.1 Earth leakage monitoring type (M)

CBAR, hereafter called "type M", which monitors the downstream circuit to assess the presence of an earth fault, and does not allow reclosing when the assessed earth leakage current exceeds $I_{\Delta ar}$.

The monitoring shall be achieved through the use of the line voltage. It may be either continuous or intermittent.

Type M CBARs with limitation of test voltage monitors the downstream circuit by means of a non-hazardous voltage, hereinafter called "monitoring voltage".

Type M CBARs with limitation of test current monitors the downstream circuit by means of a non-hazardous current, hereinafter called "monitoring current".

R.3.2.2 Time-delay type (TD)

CBAR, hereafter called "type TD", for which the automatic re-closing takes place after a time-delay without consideration of the circuit conditions.

R.4 Characteristics

Clause 4 and Clause B.4 of this standard apply with the following addition.

R.4.1 Rated automatic reclosing operating residual current ($I_{\Delta ar}$)

The value of the rated automatic reclosing operating residual current shall be declared by the manufacturer, without exceeding $I_{\Delta n}$. The manufacturer may declare different values of $I_{\Delta ar}$ for different rated voltages.

R.4.2 Maximum number of consecutive reclosing operations

The reset time and the maximum number of consecutive reclosing operations within the reset time shall be declared by the manufacturer.

R.5 Marking and instructions

As a complement to Clause 5 and Clause B.5 of this standard, the following additional marking shall apply:

a) The following data shall be marked on the device, in addition to the marking specified in 5.2 a) and B.5, and be clearly visible in the installed position:
   – indication of mode selection of the selector switch: "automatic reclosing" and "manual reclosing";

b) The following data shall also be marked externally on the device, as specified in item a), except that they need not be visible when the device is installed. This data shall also be made available in the manufacturer's literature:
   – rated control circuit supply voltage (U_s) of the CBAR, if applicable;
   – rated automatic reclosing operating residual current ($I_{\Delta ar}$);
   – meaning of the indicators (e.g. lamps), if applicable;

c) The following data shall either be marked on the device as specified in item b), or made available in the manufacturer's literature:
   – procedure for replacement of any built-in fuse;
   – procedure for the connection of the earth terminal when necessary for the automatic reclosing function;
   – reset time and corresponding maximum number of reclosing operations;
   – monitoring time and reclosing time for type M CBARs;
   – reclosing time-delay for type TD CBARs.

R.6 Normal service, mounting and transport conditions

Clause 6 applies.

R.7 Design and operating requirements

R.7.1 Design requirements

As a complement to 7.1 and B.7.1 of this standard, the following additional requirements apply:

R.7.1.1 Mode selection

The device shall be equipped with a selector switch (see R.2.3).

Compliance is checked by the tests of R.8.4.4.

R.7.1.2 Indicators

The device shall be provided with an indicator showing the blocked state.

All indicators shall be visible in the installed position.

R.7.1.3 Type M CBARs

It shall be ensured that no hazardous voltage or current is applied to the load terminals. One of the following methods shall be employed:

– The monitoring voltage (see R.3.2.1) shall be supplied by a transformer providing Class II isolation between primary and secondary circuits. The monitoring voltage shall not exceed 25 V a.c. or 60 V d.c.; or

– The monitoring current (see R.3.2.1) shall be supplied from a current-limiting source or a protective impedance device complying with IEC 61140. The steady-state current shall not exceed 1 mA a.c. or 2 mA d.c.

R.7.2 Operating requirements

As a complement to 7.2 and B.7.2 of this standard, the following additional requirements apply:

R.7.2.1 General

CBARs shall only reclose automatically after tripping due to the residual current function. Compliance is checked by the tests of R.8.2.

CBARs shall not reclose automatically after intentional opening of the circuit-breaker. Compliance is checked by the tests of R.8.3.

When the maximum number of automatic reclosing operations within the reset time is reached, the automatic reclosing function shall be blocked until a manual reset is performed.

The reset time shall be not less than 5 s.

R.7.2.2 Type M CBARs

After tripping of the residual current release, if the assessed earth leakage current is lower than $I_{\Delta ar}$, a type M CBAR shall automatically reclose within the reclosing time declared by the manufacturer.

After tripping of the residual current release, if the assessed earth leakage current is higher than $I_{\Delta ar}$, the automatic reclosing shall be inhibited. In this case, the monitoring shall not be effective for a period of time longer than the monitoring time declared by the manufacturer. After this time, the automatic reclosing function shall be blocked.

The monitoring time shall be less than 1 h.

Compliance is checked by the tests of R.8.4.2.

R.7.2.3 Type TD CBAR

After tripping due to the residual current function, a type TD CBAR shall automatically reclose within the reclosing time-delay declared by the manufacturer, unless it has reached the maximum number of consecutive reclosing operations within the reset time.

Compliance is checked by the tests of R.8.4.3.

NOTE A type TD CBAR will not reclose on a phase-to-phase short-circuit, but can potentially reclose on a phase-to-ground fault.

R.7.2.4 Residual short-circuit making and breaking capacity

CBARs shall make, carry for a specified time and break residual short-circuit currents.

Compliance is checked by the tests of R.8.7.

R.7.2.5 Effects of environmental conditions

CBARs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the tests of R.8.8.

R.8 Tests

R.8.1 General conditions

As a complement to Clause 8 and Clause B.8 of this standard, the following additional requirements apply.

Integral CBARs shall meet the test requirements from R.8.2 to R.8.8 except that the tests of R.8.6 only apply to CBARs suitable for isolation.

One sample shall be submitted to the tests of R.8.2, R.8.3 and R.8.4 in sequence.

The tests from R.8.5 to R.8.8 may be made during the test sequences of Clause 8.

External CBARs shall meet the test requirements of R.8.9.

Tests shall be performed in automatic reclosing mode, unless otherwise stated, the CBAR being supplied with the maximum rated voltage and the rated control circuit supply voltage, if applicable.

The CBAR shall be connected as per the manufacturer's instructions.

EMC tests of B.8.12 shall be performed in both automatic re-closing mode and manual re-closing mode.

R.8.2 Verification of the non-reclosing after tripping under over-current conditions

R.8.2.1 Tripping under short-circuit conditions

The circuit-breaker shall be tripped through its short-circuit release by applying a test current higher or equal to 120 % of the short-circuit current setting on one combination of two poles in series chosen at random (see 8.3.3.2.2). In case of adjustable current setting, the test shall be performed at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker short-circuit release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

R.8.2.2 Tripping under overload conditions

The circuit-breaker shall be tripped through its overload release by applying a test current higher than 130 % of the overload current setting and lower than 80 % of the short circuit current setting. This test may be performed at any ambient temperature and in case of adjustable current setting, at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker overload release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

R.8.3 Verification of the non-reclosing after intentional opening

The selector switch being in the "automatic reclosing" position and the control circuit supply voltage normally applied, the circuit-breaker is opened manually. The device shall not reclose automatically after opening. The test duration shall be twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

This test shall be repeated for opening through shunt trip or undervoltage release as applicable, using any convenient rated control voltage variant.

R.8.4 Verification of the automatic reclosing function after tripping on earth fault

R.8.4.1 General

The devices shall be installed as in normal use.

The test circuit shall be in accordance with Figure R.1.

R.8.4.2 Verification of the correct operation of type M CBARs

R.8.4.2.1 In case of continuous residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

The switch S_2 shall be maintained in the closed position for the monitoring time declared by the manufacturer (see R.7.2.2).

The monitoring voltage or current shall comply with the requirements of R.7.1.3.

The CBAR shall not reclose automatically.

At the end of the monitoring time, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

R.8.4.2.2 In case of temporary residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.The CBAR shall trip.

After tripping, the residual current is reduced to the value of $I_{\Delta ar}$ corresponding to the applied voltage.

The CBAR shall reclose automatically within the reclosing time declared by the manufacturer.

The test is repeated as many times as necessary to verify the maximum number of consecutive reclosing operations within the reset time, as declared by the manufacturer. At the end of the test, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

R.8.4.3 Verification of the correct operation of type TD CBARs

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay (Δt) as applicable.

The test circuit being calibrated at 2 × $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall reclose automatically within the reclosing time-delay, repeated for the maximum number of consecutive reclosings within the reset time, as declared by the manufacturer.

At the end of the test, the CBAR shall be in the blocked state.

R.8.4.4 Verification of the correct operation of the selector switch

The test is made on one pole only chosen at random, with the selector switch in the "manual reclosing" position, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit being calibrated at 2 × $I_{\Delta n}$, and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

Immediately after tripping, the switch S_2 is re-opened; the CBAR shall not reclose automatically within twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

R.8.5 Verification of mechanical endurance

R.8.5.1 External automatic reclosing device combined with a CBR previously tested to Annex B or CBAR previously tested to Annex B

The test circuit is in accordance with Figure R.1.

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit is calibrated at 2 × $I_{\Delta n}$. With the switch S_1 and the CBAR in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall be reclosed automatically.

The test shall be repeated for one-third of the number of "operations with current" specified in Table 8. No failure to trip or to reclose shall be permitted.

NOTE Depending on the reset time and corresponding maximum number of consecutive reclosing operations, it may be necessary to manually reset the CBAR or inhibit the blocking function.

R.8.5.2 CBAR not previously tested to Annex B

The test of R.8.5.1 may be carried out separately or during the operational performance test of B.8.1.1.1, replacing the operations performed by applying a residual current.

R.8.6 Verification of the isolation function

R.8.6.1 General

This verification only applies to CBARs suitable for isolation.

The tests of R.8.6.2 and R.8.6.3 shall be performed in all positions of the selector switch and in the blocked state.

R.8.6.2 Leakage current between open contacts

The following requirements apply:

a) Following the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA.
b) Following the test of 8.3.3.6 (Test sequence I, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.
c) Following the test of 8.3.4.4 (Test sequence II, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.
d) If applicable, following the test of 8.3.5.4 (Test sequence III, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 6 mA.

R.8.6.3 Impulse voltage between open contacts

During the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the test voltage shall be applied between the line terminals being connected together and load terminals being connected together of CBARs with the contacts in the open position and its value shall be as specified in Table 14 of IEC 60947-1:2007.

There shall be no unintentional disruptive discharge during the tests.

R.8.7 Verification of residual short-circuit making and breaking capacity

B.8.10 applies, with the following additional requirements:

The tests shall be performed in automatic reclosing mode, if applicable, with the line voltage (i.e. control circuit supply voltage) connected to the CBAR.

The following additional requirements shall be met after test:

– The CBAR shall comply with the test of B.8.10.4.2 regardless of the operation of the protection devices (fuse, etc.);
– In case of operation of the protection devices (fuse, etc.), this operation shall be shown by the appropriate indication means, if provided. If no indication mean is provided, it shall not be possible to reclose the CBAR, even manually, when the protection devices have operated.

R.8.8 Verification of the automatic reclosing function after the test sequences of Clause B.8

Following each of the verifications of B.8.1.1.2 (verification of the withstand capability to short-circuit currents), a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

Following each of the test sequences B I to B IV of Annex B, a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

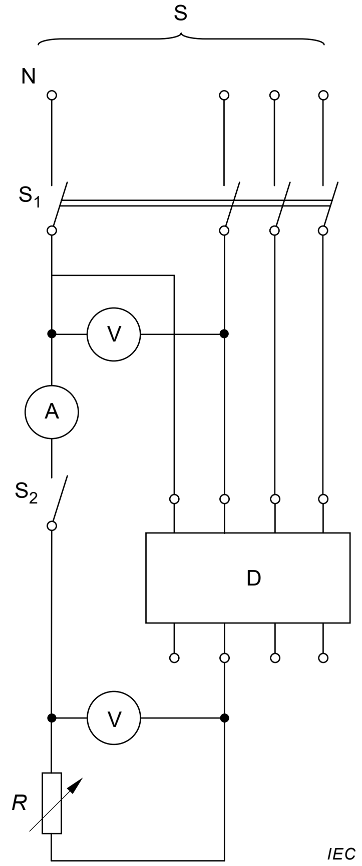
R.8.9 Test items for external type automatic reclosing devices

The following test sequences shall be performed on CBARs classified under R.3.1.2, in accordance with Figure R.1.

These tests are applicable to an automatic reclosing device assembled to a CBR and do not replace the tests of Clause B.8 made on the CBR.

Table R.1 – Test sequences for external type automatic re-closing devices

Sequence (sample)	Test	Subclause
1	Verification of the non-reclosing after tripping under over-current conditions	R.8.2
	Verification of the non-reclosing after intentional opening	R.8.3
	Verification of the automatic reclosing function after tripping on earth faults	R.8.4
	Verification of mechanical endurance	R.8.5
	Verification of the isolation function	R.8.6
2	Verification of the residual short-circuit making and breaking capacity	R.8.7
3	Rated ultimate short-circuit breaking capacity	8.3.5
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
4	Verification of the effects of environmental conditions	B.8.11
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
5	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Verification of electromagnetic compatibility	B.8.12
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8



Key:

S = power supply

N = neutral connection

S_1 = multipole switch

S_2 = single-pole switch

V = voltmeter

A = r.m.s. ammeter

D = CBAR under test

R = adjustable resistor

Figure R.1 – Test circuit for the verification of the automatic reclosing functions

Bibliography

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 60050-442:1998, *International Electrotechnical Vocabulary (IEV) – Part 442: Electrical accessories*
IEC 60050-442:1998/AMD1:2015

IEC 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials* ~~*under moist conditions*~~

~~IEC 60269-1, *Low-voltage fuses – Part 1: General requirements*~~

~~IEC 60269-2-1, *Low-voltage fuses – Part 2-1: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Sections I to VI: Examples of types of standardized fuses*~~

~~IEC 60269-3, *Low-voltage fuses – Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications)*~~

IEC 60364-7-712, *Electrical installations of buildings – Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 60410, *Sampling plans and procedures for inspection by attributes*[3]

IEC 60417-DB[4], *Graphical symbols for use on equipment*

~~IEC 60439 (all parts), *Low-voltage switchgear and controlgear assemblies*~~

IEC 60617-DB[5], *Graphical symbols for diagrams*

IEC/TR 60664-2-1:2011, *Insulation coordination for equipment within low voltage systems – Part 2-1: Application guide – Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing*

IEC/TR 60755:2008, *General requirements for residual current operated protective devices*

IEC 60898 (all parts), *Circuit-breakers for overcurrent protection for household and similar installations*

IEC 60934, *Circuit-breakers for equipment (CBE)*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

3 This publication was withdrawn.

4 "DB" refers to the IEC on-line database.

5 "DB" refers to the IEC on-line database.

IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61000-4-13, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*

IEC 61008-1:2010, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*
IEC 61008-1:2010/AMD1:2012
IEC 61008-1:2010/AMD2:2013

IEC 61009-1:2010, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 1: General rules*
IEC 61009-1:2010/AMD1:2012
IEC 61009-1:2010/AMD2:2013

IEC 61131-1:2003, *Programmable controllers – Part 1: General information*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

EN 50557, *Requirements for automatic reclosing devices (ARDs) for circuit-breakers RCBOs-RCCBs for household and similar uses*

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INTERNATIONAL STANDARD

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**Low-voltage switchgear and controlgear –
Part 2: Circuit-breakers**

**Appareillage à basse tension –
Partie 2: Disjoncteurs**

IEC 60947-2:2016-06(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60947-2 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low-voltage.

This fifth edition cancels and replaces the fourth edition published in 2006, Amendment 1:2009 and Amendment 2:2013. This edition constitutes a technical revision.

This edition includes the following significant additions with respect to the previous edition:

- tests for verification of selectivity in Annex A (see A.5.3);
- critical load current tests for d.c. circuit-breakers (see 8.3.9);
- new Annex P for circuit-breakers for use in photovoltaic applications;
- new Annex R for residual-current circuit-breakers with automatic reclosing functions.

The text of this standard is based on the following documents:

FDIS	Report on voting
121A/71/FDIS	121A/83/RVD

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

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

A list of all parts in the IEC 60947 series, published under the general title *Low-voltage switchgear and controlgear*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 60947-1:2007 and its Amendment 1:2010 and Amendment 2:2014.

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1 and its amendments when applicable, for example, 1.2.3 of IEC 60947-1:2007, Table 4 of IEC 60947-1:2007/AMD1:2010, or Annex A of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

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

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

The contents of the corrigendum of November 2016 have been included in this copy.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

1 General

1.1 Scope and object

This part of IEC 60947 series applies to circuit-breakers, the main contacts of which are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.; it also contains additional requirements for integrally fused circuit-breakers.

Circuit-breakers rated above 1 000 V a.c. but not exceeding 1 500 V a.c. may also be tested to this standard.

It applies whatever the rated currents, the method of construction or the proposed applications of the circuit-breakers may be.

The requirements for circuit-breakers which are also intended to provide earth leakage protection are contained in Annex B.

The additional requirements for circuit-breakers with electronic over-current protection are contained in Annex F.

The additional requirements for circuit-breakers for IT systems are contained in Annex H.

The requirements and test methods for electromagnetic compatibility of circuit-breakers are contained in Annex J.

The requirements for circuit-breakers not fulfilling the requirements for over-current protection are contained in Annex L.

The requirements for modular residual current devices (without integral current breaking device) are contained in Annex M.

The requirements and test methods for electromagnetic compatibility of circuit-breaker auxiliaries are contained in Annex N.

The requirements and test methods for d.c. circuit-breakers for use in photovoltaic (PV) applications are contained in Annex P.

The requirements and test methods for circuit-breakers incorporating residual current protection with automatic reclosing functions are contained in Annex R.

Supplementary requirements for circuit-breakers used as direct-on-line starters are given in IEC 60947-4-1, applicable to low-voltage contactors and starters.

The requirements for circuit-breakers for the protection of wiring installations in buildings and similar applications, and designed for use by uninstructed persons, are contained in IEC 60898.

The requirements for circuit-breakers for equipment (for example electrical appliances) are contained in IEC 60934.

For certain specific applications (for example traction, rolling mills, marine service) particular or additional requirements may be necessary.

NOTE Circuit-breakers which are dealt with in this standard can be provided with devices for automatic opening under predetermined conditions other than those of over-current and undervoltage as, for example, reversal of power or current. This standard does not deal with the verification of operation under such pre-determined conditions.

The object of this standard is to state:

a) the characteristics of circuit-breakers;
b) the conditions with which circuit-breakers shall comply with reference to:
   1) operation and behaviour in normal service;
   2) operation and behaviour in case of overload and operation and behaviour in case of short-circuit, including co-ordination in service (selectivity and back-up protection);
   3) dielectric properties;
c) tests intended for confirming that these conditions have been met and the methods to be adopted for these tests;
d) information to be marked on or given with the apparatus.

1.2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

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

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

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

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection*

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

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

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

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

IEC 62475:2010, *High-current test techniques – Definitions and requirements for test currents and measuring systems*

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

CISPR 22, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*

2 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60947-1, as well as the following apply.

NOTE Where these definitions are taken unchanged from the *International Electrotechnical Vocabulary (IEV)*, IEC 60050-441, the reference to this publication is given in brackets.

2.1
circuit-breaker
a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20]

2.1.1
frame size
a term designating a group of circuit-breakers, the external physical dimensions of which are common to a range of current ratings.

Note 1 to entry: Frame size is expressed in amperes corresponding to the highest current rating of the group.

Note 2 to entry: Within a frame size, the width may vary according to the number of poles.

Note 3 to entry: This definition does not imply dimensional standardization.

2.1.2
construction break
a significant difference in construction between circuit-breakers of a given frame size, requiring additional type testing

2.2
integrally fused circuit-breaker
a combination, in a single device, of a circuit-breaker and fuses, one fuse being placed in series with each pole of the circuit-breaker intended to be connected to a phase conductor

[SOURCE: IEC 60050-441:1984, 441-14-22]

2.3
current-limiting circuit-breaker
circuit-breaker that, within a specified range of current, prevents the let-through current reaching the prospective peak value and which limits the let-through energy (I^2t) to a value less than the let-through energy of a half-cycle wave of the symmetrical prospective current

Note 1 to entry: Reference may be made to either the symmetrical or asymmetrical prospective peak value of let-through current.

Note 2 to entry: The let-through current is also referred to as the cut-off current (see IEC 60050-441:1984, 441-17-12).

Note 3 to entry: Templates for the graphical representation of the cut-off current characteristic and the let-through energy characteristic are given from Figure K.2 to Figure K.5 and examples of the use of the templates in Figure K.6 and in Figure K.7.

2.4
plug-in circuit-breaker
a circuit-breaker which, in addition to its interrupting contacts, has a set of contacts which enable the circuit-breaker to be removed

Note 1 to entry: Some circuit-breakers may be of the plug-in type on the line side only, the load terminals being usually suitable for wiring connection.

2.5
withdrawable circuit-breaker
circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be withdrawn from the main circuit, and, in the disconnected position, to achieve an isolating distance in accordance with specified requirements

2.6
moulded-case circuit-breaker
a circuit-breaker having a supporting housing of moulded insulating material forming an integral part of the circuit-breaker

[SOURCE: IEC 60050-441:1984, 441-14-24]

2.7
air circuit-breaker
a circuit-breaker in which the contacts open and close in air at atmospheric pressure

[SOURCE: IEC 60050-441:1984, 441-14-27]

2.8
vacuum circuit-breaker
a circuit-breaker in which the contacts open and close within a highly evacuated envelope

[SOURCE: IEC 60050-441:1984, 441-14-29]

2.9
gas circuit-breaker
a circuit-breaker in which the contacts open and close in a gas other than air at atmospheric or higher pressure

2.10
making-current release
a release which permits a circuit-breaker to open, without any intentional time-delay, during a closing operation, if the making current exceeds a predetermined value, and which is rendered inoperative when the circuit-breaker is in the closed position

2.11
short-circuit release
an over-current release intended for protection against short circuits

2.12
short-time delay short-circuit release
an over-current release intended to operate at the end of the short-time delay

2.13
alarm switch
an auxiliary switch which operates only upon the tripping of the circuit-breaker with which it is associated

2.14
circuit-breaker with lock-out device preventing closing
a circuit-breaker in which each of the moving contacts is prevented from closing sufficiently to be capable of passing current if the closing command is initiated while specified conditions remain established

2.15
short-circuit breaking (or making) capacity
a breaking (or making) capacity for which the prescribed conditions include a short circuit

2.15.1
ultimate short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence do not include the capability of the circuit-breaker to carry its rated current continuously

2.15.2
service short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence include the capability of the circuit-breaker to carry its rated current continuously

2.16
opening time
interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry:

- in the case of a directly operated circuit-breaker, the instant of initiation of the opening time is the instant of initiation of a current large enough to cause the circuit-breaker to operate;
- in the case of a circuit-breaker operated by any form of auxiliary power, the instant of initiation of the opening time is the instant of application or removal of the auxiliary power to the opening release.

Note 2 to entry: For circuit-breakers "opening time" is commonly referred to as "tripping time", although, strictly speaking, tripping time applies to the time between the instant of initiation of the opening time and the instant when the opening command becomes irreversible.

[SOURCE: IEC 60947-1:2007, 2.5.39, modified – addition of Notes to entry.]

2.17
over-current protective co-ordination

2.17.1
over-current selectivity
co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the other(s) does (do) not

2.17.2
total selectivity
over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection without causing the other protective device to operate

2.17.3
partial selectivity
over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection up to a given level of over-current, without causing the other protective device to operate

2.17.4
selectivity limit current
I_s
current co-ordinate of the intersection between the total time-current characteristic of the protective device on the load side and the pre-arcing (for fuses), or tripping (for circuit-breakers) time-current characteristic of the other protective device

Note 1 to entry: The selectivity limit current (see Figure A.1) is a limiting value of current:

– below which, in the presence of two over-current protective devices in series, the protective device on the load side completes its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is ensured);

– above which, in the presence of two over-current protective devices in series, the protective device on the load side may not complete its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is not ensured).

2.17.5
take-over current
I_B
current co-ordinate of the intersection between the maximum break time current characteristics of two over-current protective devices in series

Note 1 to entry: This applies to two over-current protective devices in series for operating times ≥ 0,05 s. For operating times < 0,05 s, the two over-current devices in series are considered as an association (see Annex A).

2.18
I^2t characteristic of a circuit-breaker
information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (r.m.s. symmetrical for a.c.) up to the maximum prospective current corresponding to the rated short-circuit breaking capacity and associated voltage

2.19
resetting time
time elapsed between a circuit-breaker tripping due to an overcurrent and subsequently reaching a condition where it can be reclosed

2.20
rated instantaneous short-circuit current setting
I_i
rated value of the current causing the operation of a release without any intentional time-delay

2.21
overload current setting
I_r
current setting of an adjustable overload release

Note 1 to entry: In case of a non-adjustable overload release, this value is equal to the rated current I_n.

2.22
programmable logic controller
PLC
digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analogue inputs and outputs, various types of machines or processes. Both the PLC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions

[SOURCE: IEC 61131-1:2003, 3.5, modified – deletion of the note.]

3 Classification

Circuit-breakers may be classified:

3.1 According to their selectivity category, A or B (see 4.4)

3.2 According to the interrupting medium, for example:

– air-break;
– vacuum break;
– gas-break.

3.3 According to the design, for example:

– open construction;
– moulded case.

3.4 According to the method of controlling the operating mechanism, viz:

– dependent manual operation;
– independent manual operation;
– dependent power operation;
– independent power operation;
– stored energy operation.

3.5 According to the suitability for isolation:

– suitable for isolation;
– not suitable for isolation.

3.6 According to the provision for maintenance:

– maintainable;

– non-maintainable.

3.7 According to the method of installation, for example:

– fixed;
– plug-in;
– withdrawable.

3.8 According to the degree of protection provided by the enclosure (see 7.1.12 of IEC 60947-1:2007)

4 Characteristics of circuit-breakers

4.1 Summary of characteristics

The characteristics of a circuit-breaker shall be stated in terms of the following, as applicable:

– type of circuit-breaker (4.2);
– rated and limiting values of the main circuit (4.3);
– selectivity categories (4.4);
– control circuits (4.5);
– auxiliary circuits (4.6);
– releases (4.7);
– integral fuses (integrally fused circuit-breakers) (4.8).

4.2 Type of circuit-breaker

The following shall be stated:

– number of poles;
– kind of current (a.c. or d.c.) and, in the case of a.c., number of phases and rated frequency.

4.3 Rated and limiting values of the main circuit

4.3.1 General

The rated values established for a circuit-breaker shall be stated in accordance with 4.3.2 to 4.4, but it is not necessary to establish all the rated values listed.

4.3.2 Rated voltages

4.3.2.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of IEC 60947-1:2007 applies with the following amplification:

– Circuit-breakers covered by item a) of Note 2 (of IEC 60947-1:2007)

U_e is generally stated as the voltage between phases.

NOTE 1 In Canada and the USA, the rated operational voltage U_e is stated as

a) the voltage between phases and earth, together with the voltage between phases (for example 277 V/480 V) for three-phase four-wire neutral earthed systems;

b) the voltage between phases (for example 480 V) for three-phase three-wire unearthed or impedance earthed systems.

Circuit-breakers for unearthed or impedance earthed systems (IT) require additional tests according to Annex H.

– Circuit-breakers covered by item b) of Note 2:

These circuit-breakers require additional tests according to Annex C.

U_e shall be stated as the voltage between phases preceded by the letter C.

NOTE 2 According to present practice in Canada and the USA, circuit-breakers covered by item b) of Note 2 (of IEC 60947-1:2007) are identified by the voltage between phases only.

4.3.2.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

4.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

4.3.3 Currents

4.3.3.1 Conventional free-air thermal current (I_{th})

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

4.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

4.3.3.3 Rated current (I_n)

For circuit-breakers, the rated current is the rated uninterrupted current (I_u) (see 4.3.2.4 of IEC 60947-1:2007) and is equal to the conventional free-air thermal current (I_{th}).

4.3.3.4 Current rating for four-pole circuit-breakers

Subclause 7.1.9 of IEC 60947-1:2007 applies.

4.3.4 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

4.3.5 Rated duty

The rated duties considered as normal are:

– the eight-hour duty (see 4.3.4.1 of IEC 60947-1:2007),
– the uninterrupted duty (see 4.3.4.2 of IEC 60947-1:2007).

4.3.6 Short-circuit characteristics

4.3.6.1 Rated short-circuit making capacity (I_{cm})

The rated short-circuit making capacity of a circuit-breaker is the value of short-circuit making capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage at rated frequency and at a specified power factor for a.c., or time constant for d.c. It is expressed as the maximum prospective peak current.

For a.c. the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity, multiplied by the factor *n* of Table 2 (see 4.3.6.3).

For d.c., the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity.

A rated short-circuit making capacity implies that the circuit-breaker shall be able to make the current corresponding to that rated capacity at the appropriate applied voltage related to the rated operational voltage.

4.3.6.2 Rated short-circuit breaking capacities

4.3.6.2.1 General

The rated short-circuit breaking capacities of a circuit-breaker are the values of short-circuit breaking capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage, under specified conditions.

A rated short-circuit breaking capacity requires that the circuit-breaker shall be able to break any value of short-circuit current up to and including the value corresponding to the rated capacity at a power-frequency recovery voltage corresponding to the prescribed test voltage values and:

– for a.c., at any power factor not less than that of Table 11 (see 8.3.2.2.4);

– for d.c., with any time constant not greater than that of Table 11 (see 8.3.2.2.5).

For power-frequency recovery voltages in excess of the prescribed test voltage values (see 8.3.2.2.6), no short-circuit breaking capacity is guaranteed.

For a.c., the circuit-breaker shall be capable of breaking a prospective current corresponding to its rated short-circuit breaking capacity and the related power factor given in Table 11, irrespective of the value of the inherent d.c. component, on the assumption that the a.c. component is constant.

The rated short-circuit breaking capacities are stated as:

– rated ultimate short-circuit breaking capacity;

– rated service short-circuit breaking capacity.

4.3.6.2.2 Rated ultimate short-circuit breaking capacity (I_{cu})

The rated ultimate short-circuit breaking capacity of a circuit-breaker is the value of ultimate short-circuit breaking capacity (see 2.15.1) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.5. It is expressed as the value of the prospective breaking current, in kA (r.m.s. value of the a.c. component in the case of a.c.).

4.3.6.2.3 Rated service short-circuit breaking capacity (I_{cs})

The rated service short-circuit breaking capacity of a circuit-breaker is the value of service short-circuit breaking capacity (see 2.15.2) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.4. It is expressed as a value of prospective breaking current, in kA, or as a % of I_{cu} (for example I_{cs} = 25 % I_{cu}).

I_{cs} shall be at least equal to 25 % of I_{cu}.

Table 1 (void)

4.3.6.3 Standard relationship between short-circuit making and breaking capacities and related power factor, for a.c. circuit-breakers

The standard relationship between short-circuit breaking capacity and short-circuit making capacity is given in Table 2.

Table 2 – Ratio *n* between short-circuit making capacity and short-circuit breaking capacity and related power factor (for a.c. circuit-breakers)

Short-circuit breaking capacity kA r.m.s.	Power factor	Minimum value required for n $n = \frac{\text{short-circuit making capacity}}{\text{short-circuit breaking capacity}}$
$I \leq 1{,}5$	0,95	1,41
$1{,}5 < I \leq 3$	0,9	1,42
$3 < I \leq 4{,}5$	0,8	1,47
$4{,}5 < I \leq 6$	0,7	1,53
$6 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

The rated short-circuit making and breaking capacities are only valid when the circuit-breaker is operated in accordance with the requirements of 7.2.1.1 and 7.2.1.2.

For special requirements, the manufacturer may assign a value of rated short-circuit making capacity higher than that required by Table 2. Tests to verify these rated values shall be the subject of agreement between manufacturer and user.

4.3.6.4 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of a circuit-breaker is the value of short-time withstand current assigned to that circuit-breaker by the manufacturer under the test conditions specified in 8.3.6.3.

For a.c., the value of this current is the r.m.s. value of the a.c. component of the prospective short-circuit current, assumed constant during the short-time delay.

The short-time delay associated with the rated short-time withstand current shall be at least 0,05 s, preferred values being as follows:

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

The rated short-time withstand current shall be not less than the appropriate values shown in Table 3.

Table 3 – Minimum values of rated short-time withstand current

Rated current I_n A	Rated short-time withstand current I_{cw} – Minimum values kA
$I_n \leq 2\ 500$	12 I_n or 5 kA, whichever is the greater
$I_n > 2\ 500$	30 kA

4.4 Selectivity categories

Circuit-breakers according to this standard are divided into two selectivity categories:

– **Selectivity category B** comprises circuit-breakers providing selectivity by having a short-time withstand current rating and an associated short-time delay according to 4.3.6.4.

  Selectivity of circuit-breakers of selectivity category B is not necessarily ensured up to the ultimate short-circuit breaking capacity (e.g. in the case of operation of an instantaneous release) but at least up to the value specified in Table 3.

– **Selectivity category A** comprises all other circuit-breakers.

  These circuit-breakers may provide selectivity under short-circuit conditions by other means.

  A circuit-breaker of selectivity category A may have an intentional short-time delay with a short-time withstand current less than that according to 4.3.6.4. In that case, the tests include test sequence IV (see 8.3.6) at the assigned short-time withstand current.

Attention is drawn to the differences of the tests applying to the two selectivity categories (see Table 9 and 8.3.4, 8.3.5, 8.3.6 and 8.3.8).

Table 4 (void)

4.5 Control circuits

4.5.1 Electrical control circuits

Subclause 4.5.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, with the following addition:

If the rated control supply voltage is different from that of the main circuit, it is recommended that its value be chosen from Table 5.

Table 5 – Preferred values of the rated control supply voltage, if different from that of the main circuit

Direct current V	Single-phase alternating current V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230

4.5.2 Air-supply control circuits (pneumatic or electro-pneumatic)

Subclause 4.5.2 of IEC 60947-1:2007 applies.

4.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies.

4.7 Releases

4.7.1 Types

For the purpose of this standard, the following types of releases are considered:

1) shunt release;
2) over-current release:
   a) instantaneous;
   b) definite time delay;
   c) inverse time delay:
      – independent of previous load;
      – dependent on previous load (for example thermal type release).

NOTE 1 The term "overload release" is used to identify over-current releases intended for protection against overloads (see 2.4.30 of IEC 60947-1:2007). The term "short-circuit release" is used to identify over-current releases intended for protection against short circuits (see 2.11).

NOTE 2 The term "adjustable release" used in this standard also includes interchangeable releases.

3) undervoltage release (for opening);
4) other releases.

4.7.2 Characteristics

The following characteristics shall be considered:

1) shunt release and undervoltage release (for opening):
   – rated control circuit voltage (U_c);
   – kind of current;
   – rated frequency, if a.c.
2) over-current release:
   – rated current (I_n);
   – kind of current;
   – rated frequency, if a.c.;
   – current setting (or range of settings);
   – time setting (or range of settings) if applicable.

The rated current of an over-current release is the value of current (r.m.s. if a.c.) corresponding to the maximum current setting which it shall be capable of carrying under the test conditions specified in 8.3.2.5, without the temperature-rise exceeding the values specified in Table 7.

4.7.3 Current setting of over-current releases

For circuit-breakers fitted with adjustable releases (see Note 2 to 4.7.1, item 2)), the current setting (or range of current-settings, as applicable) shall be marked or displayed on the release or on its scale. The marking or display may be either directly in amperes or as a multiple of the current value. Means shall be available from the manufacturer to read the display regardless of the status of the circuit-breaker.

For circuit-breakers fitted with non-adjustable releases, the marking may be on the circuit-breaker. If the operating characteristics of the overload release comply with the requirements of Table 6, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

In the case of indirect releases operated by current transformers, the marking may refer either to the primary current of the current transformer through which they are supplied, or to the current setting of the overload release. In either case, the ratio of the current transformer shall be stated.

Unless otherwise specified

- the operating value of overload releases other than those of the thermal type is independent of the ambient air temperature within the limits of –5 °C to +40 °C;
- for releases of the thermal type, the values stated are for a reference temperature of +30 °C ± 2 °C. The manufacturer shall be prepared to state the influence of variations in the ambient air temperature (see 7.2.1.2.4, item b)).

4.7.4 Tripping time setting of over-current releases

The tripping time shall be stated as follows, depending on the type of over-current release:

1) Definite time-delay over-current releases

   The time-delay of such releases is independent of the over-current. The tripping time setting shall be stated as the duration in seconds of the opening time of the circuit-breaker, if the time-delay is not adjustable, or the extreme values of the opening time, if the time-delay is adjustable.

2) Inverse time-delay over-current releases

   The time-delay of such releases is dependent on the over-current.

   The time/current characteristics shall be given in the form of curves supplied by the manufacturer. These shall indicate how the opening time, starting from the cold state, varies with current within the range of operation of the release. The manufacturer shall indicate, by suitable means, the tolerances applicable to these curves.

   These curves shall be given for each extreme value of the current setting and, if the time setting for a given current setting is adjustable, it is recommended that they be given in addition for each extreme value of the time setting.

   It is recommended that the current be plotted as abscissa and the time as ordinate, using logarithmic scales. Furthermore, in order to facilitate the study of co-ordination of different types of over-current protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheets detailed in 5.6.1 of IEC 60269-1:2006.

4.8 Integral fuses (integrally fused circuit-breakers)

Subclause 4.8 of IEC 60947-1:2007/AMD1:2010 applies.

The manufacturer shall provide the necessary information.

5 Product information

5.1 Nature of the information

Subclause 5.1 of IEC 60947-1:2007 applies, as far as appropriate for a particular design.

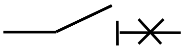
In addition the manufacturer shall make available, upon request, information concerning typical power losses for the various frame sizes (see 2.1.1). See Annex G.

5.2 Marking

Each circuit-breaker shall be marked in a durable manner.

a) The following data shall be marked on the circuit-breaker itself or on a nameplate or nameplates attached to the circuit-breaker, and located in a place such that they are visible and legible when the circuit-breaker is installed;

– rated current (I_n);

– suitability for isolation, if applicable, with the symbol ;

– indication of the open and closed positions, with O and | respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007).

b) The following data shall also be marked externally on the circuit-breaker, as specified in item a), except that they need not be visible when the circuit-breaker is installed;

– manufacturer's name or trade mark;

– type designation or serial number;

– IEC 60947-2 if the manufacturer claims compliance with this standard;

– selectivity category;

– rated operational voltage(s) U_e (see 4.3.2.1 and, where applicable, Annex H);

– rated impulse withstand voltage (U_{imp});

– value (or range) of the rated frequency (for example 50 Hz), and/or the indication "d.c." (or the symbol ⎓);

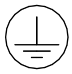
– rated service short-circuit breaking capacity (I_{cs}) at the corresponding rated voltage (U_e);

– rated ultimate short-circuit breaking capacity (I_{cu}) at the corresponding rated voltage (U_e);

– rated short-time withstand current (I_{cw}), and associated short-time delay, for selectivity category B;

– line and load terminals, unless their connection is immaterial;

– neutral pole terminals, if applicable, by the letter N;

– protective earth terminal, where applicable, by the symbol  (see 7.1.10.3 of IEC 60947-1:2007);

– reference temperature for non-compensated thermal releases, if different from 30 °C;

– range of the current setting (I_r) of adjustable overload release;

– range of the rated instantaneous short-circuit current setting (I_i), for ajustable releases.

Where applicable, I_r and I_i ranges may be displayed instead of being marked on the circuit-breaker.

c) The following data shall either be marked on the circuit-breaker as specified in item b), or shall be made available in the manufacturer's published information:

– rated short-circuit making capacity (I_{cm}), if higher than that specified in 4.3.6.1;

– rated insulation voltage (U_i), if higher than the maximum rated operational voltage;

– pollution degree if other than 3;

– conventional enclosed thermal current (I_{the}) if different from the rated current;

– IP Code, where applicable (see Annex C of IEC 60947-1:2007/AMD1:2010);

– minimum enclosure size and ventilation data (if any) to which marked ratings apply;

– details of minimum distance between circuit-breaker and earthed metal parts for circuit-breakers intended for use without enclosures;

– suitability for environment A or environment B, as applicable;

– r.m.s. sensing, if applicable, according to F.4.1.1;

– minimum cable cross-section, if different from Table 9 of IEC 60947-1:2007, for ratings ≤ 20 A according to rated ultimate short-circuit breaking capacity I_{cu};
– values of tightening torque for the circuit-breaker terminals.

d) The following data concerning the opening and closing devices of the circuit-breaker shall be placed either on their own nameplates or on the nameplate of the circuit-breaker; alternatively, if space available is insufficient, they shall be made available in the manufacturer's published information:

– rated control circuit voltage of the closing device (see 7.2.1.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014) and rated frequency for a.c.;
– rated control circuit voltage of the shunt release (see 7.2.1.4 of IEC 60947-1:2007/AMD2:2014) and/or of the under-voltage release (or of the no-voltage release) (see 7.2.1.3 of IEC 60947-1:2007), and rated frequency for a.c.;
– rated current of indirect over-current releases;
– number and type of auxiliary contacts and kind of current, rated frequency (if a.c.) and rated voltages of the auxiliary switches, if different from those of the main circuit.

e) Terminal marking

Subclause 7.1.8.4 of IEC 60947-1:2007 applies (see also item b) above).

5.3 Instructions for installation, operation and maintenance

Subclause 5.3 of IEC 60947-1:2007/AMD2:2014 applies.

6 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1:2007/AMD2:2014 applies with the following addition:

Pollution degree (see 6.1.3.2 of IEC 60947-1:2007).

Unless otherwise stated by the manufacturer, a circuit-breaker is intended for installation under environmental conditions of pollution degree 3.

7 Constructional and performance requirements

7.1 Constructional requirements

7.1.1 General

Subclause 7.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies. Where, in 7.1.2.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, the test temperature is to be specified, the test temperature required by this standard is 960 °C.

7.1.2 Withdrawable circuit-breakers

In the disconnected position, the isolating contacts of the main circuit and, where applicable, auxiliary circuits of withdrawable circuit-breakers shall have isolating distances which comply with the requirements specified for the isolating function, taking account of manufacturing tolerances and changes in dimensions due to wear.

The withdrawable mechanism shall be fitted with a reliable indicating device which indicates unambiguously the positions of the isolating contacts.

The withdrawable mechanism shall be fitted with interlocks which only permit the isolating contacts to be separated or reclosed when the main contacts of the circuit-breaker are open.

In addition, the withdrawable mechanism shall be fitted with interlocks which only permit the main contacts to be closed

– when the isolating contacts are fully closed, or
– when the specified isolating distance is achieved between the fixed and moving parts of the isolating contacts (disconnected position).

When the circuit-breaker is in the disconnected position, means shall be provided to ensure that the specified isolating distances between the isolating contacts cannot be inadvertently reduced.

7.1.3 Additional requirements for circuit-breakers suitable for isolation

For additional requirements concerning performance, see 7.2.7.

Subclause 7.1.7 of IEC 60947-1:2007/AMD1:2010 applies with the following addition:

If the tripped position is not the indicated open position, it should be clearly identified.

7.1.4 Clearances and creepage distances

Minimum values are given in Table 13 of IEC 60947-1:2007 and in Table 15 of IEC 60947-1:2007/AMD1:2010.

For U_{imp} values exceeding the values given in Table 13 of IEC 60947-1:2007, clearances shall be obtained from Table F.2 of IEC 60664-1:2007.

7.1.5 Requirements for the safety of the operator

There shall be no path or opening which allows incandescent particles to be discharged from the area of the manual operating means.

Compliance is checked by the provisions of 8.3.2.6.1, item b).

7.1.6 List of construction breaks

Circuit-breakers of a given frame size are considered to have a construction break (see 2.1.2) if any one of the following features are not the same:

– material, finish and dimensions of internal current-carrying parts, admitting, however, the variations listed in a), b), c), f) and g) below;
– size, material, configuration and method of attachment of the main contacts;
– any integral manual operating mechanism, its materials and physical characteristics;
– moulding and insulating materials;
– the principle of operation, materials and construction of the arc extinction device;
– the basic design of the over-current tripping devices, admitting, however, the variations detailed in a), b) and c) below.

Variations in the following do not constitute a construction break:

a) dimensions of terminals, provided that creepage and clearance distances are not reduced;
b) in the case of thermal and magnetic releases those dimensions and materials of the release components, including flexible connections, which determine the current rating;
c) secondary windings of current transformer operated releases;
d) external operating means, additional to the integral operating means;
e) type designation and/or purely aesthetic features (e.g. labels);

f) in the case of the 2-pole and 4-pole variants, replacement of the trip unit in one pole by a link, to provide an unprotected neutral;

g) creating a 2-pole breaker from a 3-pole breaker by removing the centre current path;

h) difference in embedded software (firmware) in electronic trip units, which has no impact on the required performance, in particular the tripping function;

i) electronic trip unit hardware, due to omitted components on identical printed circuit board layout (e.g. rotary knobs, display, etc.).

7.1.7 Additional requirements for circuit-breakers provided with a neutral pole

Subclause 7.1.9 of IEC 60947-1:2007 applies with the following addition:

If a pole with an appropriate making and breaking capacity is used as a neutral pole, then all poles, including the neutral pole, may operate substantially together.

7.1.8 Digital inputs and outputs for use with programmable logic controllers (PLCs)

Annex S of IEC 60947-1:2007 applies. For the purposes of this standard, this requirement does not apply to digital inputs and outputs dedicated to devices other than PLCs.

7.2 Performance requirements

7.2.1 Operating conditions

7.2.1.1 Closing

7.2.1.1.1 General

For a circuit-breaker to be closed safely on to the making current corresponding to its rated short-circuit making capacity, it is essential that it should be operated with the same speed and the same firmness as during the type test for proving the short-circuit making capacity.

7.2.1.1.2 Dependent manual closing

For a circuit-breaker having a dependent manual closing mechanism, it is not possible to assign a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

Such a circuit-breaker should not be used in circuits having a prospective peak making current exceeding 10 kA.

However, this does not apply in the case of a circuit-breaker having a dependent manual closing mechanism and incorporating an integral fast-acting opening release which causes the circuit-breaker to break safely, irrespective of the speed and firmness with which it is closed on to prospective peak currents exceeding 10 kA; in this case, a rated short-circuit making capacity can be assigned.

7.2.1.1.3 Independent manual closing

A circuit-breaker having an independent manual closing mechanism can be assigned a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

7.2.1.1.4 Dependent power closing

The power-operated closing mechanism, including intermediate control relays where necessary, shall be capable of securing the closing of the circuit-breaker in any condition between no-load and its rated making capacity, when the supply voltage, measured during the closing operation, remains between the limits of 110 % and 85 % of the rated control supply voltage, and, when a.c., at the rated frequency.

At 110 % of the rated control supply voltage, the closing operation performed on no-load shall not cause any damage to the circuit-breaker.

At 85 % of the rated control supply voltage, the closing operation shall be performed when the current established by the circuit-breaker is equal to its rated making capacity within the limits allowed by the operation of its relays or releases and, if a maximum time limit is stated for the closing operation, in a time not exceeding this maximum time limit.

7.2.1.1.5 Independent power closing

A circuit-breaker having an independent power closing operation can be assigned a rated short-circuit making capacity irrespective of the conditions of power closing.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating in accordance with the manufacturer's specification.

7.2.1.1.6 Stored energy closing

This type of closing mechanism shall be capable of ensuring closing of the circuit-breaker in any condition between no-load and its rated making capacity.

When the stored energy is retained within the circuit-breaker, a device shall be provided which indicates when the storing mechanism is fully charged.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating when the auxiliary supply voltage is between 85 % and 110 % of the rated control supply voltage.

It shall not be possible for the moving contacts to move from the open position unless the charge is sufficient for satisfactory completion of the closing operation.

When the energy storing mechanism is manually operated, the direction of operation shall be indicated.

This last requirement does not apply to circuit-breakers with an independent manual closing operation.

7.2.1.2 Opening

7.2.1.2.1 General

Circuit-breakers which open automatically shall be trip-free (see 2.4.23 of IEC 60947-1:2007) and, unless otherwise agreed between manufacturer and user, circuit-breakers shall have their energy for the tripping operation stored automatically prior to the completion of the closing operation.

7.2.1.2.2 Opening by undervoltage releases

Subclause 7.2.1.3 of IEC 60947-1:2007 applies.

7.2.1.2.3 Opening by shunt releases

Subclause 7.2.1.4 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.1.2.4 Opening by over-current releases

a) Opening under short-circuit conditions

The short-circuit release shall cause tripping of the circuit-breaker with an accuracy of ±20 % of the tripping current value of the current setting for all values of the current setting of the short-circuit current release.

Where necessary for over-current co-ordination (see 2.17), the manufacturer shall provide information (usually curves) showing:

– maximum cut-off (let-through) peak current (see 2.5.19 of IEC 60947-1:2007) as a function of prospective current (r.m.s. symmetrical);

– I^2t characteristics (see 2.18) for circuit-breakers of selectivity category A and, if applicable, category B for circuit-breakers with instantaneous override (see note to 8.3.5.1).

Conformity with this information may be checked during the relevant type tests in test sequences II and III (see 8.3.4 and 8.3.5).

NOTE 1 It is possible to provide other forms of data to verify co-ordination characteristics of circuit-breakers, for example, tests on combinations of short-circuit protective devices.

b) Opening under overload conditions

1) Instantaneous or definite time-delay operation

The release shall cause tripping of the circuit-breaker with an accuracy of ±10 % of the tripping current value of the current setting for all values of current setting of the overload release.

2) Inverse time-delay operation

Conventional values for inverse time-delay operation are given in Table 6.

At the reference temperature (see 4.7.3) and at 1,05 times the current setting (see 2.4.37 of IEC 60947-1:2007), i.e. with the conventional non-tripping current (see 2.5.30 of IEC 60947-1:2007), the opening release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 2.5.30 of IEC 60947-1:2007) from the cold state, i.e. with the circuit-breaker at the reference temperature.

Moreover, when at the end of the conventional time the value of current is immediately raised to 1,30 times the current setting, i.e. with the conventional tripping current (see 2.5.31 of IEC 60947-1:2007), tripping shall then occur in less than the conventional time later.

NOTE 2 The reference temperature is the ambient air temperature on which the time-current characteristic of the circuit-breaker is based.

Table 6 – Characteristics of the opening operation of inverse time-delay over-current opening releases at the reference temperature

All poles loaded		Conventional time h
Conventional non-tripping current	**Conventional tripping current**	
1,05 times current setting	1,30 times current setting	2 [a]
[a] 1 h when $I_n \leq 63$ A		

If a release is declared by the manufacturer as substantially independent of ambient temperature, the current values of Table 6 shall apply within the temperature band declared by the manufacturer, within a tolerance of 0,3 %/K.

The width of the temperature band shall be at least 10 K on either side of the reference temperature.

7.2.2 Temperature-rise

7.2.2.1 Temperature-rise limits

The temperature-rises of the several parts of a circuit-breaker, measured under the conditions specified in 8.3.2.5, shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.3.7. The temperature-rises of the terminals shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.4.5 and 8.3.6.4.

7.2.2.2 Ambient air temperature

The temperature-rise limits given in Table 7 are applicable only if the ambient air temperature remains within the limits given in 6.1.1 of IEC 60947-1:2007/AMD2:2014.

7.2.2.3 Main circuit

The main circuit of a circuit-breaker, including the over-current releases which may be associated with it, shall be capable of carrying its rated current I_n, under the conditions of Clause 8, without the temperature-rises exceeding the limits specified in Table 7.

7.2.2.4 Control circuits

The control circuits, including control circuit devices, used for the closing and opening operations of a circuit-breaker, shall permit the rated duty, as specified in 4.3.5, and also the temperature-rise tests under the test conditions specified in 8.3.2.5, to be made without the temperature rises exceeding the limits specified in Table 7.

The requirements of this subclause shall be verified on a new circuit-breaker. Alternatively, at the discretion of the manufacturer, the verification may be made during the temperature-rise test of 8.3.3.7.

7.2.2.5 Auxiliary circuits

Auxiliary circuits, including auxiliary devices, shall be capable of carrying their conventional thermal current without the temperature-rises exceeding the limits specified in Table 7 when tested in accordance with 8.3.2.5.

Table 7 – Temperature-rise limits for terminals and accessible parts

Description of part [a]	Temperature-rise limits [b] K
– Terminals for external connections	80
– Manual operating means:	
Metallic	25
non-metallic	35
– Parts intended to be touched but not hand-held:	
Metallic	40
non-metallic	50
– Parts which need not be touched for normal operation:	
Metallic	50
non-metallic	60

[a] No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.

[b] The temperature-rise limits specified are not intended to apply to a new sample, but are those applicable to the temperature-rise verifications during the appropriate test sequences specified in Clause 8.

7.2.3 Dielectric properties

7.2.3.1 General

Subclauses 7.2.3 a) and 7.2.3 b) of IEC 60947-1:2007 apply.

Type tests shall be made in accordance with 8.3.3.3.

The verification of dielectric withstand during all test sequences shall be made in accordance with 8.3.3.6.

Routine tests shall be made in accordance with 8.4.6.

7.2.3.2 Impulse withstand voltage

Subclause 7.2.3.1 of IEC 60947-1:2007 applies.

For circuit-breakers rated above 1 000 V a.c., the impulse withstand voltage shall be agreed between the manufacturer and the user but shall not be less than the corresponding values for 1 000 V a.c.

7.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

Power-frequency tests are used in the following cases:

– dielectric tests as type tests for the verification of solid insulation;
– dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;
– routine tests.

7.2.3.4 Clearances

Subclause 7.2.3.3 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.3.5 Creepage distances

Subclause 7.2.3.4 of IEC 60947-1:2007 applies.

7.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with 8.3.3.4.1, item 3) of IEC 60947-1:2007/AMD1:2010/AMD2:2014, or d.c. tests (test voltages for d.c. tests are under consideration).

For the purposes of this standard, circuits incorporating solid-state devices shall be disconnected for the tests.

7.2.3.7 Spacing between separate circuits

Subclause 7.2.3.6 of IEC 60947-1:2007 applies.

7.2.4 Ability to make and break under no load, normal load and overload conditions

7.2.4.1 Overload performance

This requirement applies to circuit-breakers of rated current up to and including 630 A.

The circuit-breaker shall be capable of carrying out the number of operating cycles with current in the main circuit exceeding its rated current, under the test conditions according to 8.3.3.5.

Each operating cycle consists of a making operation followed by a breaking operation.

7.2.4.2 Operational performance capability

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following additions:

The circuit-breaker shall be capable of meeting the requirements of Table 8:

– for the test of operational performance without current in the main circuit under the test conditions specified in 8.3.3.4.3;

– for the test of operational performance with current in the main circuit under the test conditions specified in 8.3.3.4.4.

Each operating cycle consists of, either a closing operation followed by an opening operation (test of operational performance without current), or a making operation followed by a breaking operation (test of operational performance with current).

Table 8 – Number of operating cycles

1	2	3	4	5
Rated current [a]	**Number of operating cycles per hour** [b]	**Number of operating cycles**		
A		**Without current**	**With current** [c]	**Total**
$I_n \leq 100$	120	8 500	1 500	10 000
$100 < I_n \leq 315$	120	7 000	1 000	8 000
$315 < I_n \leq 630$	60	4 000	1 000	5 000
$630 < I_n \leq 2\,500$	20	2 500	500	3 000
$2\,500 < I_n$	10	1 500	500	2 000

[a] This means the maximum rated current for a given frame size.

[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

[c] During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

7.2.5 Ability to make and break under short-circuit conditions

Subclause 7.2.5 of IEC 60947-1:2007 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 4.3.6.1 and 4.3.6.3.

The rated short-circuit breaking capacity shall be in accordance with 4.3.6.2.

The rated short-time withstand current shall be in accordance with 4.3.6.4.

NOTE It is the manufacturer's responsibility to ensure that the tripping characteristic of the circuit-breaker is compatible with the capability of the circuit-breaker to withstand the inherent thermal and electrodynamic stresses.

7.2.6 Vacant

7.2.7 Additional requirements for circuit-breakers suitable for isolation

Subclause 7.2.7 of IEC 60947-1:2007 applies and tests shall be made in accordance with 8.3.3.3, 8.3.3.6, 8.3.3.10, 8.3.4.4, 8.3.5.4 and 8.3.7.8, as applicable.

7.2.8 Specific requirements for integrally fused circuit-breakers

NOTE For the co-ordination between circuit-breakers and separate fuses associated in the same circuit, see 7.2.9.

An integrally fused circuit-breaker shall comply with this standard in all respects up to the rated ultimate short-circuit breaking capacity. In particular, it shall meet the requirements of test sequence V (see 8.3.7).

The circuit-breaker shall function, without causing the fuses to operate, at the occurrence of over-currents not exceeding the selectivity limit current I_s declared by the manufacturer.

For all over-currents up to and including the rated ultimate short-circuit breaking capacity assigned to the composite unit, the circuit-breaker shall open when one or more fuses operate (in order to prevent single-phasing). If the circuit-breaker is stated by the manufacturer to be with lock-out device preventing closing (see 2.14), it shall not be possible to reclose the circuit-breaker until either the melted fuse-links or any missing fuse-links have been replaced or the lock-out means has been reset.

7.2.9 Co-ordination between a circuit-breaker and another short-circuit protective device

For the co-ordination between a circuit-breaker and another short-circuit protective device, see Annex A.

7.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

8 Tests

8.1 Kind of tests

8.1.1 General

Subclause 8.1 of IEC 60947-1:2007 applies, with the following additions:

The tests to verify the characteristics of circuit-breakers are:

– type tests (see 8.3);
– routine tests (see 8.4);
– special tests (see 8.5).

8.1.2 Type tests

Type tests include the following tests:

Test	Subclause
Temperature-rise	8.3.2.5
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Short-circuit breaking capacities	8.3.4 and 8.3.5
Short-time withstand current (where applicable)	8.3.6
Performance of integrally fused circuit-breakers	8.3.7
Critical d.c. load current	8.3.9

Type tests shall be carried out by the manufacturer, in his workshop or at any suitable laboratory of his choice.

8.1.3 Routine tests

Routine tests comprise the tests listed in 8.4.

8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

8.3 Type tests

In order to avoid repetition of identical tests applicable to the various test sequences, the general test conditions have been grouped together at the beginning of this subclause under three headings:

– test conditions applicable to all sequences (8.3.3 to 8.3.8);

– test conditions applicable to temperature-rise tests (8.3.2.5);

– test conditions applicable to short-circuit tests (8.3.2.6).

Wherever appropriate, these general test conditions refer back to, or are based on, the general rules of IEC 60947-1.

Each test sequence refers back to the general test conditions applicable. This requires the use of cross-references, but enables each test sequence to be presented in a much simplified form.

Throughout this clause the term "test" has been used for every test to be made; "verification" should be interpreted as "test for the verification" and has been used where it is intended to verify the condition of the circuit-breaker following an earlier test in a test sequence whereby it may have been adversely affected.

In order to facilitate locating a particular test condition or test, an alphabetical index is given in 8.3.1.3, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

8.3.1 Test sequences

8.3.1.1 General

Type tests are grouped together in a number of sequences, as shown in Table 9.

For each sequence, tests shall be made in the order listed unless otherwise specified in this standard.

8.3.1.2 Tests omitted from sequence I and made separately

With reference to 8.1.1 of IEC 60947-1:2007, the following tests of test sequence I (see 8.3.3) may be omitted from the sequence and made on separate samples:

– tripping limits and characteristics (8.3.3.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 8.3.3.2.3 only on the phase poles at the maximum setting, at room temperature and without the additional test of item b) to verify the time-current characteristic;

– test of dielectric properties (8.3.3.3);

– test of under-voltage releases of 8.3.3.4.2.3 and 8.3.3.4.3 to verify the requirements of 7.2.1.3 of IEC 60947-1:2007, and tests of under-voltage releases at alternative frequencies (see 8.3.2.1);

– test of shunt releases of 8.3.3.4.2.4 and 8.3.3.4.3 to verify the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014, and tests of shunt releases at alternative frequencies (see 8.3.2.1);

– additional tests for operational performance capability without current for withdrawable circuit-breakers (8.3.3.4.5).

8.3.1.3 Applicability of sequences according to the relationship between short-circuit ratings

The applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} is given in Table 9a.

Alphabetical index of tests

General test conditions	Subclause
Arrangement of circuit-breakers, general	8.3.2.1
Arrangement of circuit-breakers for short-circuit tests	8.3.2.6.1
Frequency	8.3.2.2.3
Power factor	8.3.2.2.4
Records (interpretation of)	8.3.2.6.6
Recovery voltage	8.3.2.2.6
Short-circuit test circuits	8.3.2.6.2
Short-circuit test procedure	8.3.2.6.4
Temperature-rise test	8.3.2.5
Time constant	8.3.2.2.5
Tolerances	8.3.2.2.2
Tests (for overall schema of test sequences, see Table 9)	**Subclause**
Critical d.c. load current	8.3.9
Dielectric properties	8.3.3.3
Dielectric withstand (verification)	8.3.3.6 – 8.3.4.4 – 8.3.5.4 – 8.3.6.6 – 8.3.7.4 – 8.3.7.8 – 8.3.8.6
Individual pole short-circuit test (for phase-earthed systems)	Annex C
Individual pole short-circuit test (for IT systems)	Annex H – see H.2
Indication of main contact position	8.3.3.10
Integrally fused circuit-breakers (short-circuit tests)	8.3.7.2 – 8.3.7.6 – 8.3.7.7
Operational performance capability	8.3.3.4 – 8.3.4.3 – 8.3.4.5
Overload performance	8.3.3.5
Overload releases (verification)	8.3.3.8 – 8.3.4.5 – 8.3.5.2 – 8.3.5.5 – 8.3.6.2 – 8.3.6.7 – 8.3.7.5 – 8.3.7.9 – 8.3.8.2 – 8.3.8.8
Service short-circuit breaking capacity	8.3.4.2 – 8.3.8.4
Short-circuit breaking capacity test at maximum short-time withstand current	8.3.6.5
Short-time withstand current	8.3.6.3 – 8.3.8.3
Temperature-rise (verification)	8.3.3.7 – 8.3.4.5 – 8.3.6.4 – 8.3.7.3 – 8.3.8.7
Tripping limits and characteristics	8.3.3.2
Ultimate short-circuit breaking capacity	8.3.5.3
Withdrawable circuit-breakers (additional tests)	8.3.3.4.5

Table 9 – Overall schema of test sequences[a]

Test sequence	Applicable to	Tests
I General performance characteristics (8.3.3)	All circuit-breakers	Tripping limits and characteristics Dielectric properties Mechanical operation and operational performance capability Overload performance (where applicable) Verification of dielectric withstand Verification of temperature-rise Verification of overload releases Verification of undervoltage and shunt releases (where applicable) Verification of main contact position (where applicable)
II Rated service short-circuit breaking capacity (8.3.4)	All circuit-breakers [b]	Rated service short-circuit breaking capacity Verification of operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
III Rated ultimate short-circuit breaking capacity (8.3.5)	All circuit-breakers [c] of selectivity category A and circuit-breakers of selectivity category B with instantaneous override[d]	Verification of overload releases Rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
IV Rated short-time withstand current (8.3.6)	Circuit-breakers of selectivity category B [b] and circuit-breakers of selectivity category A with a rated short-time withstand current (see 4.4)	Verification of overload releases Rated short-time withstand current Verification of temperature-rise Short-circuit breaking capacity at maximum short-time withstand current Verification of dielectric withstand Verification of overload releases
V Performance of integrally fused circuit-breakers (8.3.7)	Stage 1 Integrally fused circuit-breakers Stage 2	Short-circuit at the selectivity limit current Verification of temperature-rise Verification of dielectric withstand Verification of overload releases Short-circuit at 1,1 times the take-over current Short-circuit at rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
VI Combined test sequence (8.3.8)	Circuit-breakers of selectivity category B: when $I_{cw} = I_{cs}$ (replaces test sequences II and IV) when $I_{cw} = I_{cs} = I_{cu}$ (replaces test sequences II, III and IV)	Verification of overload releases Rated short-time withstand current Rated service short-circuit breaking capacity Operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
Critical d.c. load current (8.3.9)	Circuit-breakers with d.c. ratings	Critical d.c. load current tests
Individual pole short-circuit test sequence (Annex C)	Circuit-breakers for use on phase-earthed systems	Individual pole short-circuit breaking capacity (I_{su}) Verification of dielectric withstand Verification of overload releases
Test sequence for circuit-breakers for IT systems (Annex H)	Circuit-breakers for use in IT systems	Individual pole short-circuit breaking capacity (I_{IT}) Verification of dielectric withstand Verification of overload releases

a For the selection of circuit-breakers for tests and the applicability of the various test sequences according to the relationship between I_{cs} , I_{cu} and I_{cw}, see Table 9a.

b Except where Sequence VI is applied.

c Except

– where $I_{cs} = I_{cu}$ (but see 8.3.5),
– where sequence VI is applied,
– for integrally fused circuit-breakers.

d See note to 8.3.5.1

Table 9a – Applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} [a]

I_{cs}, I_{cu} and I_{cw} relationship	Test sequence	Selectivity category			
		A	A Integrally fused	B	B Integrally fused
CASE 1	I	X	X	X	X
	II	X	X	X	X
$I_{cs} \neq I_{cu}$ for selectivity category A	III	X		X [b]	
$I_{cs} \neq I_{cu} \neq I_{cw}$ for selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 2	I			X	X
$I_{cs} = I_{cw} \neq I_{cu}$ for selectivity	II			X	X
category B	III			X [b]	
	IV			X	X
	V				X
	VI (combined)			X [c]	X [c]
CASE 3	I	X	X	X	X
	II	X	X	X	X
$I_{cs} = I_{cu}$ for selectivity category A	III				
$I_{cs} = I_{cu} \neq I_{cw}$ for selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 4	I			X	
	II			X	
$I_{cs} = I_{cu} = I_{cw}$ for selectivity	III				
category B	IV			X	
	V				
	VI (combined)			X [c]	

[a] This table applies to any one value of U_e. For multiple U_e ratings, the table applies to each U_e rating. The applicability of a test sequence is indicated by X in the relevant space.

[b] Test applicable only if $I_{cu} > I_{cw}$.

[c] At the discretion of, or in agreement with the manufacturer, this sequence may be applied to circuit-breakers of selectivity category B, in which case it replaces test sequences II and IV.

[d] Test sequence IV applies only to circuit-breakers with a rated short-time withstand current (see 4.4).

8.3.1.4 Alternative test programmes for a.c. circuit-breakers having a different number of poles

These alternative test programmes may only be applied to a.c. ratings and when all the ratings are the same or lower than the variant submitted to the full programme of Table 9, and construction breaks are the same for all variants. In the case of 1-pole circuit-breakers the voltage ratings shall be equal to or lower than the line-to neutral voltage of the variant tested to Table 9. A 2-pole circuit-breaker produced by removing the centre current path from a 3-pole circuit-breaker tested to programme 1 or programme 2 of this subclause need not be tested as it is considered to be covered by the tests on the 3-pole variant.

Compliance with the test requirements is met by carrying out one of the alternative programmes 1 or 2 below.

– Programme 1: The applicable test sequences according to Table 9 shall be carried out on the three-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9b shall be carried out on the other variants.

– Programme 2: The applicable test sequences according to Table 9 shall be carried out on the four-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9c shall be carried out on the other variants.

The principle for the application of the alternative test programmes is illustrated below:

	Programme 1					**Programme 2**			
	1-pole	2-poles	3-poles	4-poles		1-pole	2-poles	3-poles	4-poles
Construction 1[a]	□	□	■	□		○	○	○	■
Construction 2	–	–	■	□		–	–	–	■
Construction 3	–	–	■	□		–	–	–	■
…	–	–	■	□		–	–	–	■
Construction *n*	–	–	■	□		–	–	–	■
Key	■ fully tested per Table 9 □ tested per Table 9b ○ tested per Table 9c – no test required								

[a] Construction 1 is the construction which covers the max rating.

Table 9b – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers according to the alternative programme 1 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 4-pole variant[f, h]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General	X	X
	8.3.3.2.2	Short-circuit releases	X[a]	X[e]
	8.3.3.2.3 a)[k] or 8.3.3.2.3 b)[k] (as applicable)	Overload releases: – instantaneous/definite time-delay – inverse time-delay	X X	X[e]
	8.3.3.2.4	Additional test for definite time-delay releases:		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation	X[d]	X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers	X	
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current	X 4th pole and adjacent pole only (see 8.3.2.6.4)	
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breakers for IT systems		
NOTE The applicability of a test or test sequence is indicated by X in the relevant space.				

a	One test on one pair of phase poles chosen at random. In the case of an electronic trip unit, this test may be made on one pole chosen at random.
b	This test sequence also applies when, for the 3-pole testing, Sequence III on the 3-poles variant is replaced by Sequence II or Sequence VI (see Table 9).
c	One sample of maximum current rating only, tested at max kVA rating (I_{cu} × corresponding U_e).
d	Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).
e	Applicable only to 1-pole variant; not required for 2-poles variants.
f	In case of 4-poles devices with different levels of neutral protection (e.g. 60 % or 100 %), only the variant with the highest level has to be tested according to Table 9b.
g	One sample of maximum current rating only, for each test sequence.
h	One sample of maximum current rating for each test sequence; in the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction.
i	Vacant.
j	Vacant.
k	This test is not required for electronic trip units.

Table 9c – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers according to the alternative programme 2 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 3-pole variant[g]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General		X
	8.3.3.2.2	Short-circuit releases		X [e]
	8.3.3.2.3 a)[k] or 8.3.3.2.3 b)[k] (as applicable)	Overload releases: – instantaneous/definite time-delay – inverse time-delay		X[e]
	8.3.3.2.4	Additional test for definite time-delay releases		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation		X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers		
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current		
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		

Test sequence	Test subclause	Test	Applicability to 3-pole variant[g]	Applicability to 1-pole or 2-pole variants[g]
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breaker for IT systems		
NOTE The applicability of a test or test sequence is indicated by X in the relevant space.				

[a] Vacant.

[b] This test sequence also applies when, for the 4-poles testing, Sequence III on the 4-poles variant is replaced by Sequence II or Sequence VI (see Table 9).

[c] One sample of maximum current rating only, tested at max kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).

[e] Applicable only to 1-pole variant; not required for 2-poles variants.

[f] Vacant.

[g] One sample of maximum current rating only, for each test sequence.

[h] Vacant.

[i] Vacant.

[j] Vacant.

[k] This test is not required for electronic trip units.

8.3.2 General test conditions

NOTE Tests according to the requirements of this standard do not preclude the need for additional tests concerning circuit-breakers incorporated in assemblies, for example tests in accordance with IEC 61439 series.

8.3.2.1 General requirements

Unless otherwise agreed by the manufacturer, each test sequence shall be made on a sample circuit-breaker (or set of samples) in a clean and new condition.

The number of samples to be tested for each test sequence and the test conditions (for example setting of overload releases, terminal connections), according to the circuit-breaker parameters, are given in Table 10 or, where applicable, for the alternative test programmes in Table 9b and Table 9c (see 8.3.1.4).

Where necessary, additional information is given in the relevant subclauses.

Unless otherwise specified, tests are to be performed on a circuit-breaker having the maximum rated current for a given frame size and are deemed to cover all rated currents of that frame size.

In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, further samples shall be tested in accordance with Table 9b and/or Table 10 as applicable.

Unless otherwise stated, short-circuit releases shall be set at maximum (time and current) for all tests.

The circuit-breakers to be tested shall, in all their essential details, correspond to the design of the type which they represent.

Unless otherwise stated, the tests shall be made with the same kind of current and, in the case of a.c., at the same rated frequency and with the same number of phases as in the intended service. Tests performed at 50 Hz cover 60 Hz applications and vice-versa, except for the performance of under-voltage and shunt releases (see 7.2.2 of IEC 60947-1:2007/AMD2:2010 and 7.2.2.6 of IEC 60947-1:2007).

If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as specified in 7.2.1.1.4. In addition, electrically controlled mechanisms shall be energized via the appropriate circuit-breaker control circuits complete with switching devices. It shall be verified that the circuit-breaker operates correctly on no-load when it is operated under the above conditions.

In case of circuit-breakers with dependent manual operation (see 2.4.12 of 60947-1:2007), the circuit-breaker shall be operated with an operating speed, during actuation, of 0,1 m/s ± 25 %, this speed being measured where the operating means of the test apparatus touches the actuating means of the circuit-breaker under test. For rotary handles the angular velocity shall correspond substantially to the above conditions, referred to the speed of the operating means (at its extremities) of the circuit-breaker under test.

The circuit-breaker under test shall be mounted complete on its own support or an equivalent support.

Circuit-breakers shall be tested in free air.

If a circuit-breaker may be used in specified individual enclosures and has been tested in free air, it shall be additionally tested in the smallest of such enclosures stated by the manufacturer, using a new sample, for each of the following:

a) A short-circuit test according to 8.3.5, at U_e max, and corresponding I_{cu}, with release settings at maximum (see Footnote [a] of Table 10).

b) A temperature rise test according to the general conditions of 8.3.2.5 on a circuit-breaker having a maximum I_{th}, at the conventional enclosed thermal rating I_{the} (see 4.3.3.2). The temperature rises shall meet the requirements of 7.2.2 except that the temperature rise of the terminals shall not exceed 70 K.

Details of these tests, including the dimensions of the enclosure, shall be stated in the test report.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one circuit-breaker only.

However, if a circuit-breaker may be used in specified individual enclosures and is tested throughout in the smallest of such enclosures stated by the manufacturer, the tests in free air need not be made provided that such enclosure is bare metallic, without insulation. Details, including the dimensions of the enclosure, shall be stated in the test report.

For the tests in free air, for tests concerning overload performance (8.3.3.5), short-circuit (8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.6, 8.3.7.7 and 8.3.8.4), and short-time withstand current (8.3.6.3 and 8.3.8.3) where applicable, a metallic screen shall be placed on all sides of the circuit-breaker in accordance with the manufacturer's instructions. Details, including distances of the metallic screen from the circuit-breaker, shall be stated in the test report.

The characteristics of the metallic screen shall be as follows:

- structure: woven wire mesh; or
  perforated metal; or
  expanded metal;
- ratio hole area/total area: 0,45 to 0,65;
- size of hole: not exceeding 30 mm^2;
- finish: bare or conductive plating;
- resistance: shall be included in the calculation for the prospective fault current in the fusible element circuit (see 8.3.4.1.2, item d) of IEC 60947-1:2007) when measured from the furthest point on the metallic screen likely to be reached by arc emissions.

The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions (see 5.2 e)).

Maintenance or replacements of parts is not permitted.

If, for convenience of testing, it appears useful to increase the severity of a test (for example to adopt a higher frequency of operation in order to reduce the duration of the test), this shall not be done without the consent of the manufacturer.

For single-phase tests on individual poles of multipole circuit-breakers intended for use on phase-earthed systems, see Annex C.

For additional tests for circuit-breakers for unearthed or impedance earth systems (IT), see Annex H.

Table 10 – Number of samples for test *(1 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Temper-ature-rise verification	Footnotes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	See 8.3.3		X	[g]
II (I_{cs}) and VI (combined)	X			X		2	1		X	U_e	X		X	[h]
							2	X		U_e	X			[b]
	X				X	3	1		X	U_e	X		X	[h]
							2	X		U_e	X			[b]
							3		X	U_e	X		X	[j]
		X		X	X	3	1		X	U_e max corr.		X	X	[h]
							2	X		U_e max corr.		X		[b]
							3		X	U_e max	X		X	[k]
			X	X	X	4	1		X	U_e max corr.		X	X	[h]
							2	X		U_e max corr.		X		[b]
							3		X	U_e intermed.	X		X	[e]
							4		X	U_e max	X		X	[k]
III (I_{cu})	X			X		2	1		X	U_e	X			[g]
							2	X		U_e	X			[b]
	X				X	3	1		X	U_e	X			[g]
							2	X		U_e	X			[b]
							3		X	U_e	X			[c]
		X		X	X	3	1		X	U_e max corr.		X		[g]
							2	X		U_e max corr.		X		[b]
							3		X	U_e max	X			[d]
			X	X	X	4	1		X	U_e max corr.		X		[g]
							2	X		U_e max corr.		X		[b]
							3		X	U_e intermed.	X			[e]
							4		X	U_e max	X			[d]

Table 10 *(2 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Time delay		Temperature-rise verification	Foot-notes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.	Corr.	Max.		
IV (I_{cw}) [l]	X			X	X	2	1		X	U_e max		X		X	X	g
							2		X	U_e max		X		X	X	m
			X	X	X	3	1		X	U_e max corr.		X	X		X	g
							2		X	U_e max corr.	X		X		X	i
							3		X	U_e max	X		X		X	n, d
V Integral fused (I_{cu})	X	X	X	X	X	2	1		X	U_e max	X				X	f, g
							2	X		U_e max	X					b
Individual pole (Annex C) (I_{su})	X	X	X	X	X	2	1		X	U_e max	I_{su}					g
							2	X		U_e max	I_{su}					–
Individual pole (Annex H) (I_{IT})	X	X	X	X	X	1	1		X	U_e max	I_{IT}					g

Key

Mul. = multiple; Corr. = corresponding; Intermed. = intermediate

NOTE 1 Table 10 applies to the test programmes of Table 9. In the case of the alternative test programmes (see 8.3.1.4), Table 9b and Table 9c are applicable.

NOTE 2 The applicability of a test or test sequence is indicated by X in the relevant space.

[a] Min means the minimum I_n of a given frame size; in the case of adjustable overload releases, it means the minimum setting of the minimum I_n. Max means the maximum I_n of a given frame size.

[b] This sample is omitted in the following cases:

- a circuit-breaker having a single non-adjustable current setting for a given frame size;
- a circuit-breaker provided only with a shunt release (i.e. without an integral overcurrent release);
- a circuit-breaker with electronic overcurrent protection, of a given frame size, having an adjustable current rating by electronic means only (i.e. without change of current sensors).

[c] Connections reversed.

[d] Connections reversed, if terminals unmarked.

[e] To be agreed between test station and manufacturer.

[f] If terminals unmarked, an additional sample shall be tested with connections reversed.

[g] In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction, under the conditions applicable to sample 1.

[h] The requirement of footnote g applies to sequence VI (combined) and also to sequence II where $I_{cs} = I_{cu}$.

[i] This sample is selected based on the highest value of thermal energy (I_{cw}^2t; where "t" is the corresponding short-time delay, see 4.3.6.4). This sample is omitted if the highest thermal energy condition is met by sample 1 or 3.

[j] This sample, with connections reversed, is only required when sequence III is replaced by sequence II ($I_{cu}= I_{cs}$, see 8.3.5).

[k] Connections reversed, if terminals unmarked, when sequence III is replaced by sequence II ($I_{cu} = I_{cs}$, see 8.3.5) or when sequence VI replaces sequences II, III and IV ($I_{cu} = I_{cs} = I_{cw}$, see 8.3.8), otherwise this sample is tested forward connected.

[l] Applies only to circuit breakers with a rated short-time withstand current (see 4.4).

[m] This sample, with connections reversed, is only required when terminals unmarked and sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

[n] This sample is only required when sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

8.3.2.2 Test quantities

8.3.2.2.1 Values of test quantities

Subclause 8.3.2.2.1 of IEC 60947-1:2007 applies.

8.3.2.2.2 Tolerances on test quantities

Subclause 8.3.2.2.2 of IEC 60947-1:2007 applies.

8.3.2.2.3 Frequency of the test circuit for a.c.

All tests shall be made at the rated frequency of the circuit-breaker. For all short-circuit tests, if the rated breaking capacity is essentially dependent on the value of the frequency, the tolerance shall not exceed ±5 %.

If the manufacturer declares the rated breaking capacity to be substantially unaffected by the value of the frequency, the tolerance shall not exceed ±25 %.

8.3.2.2.4 Power factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

Table 11 – Values of power factors and time constants corresponding to test currents

Test current *I* kA	Power factor			Time constant ms		
	Short-circuit	Operational performance capability	Overload	Short-circuit	Operational performance capability	Overload
I ≤ 3	0,9	0,8	0,5	5	2	2,5
3 < *I* ≤ 4,5	0,8			5		
4,5 < *I* ≤ 6	0,7			5		
6 < *I* ≤ 10	0,5			5		
10 < *I* ≤ 20	0,3			10		
20 < *I* ≤ 50	0,25			15		
50 < *I*	0,2			15		

8.3.2.2.5 Time constant of the test circuit

Subclause 8.3.4.1.4 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

8.3.2.2.6 Power-frequency recovery voltage

Subclause 8.3.2.2.3, item a) of IEC 60947-1:2007/AMD2:2014 applies.

8.3.2.2.7 Ripple of the test current for d.c.

The test current shall comply with the requirements of 6.3.1 of IEC 62475:2010.

8.3.2.3 Evaluation of test results

The condition of the circuit-breaker after tests shall be checked by the verifications applicable to each sequence.

A circuit-breaker is deemed to have met the requirements of this standard if it meets the requirements of each sequence as applicable.

The case shall not be broken but hairline cracks are acceptable.

NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of a superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

8.3.2.4 Test reports

Subclause 8.3.2.4 of IEC 60947-1:2007 applies.

8.3.2.5 Test conditions for temperature-rise test

The circuit-breaker shall meet the requirements of 7.2.2.

Subclause 8.3.3.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except 8.3.3.3.6, with the following addition:

The circuit-breaker shall be mounted in accordance with 8.3.2.1.

During the temperature rise test of sequence I (see 8.3.3.7) coils of under-voltage releases, where applicable, shall be supplied at one rated frequency and corresponding voltage, chosen at random. Additional tests to verify coils at other rated frequencies and voltages shall be made outside the sequence.

For four-pole circuit-breakers, a test shall first be made on the three poles which incorporate over-current releases. For a circuit-breaker having a value of rated current not exceeding 63 A, an additional test shall be made by passing the test current through the fourth pole and its adjacent pole. For higher rated current values, the method of testing shall be the subject of a separate agreement between manufacturer and user.

8.3.2.6 Test conditions for short-circuit tests

8.3.2.6.1 General requirements

Subclause 8.3.4.1.1 of IEC 60947-1:2007 is amplified as follows:

a) The circuit-breaker shall be mounted in accordance with 8.3.2.1.

b) Unless it can be shown that, with the manual operating means in any position, there is no opening around the manual operating means through which a music wire of 0,26 mm diameter can be inserted so as to reach the arc chamber area, the following test arrangement shall apply:

   For opening operations only, a clear, low density polyethylene sheet, 0,05 mm ± 0,01 mm thick, of a size 100 mm × 100 mm, positioned as shown in Figure 1, fixed and reasonably stretched in a frame, is placed at a distance of 10 mm from:

   – either the maximum projection of the manual closing means of a circuit-breaker without recess for this closing means;

   – or the rim of the recess for the manual closing means of a circuit-breaker with recess for this closing means.

   The polyethylene sheet shall have the following physical properties:

   – density at 23 °C: 0,92 g/cm^3 ± 0,05 g/cm^3;

– melting point: 110 °C to 120 °C.

On the side remote from the circuit-breaker there shall be an appropriate backing to obviate tearing of the polyethylene sheet due to the pressure wave which may occur during the short-circuit test (see Figure 1).

For tests other than those in an individual enclosure, a shield which may be of insulating material or of metal is placed between the metallic screen and the polyethylene sheet (see Figure 1).

NOTE This test arrangement applies to O operations only, since it is difficult to arrange for CO operations and it is accepted that O operations are no less severe than CO operations (see 8.3.2.6.4).

c) The circuit-breaker shall be operated during tests to simulate service conditions as closely as possible

A circuit-breaker having a dependent power operation shall be closed during tests with the control supply (voltage or pressure) at 85 % of its rated value.

A circuit-breaker having an independent power operation shall be closed during tests with the operating mechanism charged to its maximum value stated by the manufacturer.

A circuit-breaker having a stored energy operation shall be closed during tests with the operating means charged at 85 % of the rated voltage of the auxiliary supply.

d) If a circuit-breaker is fitted with adjustable over-current releases, the setting of these releases shall be as specified for each test sequence.

For circuit-breakers without over-current releases but fitted with a shunt release, this release shall be energized by the application of a voltage equal to 70 % of the rated control supply voltage of the release (see 7.2.1.2.3), at a time not earlier than that of the initiation of the short-circuit nor later than 10 ms after the initiation of the short-circuit.

e) For all these tests, the line side of the test circuit shall be connected to the corresponding terminals of the circuit-breaker as marked by the manufacturer. In the absence of such markings, the test connections shall be as specified in Table 10.

8.3.2.6.2 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies.

8.3.2.6.3 Calibration of the test circuit

Subclause 8.3.4.1.5 of IEC 60947-1:2007 applies.

8.3.2.6.4 Test procedure

8.3.2.6.4.1 General

Subclause 8.3.4.1.6 of IEC 60947-1:2007 applies, with the following addition.

8.3.2.6.4.2 Tests on one-, two- and three-pole circuit-breakers

After calibration of the test circuit in accordance with 8.3.2.6.3, the temporary connections are replaced by the circuit-breaker under test and its connecting cables if applicable.

Tests for the performance under short-circuit conditions shall be made according to the sequences in Table 9 (see 8.3.1).

For circuit-breakers having a rated current up to and including 630 A, a cable of maximum length 75 cm, having a cross-section corresponding to the conventional thermal current (see 8.3.3.3.4, Tables 9 and 10 of IEC 60947-1:2007) shall be included as follows:

– approximately 50 cm on the supply side;
– approximately 25 cm on the load side.

For ratings ≤ 20 A, the manufacturer may specify a larger cross-section, in which case this cross-section shall be used for all relevant short-circuit tests, and stated in the test report. In addition, a verification of inverse-time delay releases according to 8.3.3.2.3 b) shall be made with this cross-section.

The sequence of operations shall be that which is applicable to each test sequence, as specified in 8.3.4.2, 8.3.5.3, 8.3.6.5 and 8.3.7.7.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.3 Tests on four-pole circuit-breakers

The requirements of 8.3.2.6.4.2 apply.

Additional sequences of operations on one or more new samples, in accordance with Table 10, shall be made on the fourth pole and its adjacent pole, according to sequences III or V, as applicable, and sequence IV if applicable. This requirement applies even when sequence III is replaced by sequence II (I_{cu} = I_{cs}) or sequence IV is replaced by sequence VI (I_{cw} = I_{cs}).

Alternatively, at the request of the manufacturer, these tests may be combined with the three-pole tests of 8.3.2.6.4.2 and made on the same samples, in which case the test in each relevant test sequence shall comprise

– the test on three adjacent poles,
– the test on the fourth pole and the adjacent pole.

The tests on the fourth pole and the adjacent pole are made at an applied voltage of $U_e/\sqrt{3}$, in the circuit shown in Figure 12 of IEC 60947-1:2007/AMD1:2010 with the connections C1 and C2 removed. The test current shall be agreed between manufacturer and user but shall be not less than 60 % of I_{cu} or I_{cw}, as applicable.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.4 Test operations

The following symbols are used for defining the sequence of operations:

O represents a breaking operation;

CO represents a making operation followed, after the appropriate opening time, by a breaking operation:

t represents the time interval between two successive short-circuit operations which shall be as short as possible, allowing for the resetting time of the circuit-breaker (see 2.19), but not less than 3 min. The actual value of *t* shall be stated in the test report.

The maximum resetting time shall be 15 min or such longer time as may be stated by the manufacturer, but not exceeding 1 h, during which time the circuit-breaker shall not be displaced. Attempts to reclose the circuit-breaker during the resetting time shall be spaced by at least 1 min.

The maximum value of I^2t (see 2.5.18 of IEC 60947-1:2007) during these tests may be recorded in the test report (see 7.2.1.2.4, item a)).

8.3.2.6.5 Behaviour of the circuit-breaker during short-circuit making and breaking tests

Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies.

8.3.2.6.6 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1:2007 applies.

8.3.2.6.7 Verification after short-circuit tests

After the opening operations of the short-circuit making and breaking capacity tests of 8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.7, 8.3.8.4, as applicable, the following conditions shall be met:

- there shall be no damage to the insulation on conductors used to wire the device;
- the polyethylene sheet, where applicable, shall show no holes visible with normal or corrected vision without additional magnification. Minuscule holes of less than 0,26 mm diameter can be ignored;
- the case shall not be broken but hairline cracks are acceptable.

NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

Additionally, after the short-circuit tests, the circuit-breaker shall comply with the verifications specified for each test sequence, as applicable.

8.3.3 Test sequence I: General performance characteristics

8.3.3.1 General

This test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Mechanical operation and operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Verification of dielectric withstand	8.3.3.6
Verification of temperature-rise	8.3.3.7
Verification of overload releases	8.3.3.8
Verification of undervoltage and shunt releases (if applicable)	8.3.3.9
Verification of main contact position (for circuit-breakers suitable for isolation)	8.3.3.10

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

See 8.3.1 for tests that may be omitted from the sequence and made on separate samples.

8.3.3.2 Test of tripping limits and characteristics

8.3.3.2.1 General

Subclause 8.3.3.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 is amplified as follows:

The ambient air temperature shall be measured as for the temperature-rise tests (see 8.3.2.5).

When the over-current opening release is normally a built-in part of the circuit-breaker, it shall be verified inside the corresponding circuit-breaker.

Any separate release shall be mounted approximately as under normal service conditions. The complete circuit-breaker shall be mounted in accordance with 8.3.2.1. The equipment under test shall be protected against undue external heating or cooling.

The connections of the separate release, if appropriate, or of the complete circuit-breaker shall be made as for normal service, with conductors of cross-section corresponding to the rated current (I_n) (see Tables 9 and 10 of 8.3.3.3.4 of IEC 60947-1:2007) and of length according to 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

For circuit-breakers with adjustable over-current releases, tests shall be made at:

a) minimum current setting and minimum time-delay setting, as applicable; and
b) maximum current setting and maximum time-delay setting, as applicable,

in each case with conductors corresponding to the rated current I_n (see 4.7.2).

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

For circuit-breakers having a neutral pole provided with an overload release, the verification of this overload release shall be made on the neutral pole alone.

The tests may be made at any convenient voltage.

8.3.3.2.2 Short-circuit releases

The operation of short-circuit releases (see 4.7.1) shall be verified at 80 % and 120 % of the short-circuit current setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms.

At a test current having a value equal to 80 % of the short-circuit current setting, the release shall not operate, the current being maintained:

– for 0,2 s in the case of instantaneous releases (see 2.20);
– for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 120 % of the short-circuit current setting, the release shall operate:

– within 0,2 s in the case of instantaneous releases (see 2.20);
– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers with an electronic overcurrent release, the operation of the short-circuit releases shall be verified by one test only on each pole individually.

For circuit-breakers with electromagnetic overcurrent releases, the operation of multipole short-circuit releases shall be verified by one test only on each combination of two phase poles in series. For circuit-breakers having an identified neutral pole provided with a short-circuit release, the neutral pole shall be tested in series with one phase pole chosen at random. In addition, the operation of the short-circuit releases shall be verified once on each pole individually, at 120 % of either the value declared by the manufacturer for individual poles, or the short-circuit current setting (if no value is declared for indivudal poles), at which value they shall operate:

– within 0,2 s in the case of instantaneous releases (see 2.20);
– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

8.3.3.2.3 Overload releases

a) Instantaneous or definite time-delay releases

The operation of instantaneous or definite time-delay overload releases (see Note 1 of 4.7.1) shall be verified at 90 % and 110 % of the overload setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms. The operation of multipole overload releases shall be verified with all phase poles loaded simultaneously with the test current.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

At a test current having a value equal to 90 % of the current setting, the release shall not operate, the current being maintained

– for 0,2 s in the case of instantaneous releases (see 2.20),
– for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 110 % of the current setting, the release shall operate

– within 0,2 s in the case of instantaneous releases (see 2.20),
– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.3), the test current for this release shall have a value equal to 1,2 times 110 % of the current setting.

b) Inverse time-delay releases

The operating characteristics of inverse time-delay overload releases shall be verified in accordance with the performance requirements of 7.2.1.2.4, item b), 2).

For circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.4), the test currents for this release shall be those given in Table 6 except that the test current at the conventional tripping current shall be multiplied by the factor 1,2.

For releases dependent on ambient air temperature, the operating characteristic shall be verified at the reference temperature (see 4.7.3 and 5.2 item b)), the release being energized on all phase poles.

If this test is made at a different ambient air temperature, a correction shall be made in accordance with the manufacturer's temperature/current data.

For thermal-magnetic releases declared by the manufacturer to be independent of ambient air temperature, the operating characteristic shall be verified by two measurements, one at 30 °C ± 2 °C, the other at 20 °C ± 2 °C or at 40 °C ± 2 °C, the release being energized on all phase poles.

For electronic releases, the operating characteristic shall be verified at the ambient temperature of the test room (see 6.1.1 of IEC 60947-1:2007/AMD2:2014), the release being energised on all phase poles.

An additional test, at a current value to be agreed between manufacturer and user, shall be made to verify that the time/current characteristics of the release conform (within the stated tolerances) to the curves provided by the manufacturer.

NOTE In addition to the tests in this subclause, the releases of circuit-breakers are also verified on each pole singly, during test sequences III, IV, V and VI (see 8.3.5.2, 8.3.5.5, 8.3.6.2, 8.3.6.7, 8.3.7.5, 8.3.7.9, 8.3.8.2 and 8.3.8.8).

8.3.3.2.4 Additional tests for definite time-delay releases

Definite time-delay releases shall be tested to verify the values of the time-delay and the non-tripping duration

a) Time-delay

This test is made at a current equal to 1,5 times the current setting:

- in the case of overload releases, with all phase poles loaded;
- for circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.1), the test current for this release shall be 1,5 times the current setting;
- in the case of electromagnetic short-circuit releases, with two poles in series carrying the test current, using successively all possible combinations of phase poles having a short-circuit release.
- in the case of electronic short-circuit releases, on one pole chosen at random.

The time-delay measured, shall be between the limits stated by the manufacturer.

If the test current overlaps with another tripping characteristic (e.g. an instantaneous tripping characteristic), the trip setting (e.g. I_{sd}, see Figure K.1) and the test current shall be reduced as necessary to prevent premature tripping. Both values shall be recorded in the test report.

b) Non-tripping duration

This test is made under the same conditions as for the test of item a) above for both overload and short-circuit releases:

Firstly, the test current equal to 1,5 times the current setting is maintained for a time interval equal to the non-tripping duration stated by the manufacturer; then, the current is reduced to the value corresponding to the overload current setting (I_r) and maintained at this value for twice the time-delay stated by the manufacturer. The circuit-breaker shall not trip.

8.3.3.3 Test of dielectric properties

Subclause 8.3.3.4.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except for item 5), with the following additions:

(i) with reference to 8.3.3.4.1, item 2) c) i) and ii), of IEC 60947-1:2007: the normal positions of operation include the tripped position, if any;

(ii) with reference to 8.3.3.4.1, item 3 c), of IEC 60947-1:2007/AMD1:2010/AMD2:2014: for the purposes of this standard circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the test;

(iii) circuit-breakers not declared as suitable for isolation shall be tested with the test voltage applied across the poles of the main circuit, the line terminals being connected together and the load terminals being connected together. The test voltage shall be in accordance with Table 12 of IEC 60947-1:2007;

(iv) for circuit-breakers suitable for isolation (see 3.5) and having an operational voltage greater than 50 V, the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA;

(v) circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater;

(vi) withdrawable circuit-breakers (see 7.1.2) shall be subject to verification of impulse withstand voltage, as per 8.3.3.4.1, item 2) b) of IEC 60947-1:2007. The test voltage shall be selected from Table 14 of IEC 60947-1:2007, and shall be applied between the withdrawable unit's main contacts and their associated fixed contacts, in the disconnected position. Acceptance criteria are as per 8.3.3.4.1, item 2) d) of IEC 60947-1:2007.

8.3.3.4 Tests of mechanical operation and of operational performance capability

8.3.3.4.1 General test conditions

The circuit-breaker shall be mounted in accordance with 8.3.2.1 except that, for the purpose of these tests, the circuit-breaker may be mounted on a metal frame. The circuit-breaker shall be protected against undue external heating or cooling.

The tests shall be made at the ambient temperature of the test room.

The control supply voltage of each control circuit shall be measured at its terminals at the rated current.

All resistors or impedances forming part of the control device shall be in circuit. However, no supplementary impedances shall be inserted between the current source and the terminals of the device.

The tests of 8.3.3.4.2, 8.3.3.4.3 and 8.3.3.4.4 shall be made on the same circuit-breaker but the order in which these tests are carried out is optional. However, for the tests of undervoltage and shunt releases the tests of 8.3.3.4.2 and 8.3.3.4.3 may, alternatively, be made on a new sample.

In the case of maintainable circuit-breakers, if it is desired to carry out a number of operations greater than that specified in Table 8, these additional operations shall be carried out first, followed by maintenance in accordance with the manufacturer's instructions, and then by the number of operations in accordance with Table 8, without any further maintenance being permitted during the remainder of this test sequence.

For convenience of testing it is permissible to subdivide each of the tests into two or more periods. No such period should, however, be less than 3 h.

8.3.3.4.2 Construction and mechanical operation

8.3.3.4.2.1 Construction

A withdrawable circuit-breaker shall be checked for the requirements stated in 7.1.2.

A circuit-breaker with stored energy operation shall be checked for compliance with 7.2.1.1.6, regarding the charge indicator and the direction of operation of manual energy storing.

8.3.3.4.2.2 Mechanical operation

Tests shall be made as specified in 8.3.3.4.1 for the following purposes:

– to prove satisfactory tripping of the circuit-breaker with the closing device energized;
– to prove satisfactory behaviour of the circuit-breaker when the closing operation is initiated with the tripping device actuated;
– to prove that the operation of a power-operated device, when the circuit-breaker is already closed, shall neither cause damage to the circuit-breaker nor endanger the operator.

The mechanical operation of a circuit-breaker may be checked under no-load conditions.

A circuit-breaker with dependent power operation shall comply with the requirements stated in 7.2.1.1.4.

A circuit-breaker with dependent power operation shall operate with the operating mechanism charged to the minimum and maximum limits stated by the manufacturer.

A circuit-breaker with stored energy operation shall comply with the requirements stated in 7.2.1.1.6 with the auxiliary supply voltage at 85 % and 110 % of the rated control supply voltage. It shall also be verified that the moving contacts cannot be moved from the open position when the operating mechanism is charged to slightly below the full charge as evidenced by the indicating device.

For a trip-free circuit-breaker it shall not be possible to maintain the contacts in the touching or closed position when the tripping release is in the position to trip the circuit-breaker.

If the closing and opening times of a circuit-breaker are stated by the manufacturer, such times shall comply with the stated values.

8.3.3.4.2.3 Undervoltage releases

Undervoltage releases shall comply with the requirements of 7.2.1.3 of IEC 60947-1:2007. For this purpose, the release shall be fitted to a circuit-breaker having the maximum current rating for which the release is suitable.

i) Drop-out voltage

It shall be verified that the release operates to open the circuit-breaker between the voltage limits specified.

The voltage shall be reduced from rated control supply voltage at a rate to reach 0 V in approximately 30 s.

The test for the lower limit is made without current in the main circuit and without previous heating of the release coil.

In the case of a release with a range of rated control supply voltage, this test applies to the maximum voltage of the range.

The test for the upper limit is made starting from a constant temperature corresponding to the application of rated control supply voltage to the release and rated current in the main poles of the circuit-breaker. This test may be combined with the temperature-rise test of 8.3.3.7.

In the case of a release with a range of rated control supply voltage, this test is made at both the minimum and maximum rated control supply voltages.

ii) Test for limits of operation

Starting with the circuit-breaker open, at the temperature of the test room, and with the supply voltage at 30 % rated maximum control supply voltage, it shall be verified that the circuit-breaker cannot be closed by the operation of the actuator. When the supply voltage is raised to 85 % of the minimum control supply voltage, it shall be verified that the circuit-breaker can be closed by the operation of the actuator.

iii) Performance under overvoltage conditions

With the circuit-breaker closed and without current in the main circuit, it shall be verified that the undervoltage release will withstand the application of 110 % rated control supply voltage for 4 h without impairing its functions.

8.3.3.4.2.4 Shunt releases

Shunt releases shall comply with the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. For this purpose, the release shall be fitted to a circuit-breaker having the maximum rated current for which the release is suitable.

It shall be verified that the release will operate to open the circuit-breaker at 70 % rated control supply voltage when tested at an ambient temperature of +55 °C ± 2 °C without current in the main poles of the circuit-breaker. In the case of a release having a range of rated control supply voltages, the test voltage shall be 70 % of the minimum rated control supply voltage.

8.3.3.4.3 Operational performance capability without current

These tests shall be made under the conditions specified in 8.3.2.1. The number of operating cycles to be carried out on the circuit-breaker is given in column 3 of Table 8; the number of operating cycles per hour is given in column 2 of this table.

The tests shall be carried out without current in the main circuit of the circuit-breaker.

For circuit-breakers which can be fitted with shunt releases, 10 % of the total number of operating cycles shall be closing/tripping operations, with the shunt release energized at maximum rated control supply voltage.

For circuit-breakers which can be fitted with undervoltage releases, 10 % of the total number of operating cycles shall be closing/tripping operations at the minimum rated control supply voltage, this voltage to the release being removed after each closing operation, to trip the circuit-breaker.

In each case, half the relevant number of operating cycles shall be made at the beginning and the other half at the end of the tests.

For circuit-breakers fitted with undervoltage releases, prior to the operational performance test, without the undervoltage release being energized, it shall be verified that the circuit-breaker cannot be closed by attempting 10 times to effect a closing operation of the circuit-breaker.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing devices, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature-rises of the electrical components do not exceed the limits indicated in Table 7.

In the case of manually operated circuit-breakers, they shall be operated as in normal use.

8.3.3.4.4 Operational performance capability with current

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, the test circuit being in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The operating rate and the number of operating cycles to be carried out are given in columns 2 and 4 of Table 8.

The circuit-breaker shall be operated so as to make and break its rated current at its maximum rated operational voltage, assigned by the manufacturer, at a power factor or time constant as applicable in accordance with Table 11, the tolerance being in accordance with 8.3.2.2.2.

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

For circuit-breakers fitted with adjustable releases, the tests shall be made with the overload setting at maximum and the short-circuit setting at minimum.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing devices, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature rises of the electrical components do not exceed the values indicated in Table 7.

Manually operated circuit-breakers shall be operated as in normal use.

8.3.3.4.5 Additional test of operational performance capability without current for withdrawable circuit-breakers

A test of operational performance capability without current shall be carried out on the withdrawal mechanism and associated interlocks of withdrawable circuit-breakers.

The number of operating cycles shall be 100.

After this test, the isolating contacts, withdrawal mechanism and interlocks shall be suitable for further service. This shall be verified by inspection.

8.3.3.5 Overload performance

This test applies to circuit-breakers of rated current up to and including 630 A.

NOTE 1 At the request of the manufacturer, the test can also be made on circuit-breakers of rated current higher than 630 A.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The test shall be made at a voltage corresponding to the maximum operational voltage $U_{e\ max}$ assigned by the manufacturer to the circuit-breaker, taking into account the requirement for recovery voltage of Table 12 (see also 8.3.2.2.3 a) of IEC 60947-1:2007/AMD2:2014).

For circuit-breakers fitted with adjustable releases, the test shall be made with its releases set at maximum.

The circuit-breaker shall be opened nine times manually and three times automatically by the action of an overload release, except for circuit-breakers having a short-circuit release of a maximum setting less than the test current, in which case all 12 operations shall be automatic.

If the testing means do not withstand the let-through energy occurring during the automatic operation, the test may be performed as follows, with the agreement of the manufacturer:

– 12 manual operations;
– three additional operations with automatic opening, made at any convenient voltage.

During each of the manually operated cycles, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The number of operating cycles per hour shall be that specified in column 2 of Table 8. If the circuit-breaker does not latch in at the specified rate, this rate may be reduced sufficiently so that the circuit-breaker may be closed, the full current being established.

If test conditions at the testing station do not permit testing at the operating rate given in Table 8, a slower rate may be used, but details shall be stated in the test report.

The values of the test current and of the recovery voltage shall be in accordance with Table 12, at the power factor or time constant, as applicable, in accordance with Table 11, the tolerances being in accordance with 8.3.2.2.2.

NOTE 2 With the agreement of the manufacturer the test can be made under more severe conditions than specified.

Table 12 – Test circuit characteristics for overload performance

	Alternating current	Direct current
Current	6 I_n	2,5 I_n
Recovery voltage	1,05 $U_{e\ max}$	1,05 $U_{e\ max}$
$U_{e\ max}$ = maximum operational voltage of the circuit-breaker.		

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

The prospective current at the supply terminals of the circuit-breaker shall be at least 10 times the test current, or at least 50 kA, whichever of the two values is the lower.

8.3.3.6 Verification of dielectric withstand

8.3.3.6.1 General

The test shall be performed on the circuit-breaker whilst it remains mounted for the preceding test. If this is not practicable it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

8.3.3.6.2 Test voltage

Subclause 8.3.3.4.1, item 3) b), of IEC 60947-1:2007/AMD1:2010 applies.

The value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s., or 1 415 V d.c. if an a.c. voltage cannot be applied. The value of U_e referred to is that at which the preceding switching and/or short-circuit tests have been performed.

8.3.3.6.3 Application of the test voltage

The test voltage shall be applied for 5 s in accordance with 8.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:2007 and, in addition, between the incoming and outgoing terminals of each pole with the circuit-breaker open. The use of the metal foil as specified in 8.3.3.4.1, item 1), of IEC 60947-1:2007/AMD1:2010/AMD2:2014 is not required. For the purposes of this standard, circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the tests. The normal positions of operation include the tripped position, if any.

For circuit-breakers suitable for isolation the leakage current shall be measured in accordance with 8.3.3.3, item (iv), except that the leakage current shall not exceed 2 mA.

8.3.3.6.4 Acceptance criteria

Subclause 8.3.3.4.1, item 3) d), of IEC 60947-1:2007 applies.

8.3.3.7 Verification of temperature-rise

Following the test according to 8.3.3.6, a temperature-rise test shall be made at the conventional thermal current according to 8.3.2.5. At the end of the test, the values of temperature-rise shall not exceed those specified in Table 7.

8.3.3.8 Verification of overload releases

Immediately following the test according to 8.3.3.7, the operation of overload releases shall be verified at 1,45 times the value of their current setting at the reference temperature (see 7.2.1.2.4, item b), 2)).

For this test, all poles shall be connected in series. Alternatively, this test may be made using a 3-phase supply.

This test may be made at any convenient voltage.

The operating time shall not exceed the conventional tripping time.

With the manufacturer's consent, a time interval between the tests of 8.3.3.7 and 8.3.3.8 may occur.

The test may, alternatively, be made at the ambient air temperature at a test current corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

8.3.3.9 Verification of undervoltage and shunt releases

Circuit-breakers fitted with undervoltage releases shall be subjected to the test of 8.3.3.4.2.3 i), except that the tests for upper and lower limits shall be made at the temperature of the test room without current in the main circuit. The release shall not operate at 70 % of the minimum control supply voltage and shall operate at 35 % of the maximum rated control supply voltage.

Circuit-breakers fitted with shunt releases shall be subjected to the test of 8.3.3.4.2.4, except that the test may be made at the temperature of the test room. The release shall operate at 70 % of the minimum rated control supply voltage.

8.3.3.10 Verification of the main contact position

For circuit-breakers suitable for isolation (see 3.5), following the verification of 8.3.3.8, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 8.2.5 of IEC 60947-1:2007/AMD1:2010.

8.3.4 Test sequence II: Rated service short-circuit breaking capacity

8.3.4.1 General

Except when the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Rated service short-circuit breaking capacity	8.3.4.2
Verification of operational performance capability	8.3.4.3
Verification of dielectric withstand	8.3.4.4
Verification of temperature-rise	8.3.4.5
Verification of overload releases	8.3.4.6

For the case where $I_{cs} = I_{cu}$, see 8.3.5.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.4.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{cs}, as declared by the manufacturer, in accordance with 4.3.6.2.3.

The power factor for this test shall be according to Table 11, for the appropriate test current.

The sequence of operations shall be:

O – *t* – CO – *t* – CO

In the case of integrally fused circuit-breakers, any blown fuse shall be replaced after each operation. The time interval *t* may need to be extended for this purpose.

8.3.4.3 Verification of operational performance capability

Following the test according to 8.3.4.2, the operational performance capability shall be verified in accordance with 8.3.3.4.4 except that this verification shall be made at the same rated operational voltage as used for the test of 8.3.4.2, and that the number of operations shall be 5 % of the number given in column 4 of Table 8.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting as specified in Table 10.

8.3.4.4 Verification of dielectric withstand

Following the test according to 8.3.4.3, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured in accordance with 8.3.3.6.

8.3.4.5 Verification of temperature-rise

Following the test according to 8.3.4.4, the temperature-rise at the main terminals shall be verified in accordance with 8.3.2.5. The temperature-rise shall not exceed the values given in Table 7.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.4.6 Verification of overload releases

Immediately following the test according to 8.3.4.5, the operation of overload releases shall be verified in accordance with 8.3.3.8.

With the manufacturer's consent, a time interval between the tests of 8.3.4.5 and 8.3.4.6 may occur.

8.3.5 Test sequence III: Rated ultimate short-circuit breaking capacity

8.3.5.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers of selectivity category A and to circuit-breakers of selectivity category B having a rated ultimate short-circuit breaking capacity higher than the rated short-time withstand current.

NOTE For this type of selectivity category B circuit-breaker, the instantaneous release operates at values of current in excess of those stated in column 2 of Table 3 (4.3.6.4); this type of release can be referred to as "instantaneous override".

For circuit-breakers of selectivity category B having a rated short-time withstand current equal to their rated ultimate short-circuit breaking capacity, this test sequence need not be made, since, in this case, the ultimate short-circuit breaking capacity is verified when carrying out test sequence IV.

For integrally fused circuit-breakers, test sequence V applies in place of this sequence.

Where $I_{cs} = I_{cu}$, this test sequence need not be made, in which case construction break tests are required in Sequence II (see Table 10) and the following verifications shall additionally be made in test sequence II:

– the verification of 8.3.5.2, at the beginning of the test sequence;
– the verification of 8.3.5.5, at the end of the test sequence.

This test sequence comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.5.2
Rated ultimate short-circuit breaking capacity	8.3.5.3
Verification of dielectric withstand	8.3.5.4
Verification of overload releases	8.3.5.5

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.5.2 Verification of overload releases

The operation of overload releases shall be verified at twice the value of their current setting on each pole separately. This test may be made at any convenient voltage.

If the ambient temperature differs from the reference temperature, the test current shall be corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the current setting at the reference temperature, on a pole singly.

8.3.5.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to 8.3.5.2, a short-circuit breaking capacity test is made with a value of prospective current equal to the ultimate rated short-circuit breaking capacity as declared by the manufacturer, under the general conditions according to 8.3.2.

The sequence of operations shall be:

$$O - t - CO$$

8.3.5.4 Verification of dielectric withstand

Following the test according to 8.3.5.3 the dielectric withstand shall be verified according to 8.3.3.6. For circuit breakers suitable for isolation, the leakage current shall not exceed 6 mA.

8.3.5.5 Verification of overload releases

Following the test according to 8.3.5.4, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.6 Test sequence IV: Rated short-time withstand current

8.3.6.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers with a rated short-time withstand current (see 4.4); it comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.6.2
Rated short-time withstand current	8.3.6.3
Verification of temperature-rise	8.3.6.4
Short-circuit breaking capacity at maximum short-time withstand current	8.3.6.5
Verification of dielectric withstand	8.3.6.6
Verification of overload releases	8.3.6.7

Where integrally fused circuit-breakers are of selectivity category B, they shall meet the requirements of this sequence.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.6.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.6.3 Test of rated short-time withstand current

Subclause 8.3.4.3 of IEC 60947-1:2007 applies with the following addition:

For the purpose of this test only, any over-current release, including the instantaneous override, if any, likely to operate during the test, shall be rendered inoperative.

8.3.6.4 Verification of temperature-rise

Following the test according to 8.3.6.3, the temperature-rise at the main terminals shall be verified according to 8.3.2.5. The temperature-rise shall not exceed the value given in Table 7.

With the manufacturer's agreement the verification of the temperature-rise may be made after the verification of the dielectric withstand (8.3.6.6). This verification need not be made where, for a given frame size, the test of 8.3.7.3 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.6.5 Test of short-circuit breaking capacity at the maximum short-time withstand current

Following the test according to 8.3.6.4, a short-circuit test shall be made with the following sequence of operations:

$$O - t - CO$$

under the general conditions of 8.3.2, with a value of prospective current equal to that of the short-time withstand current test (see 8.3.6.3) and at the highest voltage applicable to the rated short-time withstand current.

The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release, and the instantaneous override, if any, shall not operate. If the circuit-breaker has a making current release (see 2.10), this requirement does not apply to the CO operation, if the prospective current exceeds the pre-determined value, since it will then operate.

8.3.6.6 Verification of dielectric withstand

Following the test carried out according to 8.3.6.5, the dielectric withstand shall be verified according to 8.3.3.6.

8.3.6.7 Verification of overload releases

Following the test according to 8.3.6.6, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.7 Test sequence V: Performance of integrally fused circuit-breakers

8.3.7.1 General

This test sequence applies to integrally fused circuit-breakers. It replaces test sequence III and comprises the following tests:

	Test	Subclause
Stage 1	Short-circuit at the selectivity limit current	8.3.7.2
	Verification of temperature-rise	8.3.7.3
	Verification of dielectric withstand	8.3.7.4
Stage 2	Verification of overload releases	8.3.7.5
	Short-circuit at 1,1 times take-over current	8.3.7.6
	Short-circuit at ultimate short-circuit breaking capacity	8.3.7.7
	Verification of dielectric withstand	8.3.7.8
	Verification of overload releases	8.3.7.9

This test sequence is divided into two stages:

– Stage 1 comprises the tests according to 8.3.7.2 to 8.3.7.4;

– Stage 2 comprises the tests according to 8.3.7.5 to 8.3.7.9.

The two stages may be carried out:

– on two separate circuit-breakers, or
– on the same circuit-breaker, with maintenance between them, or
– on the same circuit-breaker, without any maintenance, in which case the test according to 8.3.7.4 may be omitted.

The test according to 8.3.7.3 need only be made if $I_{cs} > I_s$.

Tests according to 8.3.7.2, 8.3.7.6 and 8.3.7.7 shall be made at the maximum operational voltage of the circuit-breaker.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.7.2 Short-circuit at the selectivity limit current

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current equal to the selectivity limit current, as declared by the manufacturer (see 2.17.4).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one O operation at the conclusion of which the fuses shall still be intact.

8.3.7.3 Verification of temperature-rise

NOTE This verification of temperature-rise is made since the fuses can have blown during the short-circuit test of test sequence II, 8.3.4.2, in which case the test of 8.3.7.2 is more severe.

Following the test according to 8.3.7.2 the temperature-rise at the main terminals shall be verified, in accordance with 8.3.2.5.

The temperature-rise shall not exceed the value given in Table 7.

8.3.7.4 Verification of dielectric withstand

Following the test according to 8.3.7.3 the dielectric withstand shall be verified according to 8.3.3.6.

8.3.7.5 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.7.6 Short-circuit at 1,1 times the take-over current

Following the test according to 8.3.7.5 a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to 1,1 times the take-over current declared by the manufacturer (see 2.17.5).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one "O" operation at the conclusion of which at least two of the fuses shall have blown.

8.3.7.7 Short-circuit at rated ultimate short-circuit breaking capacity

Following the test according to 8.3.7.6, a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to the ultimate short-circuit breaking capacity I_{cu}, as declared by the manufacturer.

For the purpose of this test, a new set of fuses shall be fitted.

The sequence of operations shall be:

$$O – t – CO$$

a further new set of fuses being fitted during the time interval t, which may need to be extended for that purpose.

8.3.7.8 Verification of dielectric withstand

Following the test according to 8.3.7.7 and with a new set of fuses fitted, the dielectric withstand shall be verified according to 8.3.5.4.

8.3.7.9 Verification of overload releases

Following the test according to 8.3.7.8, the operation of overload releases shall be verified in accordance with 8.3.5.2 except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.8 Test sequence VI: combined test sequence

8.3.8.1 General

At the discretion of, or in agreement with the manufacturer, this test sequence may be applied to circuit-breakers of selectivity category B:

a) when the rated short-time withstand current and the rated service short-circuit breaking capacity have the same value ($I_{cw} = I_{cs}$); in this case it replaces test sequences II and IV;

b) when the rated short-time withstand current, the rated service short-circuit breaking capacity and the rated ultimate short-circuit breaking capacity have the same value ($I_{cw} = I_{cs} = I_{cu}$); in this case it replaces test sequences II, III and IV.

This test sequence comprises the following tests:

Test	Subclauses
Verification of overload releases	8.3.8.2
Rated short-time withstand current	8.3.8.3
Rated service short-circuit breaking capacity*	8.3.8.4
Verification of operational performance capability	8.3.8.5
Verification of dielectric withstand	8.3.8.6
Verification of temperature-rise	8.3.8.7
Verification of overload releases	8.3.8.8
* For circuit-breakers falling into the case of 8.3.8.1b) above, this is also the rated ultimate short-circuit breaking capacity.	

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.8.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.8.3 Test of rated short-time withstand current

Following the test according to 8.3.8.2, a test shall be made at the rated short-time withstand current according to 8.3.6.3.

This test does not need to be made on the sample of minimum I_n specified in Table 10.

8.3.8.4 Test of rated service short-circuit breaking capacity

Following the test according to 8.3.8.3, a test shall be made at the rated service short-circuit breaking capacity according to 8.3.4.2, at the highest voltage applicable to the rated short-time withstand current. The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release.

During this test the instantaneous override (if any) shall not operate, and the making current release (if any) shall operate.

8.3.8.5 Verification of operational performance capability

Following the test according to 8.3.8.4, the operational performance capability shall be verified in accordance with 8.3.4.3.

8.3.8.6 Verification of dielectric withstand

Following the test according to 8.3.8.5, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured according to 8.3.3.6.

8.3.8.7 Verification of temperature-rise

Following the test according to 8.3.8.6, the temperature-rise at the main terminals shall be verified in accordance with 8.3.4.5.

The temperature-rise shall not exceed the value given in Table 7.

This verification need not be made where, for a given frame size, the test of 8.3.8.4 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.8.8 Verification of overload releases

After cooling down following the test according to 8.3.8.7, the operation of overload releases shall be verified in accordance with 8.3.3.8.

Thereafter, the operation of the overload releases shall be verified on each pole individually in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.9 Critical d.c. load current test

This test applies only to circuit-breakers with d.c. ratings.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007 except that the metallic screen and the fusible element shall not be used.

Samples to be tested shall be selected according to Table 10 – sequence I, except that for application of footnote g, construction breaks relative to the over-current tripping devices shall not be considered.

The test shall be made at the maximum operational d.c. voltage (U_e max) assigned by the manufacturer to the circuit-breaker.

For circuit-breakers fitted with adjustable releases, the test shall be made with the releases set at the maximum.

The circuit-breaker shall be closed and opened 5 times on to each of the test currents listed below. If the direction of current flow is specified by the manufacturer, the test shall be made with the current flowing in the specified direction, as indicated by the polarity and line/load marking; if not, 5 operations shall be made in the forward direction, and 5 in the reverse direction.

During each CO cycle, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The time constant shall be in accordance with Table 11 as for operational performance; at the discretion of the manufacturer, a higher value may be used, in which case this value shall be stated in the test report.

The number of operating cycles per hour shall be in accordance with Table 8.

The arcing time during the test shall be recorded and shall not exceed 1 s.

The test current values shall be: 4 A, 8 A, 16 A, 32 A and 63 A d.c., with ± 10 % tolerance, but not exceeding the rated current; the critical value is determined by taking the maximum mean arcing time, for each direction of current if applicable. The highest and lowest values of test current shall demonstrate shorter mean arcing times than the critical value; if necessary, the range of test currents shall be extended upwards or downwards by applying a 2 times ratio as many times as necessary, up to, but not exceeding, the rated current to find the critical value. If no critical value of current is found within these criteria, no further test according to this subclause is required.

The tolerances on test quantities other than the current shall be in accordance with 8.3.2.2.2.

Following this test, the same sample shall be subjected to an operational performance verification of 50 operations, under the same conditions, at the current and in the direction corresponding to the critical value. After this test, the dielectric withstand shall be verified according to 8.3.3.6 with a d.c. test voltage.

8.4 Routine tests

8.4.1 General

For the definition of routine tests, see 2.6.2 and 8.1.3 of IEC 60947-1:2007.

The following tests apply:

– mechanical operation (8.4.2);
– verification of the calibration of overcurrent releases (8.4.3);

– verification of the operation of undervoltage and shunt releases (8.4.4);
– additional tests for CBRs to Annex B (8.4.5);
– dielectric tests (see note) (8.4.6);
– verification of clearances (8.4.7).

NOTE If by the control of materials and manufacturing processes, the integrity of the dielectric properties has been proven, these tests can be replaced by sampling tests according to a recognized sampling plan (see IEC 60410).[1]

However, operation of the circuit-breaker during manufacture and/or other routine test may take the place of the tests listed above provided the same conditions apply and the number of operations is not less than that specified.

The tests of 8.4.3, 8.4.4 and 8.4.5 shall be made with the releases fitted to the circuit-breaker or to an appropriate test equipment simulating the behaviour of the circuit-breaker.

In the context of the tests of 8.4.2, 8.4.3, 8.4.4, 8.4.6 and 8.4.7, the term "circuit-breakers" covers CBRs, where applicable.

8.4.2 Mechanical operation tests

The following tests shall be carried out without current in the main circuit, except when required for the operation of releases. During the tests, no adjustments shall be made and the operation shall be satisfactory.

The following tests shall be made on manually-operated circuit-breakers:

– two close-open operations;
– two trip-free operations.

NOTE For the definition of a trip-free mechanical switching device, see 2.4.23 of IEC 60947-1:2007.

The following tests shall be made on power-operated circuit-breakers at 110 % of the maximum rated control supply voltage and/or of the rated supply pressure, and at 85 % of the minimum rated control supply voltage and/or of the rated supply pressure:

– two close-open operations;
– two trip-free operations;
– for automatic reclosing circuit-breakers, two automatic reclosing operations.

8.4.3 Verification of the calibration of overcurrent releases

8.4.3.1 Inverse time-delay releases

The verification of the calibration of inverse time-delay releases shall be made at a multiple of the current setting to check that the tripping time conforms (within tolerances) to the curve provided by the manufacturer.

This verification may be made at any convenient temperature, correction being made for any difference from the reference temperature (see 4.7.3).

8.4.3.2 Instantaneous and definite time-delay releases

The verification of the calibration of instantaneous and definite time-delay releases shall check the non-operation and operation of the releases at the values of current given in 8.3.3.2.2 or 8.3.3.2.3, item a), as applicable, without measurement of break time being required.

[1] This publication was withdrawn.

The tests may be made by loading two poles in series with the test current, using all possible combinations of poles having releases, or by loading each pole having a release individually with the test current.

One method of determining the tripping level consists in applying a slowly rising test current, starting from a value below the lower limit until tripping of the circuit-breaker occurs. Tripping shall occur between the lower and upper limits of test current.

8.4.4 Verification of the operation of undervoltage and shunt releases

8.4.4.1 Undervoltage releases

Tests shall be made to verify that the release will operate in accordance with 7.2.1.3 of IEC 60947-1:2007 as follows:

a) Hold-in voltage

   The release shall close on to a voltage corresponding to 85 % of the minimum rated control supply voltage.

b) Drop-out voltage

   The release shall open when the voltage is reduced to a value within the range corresponding to the limits of 70 % and 35 % of the rated control supply voltage, adjusted to take account of the need to operate under the conditions specified in 8.3.3.4.2.3 i). In the case of releases having a range of rated control supply voltages, the upper limit shall correspond to the minimum of the range and the lower limit to the maximum of the range.

8.4.4.2 Shunt releases (for opening)

A test shall be made to verify that the release will operate in accordance with 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. The test may be made at any convenient temperature provided the test voltage is reduced to take account of the need for the release to operate under the conditions specified in 8.3.3.4.2.4. In the case of a release having a range of rated control supply voltages, the test voltage shall be related to 70 % of the minimum rated control supply voltage.

8.4.5 Additional tests for CBRs

The following additional tests shall be made on CBRs or r.c. units.

a) Operation of the test device

   The CBR shall be subjected to two close-trip operations or, in the case of r.c. units, to two reset-trip operations, tripping by the manual operation of the test device with the CBR supplied at the lowest rated operational voltage.

b) Verification of the calibration of the residual current tripping device of the CBR

   Using an alternating sinusoidal residual current, it shall be verified that

   – the CBR does not trip with a residual current of 0,5 times $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable;

   – the CBR trips with a residual current of $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable.

8.4.6 Dielectric tests

The test conditions shall be in accordance with 8.3.3.4.1, item 1), of IEC 60947-1:2007/AMD1:2010/AMD2:2014, except that the use of metal foil is not required. The test voltage shall be applied as follows:

– with the circuit-breaker in the open position, between each pair of terminals which are electrically connected together when the circuit-breaker is closed;

– for circuit-breakers not incorporating electronic circuits connected to the main poles, with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable;

– for circuit-breakers incorporating electronic circuits connected to the main poles, with the circuit-breaker in the open position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable, either on the incoming side or on the outgoing side, depending on the position of the electronic components.

  Alternatively, disconnection of electronic circuits connected to the main poles is permitted, in which case the test voltage shall be applied with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable.

The method of test shall be as in a) or b) or c) below at the manufacturer's discretion:

a) Two tests shall be made:

   1) Impulse withstand voltage

      The test voltage shall not be less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or the peak value corresponding to 2 U_i whichever is the greater, and

   2) Power frequency withstand voltage

      The test apparatus shall be as stated in 8.3.3.4.1, item 3) b), of IEC 60947-1:2007/AMD1:2010, except that the overcurrent trip shall be set to 25 mA. However, at the discretion of the manufacturer, for safety reasons, test apparatus of a lower power or trip setting may be used, but the short-circuit current of the test apparatus shall be at least eight times the trip setting of the overcurrent relay; for example, for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be 5 mA ± 1 mA.

      The value of the test voltage shall be 2 U_e max, with a minimum of 1 000 V r.m.s., applied for not less than 1 s. The overcurrent relay shall not trip.

b) A single power frequency test in accordance with item a) 2) above at a test voltage such that the peak value of the sinusoidal wave corresponds to the highest of the peak values of the following: 30 % of U_{imp}, 2 U_i, 2 U_e max or 1 000 V r.m.s.

c) An insulation resistance test at 500 V d.c. The insulation resistance shall be not less than 1 MΩ at any point.

If dielectric properties are tested according to a sampling plan in accordance with the note to 8.4.1, a power frequency withstand test shall be made according to 8.4.6, item a) 2) of this subclause, but with a test voltage in accordance with Table 12A of IEC 60947-1:2007/AMD2:2010. Circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater.

8.4.7 Test for the verification of clearances less than those corresponding to case A of Table 13 of IEC 60947-1:2007

Subclause 8.3.3.4.3 of IEC 60947-1:2007 applies, except that for the purposes of this standard this test shall be a routine test.

NOTE The case of clearances greater than or equal to case A of Table 13 of IEC 60947-1:2007 is covered by the tests of 8.4.6.

8.5 Special tests – Damp heat, salt mist, vibration and shock

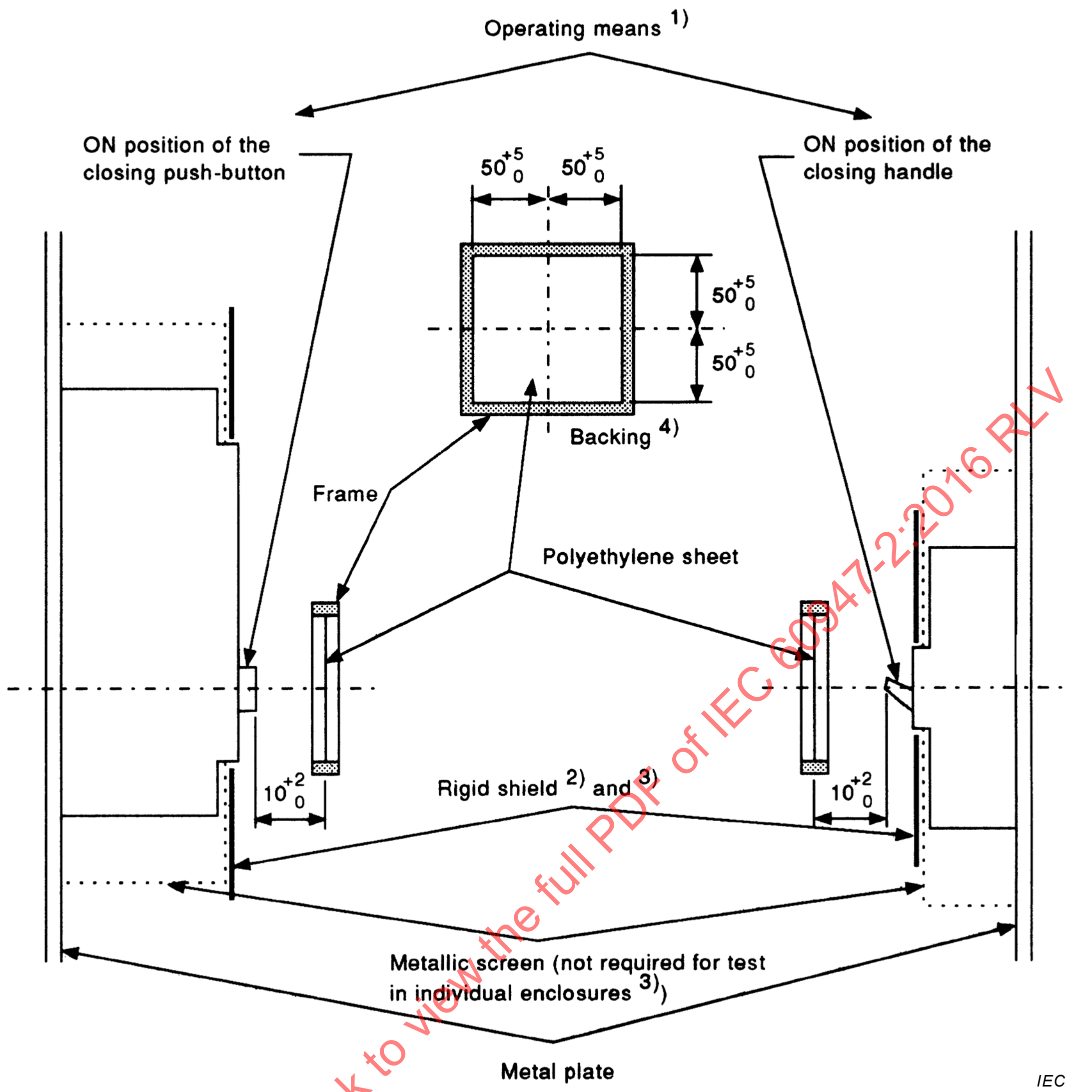
The following special tests shall be made either at the discretion of the manufacturer or according to agreement between the manufacturer and user (see 2.6.4 of IEC 60947-1:2007). As special tests, unless specifically called for, these additional tests are not mandatory, and it is not necessary for a circuit-breaker to satisfy any of these tests to conform to this standard.

Annex Q of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

During the test sequences according to Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, only the final verification of operational performance capability is required. It shall be made by carrying out the routine tests of 8.4 of this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote e) of Table Q.1 of IEC 60947-1:2007, for dry heat test, the circuit-breaker shall not carry current. Where an under-voltage release is fitted, it shall be energised with rated voltage. The circuit-breaker shall be operated according to 8.4.2 during the last hour of the test.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.



Case of circuit-breaker with closing push-button

Case of circuit-breaker with a closing handle

Dimensions in millimetres

1) The operating means includes any extension which is normally fitted for the closing operation.

2) The purpose of the rigid shield is to prevent emissions from areas other than those of the handle or push-button from reaching the polyethylene sheet (not required for tests in individual enclosures).

3) The rigid shield and the front of the metallic screen may be combined into one single conductive metal plate.

4) Made of any suitable rigid material to obviate tearing of the polyethylene sheet.

Figure 1 – Test arrangement (connecting cables not shown) for short-circuit tests

Annex A
(normative)

Co-ordination between a circuit-breaker and another short-circuit protective device associated in the same circuit

A.1 General

To ensure co-ordination between a circuit-breaker (C_1) and another short-circuit protective device (SCPD) associated with it in the same circuit, it is necessary to consider the characteristics of each of the two devices as well as their dynamic behaviour as an association.

NOTE An SCPD can incorporate additional protective means, for example, overload releases.

The SCPD may consist of a fuse (or a set of fuses) – see Figure A.1 – or of another circuit-breaker (C_2) (see Figure A.2 and Figure A.3).

The comparison of the individual operating characteristics of each of the two associated devices may not be sufficient, when reference has to be made to the behaviour of these two devices operating in series, since the impedance of the devices is not always negligible. It is recommended that this should be taken into account. For short-circuit currents it is recommended that reference be made to I^2t instead of time. Preferred templates for the representation of cut-off current and let-through energy (I^2t) characteristics are given in Annex K.

C_1 is frequently connected in series with another SCPD for reasons such as the method of power distribution adopted for the installation or because the short-circuit breaking capacity of C_1 alone may be insufficient for the proposed application. In such instances the SCPD may be mounted in locations remote from C_1. The SCPD may be protecting a main feeder supplying a number of circuit-breakers C_1 or just an individual circuit-breaker.

For such applications, the user or specifier may have to decide, on the basis of a desk study, how the optimum level of co-ordination may best be achieved. This annex is intended to give guidance for this decision, and also on the type of information which the circuit-breaker manufacturer should make available.

Guidance is also given on test requirements, where such tests are deemed necessary for the proposed application.

The term "co-ordination" includes consideration of selectivity (see 2.5.23 of IEC 60947-1:2007/AMD2:2014 and also 2.17.2 and 2.17.3 as well as consideration of back-up protection (see 2.5.24 of IEC 60947-1:2007).

Consideration of selectivity can either be carried out by desk study or by test (see A.5), whereas the verification of back-up protection normally requires the use of tests (see A.6).

When considering short-circuit breaking capacity, reference may be made to the rated ultimate short-circuit breaking capacity (I_{cu}), or to the rated service short-circuit breaking capacity (I_{cs}), according to the desired criterion.

A.2 Scope and object

This annex gives guidance on and requirements for the co-ordination of circuit-breakers with other SCPDs associated in the same circuit, as regards selectivity as well as back-up protection.

The object of this annex is to state:

– the general requirements for the co-ordination of a circuit-breaker with another SCPD;
– the methods and the tests (if deemed necessary) intended to verify that the conditions for co-ordination have been met.

A.3 General requirements for the co-ordination of a circuit-breaker with another SCPD

A.3.1 General considerations

Ideally, the co-ordination should be such that a circuit-breaker (C_1) alone will operate at all values of over-current up to the limit of its rated short-circuit breaking capacity I_{cu}.

NOTE 1 If the value of the prospective fault current at the point of installation is less than the rated ultimate short-circuit breaking capacity of C_1, it can be assumed that the SCPD is only in the circuit for considerations other than those of back-up protection.

In practice, the following considerations apply:

a) If the value of the selectivity limit current I_s (see 2.17.4) is too low, there is a risk of unnecessary loss of selectivity.
b) If the value of the prospective fault current at the point of installation exceeds the rated ultimate short-circuit breaking capacity of C_1, the SCPD shall be so selected that the behaviour of C_1 is in accordance with A.3.3 and the take-over current I_B (see 2.17.5), if any, complies with the requirements of A.3.2.

Whenever possible, the SCPD shall be located on the supply side of C_1. If the SCPD is located on the load side, it is essential that the connection between C_1 and the SCPD be so arranged as to minimize any risk of short circuit.

NOTE 2 In the case of interchangeable releases, these considerations apply to each relevant release.

A.3.2 Take-over current

For the purpose of back-up protection the take-over current I_B shall not exceed the rated ultimate short-circuit breaking capacity I_{cu} of C_1 alone (see Figure A.3a)).

A.3.3 Behaviour of C_1 in association with another SCPD

For all values of over-current up to and including the short-circuit breaking capacity of the association, C_1 shall comply with the requirements of 7.2.5 of IEC 60947-1:2007, and the association shall comply with the requirements of 7.2.1.2.4, item a).

A.4 Type and characteristics of the associated SCPD

On request, the manufacturer of the circuit-breaker shall provide information on the type and the characteristics of the SCPD to be used with C_1, and on the maximum prospective short-circuit current for which the association is suitable at the stated operational voltage.

Details of the SCPD used for any tests made in accordance with this annex, i.e. manufacturer's name, type designation, rated voltage, rated current and short-circuit breaking capacity, shall be given in the test report.

The maximum conditional short-circuit current (see 2.5.29 of IEC 60947-1:2007) shall not exceed the rated ultimate short-circuit breaking capacity of the SCPD.

If the associated SCPD is a circuit-breaker, it shall meet the requirements of this standard, or any other relevant standard.

If the associated SCPD is a fuse, it shall be in accordance with the appropriate fuse standard.

A.5 Verification of selectivity

A.5.1 General

Selectivity can normally be considered by the manufacturer by desk study alone, i.e. by a comparison of the operating characteristics of C_1 and the associated SCPD (see A.5.2). Selectivity can also be determined by tests (see A.5.3).

In certain cases, tests on the association will show a higher level of I_s than obtained by a desk study, for example:

– when C_1 is of the current-limiting type and C_2 is not provided with an intentional time-delay;

– when the opening time of the SCPD is less than that corresponding to one half-cycle.

To obtain improved selectivity when the associated SCPD is a circuit-breaker, an intentional short-time delay is sometimes provided for C_2.

Selectivity may be partial (see Figure A.3a)) or total up to the rated ultimate short-circuit breaking capacity Icu of C1.

Two illustrations of total selectivity are given in Figure A.2a) and Figure A.2b).

A.5.2 Consideration of selectivity by desk study

A.5.2.1 Selectivity in the overload zone

Two cases are considered hereafter, depending on whether the SCPD is a circuit-breaker or a fuse

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by comparison of characteristics

   Selectivity in the time-delayed over-current zone is verified by comparison of the time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to C_2, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by this standard.

b) Circuit-breaker (C_1) with fuse as SCPD – selectivity determination by comparison of characteristics

   Selectivity in the overload zone is determined by the comparison of time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to the fuse, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by the product standards.

A.5.2.2 Determination of selectivity in the fault current (short-circuit) zone

Determination from time/current characteristics, of selectivity between two circuit-breakers in the fault current (short-circuit) zone (see Figure A.2a)), is limited to the case where C_2 has a short-circuit release time-delay function provided by an electronic release.

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by consideration of peak let-through current

   In the case where the instantaneous tripping of C_2 depends on an electromagnetic effect (i.e. thermal/magnetic or magnetic-only circuit-breaker) or in the case of an electronic trip unit with an instantaneous release, the minimum level of selectivity between two circuit-breakers in the fault current zone may be determined as follows:

Selectivity is assured up to the fault current level at which the peak current let-through of C_1 is less than the peak value corresponding to the instantaneous short-circuit current setting (I_i) of C_2, taking into account the tolerance.

NOTE 1 Example of selectivity calculation

C_2 = 800 A MCCB; I_i = 8 kA r.m.s. – 12 kA r.m.s. (10 kA setting ± 20 %); C_1 = 125 A MCCB.

Minimum tripping level of C_2 is 8 × 1,414 = 11,3 kA peak.

Let-through current of C_1 at 15 kA r.m.s. prospective, due to the current limitation of C_1, is 11 kA peak, from test data.

Therefore the system is selective to at least 15 kA r.m.s. prospective.

NOTE 2 The selectivity limit obtained by this method will be on the low side and the actual limit determined by test will be significantly higher in most cases.

b) Circuit-breaker (C_1) with fuse as SCPD

Selectivity in the fault-current (short-circuit) zone (see Figure A.1) is determined from the I^2t characteristics. The selectivity limit current I_s is the maximum value at which let-through I^2t of the circuit-breaker is lower than the pre-arcing I^2t of the fuse. In the absence of an actual curve the manufacturer's quoted I^2t pre-arc value for the fuse is taken.

c) Fuse (C_1) with circuit-breaker as SCPD

Selectivity in the instantaneous tripping short-circuit zone is determined from the let-through current of the fuse.

The selectivity limit current I_s is the maximum value at which the peak let-through current of the fuse is lower than the peak value corresponding to the instantaneous tripping level (I_i) of circuit-breaker taking into account the tolerance.

A.5.2.3 Determination of selectivity limit current for specific installation conditions

Data on selectivity limits may be supplied in tabulated form, graphically or as software media. Data obtained from either a desk study or tests, to this standard, will be based on the prospective fault current level at the incoming device (C_2) and assumes that the coordinated devices are in close proximity. In practice the selectivity limit will be influenced by the impedance between the two devices. Therefore, in the practical situation taking the prospective fault current at the downstream circuit-breaker will give a more precise value for the selectivity limit.

A.5.3 Selectivity determined by test

An example of the circuit diagram for the tests is shown in Figure A.5, where:

– C_1 may be a circuit-breaker in compliance with this standard or another IEC standard or a fuse in accordance with the appropriate IEC standard;

– settings of C_1 and C_2 are adjusted to the maximum instantaneous setting, if applicable.

Tests at other release settings may be made at the discretion of the manufacturer, in which case the settings of the releases shall be recorded in the test report.

The connecting cables shall be included as specified in 8.3.2.6.4 except the total length of the cables may be distributed between the supply side and the load side of C_1 and C_2 as convenient.

The test shall consist of an O – t – CO operation, the CO operation being made by closing the downstream device C_1. If the downstream device is a fuse, the operation shall be made by closing C_2.

The test is made at the level of prospective current for which the association of C_1 and C_2 is declared by the manufacturer to be selective.

Results to be obtained:

– Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies;

– During each operation, C_1 shall operate and C_2 shall not trip. If the contacts of C_2 separate momentarily during the operations, the time between the beginning of short-circuit and the end of C_2 contact separation shall be less than or equal to 30 ms. The actual value shall be stated in the test report;

– In addition, it shall be verified that the contacts of C_2 are able to be opened by the normal operating means.

A.6 Verification of back-up protection

A.6.1 Determination of the take-over current

Compliance with the requirements of A.3.2 can be checked by comparing the operating characteristics of C_1 and the associated SCPD for all settings of C_1 and, if applicable, for all settings of C_2.

A.6.2 Verification of back-up protection

Back-up protection can be verified either by tests, or by comparison of characteristics.

a) Verification by tests

Compliance with the requirements of A.3.3 is normally verified by tests in accordance with A.6.3. In this case, all the conditions for the tests shall be as specified in 8.3.2.6 with the adjustable resistors and inductors for the short-circuit tests on the supply side of the association.

b) Verification by comparison of characteristics

In some practical cases and where the SCPD is a circuit-breaker (see Figure A.3a) and Figure A.3b)), it may be possible for the manufacturer to compare the operating characteristics of C_1 and of the associated SCPD, special attention being paid to the following:

– the Joule integral value of C_1 at its I_{cu} and that of the SCPD at the prospective current of association;

– the effects on C_1 (e.g. by arc energy, by maximum peak current, cut-off current) at the peak operating current of the SCPD.

The suitability of the association may be evaluated by considering the maximum total operating I^2t characteristic of the SCPD, over the range from the rated short-circuit breaking capacity I_{cu} of C_1 up to the prospective short-circuit current of the application, but not exceeding the maximum let-through I^2t of C_1 at its rated short-circuit breaking capacity or other lower limiting value stated by the manufacturer.

NOTE Where the associated SCPD is a fuse, the validity of the desk study is limited up to I_{cu} of C_1.

A.6.3 Tests for verification of back-up protection

If C_1 is fitted with adjustable over-current opening releases, the operating characteristics shall be those corresponding to the minimum time and current settings.

If C_1 can be fitted with instantaneous over-current opening releases, the operating characteristics to be used shall be those corresponding to C_1 fitted with such releases.

If the associated SCPD is a circuit-breaker (C_2) fitted with adjustable over-current opening releases, the operating characteristics to be used shall be those corresponding to the maximum time and current settings.

If the associated SCPD consists of a set of fuses, each test shall be made using a new set of fuses, even if some of the fuses used during a previous test have not blown.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the associated SCPD is a circuit-breaker (C_2), the full length of cable (75 cm) associated with this circuit-breaker may be on the supply side (see Figure A.4).

Each test shall consist of a O – t – CO sequence of operations made in accordance with 8.3.5, the CO operation being made on C1.

A test is made with the maximum prospective current for the proposed application. This shall not exceed the rated conditional short-circuit (see 4.3.6.4 of IEC 60947-1:2007/AMD2:2014).

A further test shall be made at a value of prospective current equal to the rated short-circuit breaking capacity I_{cu} (or I_{cs}) of C_1, for which test a new sample C_1 may be used, and also, if the associated SCPD is a circuit-breaker, a new sample C_2.

During each operation

a) If the associated SCPD is a circuit-breaker (C_2):

   – either both C_1 and C_2 shall trip at both test currents, no further tests then being required.

     This is the general case and provides back-up protection only.

   – or C_1 shall trip and C_2 shall be in the closed position at the end of each operation, at both test currents, no further tests then being required.

     The contacts of C_2 are allowed to separate momentarily during each operation. In this case restoration of the supply is provided, in addition to back-up protection (see Note 1 to Figure A.3a)). The duration of contact separation of C_2, if any, shall be recorded during these tests.

   – or C_1 shall trip at the lower test current, and both C_1 and C_2 shall trip at the higher test current.

     The contacts of C_2 are allowed to separate momentarily at the lower test current. Additional tests shall be made at intermediate currents to determine the lowest current at which both C_1 and C_2 trip, up to which current restoration of supply is provided. The duration of contact separation of C_2, if any, shall be recorded during these tests.

b) If the associated SCPD is a fuse (or a set of fuses):

   – in the case of a single-phase circuit at least one fuse shall blow;

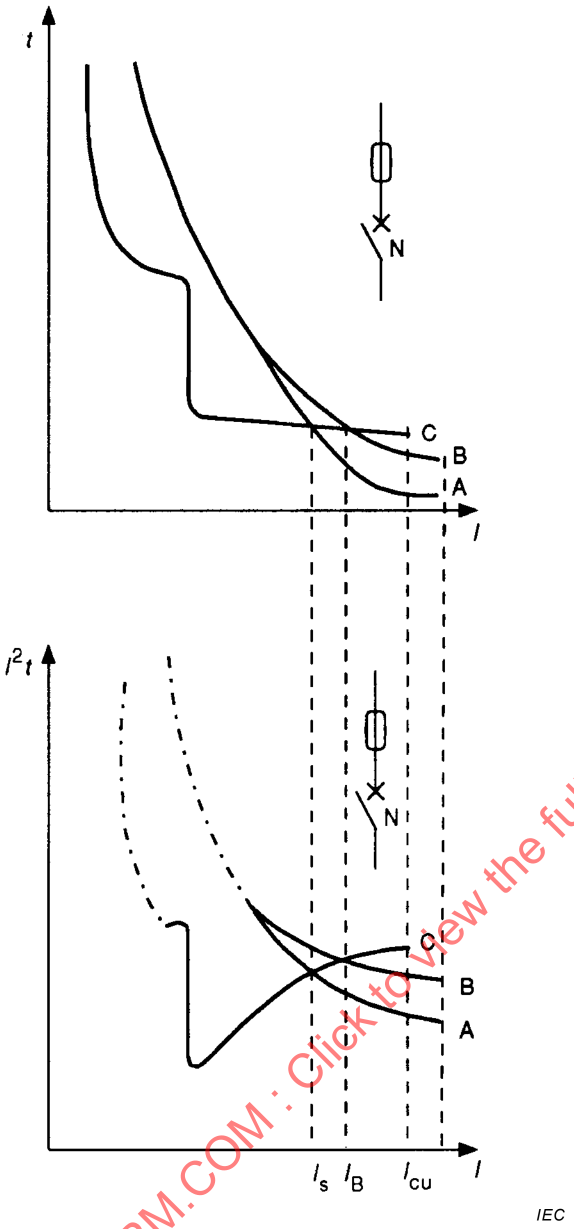
   – in the case of a multi-phase circuit either two or more fuses shall blow, or one fuse shall blow and C_1 shall trip.

A.6.4 Results to be obtained

Subclause 8.3.4.1.7 of IEC 60947-1:2007 and 8.3.2.6.7 first paragraph of this standard apply, with the following addition:

Following the tests, if C_1 is a circuit-breaker, it shall comply with 8.3.5.4 and 8.3.5.5; if C_1 is a fuse, it shall comply with the applicable requirements of IEC 60269-1.

In addition, if the associated SPCD is a circuit-breaker (C_2), it shall be verified, by manual operation or other appropriate means, that the contacts of C_2 have not welded.



I = Prospective short-circuit current

I_{cu} = Rated ultimate short-circuit breaking capacity (4.3.6.2.2)

I_s = Selectivity limit current (2.17.4)

I_B = Take-over current (2.17.5)

A = Pre-arcing characteristic of the fuse

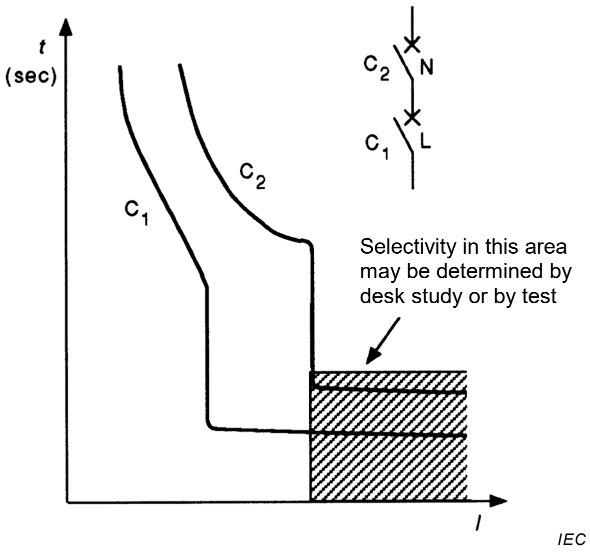
B = Operating characteristic of the fuse

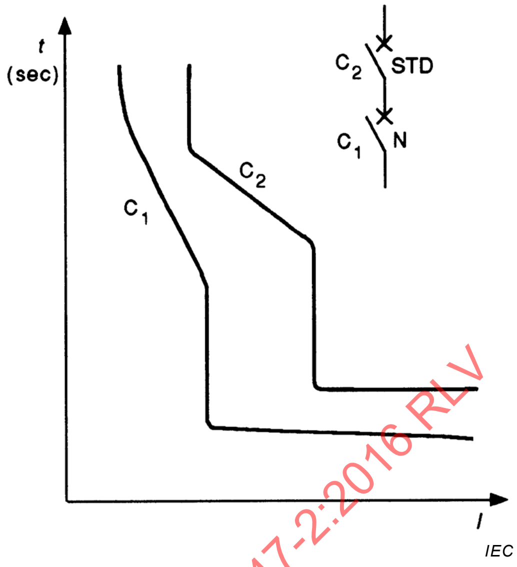
C = Operating characteristic of the circuit-breaker, non-current-limiting (N) (break-time/current and I^2t /current)

NOTE 1 A is deemed to be the lower limit; B and C are deemed to be the upper limits.

NOTE 2 Non-adiabatic zone for I^2t shown chain-dotted.

Figure A.1 – Over-current co-ordination between a circuit-breaker and a fuse or back-up protection by a fuse: operating characteristics





C_1 = Current-limiting circuit-breaker (L) (break-time characteristic)

C_2 = Current-limiting circuit breaker or non current-limiting circuit-breaker (N) (tripping characteristic)

Values of I_{cu} are not shown.

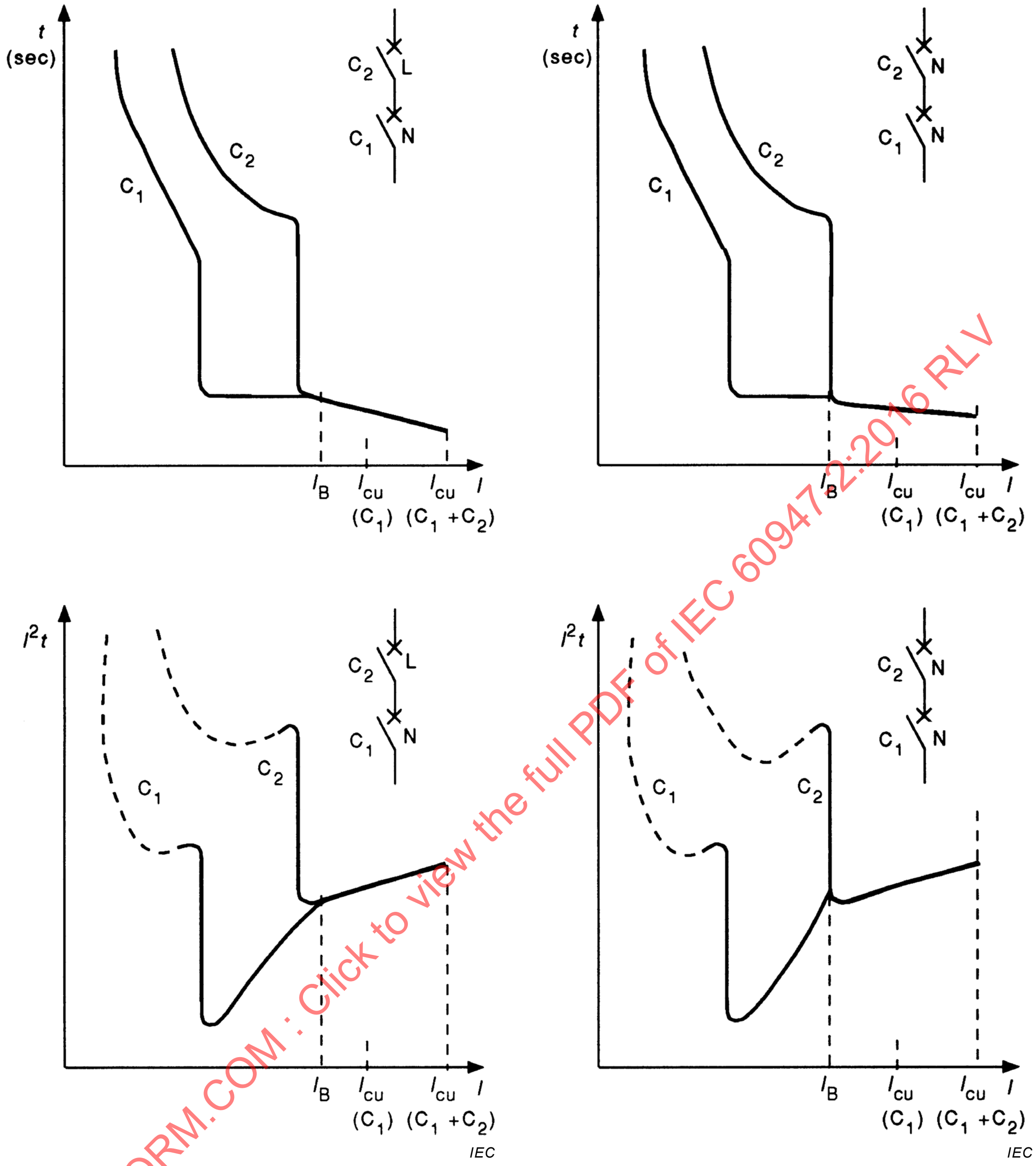
Figure A.2a) – Current-limiting CB downstream

C_1 = Non-current-limiting circuit-breaker (N) (break-time characteristic)

C_2 = Circuit-breaker with intentional short-time delay (STD) (tripping characteristic)

Figure A.2b) – Non current-limiting CB downstream

Figure A.2 – Total selectivity between two circuit-breakers



C_1 = Non current-limiting circuit-breaker (N)

C_2 = Current-limiting circuit-breaker (L)

C_1, C_2 = Non current-limiting circuit-breaker (N)

I_B = Take-over current

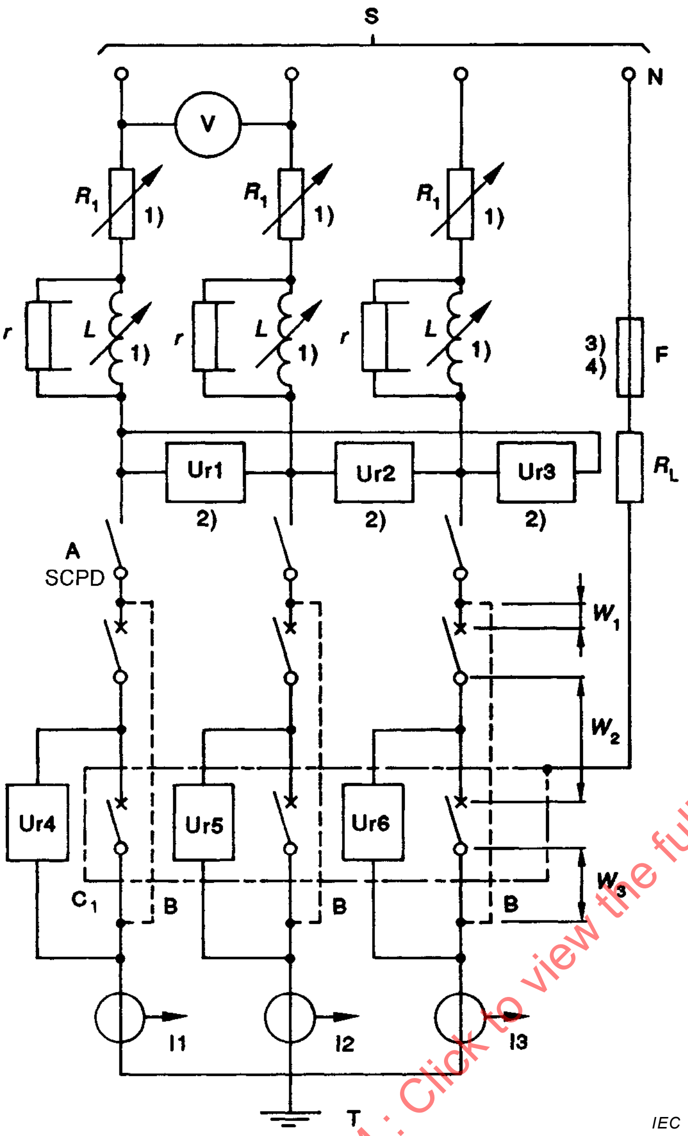
NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 I_{cu} (C_1 + C_2) ≤ I_{cu} (C_2)

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data are obtained by tests.

Figure A.3a) – Current-limiting CB upstream **Figure A.3b) – Non current-limiting CB upstream**

Figure A.3 – Back-up protection by a circuit-breaker – Operating characteristics



S	=	Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L	=	Adjustable reactors
R_L	=	Fault current limiting resistor
B	=	Temporary connections for calibration
I1, I2, I3	=	Current sensing devices
T	=	Earth: one earthing point only (load side or supply side)
r	=	Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1	=	75 cm of cable rated for SCPD
W_2	=	50 cm of cable rated for C_1
W_3	=	25 cm of cable rated for C_1
SCPD	=	Circuit-breaker C_2 or set of 3 fuses
C_1	=	Circuit-breaker under test

Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

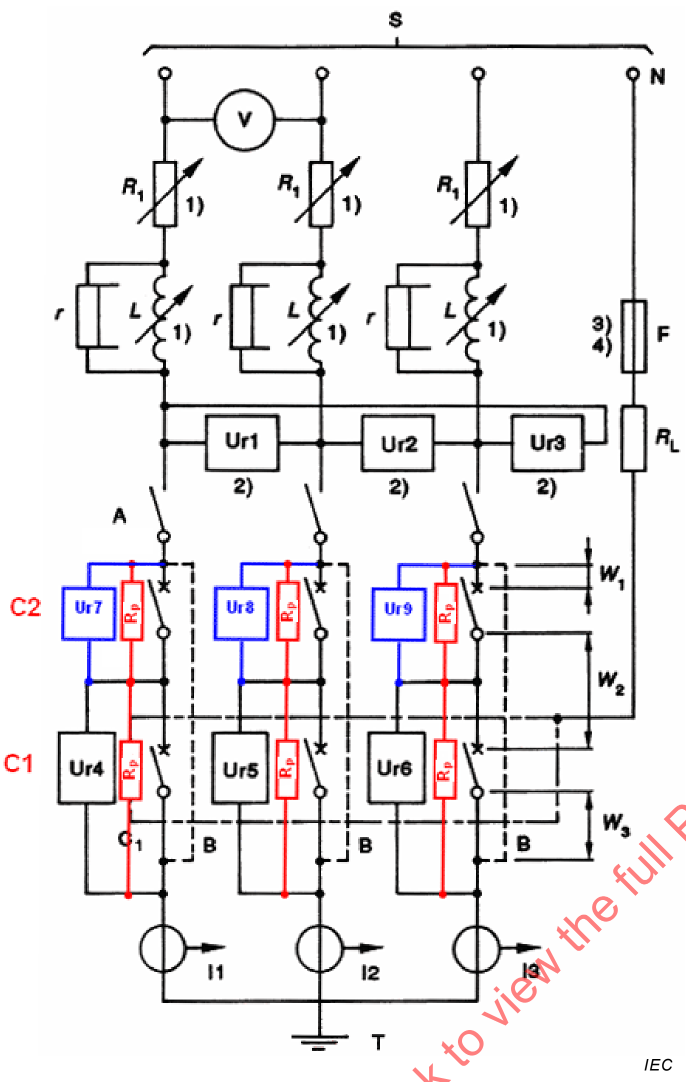
In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

In the USA and Canada (see notes to 4.3.2.1), F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage.

Figure A.4 – Example of test circuit for conditional short-circuit breaking capacity tests showing cable connections for a 3-pole circuit-breaker (C_1)



S = Supply
Ur1, Ur2, Ur3 = Voltage sensors
Ur4, Ur5, Ur6
Ur7, Ur8, Ur9
V = Voltage measuring device
A = Closing device
R_1 = Adjustable resistor
N = Neutral of supply (or artificial neutral)
F = Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L = Adjustable reactors
R_L = Fault current limiting resistor
R_p = Optional polarising resistors
B = Temporary connections for calibration
I1, I2, I3 = Current sensing devices
T = Earth: one earthing point only (load side or supply side)
r = Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1 = 75 cm of cable rated for C_2
$W_2 + W_3$ = 75 cm of cable rated for C_1 (see A.5.2)
C_1, C_2 = Circuit-breakers under test

Adjustable loads *L* and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

NOTE 1 In the USA and Canada (see notes to 4.3.2.1), F is connected:

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage.

NOTE 2 Polarizing resistors allow determination of contact opening time for the two devices in series, the value being high enough not to influence the devices under test.

Figure A.5 – Example of test circuit for the verification of selectivity

Annex B
(normative)

Circuit-breakers incorporating residual current protection

B.1 General

B.1.1 Preamble

To provide protection against the effects of electric shock hazards, devices reacting to residual differential currents are used as protective systems. Such devices are frequently used in conjunction with or as an integral part of a circuit-breaker to achieve a two-fold goal, i.e.:

– providing protection of installations against overloads and short-circuit currents;

– providing protection of persons against indirect contact, i.e. hazardous increases of ground potential due to defective insulation.

Residual current devices may also provide additional protection against fire and other hazards which may develop as a result of an earth fault of a lasting nature which cannot be detected by the over-current protective device.

Residual current devices having a rated residual current not exceeding 30 mA are also used as a means for additional protection against direct contact in case of failure of the relevant protective means.

The requirements for the installation of such devices are specified in various sections of IEC 60364 series.

This annex is essentially based upon the relevant requirements of IEC 60755, IEC 61008-1 and IEC 61009-1.

B.1.2 Scope and object

This annex applies to circuit-breakers providing residual current protection (CBRs). It covers the requirements for units which concurrently perform residual current detection, compare such measurements with a preset value and cause the protected circuit to be switched off when this value is exceeded.

This annex applies to:

– circuit-breakers according to this standard which incorporate the residual current function as an integrated feature (hereinafter called integral CBRs);

– CBRs consisting of a combination of a residual current device (hereinafter referred to as r.c. units) and a circuit-breaker according to this standard; their combination both mechanically and electrically, may be carried out either at the factory or in the field by the user according to the manufacturer's instructions.

This annex also covers requirements for CBRs concerning electromagnetic compatibility (EMC).

NOTE The neutral current sensing means, if any, can be external to the circuit-breaker or the combination, as the case may be.

This annex applies only to CBRs intended for use in a.c. circuits.

The residual current function of CBRs covered by this annex may or may not be functionally dependent on line voltage. CBRs depending on an alternative supply source are not covered by this annex.

This annex does not apply to equipment where the current sensing means (except the neutral current sensing means) or the processing device are mounted separately from the circuit-breaker.

The requirements for such devices are given in Annex M.

The object of this annex is to state:

a) the specific features of the residual current function;
b) the specific requirements which shall be complied with by the CBR
   – under normal circuit conditions;
   – under abnormal circuit conditions, whether of a residual current nature or not;
c) the tests which shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures;
d) the relevant product information.

B.2 Terms and definitions

As a complement to Clause 2 of this standard, the following definitions apply:

B.2.1 Terms and definitions relating to currents flowing from live parts to earth

B.2.1.1
earth fault current
current flowing to earth due to an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-23]

B.2.1.2
earth leakage current
current flowing from the live parts of the installation to earth in the absence of an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-24]

B.2.2 Terms and definitions relating to the energization of a CBR

B.2.2.1
energizing quantity
electrical energizing quantity which, alone or in combination with other such quantities, shall be applied to a CBR to enable it to accomplish its function under specified conditions

B.2.2.2
energizing input-quantity
energizing quantity by which the CBR is activated when it is applied under specified conditions

Note 1 to entry: These conditions can involve, e.g., the energizing of certain auxiliary elements.

[SOURCE: IEC 60050-442:1998, 442-05-58, modified – adapted to CBRs]

B.2.2.3
residual current
I_Δ
vectorial sum of the currents flowing in the main circuit of the CBR, expressed as an r.m.s. value

[SOURCE: IEC 60050-442:1998, 442-05-19, modified – adapted to CBRs]

B.2.2.4
residual operating current
$I_{\Delta n}$
value of the residual current which causes the CBR to operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-20, modified – adapted to CBRs]

B.2.2.5
residual non-operating current
$I_{\Delta no}$
value of the residual current at which (and below which) the CBR does not operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-21, modified – symbol introduced and adapted to CBRs]

B.2.3 Terms and definitions relating to the operation and the functions of a CBR

B.2.3.1
circuit-breaker incorporating residual current protection
CBR
circuit-breaker (see 2.1) designed to cause the opening of the contacts when the residual current attains a given value under specified conditions

B.2.3.2
CBR functionally independent of line voltage
CBR for which the functions of detection and evaluation, and the actuating means of interruption (see B.2.3.6) do not depend on the line voltage

B.2.3.3
CBR functionally dependent on line voltage
CBR for which the functions of detection and/or evaluation, and/or the actuating means of interruption (see B.2.3.6) depend on the line voltage

Note 1 to entry: It is understood that the line voltage for detection, evaluation or interruption is applied to the CBR.

B.2.3.4
detection (of a residual current)
function consisting in sensing the presence of a residual current

Note 1 to entry: This function can be performed, for example, by a transformer integrating the vector sum of the currents.

[SOURCE: IEC 60050-442:1998, 442-05-24]

B.2.3.5
evaluation
function consisting in giving to the CBR the possibility to operate when the detected residual current exceeds a specified reference value

[SOURCE: IEC 60050-442:1998, 442-05-25, modified – without "(for a residual current)" and adapted to CBRs]

B.2.3.6
interruption
function consisting in bringing automatically the main contacts of the CBR from the closed position into the open position, thereby interrupting the current(s) flowing through them

[SOURCE: IEC 60050-442:1998, 442-05-26, modified – without "(for a residual current device)" and adapted to CBRs]

B.2.3.7
limiting non-actuating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the CBR without bringing it actually to operate

[SOURCE: IEC 60050-442:1998, 442-05-23, modified – addition of "rated" and adapted to CBRs]

B.2.3.8
time-delay CBR
CBR specially designed to attain a predetermined value of limiting non-actuating time, corresponding to a given value of residual current

Note 1 to entry: The residual current time-delay characteristic may or may not be of an inverse time/current nature.

[SOURCE: IEC 60050-442:1998, 442-05-05, modified – adapted to CBRs and addition of Note 1 to entry]

B.2.3.9
reset-CBR
CBR with an r.c. unit which must be intentionally reset by a means different from the operating means of the CBR, following the occurrence of a residual current, before it can be reclosed

[SOURCE: IEC 60050-442:1998, 442-05-10, modified – adapted to CBRs]

B.2.3.10
test device
device simulating a residual current for checking that the CBR operates

B.2.4 Terms and definitions relating to values and ranges of energizing quantities

B.2.4.1
limiting value of the non-operating over-current in the case of a single-phase load
maximum value of a single-phase over-current which, in the absence of a residual current, can flow through a CBR (whatever the number of poles) without causing it to operate

Note 1 to entry: See B.7.2.7.

B.2.4.2
limiting value of the non-operating current in the case of a balanced load
maximum value of the current which, in the absence of any fault to frame or earth or of any earth leakage current, can flow in the circuit monitored by the CBR with a balanced load (whatever the number of poles) without causing it to operate

B.2.4.3
residual short-circuit making and breaking capacity
a value of the a.c. component of a residual prospective short-circuit current which a CBR can make, carry for its opening time and break under specified conditions of use and behaviour

B.3 Classification

B.3.1 Classification according to the method of operation of the residual current function

B.3.1.1 CBR functionally independent of line voltage (see B.2.3.2)

B.3.1.2 CBR functionally dependent on line voltage (see B.2.3.3 and B.7.2.11)

B.3.1.2.1 Opening automatically in the case of failure of the line voltage with or without delay.

B.3.1.2.2 Not opening automatically in the case of failure of line voltage.

Not opening automatically in the case of failure of the line voltage, but able to trip under specified conditions in the case of an earth fault arising on failure of the line voltage.

NOTE Classification under this subclause includes CBRs unable to open automatically when no hazardous situation exists.

B.3.2 Classification according to the possibility of adjusting the residual operating current

B.3.2.1 CBR with single rated residual operating current

B.3.2.2 CBR with multiple settings of residual operating current (see note to B.4.1.1)

A CBR may have multiple settings of residual operating current, either by fixed steps or by continuous variation.

B.3.3 Classification according to time-delay of the residual current function

B.3.3.1 CBR without time-delay: non-time-delayed type

B.3.3.2 CBR with time-delay: time-delayed type (see B.2.3.8)

B.3.3.2.1 CBR with non-adjustable time-delay

B.3.3.2.2 CBR with adjustable time-delay

A CBR may have an adjustable time-delay, either by fixed steps or by continuous variation.

B.3.4 Classification according to behaviour in presence of a d.c. component

B.3.4.1 CBRs of type AC (see B.4.4.1)

B.3.4.2 CBRs of type A (see B.4.4.2)

B.4 Characteristics of CBRs concerning their residual current function

B.4.1 Rated values

B.4.1.1 Rated residual operating current ($I_{\Delta n}$)

The r.m.s. value of a sinusoidal residual operating current (see B.2.2.4) assigned to the CBR by the manufacturer, at which the CBR shall operate under specified conditions.

NOTE For a CBR with multiple settings of residual operating current, the highest setting is used to designate its rating. See, however, Clause B.5 concerning marking.

B.4.1.2 Rated residual non-operating current ($I_{\Delta no}$)

The r.m.s. value of sinusoidal residual non-operating current (see B.2.2.5) assigned to the CBR by the manufacturer at which the CBR does not operate under specified conditions.

B.4.1.3 Rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The r.m.s. value of the a.c. component of the prospective residual short-circuit current (see B.2.4.3) assigned to the CBR by the manufacturer, which the CBR can make, carry and break under specified conditions.

B.4.2 Preferred and limiting values

B.4.2.1 Preferred values of rated residual operating current ($I_{\Delta n}$)

Preferred values of rated residual operating current are

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A

Higher values may be required.

$I_{\Delta n}$ may be expressed as a percentage of the rated current.

B.4.2.2 Minimum value of rated residual non-operating current ($I_{\Delta no}$)

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

B.4.2.3 Limiting value of non-operating over-current in the case of a single-phase load

The limiting value of non-operating over-current in the case of a single-phase load shall be in accordance with B.7.2.7.

B.4.2.4 Operating characteristics

B.4.2.4.1 Non-time-delay type

The operating characteristic for a non-time-delay type is given in Table B.1.

Table B.1 – Operating characteristic for non-time-delay type

Residual current	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	10 $I_{\Delta n}$ [b]
Maximum break times s	0,3	0,15	0,04	0,04

[a] For CBRs having $I_{\Delta n} \leq$ 30 mA, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$.

[b] 0,5 A if 0,25 A is used according to footnote a.

CBRs having $I_{\Delta n} \leq$ 30 mA shall be of the non-time-delay type.

B.4.2.4.2 Time-delay type

B.4.2.4.2.1 Limiting non-actuating time (see B.2.3.7)

For a time-delay type, the limiting non-actuating time is defined at 2 $I_{\Delta n}$ and shall be declared by the manufacturer.

The minimum limiting non-actuating time at 2 $I_{\Delta n}$ is 0,06 s.

Preferred values of limiting non-actuating time at 2 I_{Δ} are

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

B.4.2.4.2.2 Operating characteristic

For CBR's having a limiting non-actuating time higher than 0,06 s, the manufacturer shall declare the maximum break time at $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$, and 10 $I_{\Delta n}$.

For CBR's having limiting non-actuating time of 0,06 s the operating characteristic is given in Table B.2.

Table B.2 – Operating characteristic for time-delay type having a limiting non-actuating time of 0,06 s

Residual current	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	10 $I_{\Delta n}$
Maximum break time in s	0,5	0,2	0,15	0,15

In case of a CBR having an inverse current/time characteristic, the manufacturer shall state the residual current/break time characteristic.

B.4.3 Value of the rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The minimum value of $I_{\Delta m}$ is 25 % of I_{cu}.

Higher values may be tested and declared by the manufacturer.

B.4.4 Operating characteristics in case of an earth fault current in the presence or absence of a d.c. component

B.4.4.1 CBR of type AC

A CBR for which tripping is ensured for residual sinusoidal alternating currents, in the absence of a d.c. component whether suddenly applied or slowly rising.

B.4.4.2 CBR of type A

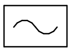
A CBR for which tripping is ensured for residual sinusoidal alternating currents in the presence of specified residual pulsating direct currents with or without a specified level of superimposed d.c., whether suddenly applied or slowly rising.

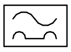
B.5 Marking

Each CBR shall be marked in a durable manner:

a) The following data shall be marked on integral CBRs (see B.1.1), in addition to the marking specified in 5.2, and be clearly visible in the installed position:
   - rated residual operating current $I_{\Delta n}$;
   - settings of residual operating current, when applicable;
   - limiting non-actuating time at 2 $I_{\Delta n}$, for time-delay type, by the symbol Δt followed by the limiting non-actuating time in ms; alternatively, where the limiting non-actuating time is 0,06 s, the symbol may be [S] (S in a square);
   - the operating means of the test device by the letter T (see also B.7.2.6);

– operating characteristic in case of residual currents in the presence or absence of a d.c. component:

for CBRs of type AC with the symbol 

for CBRs of type A with the symbol 

b) The following data shall be marked on r.c. units and be clearly visible in the installed position:

– rated voltage(s) if different from the rated voltage(s) of the circuit-breaker;

– value (or range) of the rated frequency if different from that of the circuit-breaker;

– the indication $I_n \leq$ ...A (I_n being the maximum current rating of the circuit-breaker with which the r.c. unit may be combined);

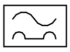
– rated residual operating current $I_{\Delta n}$;

– settings of residual operating current, when applicable;

– limiting non-actuating time, as specified in item a);

– the operating means of the test device, as specified in item a);

– operating characteristic in case of residual currents in the presence or absence of a d.c. component:

for CBRs of type A with the symbol 

for CBRs of type AC with the symbol 

c) The following data shall be marked on r.c. units and be visible after assembly with the circuit-breaker:

– manufacturer's name or trade mark;

– type designation or serial number;

– identification of the circuit-breaker(s) with which the r.c. unit may be assembled, unless incorrect assembly (such as to render the protection ineffective) is made impossible by the design;

– IEC 60947-2;

– suitability for use with a 3-phase supply only, with the symbol 

d) The following data shall be marked on integral CBRs or r.c. units, as applicable, or made available in the manufacturer's literature:

– rated residual short-circuit making and breaking capacity $I_{\Delta m}$ if higher than 25 % of I_{cu} (see B.4.3);

– diagram of connections, including those of the test circuit and, if applicable, those to the line, for CBRs dependent on the line voltage;

– value of rated residual non-operating current $I_{\Delta no}$ if greater than 0,5 $I_{\Delta n}$.

e) The following data shall be made available in the manufacturer’s literature:

– suitability for use on:

• three-phase systems only, or

• three-phase and single phase systems.

B.6 Normal service, mounting and transport conditions

Clause 6 applies.

B.7 Design and operating requirements

B.7.1 Design requirements

It shall not be possible to modify the operating characteristic of a CBR except by means which are specifically provided for setting the rated residual operating current or the definite time-delay.

CBRs combining a r.c. unit device and a circuit-breaker shall be so designed and built that:

– the coupling system of the r.c. unit and the associated circuit-breaker does not require any mechanical and/or electrical connection that may adversely affect the installation or result in injury to the user;
– the addition of the r.c. unit does not adversely affect in any way either the normal operation or the performance capabilities of the circuit-breaker;
– the r.c. unit does not sustain any permanent damage due to the short-circuit currents during test sequences.

B.7.2 Operating requirements

B.7.2.1 Operation in case of a residual current

The CBR shall open automatically in response to any earth leakage current or earth fault current equal to or exceeding the rated residual operating current for a time exceeding the non-actuating time.

The operation of the CBR shall be in compliance with the time requirements specified in B.4.2.4. Compliance shall be checked by the tests of B.8.1.1.

B.7.2.2 Rated residual current short-circuit making and breaking capacity $I_{\Delta m}$

CBRs shall meet the test requirements of B.8.10.

B.7.2.3 Operational performance capability

CBRs shall comply with the tests of B.8.1.1.1.

B.7.2.4 Effects of environmental conditions

CBRs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the test of B.8.11.

B.7.2.5 Dielectric properties

CBRs shall withstand the tests of B.8.3.

B.7.2.6 Test device

CBRs shall be provided with a test device causing the passing through the detecting device of a current simulating a residual current, in order to allow periodic testing of the ability of the CBRs to operate.

The test device shall satisfy the tests of B.8.4.

The protective conductor, if any, shall not become live when the test device is operated.

It shall not be possible to energize the protected circuit by operating the test device when the CBR is in the open position.

The test device shall not be the sole means of performing the opening operation and is not intended to be used for this function.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; a light colour should preferably be used.

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

B.7.2.7 Value of the non-operating over-current in the case of a single-phase load

CBRs shall withstand the smaller of the following two over-current values without tripping:

– 6 I_n;
– 80 % of the maximum short-circuit release current setting.

Compliance is checked by the test of B.8.5.

However this test is not necessary in the case of CBRs of selectivity category B since the requirements of this subclause are verified during test sequence IV (or the test sequence VI (combined)).

NOTE Tests for polyphase balanced loads are not necessary since they are considered to be covered by the requirements of this subclause.

B.7.2.8 Resistance of CBRs to unwanted tripping due to surge currents resulting from impulse voltages

B.7.2.8.1 Resistance to unwanted tripping in case of loading of the network capacitance

CBRs shall withstand the test of B.8.6.2.

B.7.2.8.2 Resistance to unwanted tripping in case of flashover without follow-on current

CBRs shall withstand the test of B.8.6.3.

B.7.2.9 Behaviour of CBRs of type A in case of an earth fault comprising a d.c. component

The behaviour of CBRs in case of an earth fault current comprising a d.c. component, shall be such that the maximum break times stated in Table B.1 and Table B.2, as applicable, shall also be valid, the test current values specified being, however, increased:

– by the factor 1,4 for CBRs having $I_{\Delta n} > 0,015$ A;
– by the factor 2 for CBRs having $I_{\Delta n} \leq 0,015$ A (or 0,03 A, whichever is the higher).

Compliance is checked by the tests of B.8.7.

B.7.2.10 Conditions of operation for reset-CBRs

It shall not be possible to reclose reset-CBRs (see B.2.3.9) after tripping due to a residual current, if they have not been reset.

Compliance is checked during the test of 8.3.3.4.4 in accordance with B.8.1.1.1.

B.7.2.11 Additional requirements for CBRs functionally dependent on line voltage

CBRs functionally dependent on line voltage shall operate correctly at any value of the line voltage between 0,85 and 1,1 times its rated value.

Compliance is checked by the tests of B.8.2.3.

Where a CBR has more than one rated frequency or a range of rated frequencies, the CBR shall be capable of operating in accordance with this subclause at all frequencies.

Compliance is verified by carrying out the tests of B.8.2 and B.8.4.

According to their classification CBRs functionally dependent on line voltage shall comply with the requirements given in Table B.3.

Table B.3 – Requirements for CBRs functionally dependent on line voltage

Classification of the device according to B.3.1		Behaviour in case of failure of line voltage
CBRs opening automatically in the case of failure of the line voltage (B.3.1.2.1)	Without delay	Opening without delay according to item a) of B.8.8.3
	With delay	Opening with delay according to item b) of B.8.8.3
CBRs not opening automatically in the case of failure of the line voltage but able to open in the case of a hazardous situation arising (B.3.1.2.2)		Operating according to B.8.9

B.7.3 Electromagnetic compatibility

The requirements of Annex J apply.

Additional test specifications are given in B.8.12.

Immunity to voltage variations is covered by the requirements of B.7.2.11.

B.8 Tests

B.8.1 General

This clause specifies tests for CBRs having a rated residual operating current $I_{\Delta n}$ up to and including 30 A.

The applicability of the tests specified in this clause when $I_{\Delta n} > 30$ A is subject to agreement between manufacturer and user.

The instruments for the measurement of the residual current shall be at least class 0,5 (see IEC 60051) and shall show (or permit to determine) the true r.m.s. value.

The instruments for the measurement of time shall have a relative error not greater than 10 % of the measured value.

Tests specified in this annex are supplementary to the tests of Clause 8.

a) Type tests

CBRs shall be submitted to all relevant test sequences of Clause 8. For the dielectric withstand verifications during these test sequences (see 8.3.3.6), the control circuit of residual current devices functionally dependent on line voltage shall be disconnected from the main circuit.

The tests shall be made with substantially sinusoidal currents.

For CBRs comprising a separate r.c. unit and a circuit-breaker, the assembly shall be performed in compliance with the manufacturer's instructions.

In the case of CBRs with multiple settings of residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.

In the case of CBRs with adjustable time-delay (see B.3.3.2.2) the time-delay shall be set at maximum, unless otherwise stated.

In the case of CBRs with adjustable instantaneous tripping, the instantaneous trip shall be set at maximum, unless otherwise stated.

b) Routine tests

Subclause 8.4.5 applies.

B.8.1.1 Tests to be made during the test sequences of Clause 8

B.8.1.1.1 Operational performance capability

During the operating cycles with current (see 8.3.3.4.4) specified in Table 8 (see 7.2.4.2), a third of the breaking operations shall be performed by actuating the test device, and a further third by applying a residual current of value $I_{\Delta n}$ (or, if applicable, of the lowest setting of the residual operating current) to any one pole.

In the case of a reset-CBR, it shall be verified that it is not possible to reclose the CBR after tripping without the intentional resetting action. This verification shall take place at the beginning and at the end of the operational performance capability test with current (8.3.3.4.4).

No failure to trip shall be admitted.

B.8.1.1.2 Verification of the withstand capability to short-circuit currents

B.8.1.1.2.1 Rated service short-circuit breaking capacity (test sequence II)

Following the tests of 8.3.4, verification of the correct operation of the CBR in case of residual current shall be performed in accordance with B.8.2.4.2.

B.8.1.1.2.2 Rated ultimate short-circuit breaking capacity (test sequence III)

For the purpose of verifying the correct operation of the overload releases, the single pole tests specified in 8.3.5.2 and 8.3.5.5 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.5.2 and 8.3.5.5 but applicable to two poles.

Following the tests of 8.3.5, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.3 Rated short-time withstand current (test sequence IV or test sequence VI (combined))

The following requirements apply:

a) Behaviour during rated short-time withstand current test

No tripping shall occur during the test of 8.3.6.3 or 8.3.8.3, as applicable.

b) Verification of overload releases

– For test sequence IV

For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.6.2 and 8.3.6.7, the single pole tests specified in 8.3.5.2 shall be replaced by two-pole tests, made on all possible combinations of phase poles in turn.

– For the combined test sequence

For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.8.2, the single pole test specified in 8.3.5.2 shall be replaced by two-pole tests made on all possible combinations of phase poles in turn.

For the purpose of verifying the correct operation of overload releases in accordance with 8.3.8.7, the test specified in 8.3.3.8 shall be made using a three-phase supply.

c) Verification of the residual current tripping device

Following the tests of 8.3.6 or 8.3.8, as applicable, verification of the residual current tripping device shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.4 Integrally fused circuit-breakers (test sequence V)

For the purpose of verifying the correct operation of the overload releases, the single-pole tests specified in 8.3.7.5 and 8.3.7.9 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.7.5 and 8.3.7.9 but applicable to two poles.

Following the tests of 8.3.7, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.5 Test sequence VI (combined)

Following the tests of 8.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2 Additional test sequences

Additional test sequences shall be performed on CBRs in accordance with Table B.4.

Table B.4 – Additional test sequences

Sequences	Test	Subclause
B I	Operating characteristic	B.8.2
	Dielectric properties	B.8.3
	Operation of the test device at the limits of rated voltage	B.8.4
	Limiting value of the non-operating current under over-current conditions	B.8.5
	Resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Behaviour in the case of an earth fault current comprising a d.c. component	B.8.7
	Behaviour in the case of failure of line voltage for CBRs classified under B.3.1.2.1	B.8.8
	Behaviour in the case of failure of line voltage for CBRs classified under B.3.1.2.2.	B.8.9
B II	Residual short-circuit making and breaking capacity ($I_{\Delta m}$)	B.8.10
B III	Effects of environmental conditions	B.8.11
B IV	Immunity tests	B.8.12.1
	Emission tests	B.8.12.2

For CBRs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants construction is not identical to the variant tested then those variants shall also be tested.

One sample shall be tested for each of test sequences B I, B II and B III.

For test sequence B IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Test sequence B I

B.8.2 Verification of the operating characteristic

B.8.2.1 Test circuit

The CBR is installed as in normal use.

The test circuit shall be in accordance with Figure B.1.

B.8.2.2 Test voltage for CBRs functionally independent of line voltage

Tests may be made at any convenient voltage.

B.8.2.3 Test voltage for CBRs functionally dependent on line voltage

Tests shall be made at the following values of voltage applied to the relevant terminals:

- 0,85 times the minimum rated voltage for the tests specified in B.8.2.4 and B.8.2.5.2;
- 1,1 times the maximum rated voltage for the tests specified in B.8.2.5.3.

CBRs with more than one rated frequency or a range of rated frequencies shall be tested in each case at the highest and lowest rated frequency. However, for CBRs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover the requirements.

B.8.2.4 Off-load test at 20 °C ± 5 °C

B.8.2.4.1 General

The connections being as in Figure B.1, the CBR shall perform the tests of B.8.2.4.2, B.8.2.4.3 and B.8.2.4.4 and also, where applicable, B.8.2.4.5, all made on one pole only chosen at random. Each test shall comprise three measurements or verifications, as applicable.

Unless otherwise specified, for CBR’s with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the lowest and highest settings, and at one intermediate setting.

B.8.2.4.2 Verification of the correct operation in the case of a steady increase of the residual current

For CBR’s with adjustable time-delay, the tests shall be performed at the lowest setting. The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$ so as to attain the value $I_{\Delta n}$ in approximately 30 s, the tripping current being measured each time. The three measured values shall be greater than $I_{\Delta no}$ and less than or equal to $I_{\Delta n}$.

B.8.2.4.3 Verification of the correct operation in the case of closing on residual current

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or the specific settings of the residual operating current if applicable, see B.8.2.4), and the switches S_1 and S_2 being closed, the CBR is closed onto the circuit so as to simulate service conditions as closely as possible. The break time is measured three times.

No measurement shall exceed the limiting value specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2.2, as applicable.

B.8.2.4.4 Verification of the correct operation in the case of sudden appearance of residual current

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in B.4.2.4.1 or B.4.2.4.2.2, as applicable, and the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing switch S_2.

The CBR shall trip during each test.

Three measurements of the break time are made at each value of I_{Δ}. No value shall exceed the relevant limiting value.

B.8.2.4.5 Verification of the limiting non-actuating time of CBRs of the time-delayed type

The test circuit being calibrated at the value of 2 $I_{\Delta n}$, the test switch S_1 and the CBR being in the closed position, the residual current is established by closing the switch S_2 and applied for a time equal to the limiting non-actuating time declared by the manufacturer, in accordance with B.4.2.4.2.1.

During each of the three verifications the CBR shall not trip. If the CBR has an adjustable residual operating current setting and/or an adjustable time-delay, the test is made, as applicable, at the lowest setting of residual operating current and at the maximum setting of time delay.

B.8.2.5 Tests at the temperature limits

B.8.2.5.1 General

NOTE The upper temperature limit can be the reference temperature.

The temperature limits of this subclause may be extended by agreement between manufacturer and user, in which case tests shall be performed at the agreed temperature limits.

B.8.2.5.2 Off-load test at –5 °C

The CBR is placed in a chamber having a stabilized ambient temperature within the limits of –7 °C and –5 °C. After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, if applicable, B.8.2.4.5.

B.8.2.5.3 On-load test at the reference temperature or at +40 °C

The CBR, connected in accordance with Figure B.1, is placed in a chamber having a stabilized ambient temperature equal to the reference temperature (see 4.7.3) or, in the absence of a reference temperature, equal to 40 °C ± 2 °C. A load current equal to I_n (not indicated on Figure B.1) is applied on all phase poles.

After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, where applicable, B.8.2.4.5.

B.8.3 Verification of dielectric properties

CBRs shall comply with 8.3.3.3.

B.8.4 Verification of the operation of the test device at the limits of rated voltage

The verification consists of the following tests:

a) The CBR being supplied with a voltage equal to 1,1 times the highest rated voltage, the test device is momentarily actuated 25 times at intervals of 5 s, the CBR being closed again before each operation.

b) Test a) is then repeated at 0,85 times the lowest rated voltage, the device being actuated three times.

c) Test a) is then repeated, but only once, the operating means of the test device being held in the closed position for 5 s.

For these tests:

– in the case of CBRs with identified line and load terminals, the supply connections shall be in accordance with the marking;

– in the case of CBRs 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.

At each test the CBR shall operate.

For CBRs having an adjustable residual operating current:

– the lowest setting shall be used for tests a) and c);

– the highest setting shall be used for test b).

For CBRs having an adjustable time-delay the test is made at the maximum setting of time-delay.

NOTE The verification of the endurance of the test device is considered to be covered by the tests of B.8.1.1.1.

B.8.5 Verification of the limiting value of the non-operating current under over-current conditions

The test shall be made with a single phase load, the connections being made according to Figure B.2.

The impedance Z is adjusted so as to let a current equal to the lower of the following two values flow in the circuit:

– 6 I_n;

– 80 % of the maximum short-circuit release current setting.

NOTE 1 For the purpose of this current adjustment, the CBR D (see Figure B.2) can be replaced by connections of negligible impedance.

For CBRs with an adjustable residual current setting the test is made at the lowest setting.

CBRs functionally independent of line voltage are tested at any convenient voltage.

CBRs functionally dependent on line voltage are supplied on the line side with their rated voltage (or, if relevant, with a voltage having any value within the range of rated voltages).

The test is made at a power factor of 0,5.

The switch S_1, being open, is closed and reopened after 2 s. The test is repeated three times for each possible combination of the current paths, the interval between successive closing operations being at least 1 min.

The CBR shall not trip.

NOTE 2 The time of 2 s can be reduced (but to not less than the minimum break time) to avoid the risk of tripping by action of the overload release(s) of the CBR.

B.8.6 Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages

B.8.6.1 General

For CBRs with adjustable time delay (see B.3.3.2.2) the time-delay shall be set at minimum.

B.8.6.2 Verification of resistance to unwanted tripping in case of loading of the network capacitance

The CBR is tested using a surge current generator capable of delivering a damped oscillatory current as shown in Figure B.4.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.5.

One pole of the CBR chosen at random shall be subjected 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 approximately 30 s. The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 200 A $^{+10}_{0}$ %;
– virtual front time: 0,5 µs ± 30 %;
– period of the following oscillatory wave: 10 µs ± 20 %;
– each successive peak: about 60 % of the preceding peak.

During the tests the CBR shall not trip.

B.8.6.3 Verification of resistance to unwanted tripping in case of flashover without follow-on current

The CBR is tested using a surge current generator capable of delivering an 8/20 µs surge current wave, without reverse polarity, as shown in Figure B.6.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.7.

One pole of the CBR, 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 operations shall be approximately 30 s.

The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 250 A $^{+10}_{0}$ %;
– virtual front time (T_1): 8 µs ± 10 %;
– virtual time to half value (T_2): 20 µs ± 10 %.

During the tests the CBR shall not trip.

B.8.7 Verification of the behaviour of CBRs of type A in the case of an earth fault current comprising a d.c. component

B.8.7.1 Test conditions

The test conditions of B.8 and B.8.2.1, B.8.2.2 and B.8.2.3 apply, except that the test circuits shall be those shown in Figure B.8 and Figure B.9, as applicable.

B.8.7.2 Verifications

B.8.7.2.1 Verification of the correct operation in case of a continuous rise of residual pulsating direct current

The test circuit shall be according to Figure B.8. In the case of a CBR with adjustable time delay (see B.3.3.2.2), the time-delay shall be set to minimum.

The auxiliary switches S_1 and S_2 and the CBR D shall be closed. The relevant thyristor shall be controlled in such a manner that current delay angles α of 0°, 90° and 135° are obtained. Each pole of the CBR shall be tested at each of the current delay angles, twice in position I and twice in position II of the auxiliary switch S_3.

At every test, the current, starting from zero, shall be steadily increased at an approximate rate of:

$\frac{1{,}4\ I_{\Delta n}}{30}$ A/s for CBRs of $I_{\Delta n} > 0{,}015$ A;

$\frac{2\ I_{\Delta n}}{30}$ A/s for CBRs of $I_{\Delta n} \leq 0{,}015$ A.

The tripping current shall be in accordance with Table B.5.

Table B.5 – Tripping current range for CBRs in case of an earth fault comprising a d.c. component

Angle α	Tripping current A	
	Lower limit	**Upper limit**
0°	0,35 $I_{\Delta n}$	0,03 A for $I_{\Delta n} \leq 0{,}015$ A
90°	0,25 $I_{\Delta n}$	or
135°	0,11 $I_{\Delta n}$	1,4$I_{\Delta n}$ for $I_{\Delta n} > 0{,}015$ A

B.8.7.2.2 Verification of the correct operation in case of a suddenly appearing residual pulsating direct current

The test shall be performed according to Figure B.8.

The circuit being successively calibrated at the values specified hereafter and the auxiliary switch S_1 and the CBR being in the closed position, the residual current is suddenly established by the closing switch S_2.

NOTE In the case of CBR's functionally dependent on line voltage, classified according to B.3.1.2.2, the control circuit of which is supplied from the line side of the main circuit, this verification does not take into account the time necessary to energize the CBR. In this case, therefore, the verification is considered as made by establishing the residual current by closing S_1, the CBR under test and S_2 being previously closed.

Four measurements are made at each value of test current at a current delay angle α = 0°, two with the auxiliary switch in position I and two in position II.

For CBRs with $I_{\Delta n}$ > 0,015 A, the test shall be made at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 1,4.

For CBRs with $I_{\Delta n} \leq$ 0,015 A, the test shall be made at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 2 (or at 0,03 A, whichever is the higher).

No value shall exceed the specified limiting values (see B.7.2.9).

B.8.7.2.3 Verification of the correct operation with load at the reference temperature

The tests of B.8.7.2.1 and B.8.7.2.2 are repeated, the pole under test and one other pole of the CBR being loaded with the rated current, this current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure B.8.

B.8.7.2.4 Verification of the correct operation in case of residual pulsating direct currents superimposed by a smooth direct current of 0,006 A

The CBR shall be tested according to Figure B.9, with a half-wave rectified residual current (current delay angle α = 0°) superimposed by a smooth direct current of 0,006 A.

Each pole of the CBR is tested in turn, twice at each of positions I and II.

For CBRs of $I_{\Delta n}$ > 0,015 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 1,4 $I_{\Delta n}$ / 30 A/s, tripping shall occur before the current reaches a value not exceeding 1,4 $I_{\Delta n}$ + 0,006 A.

For CBRs of $I_{\Delta n} \leq$ 0,015 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 2 $I_{\Delta n}$ / 30 A/s, tripping shall occur before the current reaches a value not exceeding 0,03 A + 0,006 A.

B.8.8 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1

B.8.8.1 General

For CBRs having an adjustable residual operating current, the test is made at the lowest setting.

For CBRs with an adjustable time-delay, the test is made at any one of the time-delay settings.

B.8.8.2 Determination of the limiting value of the line voltage

A voltage equal to the rated voltage is applied to the line terminals of the CBR and is then progressively lowered to zero over a time period corresponding to the longer of the two values given hereinafter until automatic opening occurs:

– about 30 s;
– a period long enough with respect to the delayed opening of the CBR, if any (see B.7.2.11).

The corresponding voltage is measured.

Three measurements are made. All the values shall be less than 0,85 times the minimum rated voltage of the CBR.

Following these measurements it shall be verified that the CBR trips when a residual current equal to $I_{\Delta n}$ is applied, the applied voltage being just above the highest value measured.

It shall then be verified that, for any value of voltage less than the lowest value measured, it is not be possible to close the CBR by manual operating means.

B.8.8.3 Verification of the automatic opening in the case of failure of the line voltage

The CBR being closed, a voltage equal to its rated voltage, or, in the case of a range of rated voltages, any one of the rated voltages is applied to its line terminals. The voltage is then switched off. The CBR shall trip. The time interval between the switching off and the opening of the main contacts is measured.

Three measurements are made:

a) for CBRs opening without delay (see B.7.2.11), no value shall exceed 0,2 s;

b) for CBRs opening with delay the maximum and minimum values shall be situated within the range indicated by the manufacturer.

B.8.9 Verification of the behaviour of CBRs functionally dependent on line voltage as classified under B.3.1.2.2 in the case of failure of line voltage

B.8.9.1 General

For CBRs having an adjustable residual operating current, the test is made at the lowest setting.

For CBRs having an adjustable time-delay the test is made at any one of the time-delay settings.

B.8.9.2 Case of loss of one phase in a 3-phase system (for 3-pole and 4-pole CBRs)

The CBR is connected according to Figure B.3 and is supplied on the line side at 0,85 times the rated voltage, or, in the case of a range of rated voltages, at 0,85 times the lowest value of rated voltage.

One phase is then switched off by opening switch S_4; the CBR is then submitted to the test of B.8.2.4.4. The switch S_4 being closed again, a further test is made by opening switch S_5; the CBR is then submitted to the test of B.8.2.4.4.

This test procedure is repeated by connecting the adjustable resistor *R* to each of the other two phases in turn.

B.8.9.3 Case of voltage drop due to an overcurrent resulting from a low impedance fault to earth

The CBR is connected according to Figure B.3 and is supplied on the line side with the rated voltage or, in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_1. The CBR shall not trip.

S_1 is then reclosed and the voltage is reduced as follows:

a) for CBRs for use with a three-phase supply: to 70 % of the lowest rated voltage;

b) for CBRs for use with a single phase supply: to 85 V applied as follows:

   – for single-pole and two-pole CBRs: between poles;

   – for three-pole and four-pole CBRs, declared as suitable for use with a single-phase supply (see B.5 e)): between each combination of two poles, connected according to the manufacturer's specification.

NOTE For the purpose of this annex, a single-pole CBR is a device with one overcurrent protected pole and an uninterrupted neutral (two current paths).

A current of value $I_{\Delta n}$ is then applied to a) and/or b), as applicable. The CBR shall trip.

Test sequence B II

B.8.10 Verification of the residual short-circuit making and breaking capacity

B.8.10.1 General

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

B.8.10.2 Test conditions

The CBR shall be tested according to the general test conditions specified in 8.3.2.6, using Figure 9 of IEC 60947-1:2007/AMD1:2010, but connected in such a manner that the short-circuit current is a residual current.

The test is carried out at phase to neutral voltage on one pole only which shall not be the neutral pole. The current paths which do not have to carry the residual short-circuit current are connected to the supply voltage at their line terminals.

Where applicable, the CBR is adjusted at the lowest setting of residual operating current and at the maximum setting of time-delay.

If the CBR has more than one value of I_{cu}, each one having a corresponding value of $I_{\Delta m}$, the test is made at the maximum value of $I_{\Delta m}$, at the corresponding phase-to-neutral voltage.

B.8.10.3 Test procedure

The sequence of operations to be performed is

$$O - t - CO$$

B.8.10.4 Conditions of the CBR after test

B.8.10.4.1 Following the test of B.8.10.3 the CBR shall show no damage likely to impair its further use and shall be capable, without maintenance, of:

– withstanding a voltage equal to twice its maximum rated operational voltage, under the conditions of 8.3.3.4.1 item 4) of IEC 60947-1:2007. For the purposes of this standard, circuits incorporating solid-state devices shall be disconnected for the tests;
– making and breaking its rated current at its maximum rated operational voltage.

B.8.10.4.2 The CBR shall be capable of performing satisfactorily the tests specified in B.8.2.4.4, but at a value of 1,25 $I_{\Delta n}$ and without measurement of break time. The test is made on any one pole, taken at random.

If the CBR has an adjustable residual operating current, the test is made at the lowest setting, at a current of a value of 1,25 times that setting.

B.8.10.4.3 Where applicable the CBR shall also be submitted to the test of B.8.2.4.5.

B.8.10.4.4 CBRs functionally dependent on line voltage shall also satisfy the tests of B.8.8 or B.8.9, as applicable.

Test sequence B III

B.8.11 Verification of the effects of environmental conditions

The test is carried out according to IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be

– 6 for $I_{\Delta n}$ > 1 A,
– 28 for $I_{\Delta n}$ ≤ 1 A.

The 28 cycle test shall be applied to CBRs having multiple settings of residual operating current when one of the possible settings is ≤ 1 A.

At the end of the cycles the CBR shall be capable of complying with the tests of B.8.2.4.4, but with a residual operating current of 1,25 $I_{\Delta n}$ and without measurement of break time. Only one verification need to be made.

Where applicable the CBR shall also comply with the test of B.8.2.4.5. Only one verification need to be made.

B.8.12 Verification of electromagnetic compatibility

B.8.12.1 Immunity tests

B.8.12.1.1 General

Annex J applies with the following additional requirements.

For CBRs with adjustable settings of residual operating current and/or time-delay, the tests shall be made at the lowest of these settings.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

The tests are performed without load current but with the residual current, when specified.

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1, with the following specifications:

Performance criterion A:

For step 1, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, shall correctly indicate the status.

For step 2, the CBR shall trip at each test frequency, when loaded at 1,25 $I_{\Delta n}$; the dwell time at each frequency shall be not less than the maximum break time specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2, as applicable.

Following these tests, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

Performance criterion B:

During the test, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, may be temporarily affected. Following the test, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

B.8.12.1.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

The test set-up shall be in accordance with Figure J.1 and Figure J.3.

Performance criterion B of B.8.12.1.1 applies except that during the test the CBR may trip. If this is the case a further test shall be made at the immediate lower level, and the CBR shall not trip.

B.8.12.1.3 Radiated RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test set-up shall be in accordance with Figure J.4.

The test connections shall be in accordance with Figure 5 or Figure 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer’s instructions for installation. The type of cable used shall be stated in the test report.

Performance criterion A of B.8.12.1.1 applies.

B.8.12.1.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figure 4 of IEC 61000-4-4:2012.

The test set-up shall be in accordance with Figure J.5 for testing power lines and with Figure J.6 for testing signal lines, taking into consideration the manufacturer’s instructions for installation.

Performance criterion B of B.8.12.1.1 applies.

B.8.12.1.5 Surges

Annex J applies, in particular J.2.5.

The test conditions of 7.2 of IEC 61000-4-5:2014 apply.

For convenience, the mounting specified in B.8.12.1.4 may be used but the use of the ground reference plane is optional.

The test connections shall be in accordance with Figures 6, 7, 8 or 9 of IEC 61000-4-5:2014, taking into consideration the manufacturer’s instructions for installation.

Performance criterion B of B.8.12.1.1 applies.

B.8.12.1.6 Conducted disturbances induced by RF fields (common mode)

Annex J applies, in particular J.2.6.

Performance criterion A of B.8.12.1.1 applies.

B.8.12.2 Emission tests

B.8.12.2.1 General

Annex J applies with the following additional requirements.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

Tests shall be made without load current and without residual current.

B.8.12.2.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

B.8.12.2.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

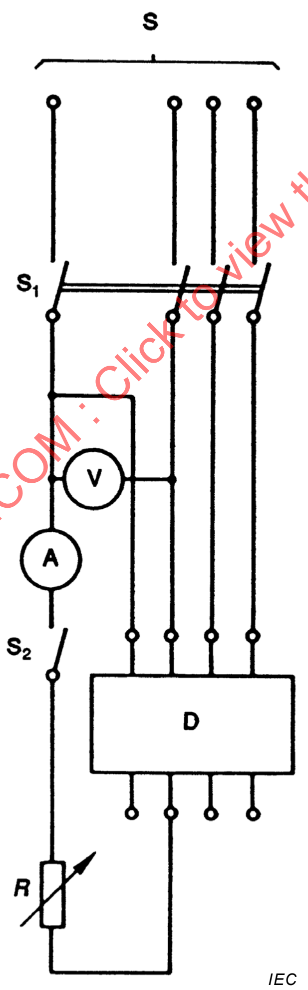
Annex J applies, in particular J.3.3.

B.8.13 Test for variations or interruptions of voltage and for voltage dips

NOTE For definition of voltage dips, see IEC 61000-4-11.

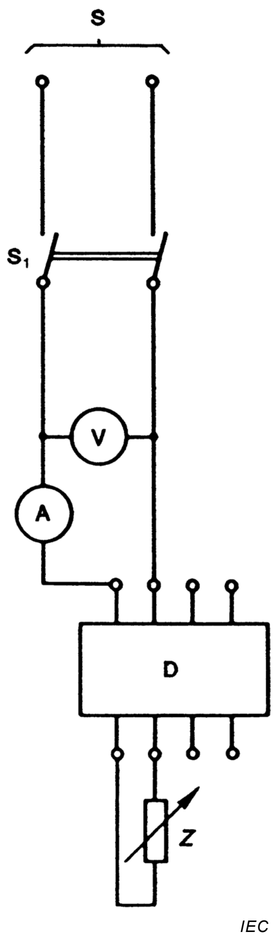
The relevant tests of B.8.8 and B.8.9 are considered adequate to cover the EMC requirements.

No additional tests are therefore required.



S = Supply
V = Voltmeter
A = Ammeter
S_1 = All-pole switch
S_2 = Single-pole switch
D = CBR under test
R = Adjustable resistor

Figure B.1 – Test circuit for the verification of the operating characteristic (see B.8.2)



S = Supply

S_1 = Two-pole switch

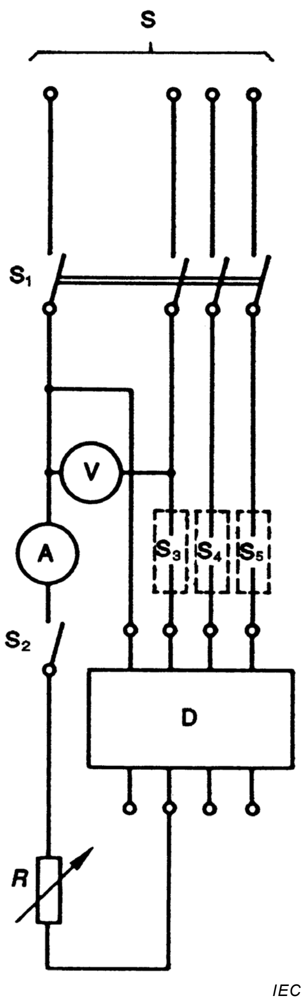
V = Voltmeter

A = Ammeter

D = CBR under test

Z = Adjustable impedance

Figure B.2 – Test circuit for the verification of the limiting value of the non-operating current under over-current conditions (see B.8.5)



S = Supply
V = Voltmeter
A = Ammeter
S_1 = All-pole switch
S_2 = Single-pole switch
S_3, S_4, S_5 = Single-pole switches opening one phase in turn
D = CBR under test
R = Adjustable resistor

Figure B.3 – Test circuit for the verification of the behaviour of CBRs classified under B.3.1.2.2 (see B.8.9)

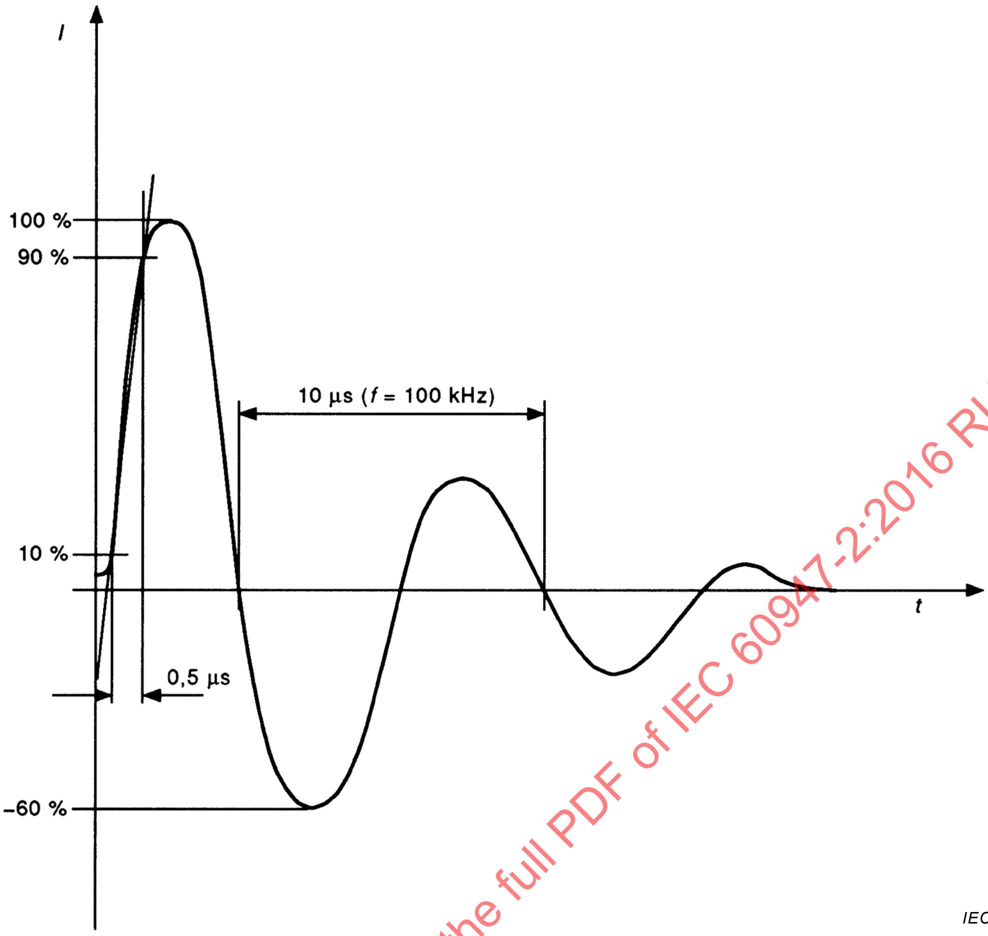
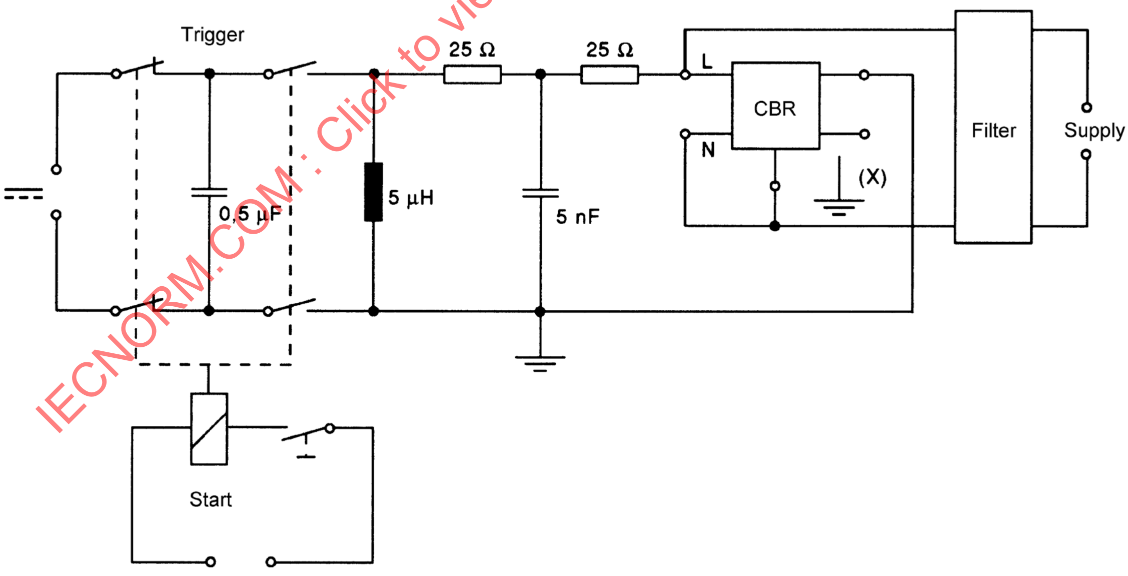


Figure B.4 – Current ring wave 0,5 µs/100 kHz



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

NOTE The circuit component values are given for guidance only and may require adjustment to comply with the wave shape requirements of Figure B.4.

Figure B.5 – Example of test circuit for the verification of resistance to unwanted tripping

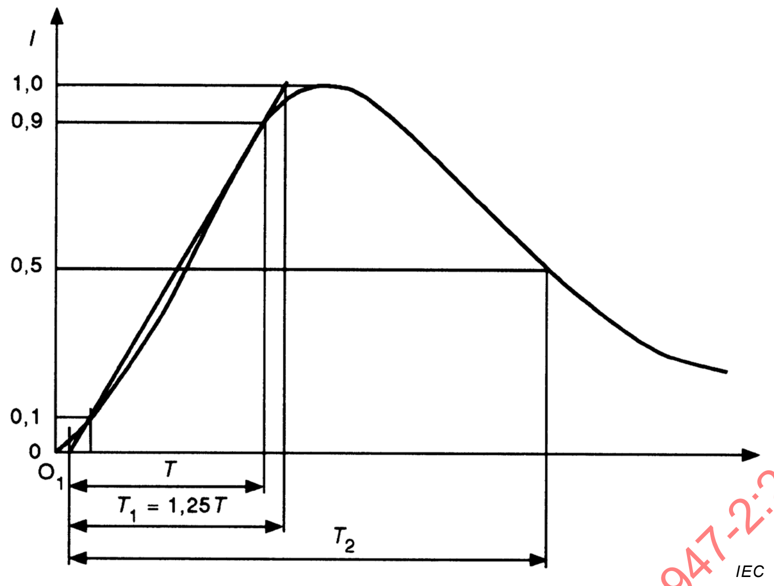
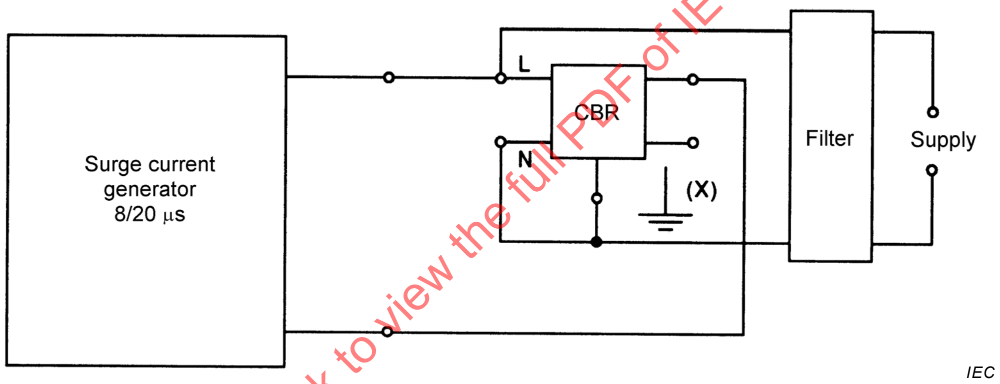
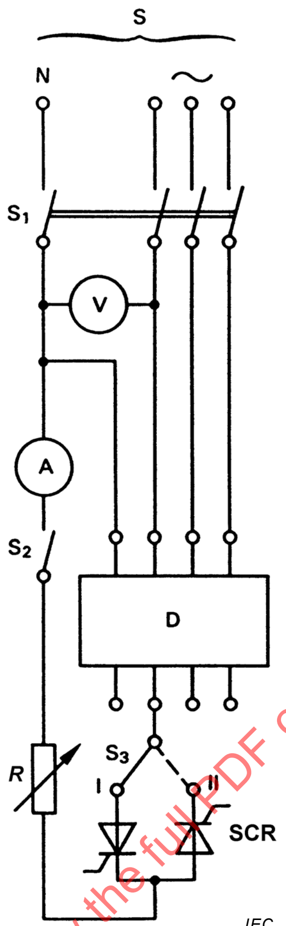


Figure B.6 – Surge current wave 8/20 µs



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

Figure B.7 – Test circuit for the verification of resistance to unwanted tripping in case of flashover without follow-on current (B.8.6.3)



S = Supply

V = Voltmeter

A = Ammeter (measuring r.m.s values)

D = CBR under test

SCR = Thyristors

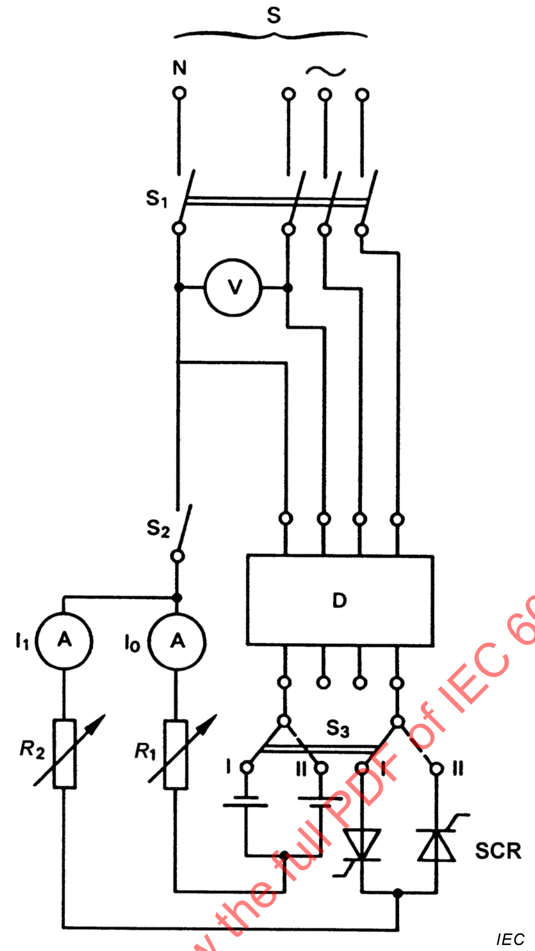
R = Variable resistor

S_1 = All-pole switch

S_2 = Single pole switch

S_3 = Two-way switch

Figure B.8 – Test circuit for the verification of the correct operation of CBRs, in the case of residual pulsating direct currents (see B.8.7.2.1, B.8.7.2.2 and B.8.7.2.3)



S = Supply

V = Voltmeter

A = Ammeter (measuring r.m.s values)

D = CBR under test

SCR = Thyristors

R_1, R_2 = Variable resistor

S_1 = All-pole switch

S_2 = Single pole switch

S_3 = Two-way switch

Figure B.9 – Test circuit for the verification of the correct operation of CBRs, in the case of a residual pulsating direct current superimposed by a smooth direct residual current (see B.8.7.2.4)

Annex C
(normative)

Individual pole short-circuit test sequence

C.1 General

This test sequence applies to multipole circuit-breakers intended for use on phase-earthed systems and identified in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit breaking capacity (I_{su})	C.2
Verification of dielectric withstand	C.3
Verification of overload releases	C.4

C.2 Test of individual pole short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{su} equal to 25 % of the ultimate rated short-circuit breaking capacity I_{cu}.

NOTE Values higher than 25 % of I_{cu} can be tested and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on phase-earthed systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10. The power factor shall be according to Table 11, appropriate to the test current.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

$$O – t – CO$$

and shall be made on each pole separately, in turn.

C.3 Verification of dielectric withstand

Following the test according to Clause C.2, the dielectric withstand shall be verified according to 8.3.5.4.

C.4 Verification of overload releases

Following the test according to Clause C.3, the operation of the overload releases shall be verified in accordance with 8.3.5.5.

Annex D

Vacant

Annex E
(informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex

– "agreement" is used in a very wide sense;

– "user" includes testing stations.

Annex J of IEC 60947-1:2007 applies with regard to clauses and subclauses of this standard, with the following additions:

Clause or subclause number of this standard	Item
4.3.6.3	Circuit-breakers for higher short-circuit making capacity than given in Table 2
7.2.1.2.1	Automatic opening operation other than trip-free operation and by stored energy
Table 10	Setting of overload releases at intermediate values for short-circuit tests
8.3.3.5	Method of temperature-rise tests for four-pole circuit-breakers having a conventional thermal current higher than 63 A
8.3.2.6.4.3	Value of test current for short-circuit tests on the fourth pole of four-pole circuit-breakers
8.3.3.2.3, item b)	Test current value for the verification of inverse time/current characteristics
8.3.3.5	To increase the severity of the conditions for testing overload performance
8.3.3.8 8.3.4.6	Permissible delay between the verification of temperature-rise and that of overload relays in test sequences I and II
8.4.3	Calibration of releases other than over-current releases, shunt releases and undervoltage releases
8.5	Special tests – Damp heat, salt mist, vibration and shock
B.8	Applicability of tests when $I_{\Delta n}$ > 30 A
B.8.2.5	Extension of the test ambient temperature limits

Annex F
(normative)

Additional tests for circuit-breakers with electronic over-current protection

F.1 General

This annex applies to circuit-breakers intended to be installed on a.c. circuits and providing over-current protection by electronic means, incorporated in the circuit-breaker and independent of the line voltage or any auxiliary supply.

The tests verify the performance of the circuit-breaker under the environmental conditions stated in this annex.

Specific tests for electronic means intended for functions other than over-current protection are not covered by this annex. However, the tests of this annex shall be performed to ensure that these electronic means do not impair the performance of the over-current protective functions.

F.2 List of tests

F.2.1 General

Tests specified in this annex are type tests and are supplementary to the tests of Clause 8.

NOTE Where a standard for specific environmental conditions exists, reference is systematically made to this standard, if relevant.

F.2.2 Electromagnetic compatibility (EMC) tests

F.2.2.1 General

Circuit-breakers with electronic overcurrent protection shall be tested according to Table J.1 and Figure J.3.

F.2.2.2 Performance criteria

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1 with the following specifications:

Performance criterion A:

For step 1, the circuit-breaker when loaded at 0,9 times the current setting shall not trip and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

For step 2, when loaded at 2,0 times the current setting, the circuit-breaker shall trip within 0,9 times the minimum value and 1,1 times the maximum value of the manufacturer's time current characteristic, and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

Performance criterion B:

During the test, the circuit-breaker when loaded at 0,9 times the current setting shall not trip. After the test, the circuit-breaker shall comply with the manufacturer's time current characteristic when loaded at 2,0 times the current setting and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

F.2.3 Suitability for multiple frequencies

The test shall be performed in accordance with F.6.

F.2.4 Dry heat test

The test shall be performed in accordance with F.7.

F.2.5 Damp heat test

The test shall be performed in accordance with F.8.

F.2.6 Temperature variation cycles at a specified rate of change

The test shall be performed in accordance with F.9.

F.3 General test conditions

F.3.1 General

Tests according to this annex may be performed separately from the tests of Clause 8.

In the case of the EMC tests, Annex J applies with the additional requirements specified in F.4 and F.5.

F.3.2 Electromagnetic compatibility tests

For immunity tests (F.4) one circuit-breaker per frame size and per type of current sensor design shall be tested; a change of winding turns is not considered as a different design in this context. In the case of withdrawable circuit-breaker, the device shall be mounted inside the enclosure in accordance with the manufacturer's instructions, the test set-up being modified accordingly.

The current setting I_r shall be adjusted to the minimum value.

Short-time and instantaneous release settings shall each, if applicable, be adjusted to the minimum value but to not less than 2,5 times I_r.

The tests shall be performed with the appropriate test circuit, as specified in the following subclauses, taking into account any phase-loss sensitive features.

For circuit-breakers having electronic overcurrent protection, it may be assumed that the tripping characteristics are the same, whether tests are performed:

– on individual poles of multipole circuit-breakers;
– on two or three phase poles in series;
– by three-phase connection.

NOTE This enables comparisons to be made between test results obtained on different phase pole combinations as required by the different test sequences.

For circuit-breakers incorporating a residual current function (see also Annex B and Annex M):

– in the cases of F.4.4, F.4.5 and F.4.6, tests are made on pairs of phase poles for multipole circuit-breakers, to avoid unintentional tripping by residual current;
– in the cases of F.4.1 and F.4.7, tests may be made on any combination of phase poles, as long as unintentional tripping by residual current is avoided.

F.4 Immunity tests

F.4.1 Harmonic currents

F.4.1.1 General

These tests apply to circuit-breakers for which the electronic current sensing means are stated by the manufacturer to be r.m.s. responsive.

This shall be indicated either by marking “r.m.s.” on the circuit-breaker or given in the manufacturer's literature, or both.

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details including the dimensions of the enclosure shall be stated in the test report.

Where applicable, the tests shall be performed at the rated frequency.

NOTE The test currents can be generated by a source of power based on the use of thyristors (see Figure F.1), saturated cores, programmable power supplies, or other appropriate sources.

F.4.1.2 Test currents

The test current waveform shall consist of one of the following two options:

– option a): two waveforms applied successively:
  - a waveform consisting of a fundamental and a third harmonic component;
  - a waveform consisting of a fundamental and a fifth harmonic component.

– option b): a waveform consisting of a fundamental and a third, fifth and seventh harmonic component.

Test currents shall be

– for option a):

  test of the third harmonic and peak factor
  - 72 % of fundamental component ≤ third harmonic ≤ 88 % of fundamental component;
  - peak factor: 2,0 ± 0,2;

  test of the fifth harmonic and peak factor
  - 45 % of fundamental component ≤ fifth harmonic ≤ 55 % of fundamental component;
  - peak factor: 1,9 ± 0,2;

– for option b):

  the test current, for each period, consists of two equal opposite half-waves defined as follows:
  - current conduction time, for each half-wave is ≤ 21 % of the period;
  - peak factor: ≥ 2,1.

NOTE 1 The peak factor is the peak value of the current divided by the r.m.s. value of the current wave. For the relevant formula, see Figure F.1.

NOTE 2 This test current for option b) has at least the following harmonic content of the fundamental component:

– third harmonic > 60 %;

– fifth harmonic > 14 %;

– seventh harmonic > 7 %;

– twenty-first harmonic > 1 %.

Other harmonics can also be present.

NOTE 3 The test current waveform for option b) can be produced by, for example, two back-to-back thyristors (see Figure F.1).

NOTE 4 The test currents 0,9 I_r and 2,0 I_r (see performance criterion A of F.2.2.2) are the r.m.s. values of the composite waveforms.

F.4.1.3 Test procedure

The tests shall be performed on two-phase poles, chosen at random in accordance with item b) of 7.2.1.2.4 carrying the test current at any convenient voltage, connections being in accordance with Figure F.2. For releases with a phase loss sensitive feature, connections shall be made in accordance with Figure F.3 or Figure F.4, as applicable.

Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The duration of the test to verify the immunity to unwanted tripping (at 0,9 times the current setting) shall be 10 times the tripping time, which corresponds to twice the current setting.

F.4.1.4 Test results

Performance criterion A of F.2.2.2 shall apply.

F.4.2 Electrostatic discharges

Annex J, in particular J.2.2, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure J.3.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

The busbar routing shown in Figure F.2, Figure F.3 and Figure F.4 may be varied providing the 0,1 m distances, with a tolerance of $^{+10}_{\ 0}$ %, to the enclosure are maintained. The actual configuration used shall be shown in the test report.

Performance criterion B of F.2.2.2 applies.

F.4.3 Radiated RF electromagnetic fields

Annex J, in particular J.2.3, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure F.17.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.4 Electrical fast transient/burst (EFT/B)

Annex J, in particular J.2.4, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure F.18 for testing power lines and with Figure F.16 and Figure F.19 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.6.

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.7 for the three phase poles in series connection or as shown in Figure F.8 on a phase pole chosen at random for the three-phase connection.

Performance criterion A of F.2.2.2 applies. However, temporary changes to the monitoring functions (e.g. unwanted LED illumination) during the tests are acceptable, in which case the correct functioning of the monitoring shall be verified after the tests. For step 2, the disturbance shall be applied until the circuit-breaker trips.

F.4.5 Surges

Annex J, in particular J.2.5, applies with the following additions.

On a.c. mains ports, the disturbance shall be applied on one phase pole chosen at random, the EUT being supplied from the other two phase poles, in accordance with Figure F.9 (line-to-earth) and Figure F.12 (line-to-line).

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.10 (line-to-earth) and Figure F.13 (line-to-line) for the three phase poles in series connection or as shown in Figure F.11 (line-to-earth) and Figure F.14 (line-to-line) on a phase pole chosen at random for the three-phase connection.

Performance criterion B of F.2.2.2 applies.

F.4.6 Conducted disturbances induced by RF fields (common mode)

Annex J, in particular J.2.6, applies with the following additions.

The test set-up shall be in accordance with Figure F.16, Figure F.20 and Figure F.21, Figure F.22 or Figure F.23 for testing power lines and with Figure F.16 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.2.

For releases which have a phase-loss sensitive feature the test circuit shall be in accordance with Figure F.3 or Figure F.4 as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.7 Current dips

F.4.7.1 Test procedure

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details including the dimensions of the enclosure shall be stated in the test report.

The test circuit shall be in accordance with Figure F.2 on two-phase poles chosen at random. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

The tests shall be performed with a sinusoidal current at any convenient voltage. The current applied shall be according to Figure F.5 and to Table F.1 below where I_r is the setting current, I_D is the dip test current and T is the period of the sinusoidal current.

The duration of each test shall be between three and four times the maximum tripping time corresponding to twice the current setting or 10 min, whichever is the lower.

Table F.1 – Test parameters for current dips and interruptions

Test No.	I_D	Δt
1	0	0,5 T
2		1 T
3		5 T
4		25 T
5		50 T
6	0,4 I_r	10 T
7		25 T
8		50 T
9	0,7 I_r	10 T
10		25 T
11		50 T

F.4.7.2 Test results

Performance criterion B of F.2.2.2 shall apply, except that the after-test verification is not required.

F.5 Emission tests

F.5.1 Harmonics

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.2 Voltage fluctuations

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.3 Conducted RF disturbances (150 kHz to 30 MHz)

Circuit-breakers covered by this annex are independent of line voltage or of any auxiliary supply. Electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

F.5.4 Radiated RF disturbances (30 MHz to 1 GHz)

Annex J, in particular J.3.3, applies with the following additions.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The limits of Table J.3 apply.

F.6 Suitability for multiple frequencies

F.6.1 General

The test verifies the tripping characteristics of circuit-breakers declared as suitable for multiple frequencies. It does not apply to circuit-breakers rated at 50 Hz to 60 Hz only.

F.6.2 Test conditions

The tests shall be performed at each rated frequency or, when a range of rated frequencies is declared, at the lowest and the highest rated frequencies.

F.6.3 Test procedure

Tests shall be performed on any pair of phase-poles chosen at random at any convenient voltage.

The test circuit shall be in accordance with Figure F.2. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Under-voltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The short-time and instantaneous trip current settings shall each, if relevant, be adjusted to 2,5 times the current setting. If this setting is not available, the next closest higher setting shall be used.

Tests shall be performed as follows:

a) A current of 0,95 times the conventional non-tripping current (see Table 6) is applied for a time equal to 10 times the tripping time which corresponds to 2,0 times the current setting.
b) Immediately following the test of a), a current of 1,05 times the conventional tripping current (see Table 6) is applied.
c) A further test starting from the cold state is made at 2,0 times the current setting.

F.6.4 Test results

For each test frequency, the overload tripping characteristics shall comply with the following requirements:

– for test a) no tripping shall occur;
– for test b) tripping shall occur within the conventional time (see Table 6);
– for test c) tripping shall occur within 1,1 times the maximum and 0,9 times the minimum values of the manufacturer’s stated time-current characteristic.

F.7 Dry heat test

F.7.1 Test procedure

The test shall be performed on the circuit-breaker in accordance with 7.2.2 at the maximum rated current for a given frame size, on all phase poles, at an ambient temperature of 40 °C. The duration of the test, once temperature equilibrium is reached, shall be 168 h.

The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions (see 5.2 e)).

As an alternative, the test may be performed as follows:

- measure and record the highest temperature rise of the air surrounding the electronic components, during the temperature rise verification of test sequence I;
- install the electronic controls in the test chamber;
- supply the electronic controls with their input energizing value;
- adjust the temperature of the test chamber to a value of 40 K above the temperature rise recorded for the air surrounding the electronic components and maintain this temperature for 168 h.

F.7.2 Test results

The circuit-breaker and the electronic controls shall meet the following requirements:

- no tripping of the circuit-breaker shall occur;
- no operation of the electronic controls which would cause the circuit-breaker to trip shall occur.

F.7.3 Verification of overload releases

Following the test of F.7.1, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.8 Damp heat test

F.8.1 Test procedure

The test shall be performed according to IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be six.

The test may be performed with only the electronic controls in the test chamber.

F.8.2 Verification of overload releases

Following the test of F.8.1 the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.9 Temperature variation cycles at a specified rate of change

F.9.1 Test conditions

Each design of electronic controls shall be submitted to temperature variation cycles in accordance with Figure F.15.

The rise and fall of temperature during the rate of variation shall be 1 K/min ± 0,2 K/min. The temperature, once reached, shall be maintained for at least 2 h.

The number of cycles shall be 28.

F.9.2 Test procedure

The test shall be carried out according to IEC 60068-2-14.

For these tests, the electronic controls may be mounted inside the circuit-breaker or separately.

The electronic controls shall be energized to simulate service conditions.

Where the electronic controls are mounted inside the circuit-breaker, the main circuit shall not be energized.

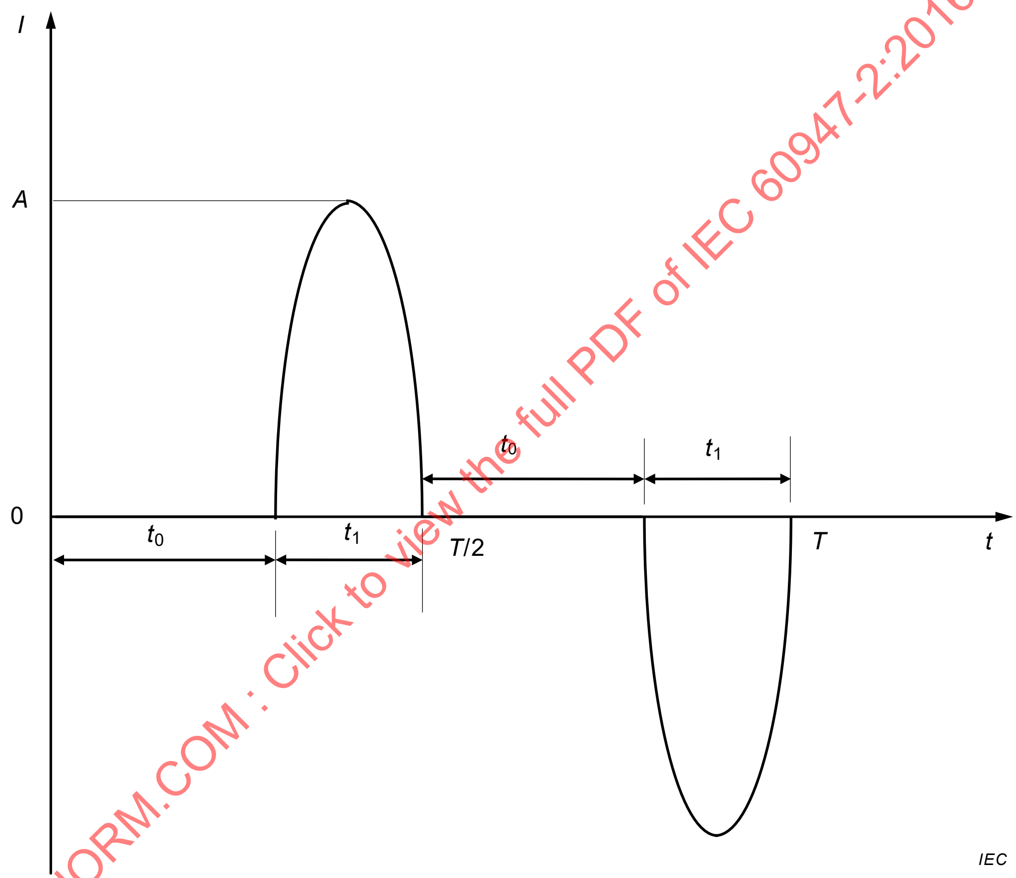
F.9.3 Test results

The electronic controls shall meet the following requirement.

No operation of the electronic controls which would cause the circuit-breaker to trip during the 28 cycles shall occur.

F.9.4 Verification of overload releases

Following the test of F.9.2, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).



Key

A peak current

T period

t_1 conducting time during each half-cycle

t_0 delay time

$$\text{Peak factor} = \frac{A}{\sqrt{\frac{2}{T}\int_0^{T/2} i^2(t)\,\mathrm{d}t}}$$

Figure F.1 – Representation of test current produced by back-to-back thyristors in accordance with F.4.1

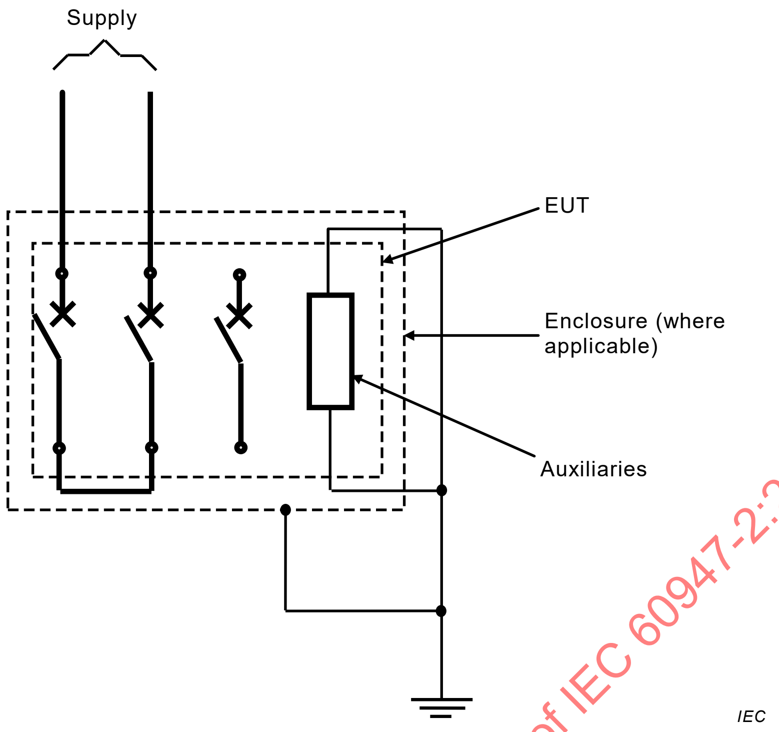


Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series

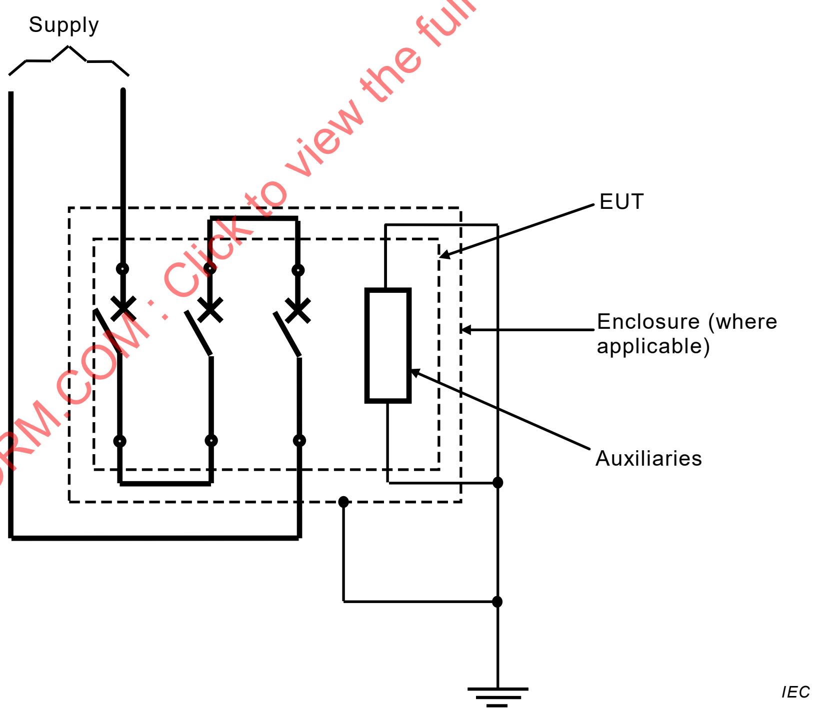
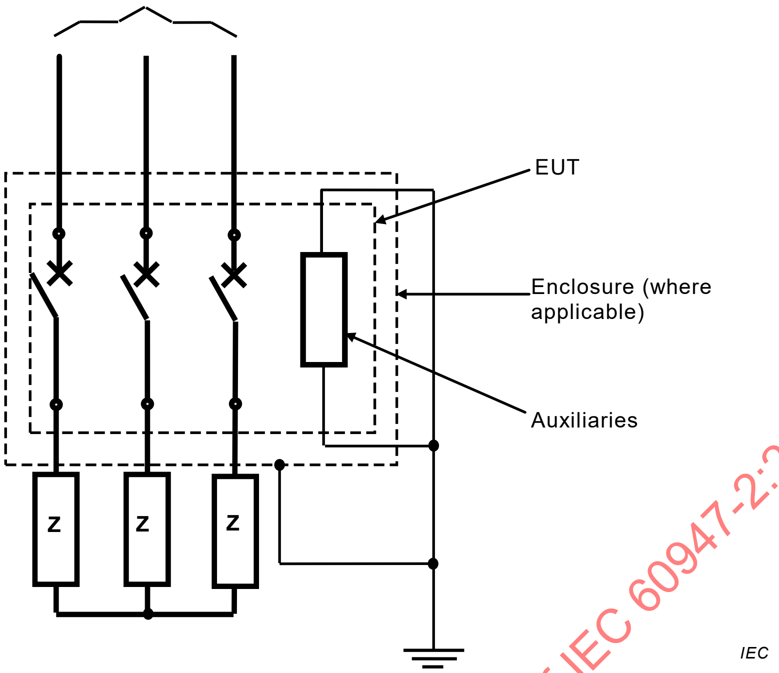


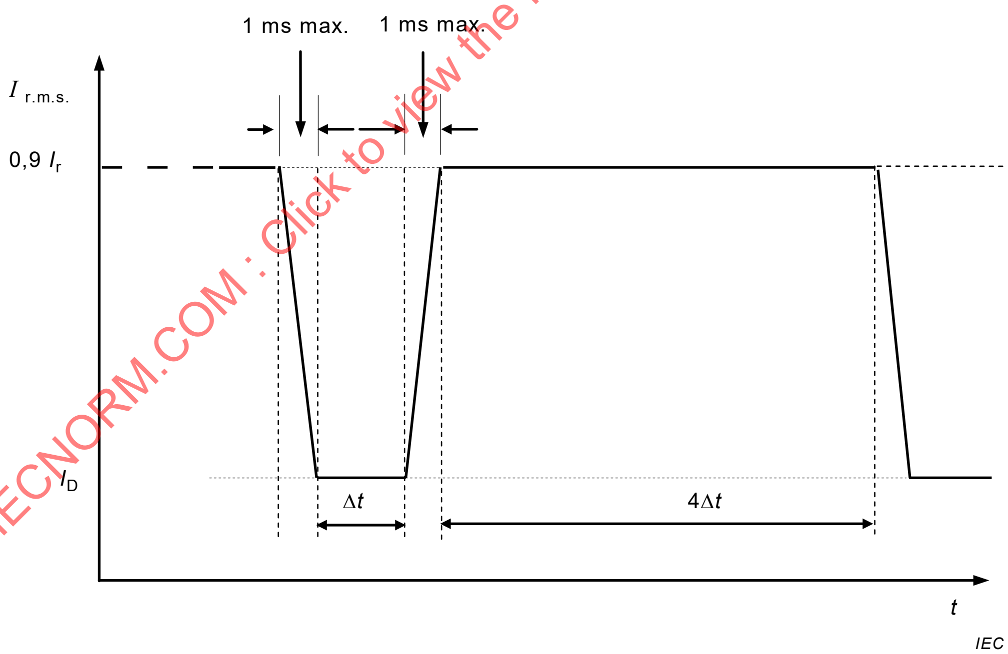
Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.4 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three-phase connection



Key

I_r	setting current
I_D	dip test current
Δt	dip time
$4\Delta t$	dwell time

Figure F.5 – Test current for the verification of the influence of the current dips and interruptions in accordance with F.4.7.1

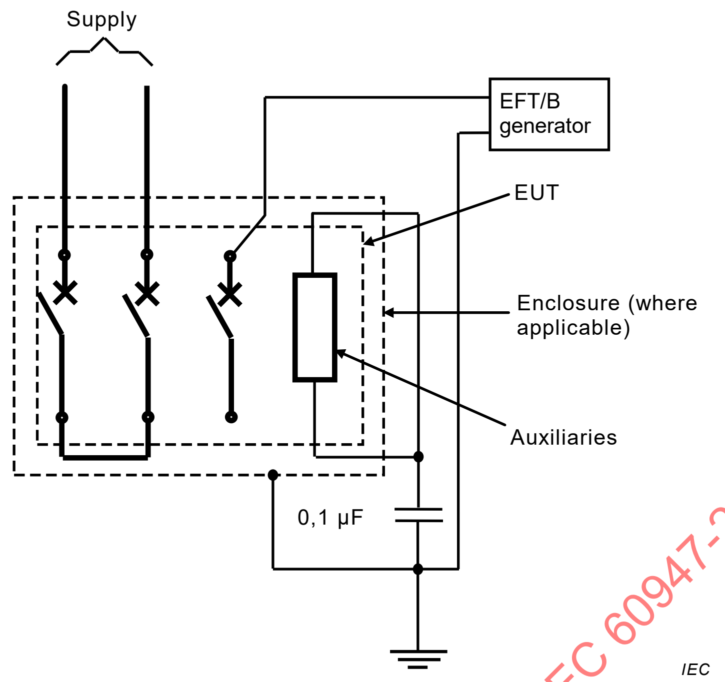


Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Two phase poles in series

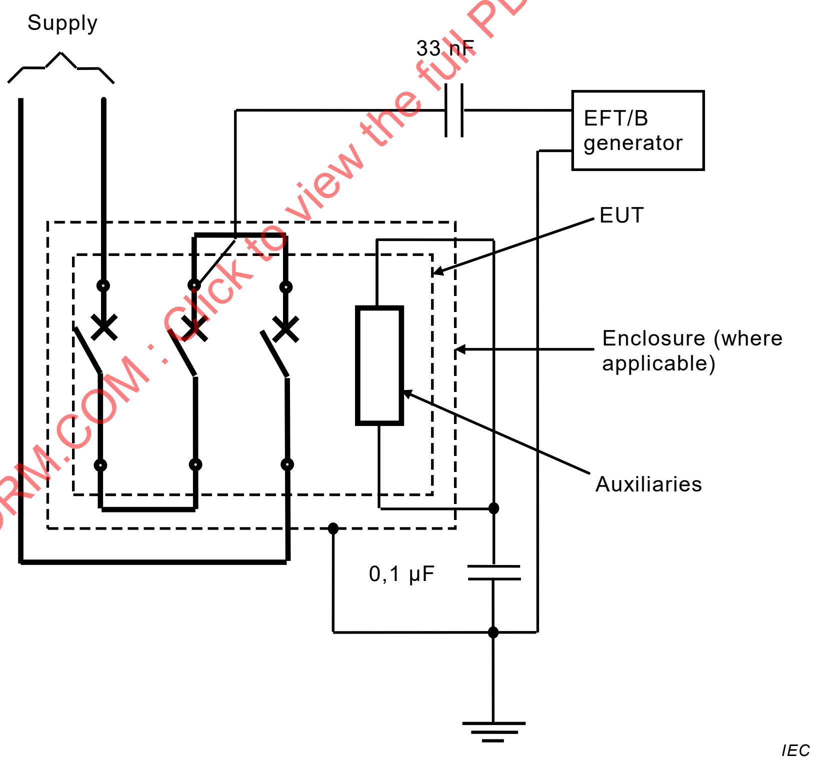
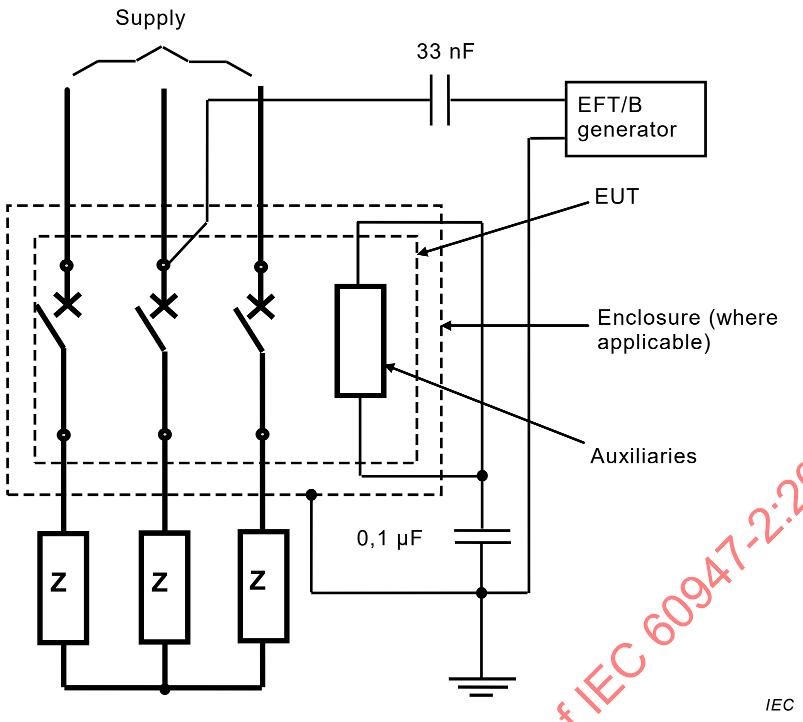


Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three-phase connection

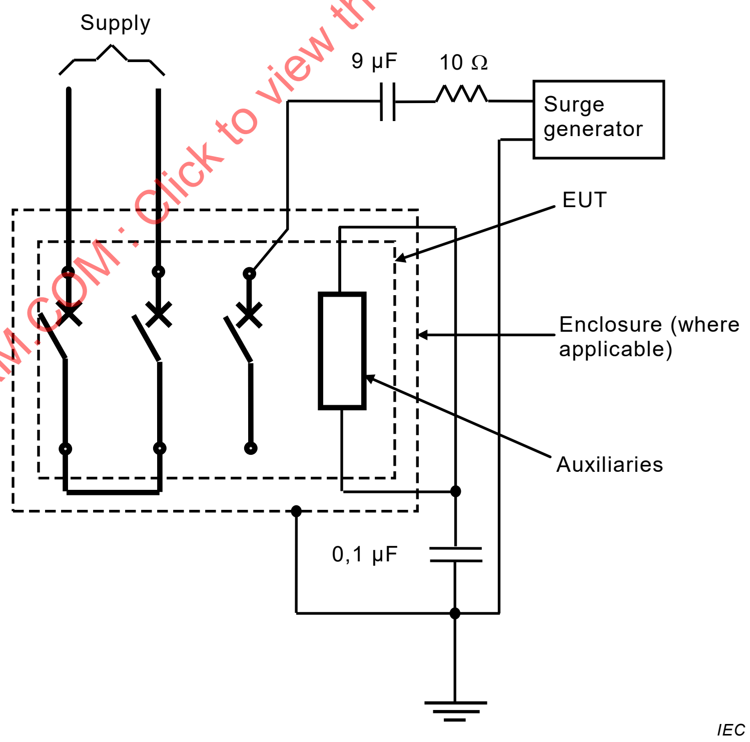


Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Two phase poles in series

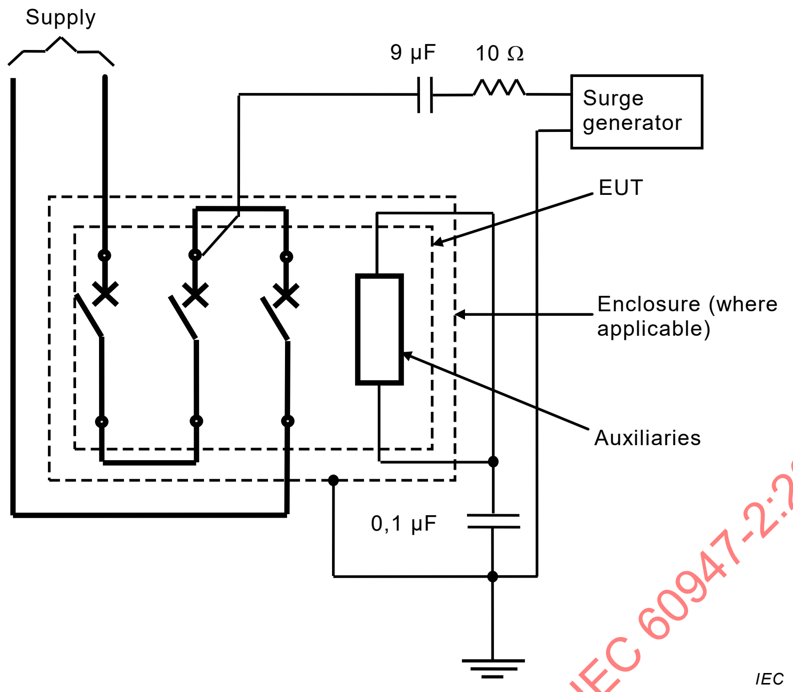
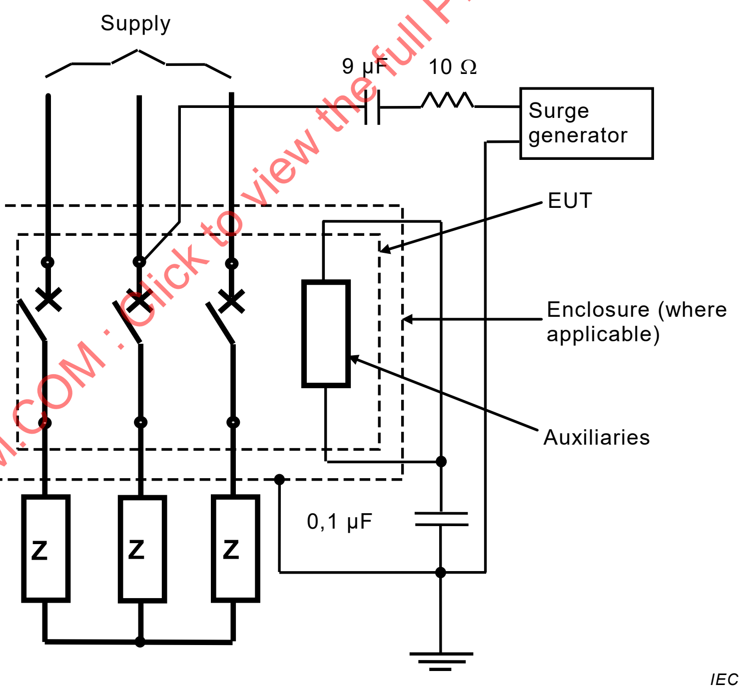


Figure F.10 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series



Key

Z   impedance for adjusting the current (where required)

Figure F.11 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three-phase connection

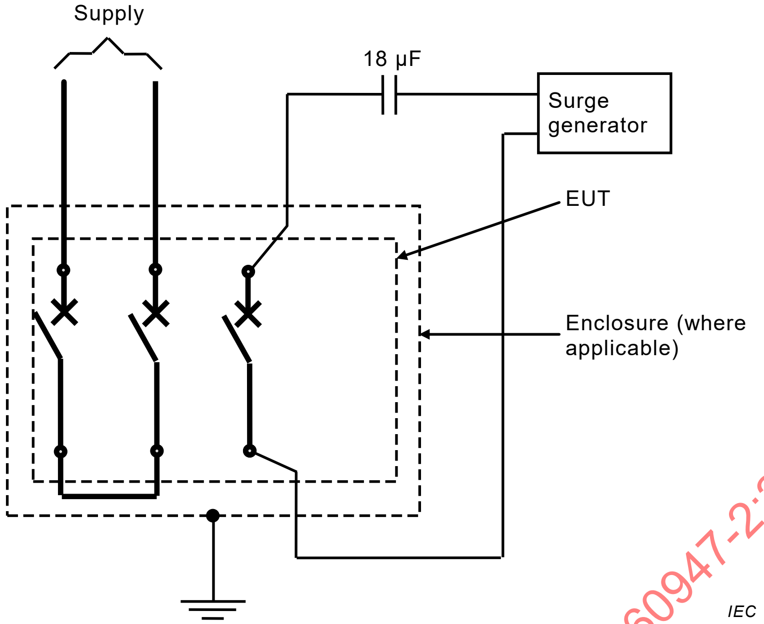


Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Two phase poles in series

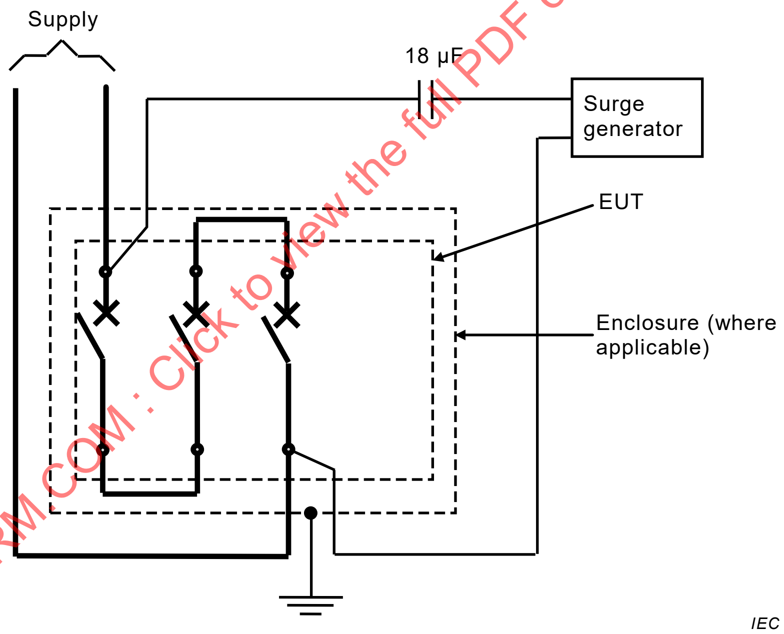
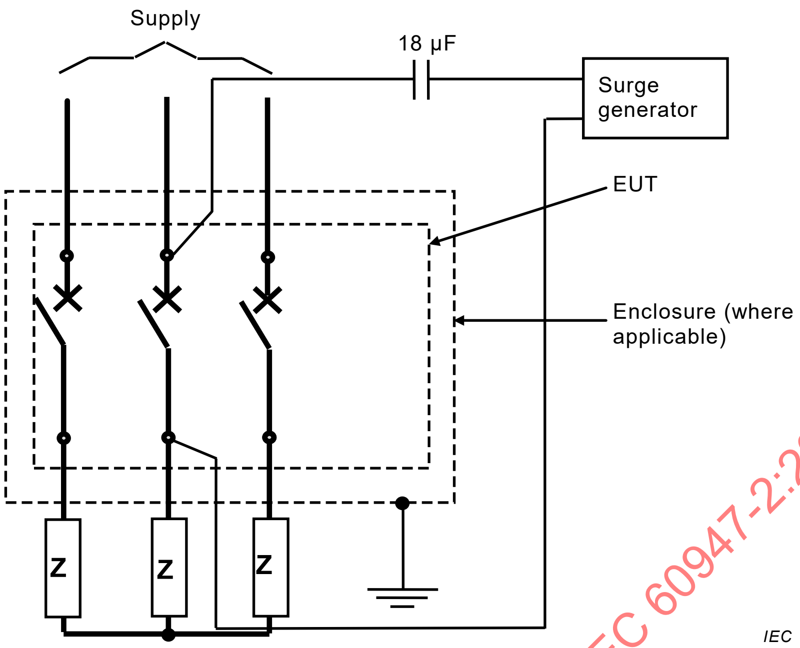


Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.14 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three-phase connection

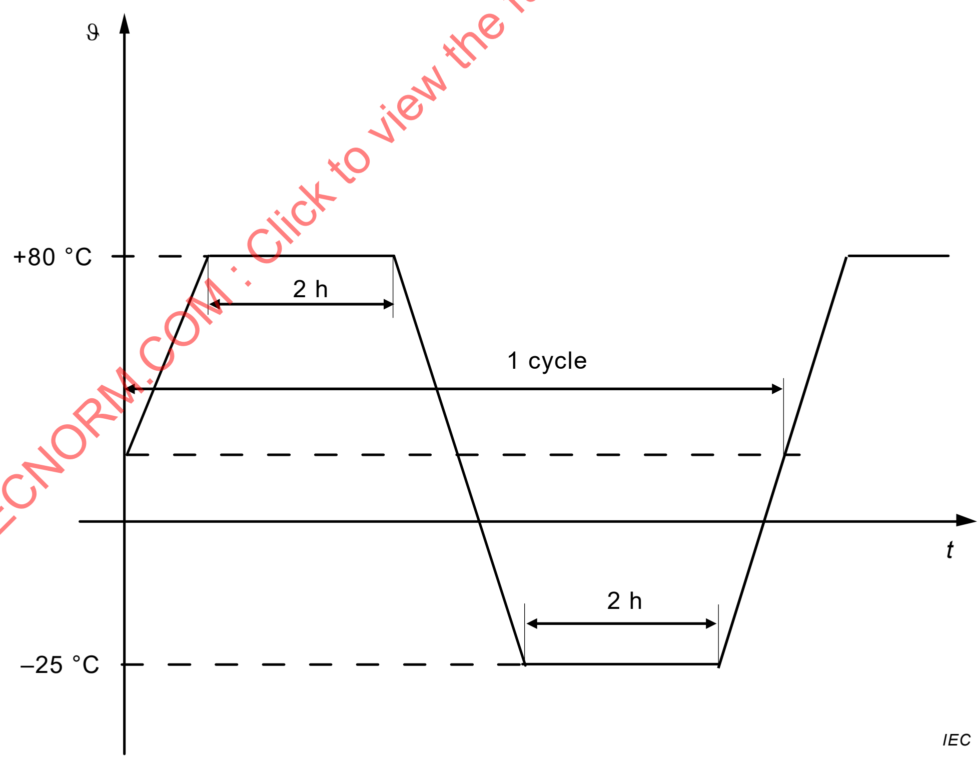
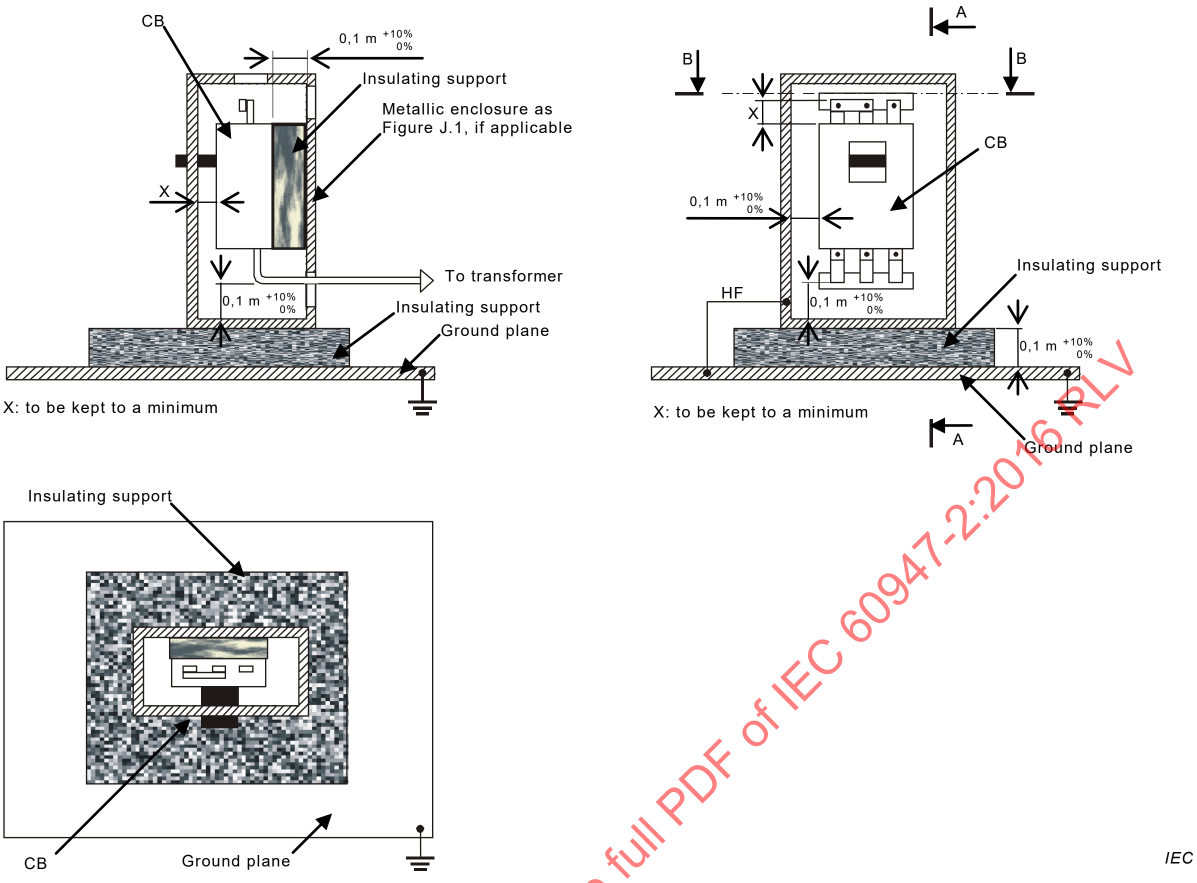


Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.9.1

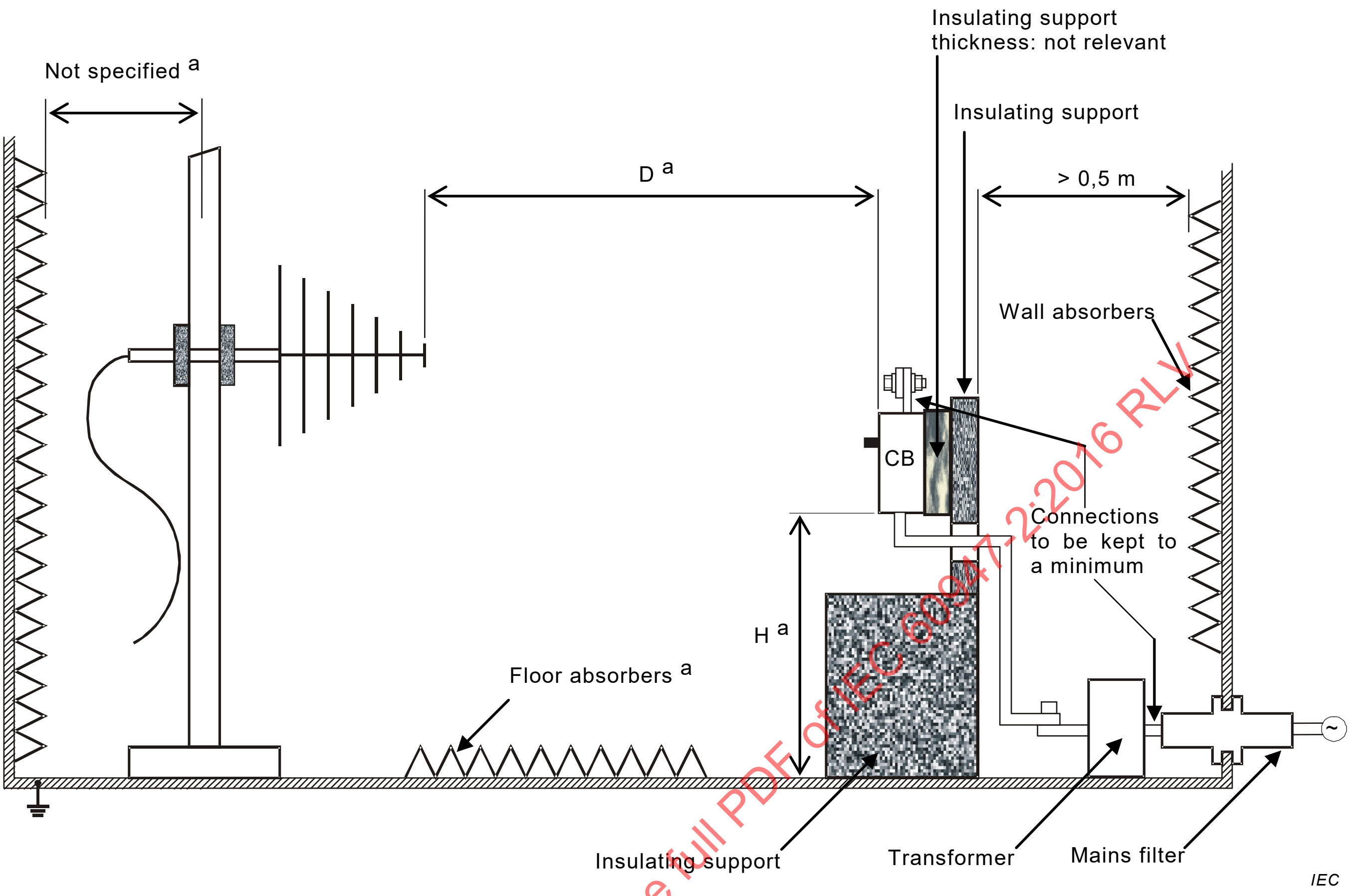


Key

CB circuit-breaker

NOTE The terminal arrangement can vary according to the type of circuit-breaker tested.

Figure F.16 – General test set-up for immunity tests

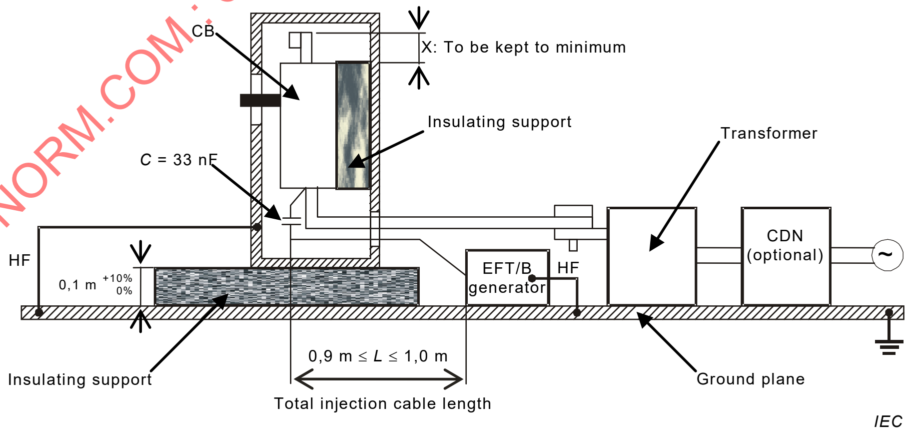


Key

CB circuit-breaker

a See IEC 61000-4-3

Figure F.17 – Test set-up for the verification of immunity to radiated RF electromagnetic fields



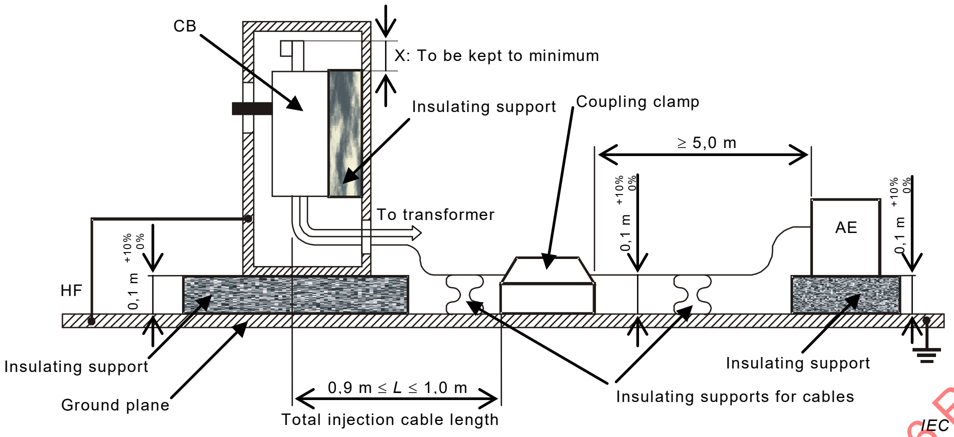
Key

CB circuit-breaker

CDN coupling-decoupling network

HF high frequency connection

Figure F.18 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines



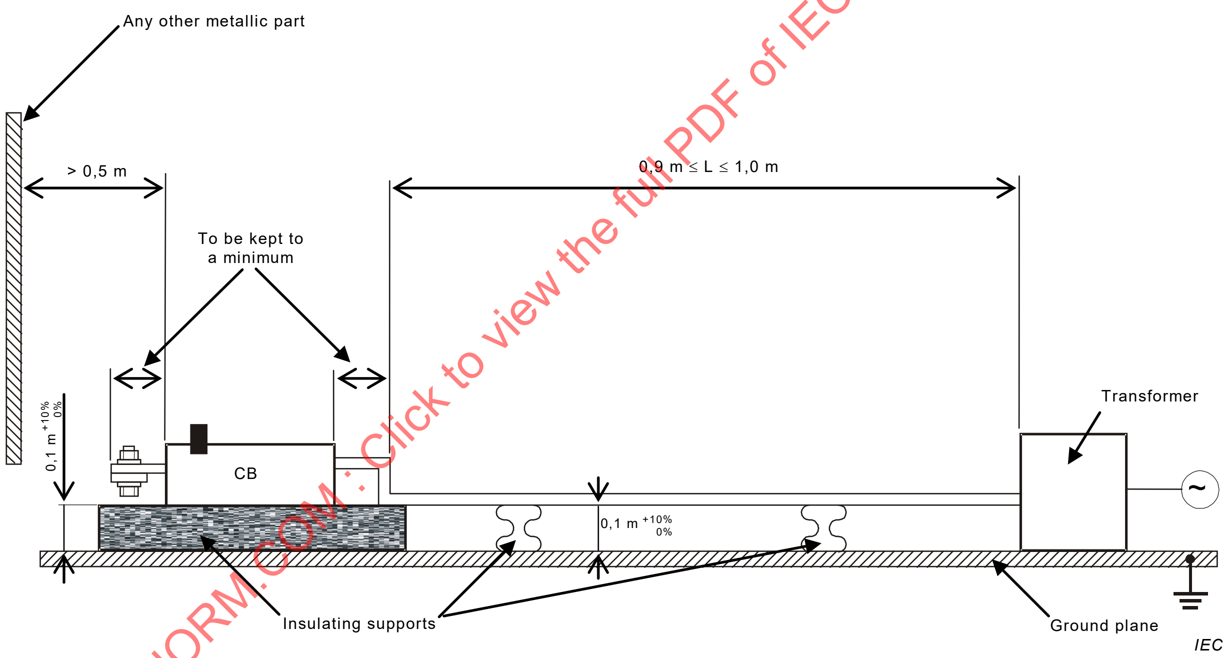
Key

AE auxiliary equipment

CB circuit-breaker

HF high frequency connection

Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

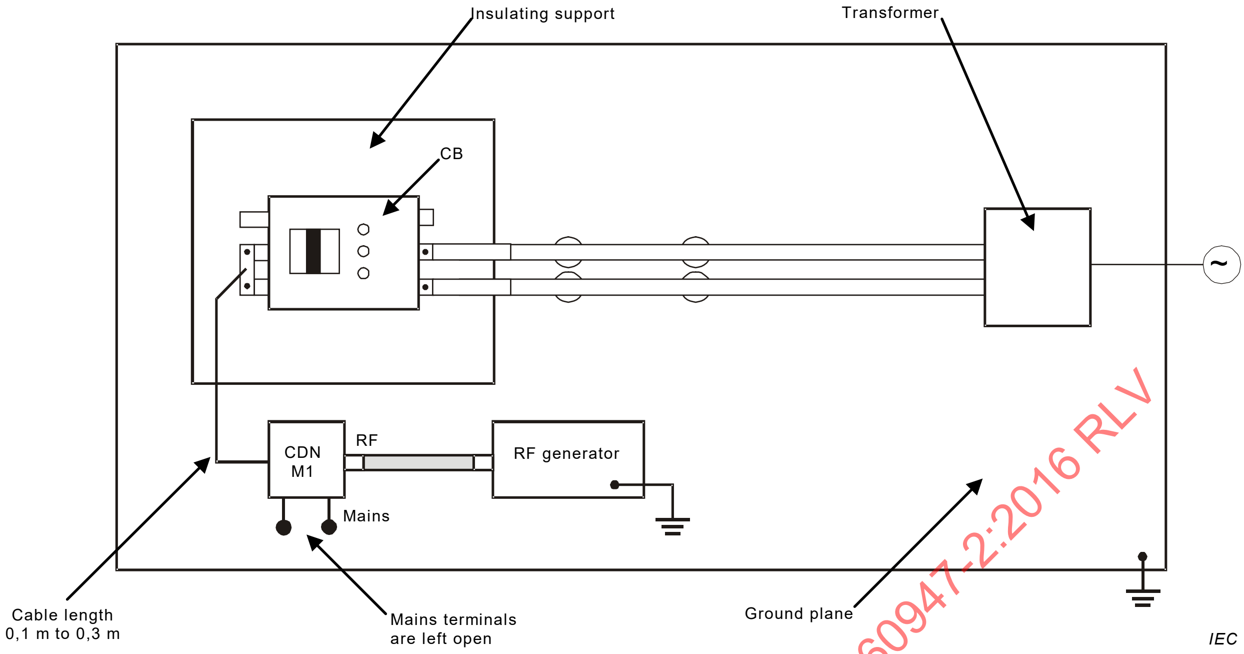


Key

CB circuit-breaker

NOTE The dimension *L* is the length of the conductor coupled at 0,1 m to the ground plane.

Figure F.20 – General test set-up for the verification of immunity to conducted disturbances induced by RF fields (common mode)



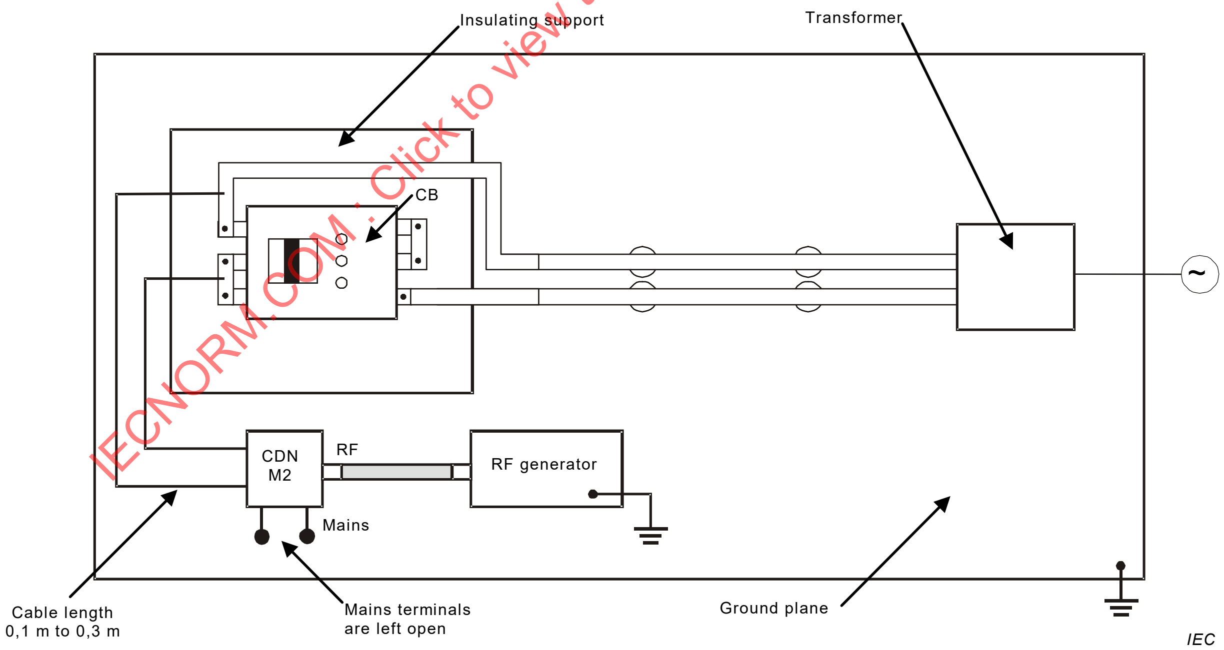
Key

CB circuit-breaker

CDN M1 coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, the coupling-decoupling network M2 or M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.21 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Two phase poles in series configuration



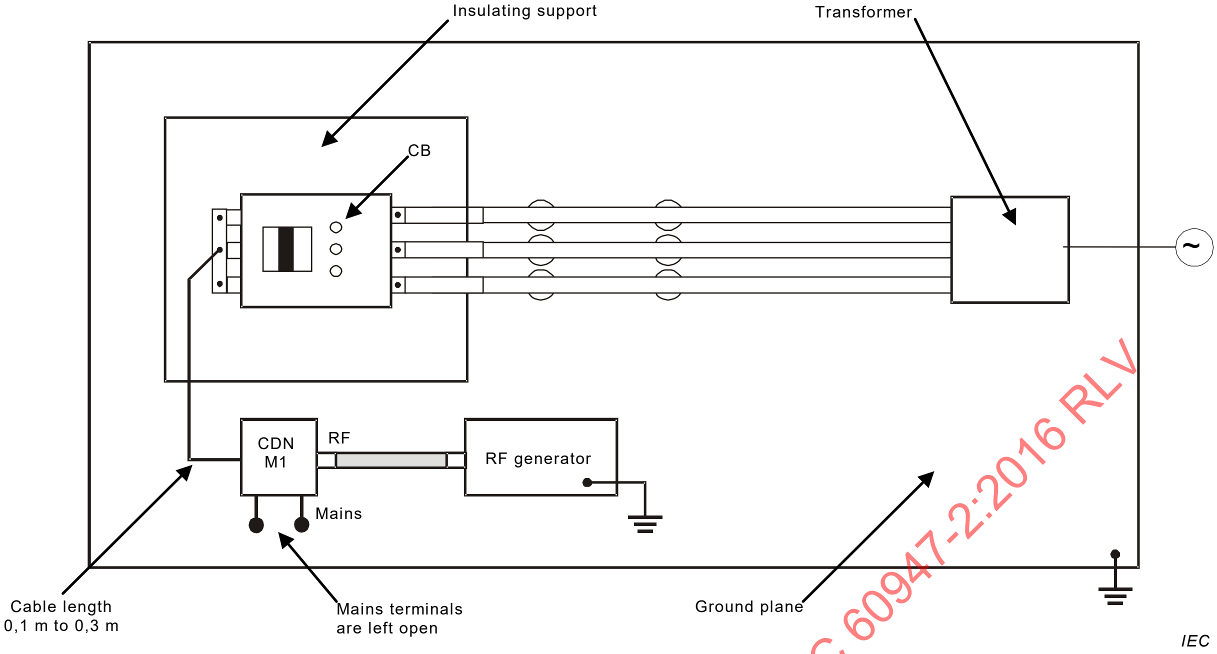
Key

CB circuit-breaker

CDN M2 coupling-decoupling network M2

NOTE As an alternative to the coupling-decoupling network M2, coupling-decoupling network M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.22 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three phase poles in series configuration



Key

CB circuit-breaker

CDN M1 coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, coupling-decoupling network M2 or M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.23 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three-phase configuration

Annex G
(normative)

Power loss

G.1 General

Power loss is not a fundamental characteristic of a circuit-breaker and need not be marked on the product.

It gives some indication of the heat generated under specified conditions.

Measurement of power loss shall be made in free air, on new samples, and shall be stated in watts.

G.2 Test methods

G.2.1 General case

Power loss is evaluated as follows, connections being in accordance with Figure G.1.

$$\sum_{k=1}^{k=p} \Delta U_k \, I_k \cos \varphi_k$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I is the test current which shall be equal to I_n within the tolerances according to 8.3.2.2.2;

$\cos \varphi$ is the power factor.

The use of a wattmeter on each pole is recommended.

G.2.2 AC circuit-breakers of rated current not exceeding 400 A

For a.c. circuit-breakers of rated current not exceeding 400 A, it is acceptable to use single-phase a.c. measurement without power factor measurement.

The power loss is evaluated as follows, connections being in accordance with Figure G.2.

$$\sum_{k=1}^{k=p} \Delta U_k \, I_n$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I_n is the rated current.

G.2.3 DC circuit-breakers

For d.c. circuit-breakers, the power loss shall be measured with d.c. current.

It is evaluated as in G.2.2.

G.3 Test procedure

The power loss evaluation shall be made under rated current steady-state temperature conditions.

The voltage drop shall be measured between incoming and outgoing terminals on each pole.

The connecting leads to measuring instruments (e.g. voltmeter, wattmeter) shall be twisted together. The measuring loop shall be as small as practicable and shall be positioned similarly for each pole.

For evaluating the power loss of three-pole and four-pole a.c. circuit-breakers according to G.2.1, the test is performed under three-phase current conditions (see Figure G.1), without current in the fourth pole in the case of four-pole circuit-breakers.

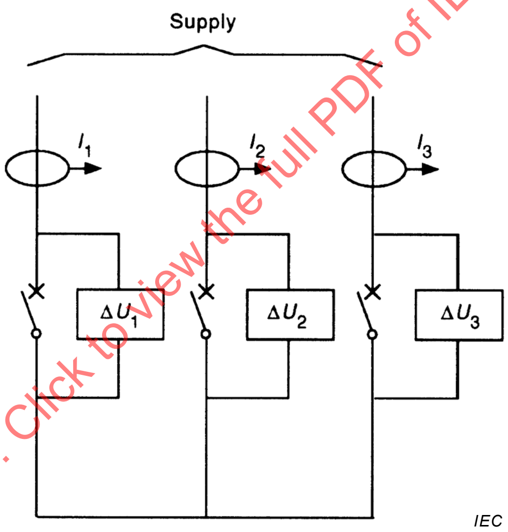


Figure G.1 – Example of power loss measurement according to G.2.1

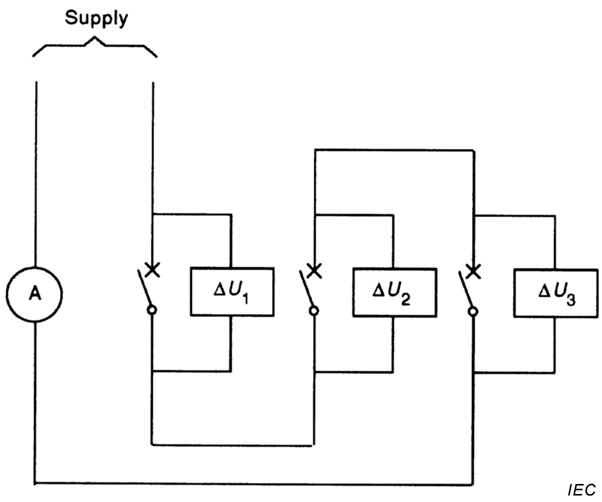


Figure G.2 – Example of power loss measurement according to G.2.2 and G.2.3

Annex H
(normative)

Test sequence for circuit-breakers for IT systems

NOTE This test sequence is intended to cover the case of a second fault to earth in presence of a first fault on the opposite side of a circuit-breaker when installed in IT systems (see 4.3.2.1).

H.1 General

This test sequence applies to multipole circuit-breakers for application on IT systems, in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit (I_{IT})	H.2
Verification of dielectric withstand	H.3
Verification of overload releases	H.4

H.2 Individual pole short-circuit

A short-circuit test is made on the individual poles of a multipole circuit-breaker under the general conditions of 8.3.2, at a value of current I_{IT} equal to

– 1,2 times the maximum setting of the short-time delay release tripping current or, in the absence of such a release, 1,2 times the maximum setting of the tripping current of the instantaneous release,

or, where relevant

– 1,2 times the maximum setting of the definite time delay release tripping current,

but not less than 500 A nor exceeding 50 kA.

NOTE 1 The prospective current of the test circuit can have to be increased to ensure that the test current exceeds the actual short-time or instantaneous pick-up current, allowing for the impedance of the circuit-breaker and its connections.

NOTE 2 Values higher than I_{IT} can be required, tested instead and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on IT systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10. The power factor shall be according to Table 11, appropriate to the test current. When I_{IT} = 50 kA, the short-time or instantaneous pick-up setting shall be adjusted to the nearest setting lower than (50/1,2) kA.

For 4-pole circuit-breakers with a protected neutral pole, the test voltage for that pole shall be phase-to-phase voltage divided by √3. This test is applicable only where the construction of the protected neutral pole differs from that of the phase poles.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

O – *t* – CO

and shall be made on each pole separately, in turn.

H.3 Verification of dielectric withstand

Following the test according to H.2, the dielectric withstand shall be verified according to 8.3.5.4.

H.4 Verification of overload releases

Following the test according to H.3, the operation of the overload releases shall be verified according to 8.3.5.5.

H.5 Marking

Circuit-breakers for which all values of rated voltage have been tested according to this annex or are covered by such testing require no additional marking.

Circuit-breakers for which all values of rated voltage have not been tested according to this annex or are not covered by such testing shall be identified by the symbol  which shall be marked on the circuit-breaker immediately following these values of rated voltage, e.g., 690 V  in accordance with 5.2, item b).

Where a circuit-breaker has not been tested according to this annex, a single marking by the symbol  may be used provided it is so placed that it unmistakably covers all voltage ratings.

Annex J
(normative)

Electromagnetic compatibility (EMC) – Requirements and test methods for circuit-breakers

J.1 General

Two sets of environmental conditions are considered and are referred to as follows:

– environment A;
– environment B.

Environment A: relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources.

NOTE 1 Environment A corresponds to equipment class A in CISPR 11 and CISPR 22.

NOTE 2 Environment A equipment can cause electromagnetic interferences when installed in environment B.

Environment B: relates to low-voltage public networks such as domestic, commercial and light industrial locations/installations. Highly disturbing sources such as arc welders are not covered by this environment.

NOTE 3 Environment B corresponds to equipment class B in CISPR 11 and CISPR 22.

NOTE 4 Environment B equipment will not cause electromagnetic interferences when installed in environment A.

For the purposes of this annex the term "EUT" means “equipment under test”.

NOTE 5 The EMC requirements for CBI (Annex L) and ICB (Annex O) are deemed to be covered by the relevant tests on the equivalent circuit-breaker (see L.2.1 and O.2.1).

The tests of J.2 and J.3 are applicable to devices incorporating electronic circuits except where specified otherwise in this standard.

The test methods in J.2 and J.3 are supplemented by specific procedures in the relevant parts of this standard to verify the performance based on the acceptance criteria.

Supplementary requirements and test details are given in the relevant parts of this standard, i.e., Annex B for circuit-breakers incorporating residual current protection (CBR), Annex F for circuit-breakers with electronic overcurrent protection, Annex M for modular residual current devices (MRCD) and Annex N for circuit-breaker auxiliaries.

A new device may be used for each test or one device may be used for several tests, at the manufacturer’s discretion. Devices rated 50 Hz/60 Hz shall be tested at either one of the rated frequencies.

In the case of a range of devices with identical electronic controls (including dimensions, components, printed circuit board assemblies and enclosure, if any) and the same design of current sensors, it is sufficient to test only one device in the range.

The tests shall be performed with a specific mounting; free air or within an enclosure, as specified in J.2 and J.3.

J.2 Immunity

J.2.1 General

Subclause 7.3.2.2 of IEC 60947-1:2007/AMD1:2010 applies with the following additions.

Immunity tests shall be performed according to Table J.1.

The reference data for the additional test specifications is given in Table J.2.

For the purposes of this clause (J.2), the term "power port" covers the main circuit, auxiliary power supply port(s) and any auxiliary connected to the main circuit.

For the immunity tests, the following performance criteria shall be defined:

Performance criterion A: during the test, the resistance against unwanted operation (step 1) and the functional characteristics (step 2) are verified. Any monitoring function shall correctly indicate the status.

Performance criterion B: during the test, the resistance against unwanted operation is verified. Monitoring functions may indicate a false status. After the test the functional characteristics are verified.

Details of the verification of performance are given in the respective annex (Annex B, Annex F, Annex M or Annex N).

For all immunity tests, the EUT shall be tested as floor-standing equipment (see IEC 61000-4 series).

Table J.1 – EMC – Immunity tests

Description	Reference standard	Test level [a]	Performance criterion	Mounting
Electrostatic discharges	IEC 61000-4-2	8 kV contact 8 kV air	B	Enclosure Figure J.1
Radiated radio-frequency electromagnetic fields	IEC 61000-4-3	10 V/m (up to 2 GHz) 3 V/m (from 2 GHz to 2,7 GHz)	A	Free air [c]
Electrical fast transients/bursts	IEC 61000-4-4	Power port: $U_e \geq 100$ V, a.c. or d.c.: 4 kV $U_e < 100$ V, a.c. or d.c.: 2 kV [f] Signal port: 2 kV [g]	B	Enclosure Figure J.1
Surges	IEC 61000-4-5	Power port, $U_e \geq 100$ V a.c.: 4 kV line-to-earth 2 kV line-to-line (Annex F and Annex N) 4 kV line-to-line (Annex B and Annex M) [e] Power port, $U_e < 100$ V a.c.: 2 kV line-to-earth 1 kV line-to-line Power port, d.c. [f]: 0,5 kV line-to-earth 0,5 kV line-to-line Signal port [h]: 2 kV line-to-earth 1 kV line-to-line	B	Enclosure Figure J.1
Conducted disturbances induced by radio-frequency fields	IEC 61000-4-6	Power port: 10 V Signal port: 10 V [g]	A	Free air [c]
Power frequency magnetic fields	Not applicable	Not applicable	Not applicable	Not applicable
Voltage dips and interruptions	IEC 61000-4-11 [d]	[d]	[d]	Free air
Harmonics	IEC 61000-4-13 [b]	[b]	[b]	Free air
Current dips	[b]	[b]	[b]	Free air

[a] The immunity levels specified are generally higher than the requirements of IEC 60947-1 in order to provide greater security for the circuit protection functions of the device.

[b] A specific test procedure is defined in the case of electronic overcurrent devices in Annex F, in the absence of an appropriate basic standard.

[c] Unless the circuit-breaker is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report. The enclosure shall be connected to the ground plane in accordance with the manufacturer's instructions.

[d] A specific test procedure and a performance criterion are defined in Annex B in the case of CBRs functionally dependent on line voltage and in Annex M in the case of MRCDs functionally dependent on a voltage source, in the absence of an appropriate basic standard. These tests are not applicable to circuit-breakers with electronic overcurrent protection as described in Annex F (see F.1), but are replaced by tests for current dips and interruptions (see F.4.7).

[e] The immunity level is higher for residual current devices because they perform safety functions.

[f] Not applicable to input ports intended for connection to a battery or a rechargeable battery which shall be removed or disconnected from the apparatus for recharging. Apparatus with a d.c. power input port intended for use with an a.c.-d.c. power adapter shall be tested on the a.c. power input of the a.c.-d.c. power adapter specified by the manufacturer or, where none is so specified, using a typical a.c.-d.c. power adapter. The test is not applicable to d.c. power input ports intended to be permanently connected to cables less than 3 m in length.

[g] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.

[h] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 10 m. When shielded cables are used, this test is applied only to the shield.

The appropriate test set-up and circuit diagram for each immunity test are as shown in Table J.2.

Table J.2 – Reference data for immunity test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Electrostatic discharges	CBR	J.2.2, B.8.12.1.2	Figure J.1, Figure J.3	Figure B.1
	CB	J.2.2, F.4.2	Figure J.3, Figure F.16	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.2, M.8.16.1.2	Figure J.1, Figure J.3	Figure M.3
	Other devices [a]	J.2.2, N.2.2	[b]	[b]
Radiated radio-frequency electromagnetic fields	CBR	J.2.3, B.8.12.1.3	Figure J.4	Figure B.1
	CB	J.2.3, F.4.3	Figure F.16, Figure F.17	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.3, M.8.16.1.3	Figure J.4, Figure M.20	Figure M.3
	Other devices [a]	J.2.3, N.2.3	[b]	[b]
Electrical fast transients/bursts	CBR	J.2.4, B.8.12.1.4	Figure J.5, Figure J.6	Figure B.1
	CB	J.2.4, F.4.4	Figure F.16, Figure F.18, Figure F.19	Figure F.6, Figure F.7 or Figure F.8
	MRCD	J.2.4, M.8.16.1.4	Figure J.5, Figure J.6, Figure M.21	Figure M.3
	Other devices [a]	J.2.4, N.2.4	[b]	[b]
Surges	CBR	J.2.5, B.8.12.1.5	[b]	Figure B.1
	CB	J.2.5, F.4.5	Line-to-earth: Figure F.16 Line-to-line: Figure F.16	Line-to-earth: Figure F.9, Figure F.10 or Figure F.11 Line-to-line: Figure F.12, Figure F.13 or Figure F.14
	MRCD	J.2.5, M.8.16.1.5	[b]	Figure M.3
	Other devices [a]	J.2.5, N.2.5	[b]	[b]
Conducted disturbances induced by radio-frequency fields	CBR	J.2.6, B.8.12.1.6	[b]	Figure B.1
	CB	J.2.6, F.4.6	Figure F.16, Figure F.20, Figure F.21, Figure F.22, Figure F.23	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.6, M.8.16.1.6	Figure M.22	Figure M.3
	Other devices [a]	J.2.6, N.2.6	[b]	[b]

[a] Devices in the scope of Annex N.

[b] No additional figure necessary.

J.2.2 Electrostatic discharges

The EUT shall be tested in a specific enclosure (see Table J.1). The test set-up and additional test requirements are given in Table J.2. Direct and indirect discharges shall be applied in accordance with IEC 61000-4-2.

The direct discharge tests shall be performed only on parts of the EUT normally accessible to the user, such as setting means, keyboards, displays, pushbuttons etc. The application points shall be stated in the test report.

Direct discharges are made 10 times for each polarity, at intervals of ≥ 1 s.

Indirect discharges shall be applied at selected points on the surface of the enclosure; the test at such points is made 10 times, for each polarity, at intervals of ≥ 1 s.

J.2.3 Radiated RF electromagnetic fields

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The EUT shall be tested on the front face only.

To enable repeatability, the actual test set-up shall be detailed in the test report.

Tests shall be performed with both horizontal and vertical antenna polarization.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the ranges of 80 MHz to 1 000 MHz, 1 400 MHz to 2 000 MHz, and 2 110 MHz to 2 700 MHz, in accordance with Clause 8 of IEC 61000-4-3:2006. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 80 MHz; 100 MHz; 120 MHz; 180 MHz; 240 MHz; 320 MHz; 480 MHz; 640 MHz; 960 MHz; 1 400 MHz; 1 920 MHz; 2 150 MHz and 2 450 MHz, the operation being verified after the field at each frequency has stabilized.

J.2.4 Electrical fast transients/bursts (EFT/B)

The test shall be performed with the EUT in a specific enclosure (see Table J.1).

The test set-up is given in Table J.2.

For power and auxiliary supply ports, the coupling-decoupling network shall be used, except for Annex F where the direct injection method shall be used (see Figure F.18).

For signal ports the coupling-decoupling network or the clamp injection method shall be used, as applicable.

The disturbance shall be applied for 1 min, except where otherwise specified.

J.2.5 Surges

The test shall be carried out with the EUT in a specific enclosure (see Table J.1). The test levels and test set-up are given in Table J.1 and Table J.2, depending upon the EUT.

Pulses with both positive and negative polarity shall be applied, the phase angles being 0° and 90°.

A series of five pulses is applied for each polarity and each phase angle (total number of pulses: 20), the interval between two pulses being approximately 1 min. A shorter interval may be used by agreement with the manufacturer.

J.2.6 Conducted disturbances induced by RF fields (common mode)

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The disturbances shall be injected, on power lines, by means of a coupling-decoupling network M1, M2 or M3 as applicable.

On signal lines, the disturbances shall be injected by means of a coupling-decoupling network. If not feasible, an E.M. clamp may be used.

The particular test set-up shall be detailed in the test report.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the range of 150 kHz to 80 MHz in accordance with Clause 8 of IEC 61000-4-6:2013. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 0,150 MHZ; 0,300 MHZ; 0,450 MHZ; 0,600 MHZ; 0,900 MHZ; 1,20 MHZ; 1,80 MHZ; 2,40 MHZ; 3,60 MHZ; 4,80 MHZ; 7,20 MHZ; 9,60 MHZ; 12,0 MHZ; 19,2 MHZ; 27,0 MHZ; 49,4 MHZ; 72,0 MHZ and 80,0 MHz, the operation being verified after the level of the disturbing voltage at each frequency has stabilized.

J.3 Emission

J.3.1 General

Subclause 7.3.3.2 of IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Emission tests are performed according to Table J.3.

The reference data for the application of the figures for emission tests is given in Table J.4.

Table J.3 – EMC – Emission tests

Description	Reference standard	Limits	Mounting
Harmonics	IEC 61000-3-2	[c]	[c]
Voltage fluctuations	IEC 61000-3-3	[c]	[c]
Conducted RF disturbances 150 kHz to 30 MHz[e]	CISPR 11 / CISPR 22	Class A or class B, group 1[b, e]	Free air[d]
Radiated RF disturbances 30 MHz to 1 000 MHz[a]	CISPR 11 / CISPR 22	Class A or class B, group 1[b]	Free air[d]

[a] Applicable only for EUT containing processing devices (e.g. microprocessors) or switched-mode power supplies operating at frequencies greater than 9 kHz.

[b] Equipment class A in CISPR 11 and CISPR 22 corresponds to environment A in IEC 60947-1. Environment A equipment can cause electromagnetic interferences when installed in environment B. The manufacturer of environment A equipment shall declare the risk of electromagnetic interference in the product documentation.

Equipment class B in CISPR 11 and CISPR 22 corresponds to environment B in IEC 60947-1. Environment B equipment will not cause electromagnetic interference when installed in environment A.

[c] No test required since the electronic control circuits operate at very low power and hence create negligible disturbances.

[d] Unless the EUT is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report.

[e] Circuit-breakers covered by Annex F are independent of line voltage or of any auxiliary supply. The electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

Table J.4 – Reference data for emission test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Conducted RF disturbances	CBR	J.3.2, B.8.12.2.1	[a]	[a]
	CB	J.3.2, F.5.3	No test	No test
	MRCD	J.3.2, B.8.12.2.1	[a]	[a]
	Other devices	J.3.2, N.3.2	[a]	[a]
Radiated RF disturbances	CBR	J.3.3, B.8.12.2.1	Figure J.2	[a]
	CB	J.3.3, F.5.4	Figure J.2	Figure F.2, Figure F.3 Figure F.4
	MRCD	J.3.3, B.8.12.2.1	Figure J.2	[a]
	Other devices	J.3.3, N.3.3	[a]	[a]

[a] No additional figure necessary.

J.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

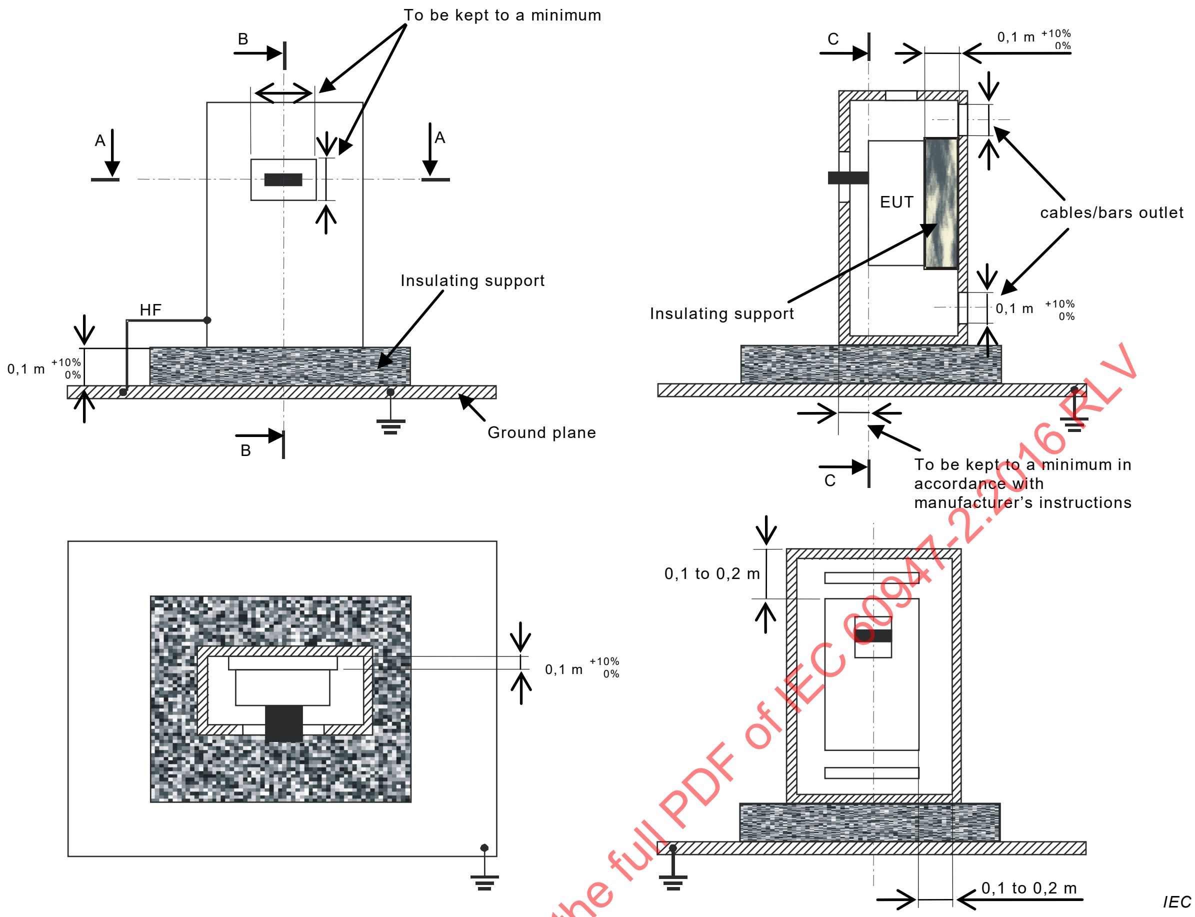
The test method and test arrangement shall be as in CISPR 11 or CISPR 22, as relevant.

The particular test set-up, including the type of cable, shall be detailed in the test report.

J.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

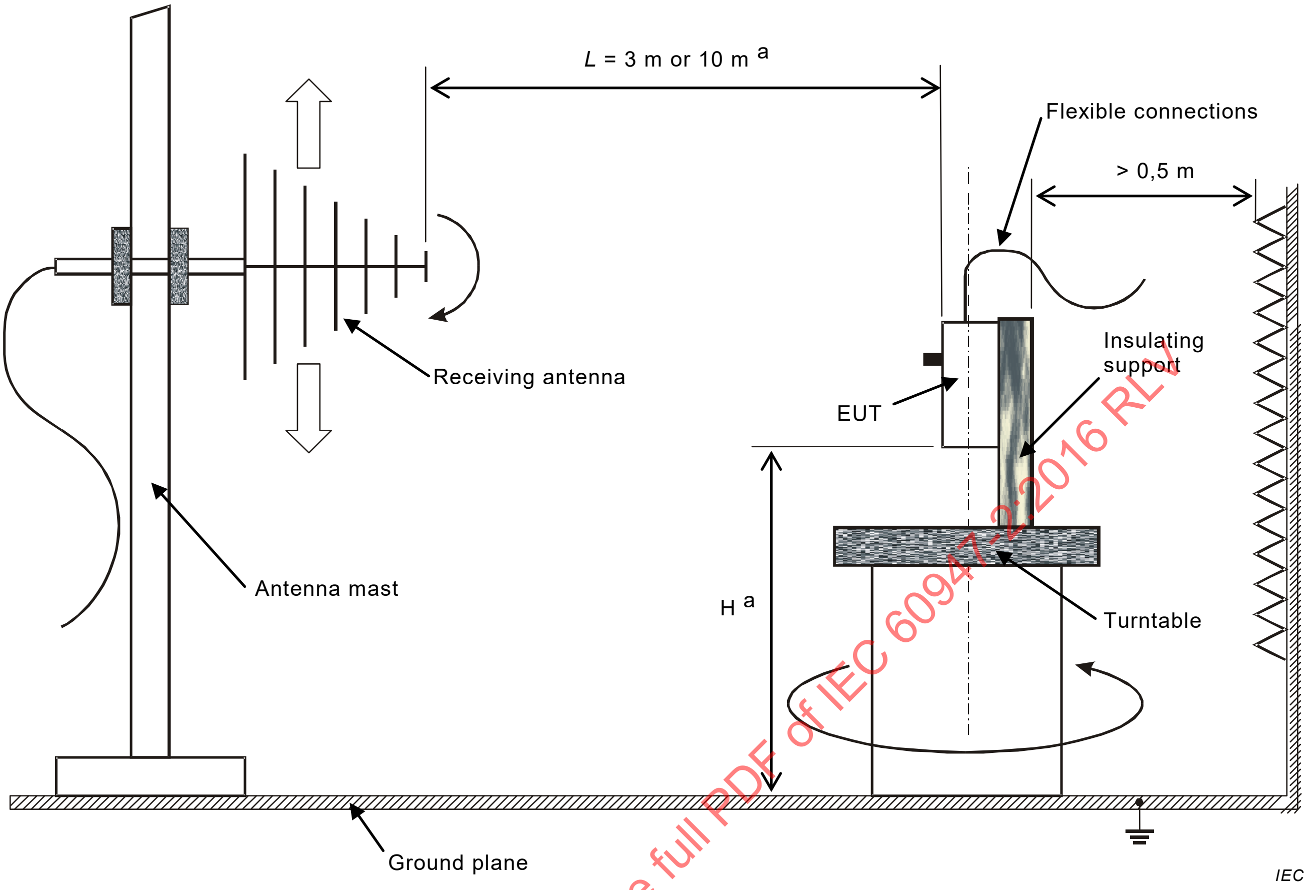
The test set-up is shown in Figure J.2.

The particular test set-up including supply bars, transformer, etc. shall be detailed in the test report.



NOTE In the case of a withdrawable circuit-breaker, the EUT includes the draw-out cradle.

Figure J.1 – EUT mounted in a metallic enclosure



[a] See CISPR 11/CISPR 22.

Figure J.2 – Test set up for the measurement of radiated RF emissions

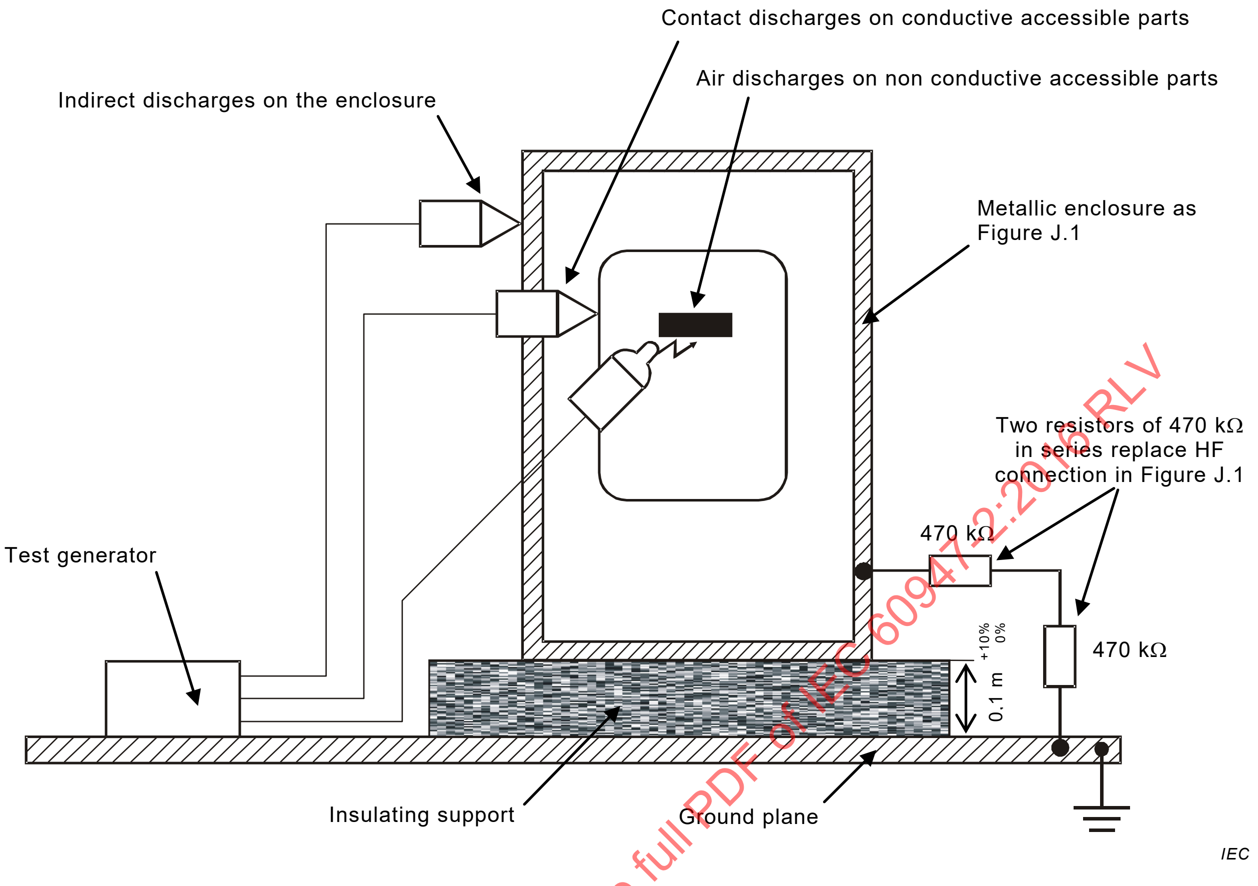
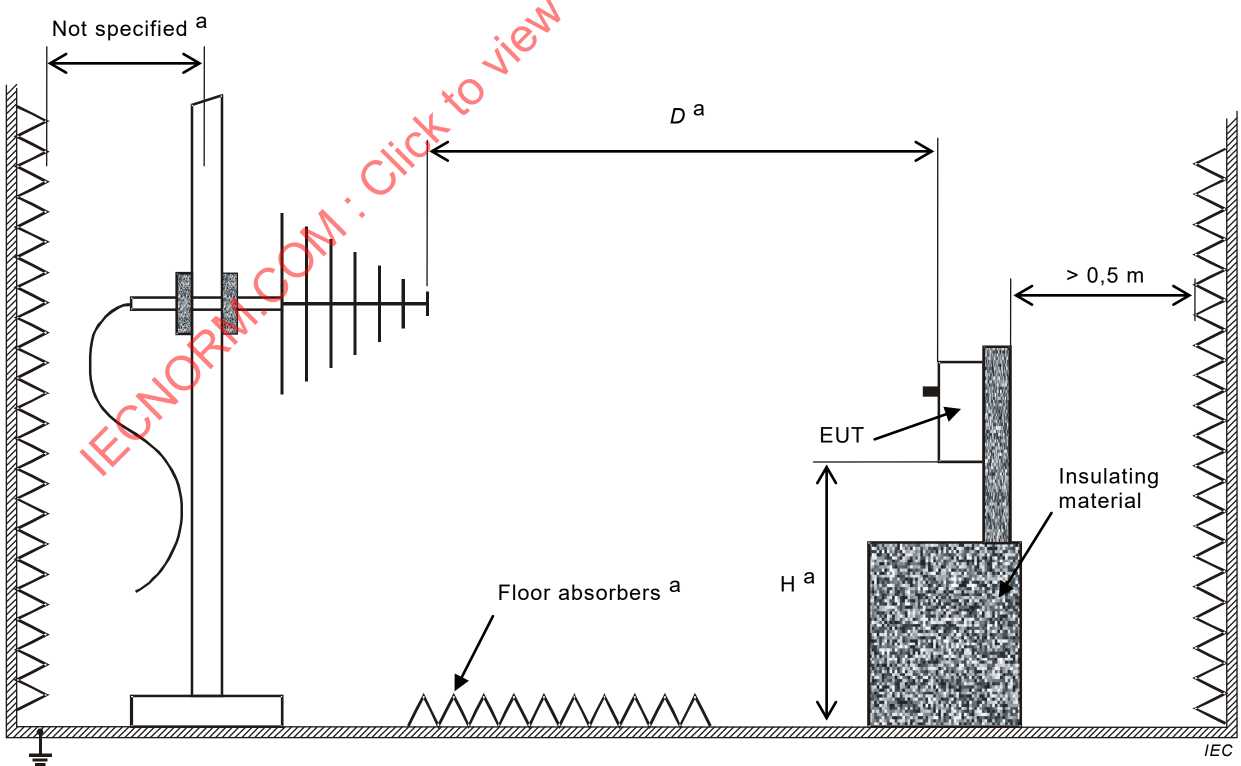
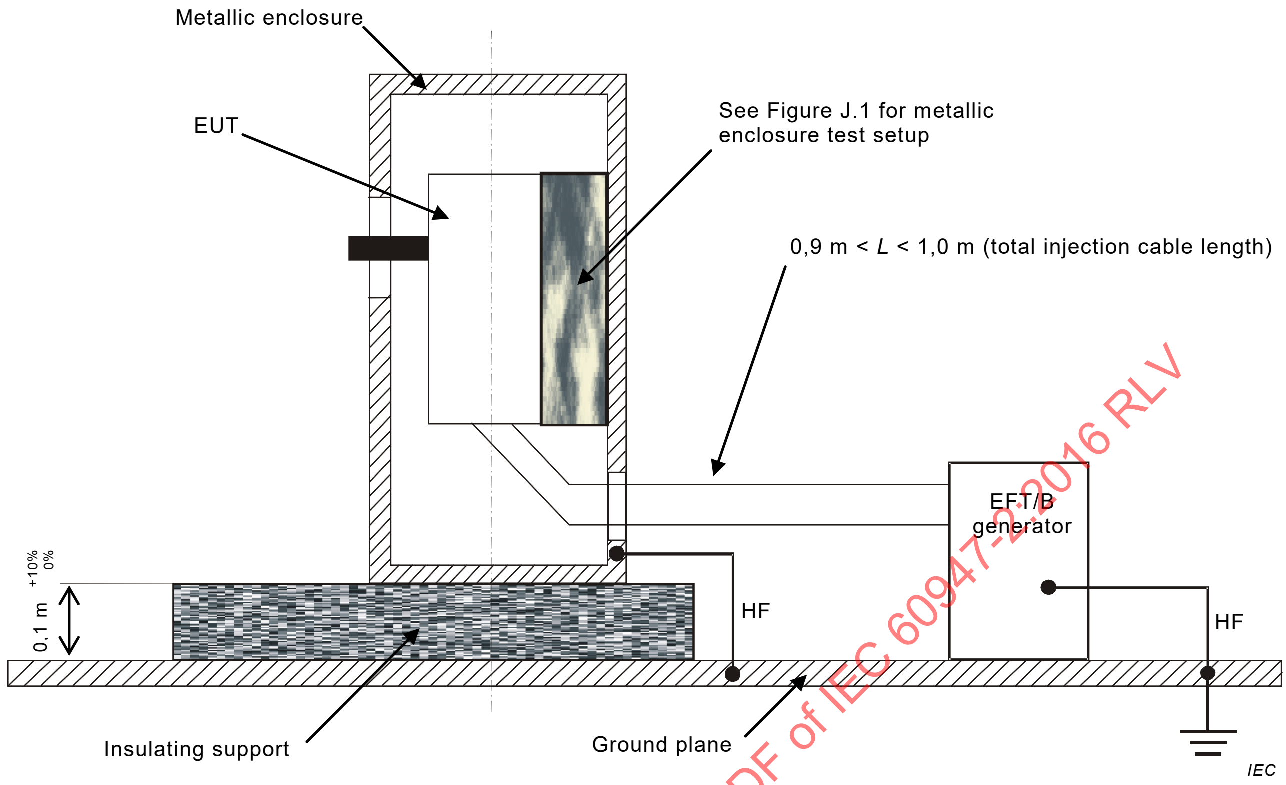


Figure J.3 – Test set up for the verification of immunity to electrostatic discharges



[a] See IEC 61000-4-3.

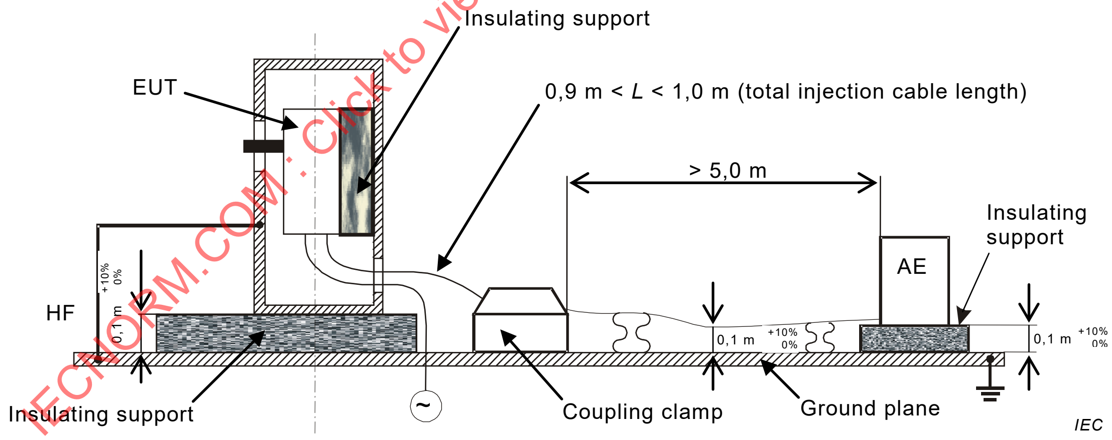
Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic fields



Key

HF high frequency connection

Figure J.5 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines



Key

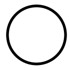
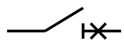
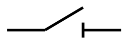
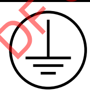
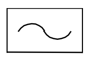
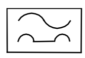
AE auxiliary equipment

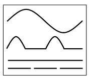
HF high frequency connection

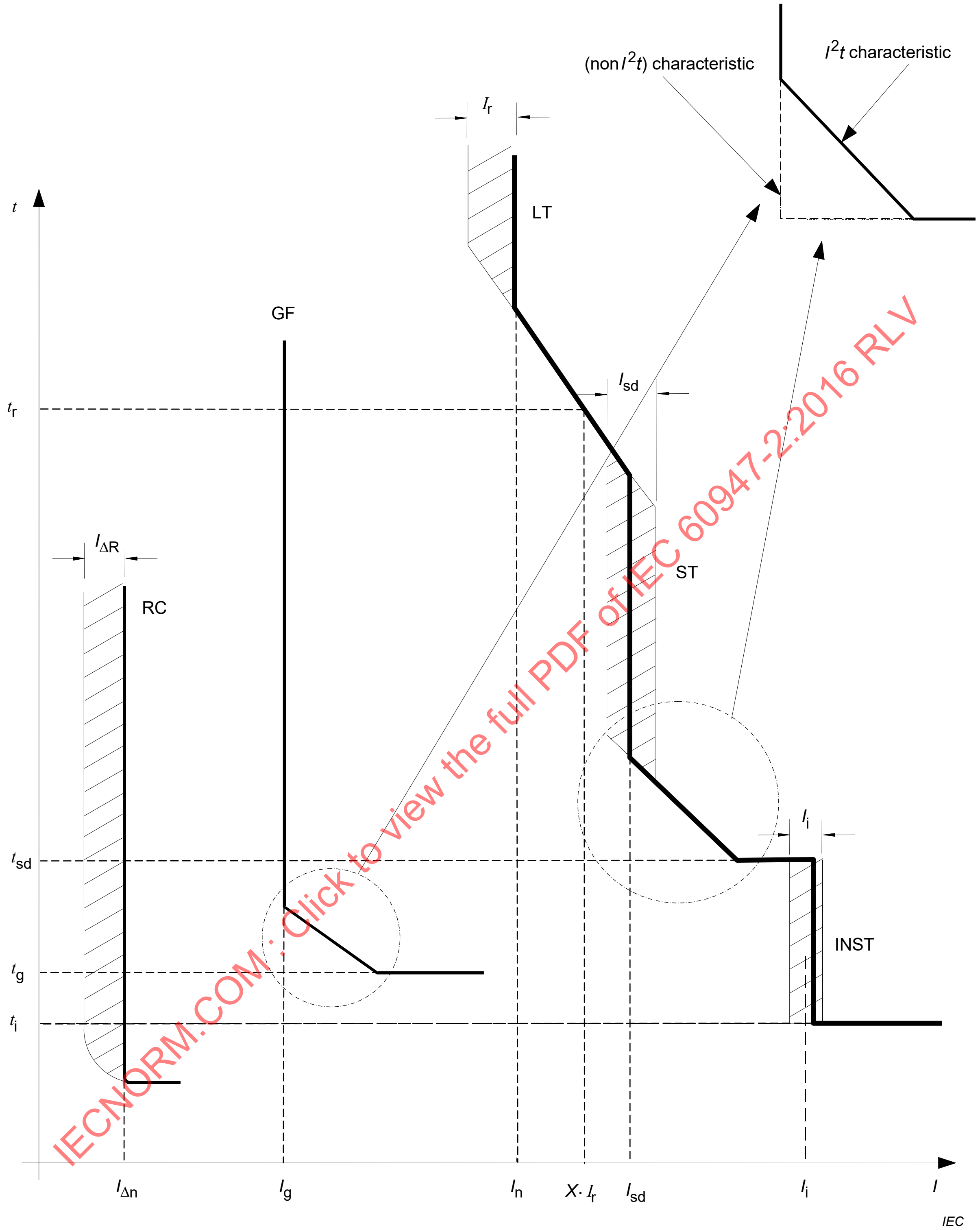
Figure J.6 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

Annex K
(informative)

Glossary of symbols and graphical representation of characteristics

Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Subclause of this standard
Circuit-breaker, closed position		IEC 60417-5007 (2002-10)	5.2
Circuit-breaker, open position		IEC 60417-5008 (2002-10)	5.2
Isolation suitability – circuit-breaker and ICB		IEC 60617-S00287 combined with IEC 60617-S00220 (2007-01)	5.2 O.4
Isolation suitability – CBI		IEC 60617-S00288 (2007-01)	L.5
Neutral pole terminal	N		5.2
Protective earth terminal		IEC 60417-5019 (2006-08)	5.2
Rated control circuit voltage	U_c		4.7.2
Rated voltage of the voltage source of an MRCD	U_s		M.4.1.2.1
Rated voltage of the monitored circuit for an MRCD	U_n		Annex M
Rated current	I_n		4.3.3.3
Rated impulse withstand voltage	U_{imp}		4.3.2.3
Rated insulation voltage	U_i		4.3.2.2
Rated operational voltage	U_e		4.3.2.1
Rated service short-circuit breaking capacity	I_{cs}		4.3.6.2.3
Rated short-circuit making capacity	I_{cm}		4.3.6.1
Rated short time withstand current	I_{cw}		4.3.6.4
Rated residual short time withstand current of an MRCD	$I_{\Delta w}$		M.4.3.5
Rated conditional short-circuit current	I_{cc}		Annex L Annex M
Rated conditional residual short-circuit current of an MRCD	$I_{\Delta c}$		M.4.3.2
Rated ultimate short-circuit breaking capacity	I_{cu}		4.3.6.2.2
Selectivity limit current	I_s		2.17.4
Take-over current	I_B		2.17.5
Conventional enclosed thermal current	I_{the}		4.3.3.2
Conventional free air thermal current	I_{th}		4.3.3.1
CBRs and MRCDs of type AC		IEC 60417-6148 (2012-01)	B.4.4.1 M.4.2.2.1
CBRs and MRCDs of type A		IEC 60417-6149 (2012-01)	B.4.4.2 M.4.2.2.2

Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Subclause of this standard
MRCDs of type B			M.4.2.2.3
Test device CBR or MRCD	T		B.7.2.6 M.7.2.6
Current setting of adjustable overload release	I_r		4.7.3
Corresponding tripping time	t_r		Figure K.1
Ground fault current setting	I_g		Figure K.1
Corresponding tripping time	t_g		Figure K.1
Individual pole short-circuit breaking capacity (phase/earthed systems)	I_{su}		Annex C
Individual pole short-circuit test current (IT systems)	I_{IT}		Annex H
Rated instantaneous short-circuit current setting	I_i		2.20 Figure K.1 Annex L Annex O
Maximum corresponding tripping time	t_i		Figure K.1
Not suitable for use in IT systems			Annex H
Rated residual short-circuit making and breaking capacity	$I_{\Delta m}$		Annex B Annex M
Rated residual non-operating current	$I_{\Delta no}$		Annex B Annex M
Rated residual operating current	$I_{\Delta n}$		Annex B Annex M
Residual operating current	$I_{\Delta R}$		Figure K.1
Short time pick-up current	I_{sd}		Figure K.1
Corresponding tripping time	t_{sd}		Figure K.1
Suitability for phase earthed systems	C		4.3.2.1
Limiting non-actuating time at 2 $I_{\Delta n}$	Δt		Annex B
Time delay CBR or MRCD with limiting non-actuating time of 0,06 s	S		B.5 a) M.3.4
CBRs for use with 3-phase supply only			B.8.9.3
Rated automatic re-closing operating residual current	$I_{\Delta ar}$		R.2.2



RC residual current

GF ground fault

LT long time

ST short time

INST instantaneous

Figure K.1 – Relationship between symbols and tripping characteristics

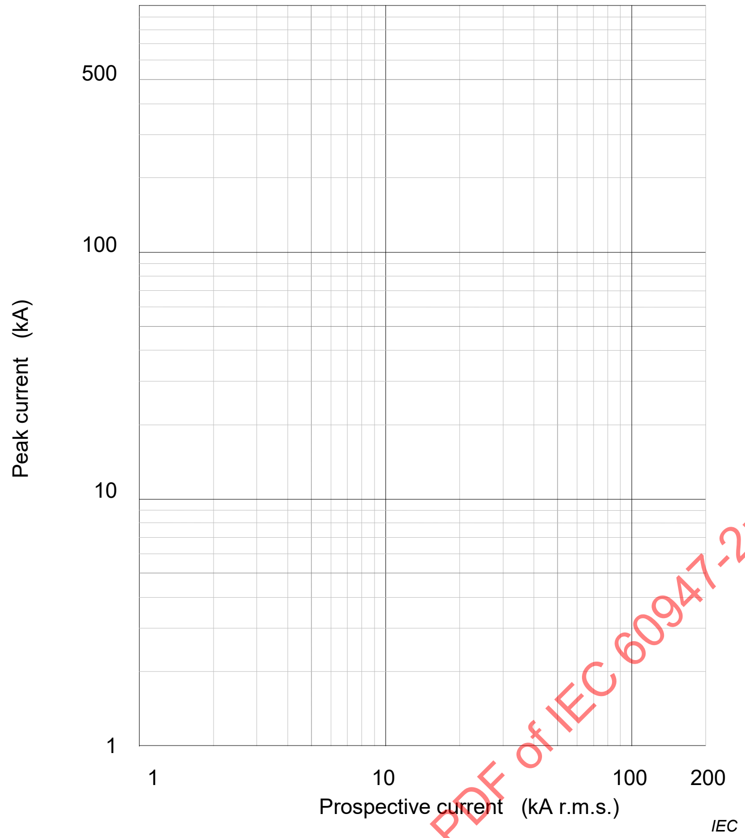


Figure K.2 – Template for characteristics of cut-off current versus prospective current from 1 kA to 200 kA

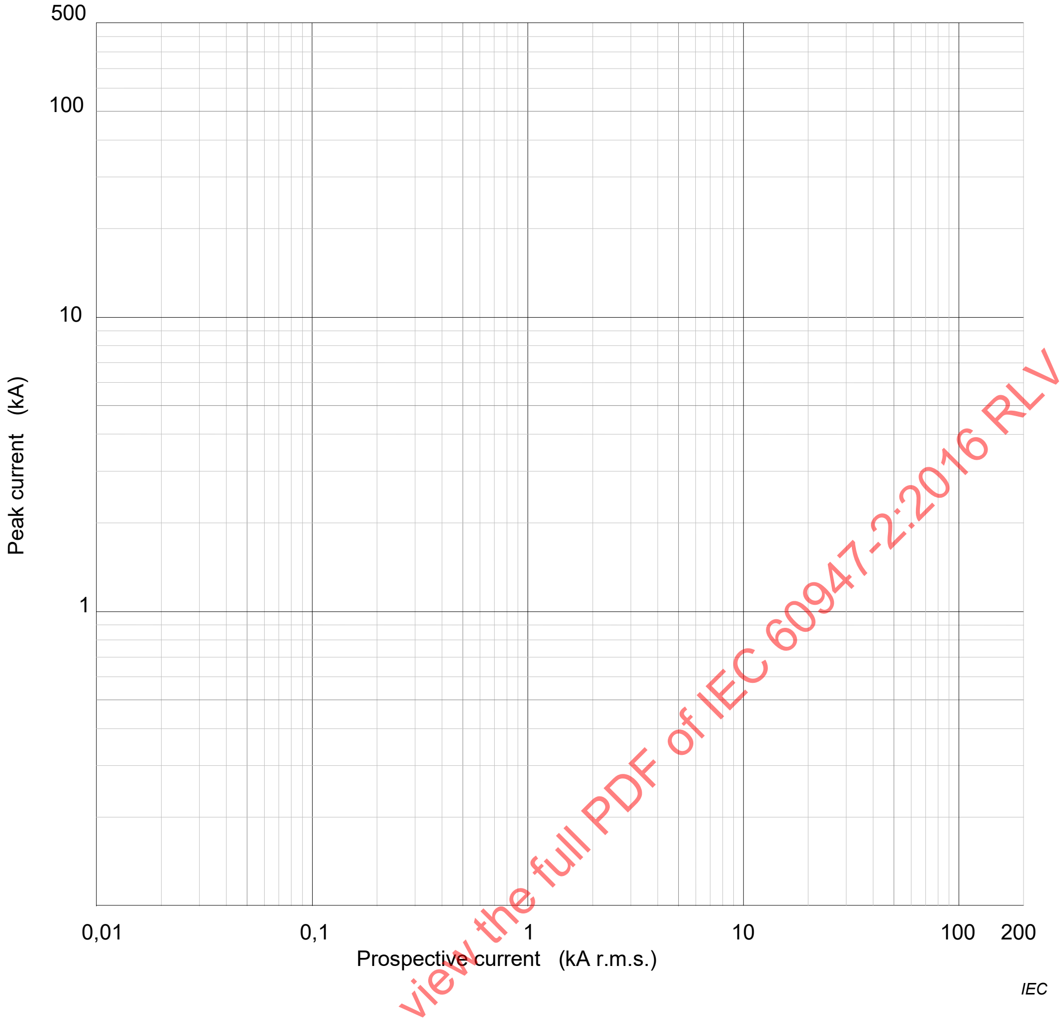


Figure K.3 – Template for characteristics of cut-off current versus prospective current from 0,01 kA to 200 kA

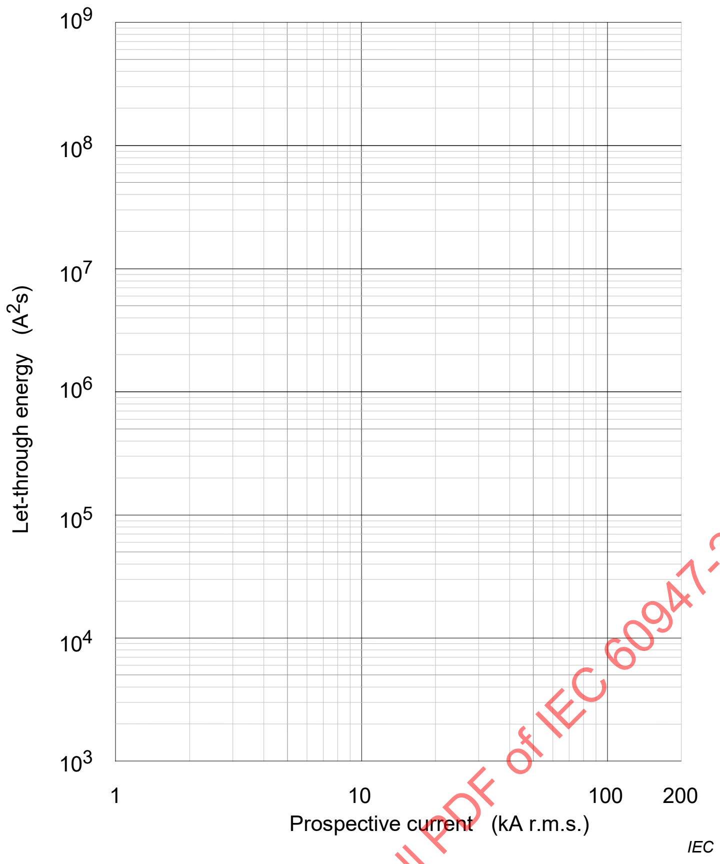


Figure K.4 – Template for characteristics of let-through energy versus prospective current from 1 kA to 200 kA

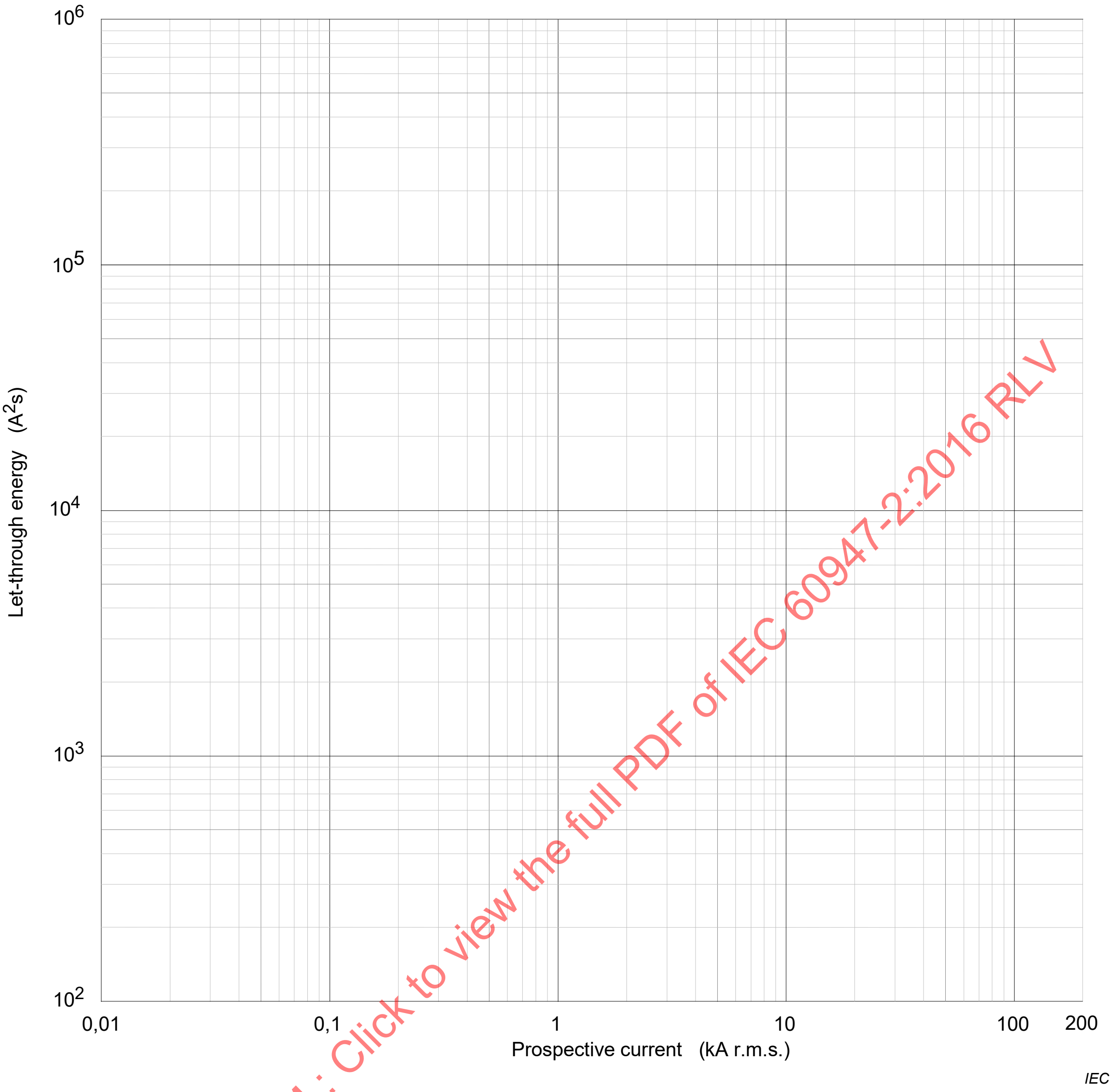
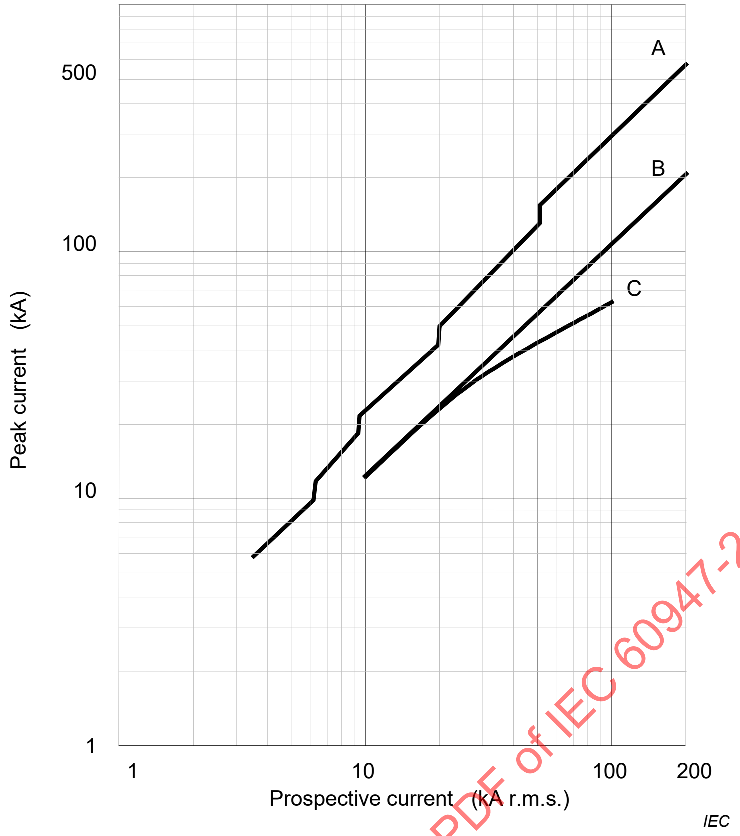


Figure K.5 – Template for characteristics of let-through energy versus prospective current from 0,01 kA to 200 kA



A Prospective asymmetric peak current under the test conditions of this standard

B Prospective symmetrical peak current

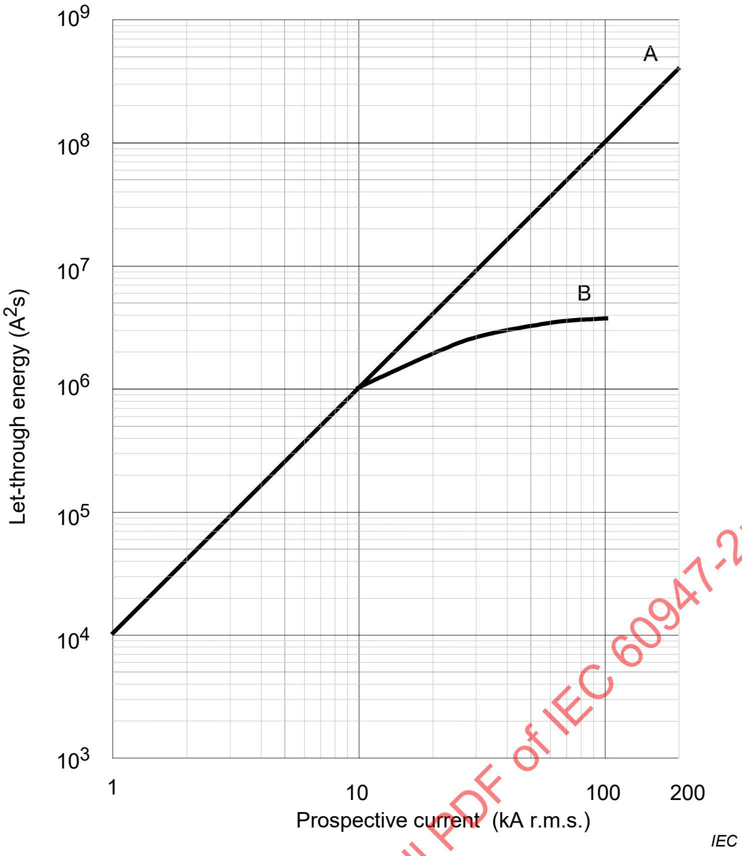
C Typical cut-off current characteristic

The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of cut-off current the effect of current limiting is shown by comparison with the current that would be let through (prospective current) if the circuit-breaker were not present. The comparison is made with the asymmetric (inrush) peak current or the symmetrical peak current (see 2.3).

The typical curve does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.6 – Example of the use of template to Figure K.2



A Let-through energy of one half cycle of prospective current at 50 Hz

B Typical let-through energy characteristic of a 250 A MCCB at 400 V 50 Hz

The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of let-through energy the effect of current limiting is shown by comparison with the energy that would be let through in one half-cycle of the symmetrical prospective current if the circuit-breaker were not present (see 2.3).

The typical curve for the 250 A MCCB does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.7 – Example of the use of template to Figure K.4

Annex L
(normative)

Circuit-breakers not fulfilling the requirements for overcurrent protection

L.1 General

This annex covers circuit-breakers which do not fulfil the requirements for overcurrent protection specified in the main part of this standard, hereinafter referred as CBIs. They are capable of being tripped by an auxiliary device, e.g. shunt or undervoltage release. They do not provide circuit protection but may trip under short-circuit conditions for self-protection. They have a conditional short-circuit rating and may be used for isolation. They may incorporate accessories such as auxiliary and alarm switches for control purposes, and/or remote operators.

A CBI forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (L.2.1) by omitting the overcurrent releases (class Y) or the overload releases only (class X), see L.3.

L.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

L.2.1
equivalent circuit-breaker
circuit-breaker from which the CBI has been derived, which has been tested according to this standard and which has the same frame size as the CBI

L.2.2
overcurrent protective device
OCPD
device intended to protect a CBI against overcurrents by interrupting them, and incorporating overload protection no less effective than that of the equivalent circuit-breaker and an I_{cu} (for a circuit-breaker) or a breaking capacity (for a fuse) equal to or higher than that of the equivalent circuit-breaker

Note 1 to entry: The OCPD may be the equivalent circuit-breaker.

L.3 Classification

CBIs are classified as follows:

- class X: with integral non-adjustable instantaneous short-circuit releases for self-protection;
- class Y: without integral short-circuit releases.

L.4 Rated values

L.4.1 Rated current (I_n)

The rated current of a CBI shall not exceed the rated current of the equivalent circuit-breaker.

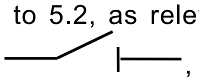
NOTE The rated current of a CBI can be correlated to the rated current corresponding to utilization category AC-22 (see Annex A of IEC 60947-1:2007/AMD2:2014).

L.4.2 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

A CBI may have a value of I_{cc} equal to or higher than that of the I_{cu} of the equivalent circuit-breaker.

L.5 Product information

A CBI shall be marked according to 5.2, as relevant, except that the symbol of suitability for isolation, if applicable, shall be , replacing the symbol shown in the second dashed item of 5.2 a).

In addition it shall be marked as follows:

– for 5.2, item a): with the symbol according to the classification:

CBI-X I_i = …	or	CBI-Y	as applicable.

where I_i is the rated instantaneous short-circuit current setting (see 2.20).

– for 5.2, item c): with the following items:
- rated conditional short-circuit-current (I_{cc});
- the OCPD, if specified.

Manufacturer's instructions should draw attention to the fact that CBIs do not provide overcurrent protection.

L.6 Constructional and performance requirements

A CBI, being derived from the equivalent circuit-breaker (see L.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4.

NOTE A CBI can additionally comply with IEC 60947-3 and be marked accordingly.

L.7 Tests

L.7.1 General

L.7.1.1 CBI of class X

The OCPD is specified.

Case 1:

$I_{cc} = I_{cu}$ of the equivalent circuit-breaker.

No additional tests are required.

NOTE The specified OCPD can be

– the equivalent circuit-breaker (see L.2.1);

– another circuit-breaker (see L.2.2);

– a fuse of conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and of a breaking capacity ≥ I_{cc} of the CBI.

Case 2:

$I_{cc} > I_{cu}$ of the equivalent circuit-breaker.

Tests shall be made according to L.7.2.1 and L.7.2.2, with the specified OCPD.

This applies when

– the specified OCPD is a circuit-breaker of the same frame size as the equivalent circuit-breaker and of $I_{cu} \geq I_{cc}$ of the CBI,

or

– the specified OCPD is a fuse having a conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and a breaking capacity ≥ I_{cc} of the CBI.

L.7.1.2 CBI of class Y

No tests are required, provided that one of the following two conditions are fulfilled:

– condition 1: $I_{cc} \leq I_{cw}$ of the equivalent circuit-breaker;
– condition 2: $I_{cc} \leq$ maximum setting of the rated instantaneous short-circuit current setting of the equivalent circuit-breaker.

If neither of the above conditions are fulfilled, tests are required as follows:

Case 1:

The OCPD is specified by the manufacturer.

Tests shall be made according to L.7.2.1 and L.7.2.2.

Case 2:

The OCPD is not specified.

Tests shall be made according to L.7.2.1 and L.7.2.3.

L.7.2 Rated conditional short-circuit tests

L.7.2.1 General

L.7.2.1.1 Applicability

These tests shall be made when required by L.7.1.1 case 2, or by L.7.1.2 case 1 or case 2, as applicable.

For CBIs having variants with different number of poles, tests shall be carried out on each variant.

L.7.2.1.2 Test conditions

Subclause 8.3.2.6 applies.

The test circuit shall be according to Figure A.4, SCPD being replaced by OCPD. If the OCPD is a circuit-breaker with adjustable overcurrent settings, these shall be set at maximum.

If the OCPD consists of a set of fuses, each test shall be made with a set of new fuses.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the OCPD is a circuit-breaker, the full length of cable (0,75 m) associated with the circuit-breaker may be on the supply side (see Figure A.4).

L.7.2.1.3 Behaviour during tests

Subclause 8.3.2.6.5 applies.

L.7.2.2 OCPD specified

L.7.2.2.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.2.2
Verification of dielectric withstand	L.7.2.2.3

L.7.2.2.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – *t* – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

After each operation, the CBI shall be manually closed and opened three times.

L.7.2.2.3 Verification of dielectric withstand

Following the test of L.7.2.2.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

L.7.2.3 OCPD not specified

L.7.2.3.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.3.2
Verification of dielectric withstand	L.7.2.3.3

L.7.2.3.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – *t* – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

During the test, the current shall be maintained for three cycles and then disconnected at the power supply.

After each operation, the CBI shall be manually closed and opened three times.

L.7.2.3.3 Verification of dielectric withstand

Following the test of L.7.2.3.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

Annex M
(normative)

Modular residual current devices (without integral current breaking device)

M.1 General

M.1.1 Field of application

The provisions of Annex B apply to this Annex M, adapting, amending or supplementing Annex B as necessary to cover its applicability to equipment where the current sensing means and/or the processing device are mounted separately from the current breaking device.

Throughout this annex, “CBR” as used in Annex B (see B.2.3.1), is replaced by “MRCD” (see M.2.2.1).

Wherever relevant, reference is made to the corresponding subclause of Annex B. In other cases, reference is made to the relevant subclause of the main body of this standard, or, where applicable, of IEC 60947-1.

This annex contains also additional definitions and characteristics not contained in Annex B, e.g. “type B” MRCDs (in the context of d.c. residual current), with consequent requirements and tests.

Since the equipment covered by this annex does not include a current breaking device, certain conventional phrases used in Annex B have been adapted accordingly in this annex, e.g. “ON position” is replaced by “ready condition”, meaning “ready to operate”.

M.1.2 Field of application

This annex applies to residual current operated devices which do not incorporate a current breaking device, hereinafter called “Modular Residual Current Device (MRCD)”. They are primarily intended to be used in conjunction with circuit-breakers in accordance with this standard.

NOTE They can also be declared suitable for use in conjunction with other current breaking devices.

They may or may not be functionally dependent on a voltage source.

The object of this annex is to state the specific requirements which shall be complied with by the MRCD.

M.2 Terms and definitions

The terms and definitions of Annex B apply.

The following additional terms and definitions apply to this annex.

M.2.1 Terms and definitions relating to the energization of an MRCD

M.2.1.1
voltage source
source intended to supply the energizing quantity; it may consist of:

– the line voltage

– a voltage other than the line voltage

M.2.2 Terms and definitions relating to the operation and the functions of an MRCD

M.2.2.1
Modular Residual Current Device
MRCD
device or an association of devices comprising a current sensing means and a processing device designed to detect and to evaluate the residual current and to control the opening of the contacts of a current breaking device

M.2.2.2 Operating time

M.2.2.2.1
operating time of an MRCD
time which elapses between the instant when the residual operating current is suddenly applied and the instant when the MRCD output changes status

M.2.2.2.2
total operating time of an MRCD and associated current breaking device (combination time)
time which elapses between the instant when the residual operating current is suddenly applied and the instant of the arc extinction of the associated current breaking device

M.2.2.2.3
limiting non-operating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the MRCD without bringing it actually to operate

M.2.3
conditional residual short-circuit current
prospective residual current that a CBR, protected by a specified short-circuit protective device, can satisfactorily withstand for the total operating time of that device under specified conditions

M.2.4
residual short-time withstand current
residual current that a CBR in the closed position can carry during a specified short time under specified conditions

M.3 Classification

M.3.1 Classification according to the configuration of the primary conductors

M.3.1.1 Terminal type: MRCD with incoming and outgoing terminals and integral primary conductors

M.3.1.2 Through-conductor type

M.3.1.2.1 MRCD with sensing means and processing device combined.

M.3.1.2.2 MRCD with sensing means and processing device separate.

M.3.2 Classification according to the method of operation

M.3.2.1 MRCD without voltage source (see M.2.1.1)

M.3.2.2 MRCD with voltage source

M.3.2.2.1 Operating automatically in case of failure of the voltage source.

M.3.2.2.2 Not operating automatically after failure of the voltage source but able to operate as intended in case of a residual current fault.

M.3.3 Classification according to the possibility of adjusting the residual operating current

Subclause B.3.2 applies.

M.3.4 Classification according to time-delay of the residual current function

Subclause B.3.3 applies.

M.3.5 Classification according to behaviour in presence of a d.c. component

M.3.5.1 MRCD of type AC (see M.4.2.2.1)

M.3.5.2 MRCD of type A (see M.4.2.2.2)

M.3.5.3 MRCD of type B (see M.4.2.2.3)

M.4 Characteristics of MRCDs

M.4.1 General characteristics

M.4.1.1 Characteristics of the monitored circuit

M.4.1.1.1 Rated frequency range

Range of frequency values of the monitored circuit for which the MRCD is designed and for which it operates correctly under specified conditions.

M.4.1.1.2 Rated voltage (U_n)

Value of the voltage assigned by the manufacturer to the MRCD.

M.4.1.1.3 Rated current (I_n)

M.4.1.1.3.1 Terminal type

Subclause 4.3.3.3 applies.

M.4.1.1.3.2 Through-conductor type

Value of current, assigned to the MRCD by the manufacturer and marked in accordance with Table M.1, item g), which the MRCD can monitor in uninterrupted duty under specified conditions (see M.8.6).

M.4.1.1.4 Rated insulation voltage (U_i)

Voltage, assigned by the manufacturer, to which the dielectric tests and the MRCD creepage distances are referred with respect to the monitored circuit.

M.4.1.1.5 Rated impulse withstand voltage (U_{imp})

Peak value of the impulse voltage that the MRCD can withstand without failure and to which the values of the clearances are referred with regard to the monitored circuit.

M.4.1.2 Characteristics of the voltage source of MRCDs

M.4.1.2.1 Rated values of the voltage source of MRCDs (U_s)

Values of the voltage source to which the operating functions of the MRCD are referred.

M.4.1.2.2 Rated values of the frequencies of the voltage source of MRCDs

Values of the frequencies of the voltage source to which the operating functions of the MRCD are referred.

M.4.1.2.3 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

M.4.1.2.4 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

NOTE In the case of a specified power supply the requirement applies to the incoming connections.

M.4.1.3 Characteristics of auxiliary contacts

Subclause 4.6 of IEC 60947-1:2007 applies.

M.4.2 Characteristics of MRCDs concerning their residual current function

M.4.2.1 General

Subclause B.4.2.4 applies, replacing “non-actuating time” by “non-operating time”, and with the following additions.

The maximum values of the MRCD operating time shall be stated by the manufacturer for residual current values equal to $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ (or 0,25 A for $I_{\Delta n} \leq 30$ mA), 10 $I_{\Delta n}$ (or 0,5 A for $I_{\Delta n} \leq 30$ mA).

The maximum combination time shall comply with Table B.1 for a non-time-delay type MRCD and with Table B.2 for a time-delay type MRCD having a limiting non-operating time of 0,06 s.

MRCDs having $I_{\Delta n} \leq 30$ mA shall be of the non-time-delay type. They shall be used only with a specified current breaking device.

M.4.2.2 Operating characteristic in case of residual current with d.c. component

M.4.2.2.1 Type AC MRCD

Subclause B.4.4.1 applies.

M.4.2.2.2 Type A MRCD

Subclause B.4.4.2 applies.

M.4.2.2.3 Type B MRCD

MRCD for which operation is ensured:

- for residual sinusoidal alternating currents,
- for residual pulsating direct currents,
- for residual pulsating direct currents superimposed by a smooth direct current of 6 mA,
- for residual currents which may result from rectifying circuits, i.e.:
  - single-phase connection with capacitive load causing smooth direct current,
  - two-pulse bridge connection line-line,
  - three-pulse star connection or six-pulse bridge connection,

  with or without phase angle control, independent of polarity, whether suddenly applied or slowly rising.

M.4.3 Behaviour under short-circuit conditions

M.4.3.1 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.2 Rated conditional residual short-circuit current ($I_{\Delta c}$)

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.3 Rated short-time withstand current (I_{cw})

Subclause 4.3.6.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.4 Peak withstand current

Subclause 2.5.28 of IEC 60947-1:2007 applies to the primary circuit of the MRCD.

M.4.3.5 Rated residual short-time withstand current ($I_{\Delta w}$)

The rated residual short-time withstand current of an equipment is the value of residual short-time withstand current, assigned to the equipment by the manufacturer, that the equipment can carry without damage, under the test conditions specified in this standard.

M.4.4 Preferred and limiting values

M.4.4.1 Preferred values of the rated residual operating current ($I_{\Delta n}$)

Subclause B.4.2.1 applies.

M.4.4.2 Minimum value of the rated residual non-operating current ($I_{\Delta no}$)

Subclause B.4.2.3 applies.

M.4.4.3 Limiting value of the non-operating overcurrent in the case of a single-phase load in a multiphase circuit

Subclause B.4.2.4 applies.

M.4.4.4 Preferred values of rated voltage of the voltage source of MRCDs

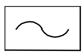
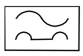
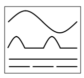
Subclause 4.5.1 applies.

M.5 Product information

The MRCD, processing device or sensing means, as applicable, shall be provided with the information as given in Table M.1. Any marking shall be durable. The marking shall be on the MRCD itself or on one or more nameplates. The manufacturer shall state:

– for a separate sensing means, the details of the sensing means including the conditions for connection to the processing device (cable type, length etc.);
– for a through-conductor type MRCD, the dimensions of the conductor aperture(s) and the position of the through-conductors relative to the sensing means;
– for a terminal type MRCD, the maximum cross sectional area of the conductors to be connected;
– for all types, distances to be respected with regard to nearby conductors;
– for all types, the conditions to be observed for the connection between the processing device and the current breaking device;
– for all types, the SCPDs to be associated with the MRCD to achieve the rated conditional (residual or not) short-circuit current;
– for a non-time-delay type, the current breaking devices to be associated with the MRCD to meet the maximum combination times of Table B.1;
– for a time-delay type having a limiting non-operating time of 0,06 s, the current breaking device(s) to be associated with the MRCD to meet the combination times of Table B.2.

Table M.1 – Product information

Information	Symbol	Location (see Note 1)	Single device	Separate devices	
				Sensing means	Process-ing device
a) manufacturer's name or trade mark		Marked	a	a	a
b) type designation or serial number		Marked	a	a	a
c) IEC 60947-2		Marked	a		a
d) rated voltage of the voltage source	U_s	Marked	a		a
e) rated voltage of the monitored circuit	U_n	Marked	a	a	
f) rated frequency of the voltage source		Literature			
g) rated frequency of the monitored circuit		Literature			
h) maximum rated current of the monitored circuit	I_n	Visible	a	a	a (see Note 2)
i) rated residual operating current (value(s) or range, as applicable)	$I_{\Delta n}$	Visible	a		a)
j) rated residual non-operating current if it differs from 0,5 $I_{\Delta n}$	$I_{\Delta no}$	Literature			
k) lowest residual current setting at 6 I_n for MRCDs with separate sensing means		Literature			
l) rated conditional short-circuit current and/or rated short-time withstand current, and rated conditional residual short-circuit current	I_{cc} I_{cw} $I_{\Delta c}$	Literature			
m) U_{imp} of the voltage source	U_{imp}	Literature			
n) U_{imp} of the monitored circuit	U_{imp}	Marked	a	a	
o) IP code, where applicable (see Annex C of IEC 60947-1:2007)	IP--	Literature			
p) position of use and mounting precautions		Literature			
q) output characteristics and/or specified current breaking device(s)		Literature			
r) operating characteristic in case of residual currents in the presence or absence of a d.c. component	Type AC  Type A  Type B 	Visible	a		a
s) limiting non-operating time (value or range) at 2 $I_{\Delta n}$ for time-delay type, as applicable	Δt or S	Visible	a		a
t) test device	T	Visible	a		a
u) wiring diagram		Literature			

a Information/marking applies.

NOTE 1 Visible = marked on the device and visible after installation.
Literature = given in the manufacturer's catalogue or instructions.
Marked = marked on the device but not necessarily visible after installation.

NOTE 2 Only applicable if the residual current is marked as a percentage of I_n.

M.6 Normal service, mounting and transport conditions

Clause 6 applies.

M.7 Design and operating requirements

M.7.1 Design requirements

It shall not be possible to modify the operating characteristic of an MRCD except by means which are specifically provided for setting the rated residual operating current or the definite time-delay.

NOTE MRCDs can be provided with means indicating the status of the outputs.

M.7.2 Operating requirements

M.7.2.1 Operation in case of a residual current

Subclause B.7.2.1 applies.

Compliance shall be checked by the tests of M.8.3.

M.7.2.2 Operation under short-circuit conditions

MRCDs shall have a rated conditional short-circuit current (I_{cc}) or a rated short-time withstand current (I_{cw}), but may have both. They shall also have a rated conditional residual short-circuit current ($I_{\Delta c}$) or a rated residual short-time withstand current ($I_{\Delta w}$), but may have both.

MRCDs shall comply with the relevant tests of M.8.14.

M.7.2.3 Mechanical and electrical endurance

MRCDs shall comply with the tests of M.8.11.

M.7.2.4 Effects of environmental conditions

MRCDs shall comply with the test of M.8.15.

M.7.2.5 Dielectric properties

MRCDs shall be capable of withstanding the impulse withstand voltage declared by the manufacturer in accordance with 7.2.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

MRCDs shall comply with the tests of M.8.4.

Clearances from the live parts of the monitored circuit to:

– the live parts of the MRCD,
– the parts intended to be grounded,
– the clearances between the current paths, for terminal type MRCDs,

shall withstand the test voltage given in Table 12 of IEC 60947-1:2007 according to the rated impulse withstand voltage.

M.7.2.6 Test device

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

The test device shall satisfy the tests of M.8.5.

The protective conductor, if any, shall not become live when the test device is operated.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; the use of a light colour is recommended.

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

M.7.2.7 Value of the non-operating overcurrent in case of a single phase load

MRCDs shall comply with the test of M.8.6.

M.7.2.8 Resistance of MRCDs to unwanted tripping due to surge currents resulting from impulse voltages

MRCDs shall withstand the test of M.8.7.

M.7.2.9 Behaviour of MRCDs of type A and B in case of an earth fault current comprising a d.c. component

MRCDs of type A and type B shall comply with the tests of M.8.8, as applicable.

M.7.2.10 Requirements for MRCDs with voltage source

MRCDs functionally dependent on a voltage source shall operate correctly at any value of the voltage between 0,85 and 1,1 times the rated value U_s (see M.2.1.1 and M.4.1.2.1).

According to their classification, MRCDs functionally dependent on a voltage source shall comply with the requirements given in Table M.2.

Table M.2 – Requirements for MRCDs with voltage source

Classification of the device according to M.3.2.2	Behaviour in case of failure of the voltage source
MRCD operating automatically without delay in case of voltage source failure (M.3.2.2.1)	Operating without delay according to M.8.12
MRCD operating automatically with delay in case of voltage source failure (M.3.2.2.1)	Operating with delay according to M.8.12
MRCD not operating automatically after failure of the voltage source but able to operate as intended in case of a residual current fault arising (M.3.2.2.2)	Operating according to M.8.13

M.7.2.11 Temperature-rise of terminal type MRCDs

M.7.2.11.1 General

The temperature-rise of the parts of terminal type MRCDs shall not exceed the values specified in 7.2.2 of IEC 60947-1:2007/AMD2:2014.

M.7.2.11.2 Ambient air temperature

The temperature-rise limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014 are only applicable if the ambient air temperature remains between the limits given in M.6.

M.7.2.11.3 Main circuit of terminal type MRCDs

The main circuit of the MRCD, to which the monitored circuit is connected, shall withstand the rated current as defined in M.4.1.2.3, without the temperature-rises exceeding the limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014.

M.7.2.12 Electromagnetic compatibility

Requirements of Annex J apply to the sensing means and the processing device of the MRCD, connected in accordance with the manufacturer's instructions.

Tests shall be made in accordance with M.8.16.

Immunity to voltage variations is covered by the requirements of M.7.2.10.

M.7.2.13 Behaviour of MRCDs in case of failure of the sensing means connection

For MRCDs with separate sensing means, if the sensing means are disconnected, then:

– the MRCD shall operate, or
– the MRCD shall provide a signal to indicate such disconnection, or
– it shall be possible to verify the disconnection by operating the test device.

Compliance is verified by the tests of M.8.9.

M.7.2.14 Behaviour of MRCDs according to the rated frequency

The MRCD shall operate correctly within its rated frequency range.

Compliance is verified by the tests of M.8.3.3 and M.8.5.

M.8 Tests

M.8.1 General

M.8.1.1 Type tests

Type tests are grouped together in a number of sequences, as shown in Table M.3.

In the case of MRCDs with multiple settings of residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.

In the case of MRCDs with adjustable time-delay (see B.3.3.2.2), the tests shall be made at the highest setting, unless otherwise stated.

The release of the associated breaking device, when applicable, shall be energized at its lowest rated voltage.

Table M.3 – Test sequences

Sequences		
M I	Operating characteristics	M.8.3
	Dielectric properties	M.8.4
	Operation of the test device at the limits of rated voltage	M.8.5
	Limiting value of the non-operating current under overcurrent conditions	M.8.6
	Resistance against unwanted tripping due to surge currents resulting from impulse voltages	M.8.7
	Behaviour in case of an earth fault current comprising a d.c. component	M.8.8
	Behaviour in case of failure of the connection to the sensing means	M.8.9
	Temperature-rise	M.8.10
	Mechanical and electrical endurance	M.8.11
	Behaviour in the case of failure of the voltage source for MRCDs classified under M.3.2.2.1	M.8.12
	Behaviour of MRCDs classified under M.3.2.2.2. in the case of failure of the voltage source	M.8.13
M II	Behaviour of MRCDs under short-circuit conditions	M.8.14
M III	Effects of environmental conditions	M.8.15
M IV	Electromagnetic compatibility	M.8.16

For terminal-type MRCDs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants construction is not identical to the variant tested then those variants shall also be tested.

One sample shall be tested for each of the test sequences M I, M II and M III.

For test sequence M IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Unless otherwise specified, each type test (or sequence of type tests) is carried out on the MRCD in new and clean condition, the influencing quantities having their normal reference values.

The MRCD shall be installed individually, according to the manufacturer's instructions, in free air, unless otherwise specified. Ambient temperature shall be between 15 °C and 30 °C unless otherwise specified. Connections and mounting shall comply with the manufacturer's instructions.

M.8.1.2 Routine tests

Subclause 8.4.5 applies.

M.8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except in so far as 7.1 applies.

Test sequence M I

M.8.3 Verification of the operating characteristics

M.8.3.1 General

The MRCD shall be installed, mounted and wired according to the manufacturer's instructions. Unless otherwise specified, it is connected to a test equipment, as specified by the manufacturer, representing normal service conditions for the output circuit (e.g. connection to a circuit-breaker) in order to verify the change in the status of the output and the combination time (see M.2.2.2.2).

M.8.3.2 Test conditions for MRCDs without voltage source

Subclause B.8.2.2 applies.

M.8.3.3 Test conditions for MRCDs with voltage source

The tests shall be carried out at the following values:

– 0,85 times the minimum rated value of the source voltage for tests specified in M.8.3.4 and M.8.3.5.2;

– 1,1 times the maximum rated value of the source voltage for tests specified in M.8.3.5.3.

MRCDs with a range of rated frequencies shall be tested at the highest and lowest frequencies. However, for MRCDs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover both frequencies.

M.8.3.4 Off-load tests at 20 °C ± 5 °C

M.8.3.4.1 General

With the connections as shown in Figure M.1, Figure M.2 or Figure M.3, the MRCD shall comply with the tests of M.8.3.4.2, M.8.3.4.3 and M.8.3.4.4 as well as with the test of M.8.3.4.5 where applicable; all these tests are carried out on a single current path. Each verification shall comprise three measurements, as applicable.

Unless otherwise specified:

– for MRCDs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the highest and at the lowest settings, as well as at an intermediate setting;

– for MRCDs of the adjustable time-delay type, the time-delay shall be set to its minimum value.

M.8.3.4.2 Verification of operation in case of a steady increase of the residual current (Figure M.1)

The test switches S_1 and S_2, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, up to $I_{\Delta n}$ in approximately 30 s. Three current measurements causing change in status of the output are carried out.

The three values measured shall be situated between the rated residual non-operating current $I_{\Delta no}$ and $I_{\Delta n}$.

M.8.3.4.3 Verification of operation in case of closing on residual current (Figure M.2)

The MRCD is connected to a breaking device, specified by the manufacturer, and installed on the monitored circuit. The characteristics of this device shall be given in the test report.

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or at each specific setting of the residual operating current if applicable), the test switch S_2 and the breaking device being closed, switches S_1 and S_a (if applicable) are closed simultaneously. The combination time is measured three times.

No measurements shall exceed the limiting value specified for $I_{\Delta n}$ in M.4.2.

M.8.3.4.4 Verification of operation in case of a sudden appearance of residual current (Figure M.2 and Figure M.3)

The MRCD is connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in M.4.2, the test switches S_1, and S_a if applicable, and the test equipment being in the closed position, and the MRCD being ready to operate, the residual current is suddenly established by closing the test switch S_2.

Three measurements of operating time and of combination time (if applicable) are made at each value of I_{Δ}:

– none of the values of operating time shall exceed the values indicated by the manufacturer,
– none of the values of combination time shall exceed the limits specified in M.4.2.

M.8.3.4.5 Verification of the limiting non-operating time of time delayed type MRCDs (Figure M.3)

The MRCD is connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at the value $2\ I_{\Delta n}$, the test switches S_1, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is established by closing the switch S_2 for a time equal to the limiting non-operating time declared by the manufacturer in accordance with M.4.2.

The test is made 3 times. The MRCD shall not operate.

If the MRCD has an adjustable current setting and/or an adjustable time-delay, the test is made, as applicable, at the lowest setting of the residual operating current and at the maximum and minimum settings of the time-delay.

M.8.3.5 Tests at the temperature limits

M.8.3.5.1 General

Subclause B.8.2.5 applies.

M.8.3.5.2 Off-load test at –5 °C

Subclause B.8.2.5.2 applies, but in accordance with M.8.3.4.4 and M.8.3.4.5 if applicable.

M.8.3.5.3 On-load test at +40 °C

Subclause B.8.2.5.3. applies.

After reaching thermal steady-state conditions, the MRCD is submitted to the tests described in M.8.3.4.4 and in M.8.3.4.5 if applicable.

M.8.4 Verification of dielectric properties

M.8.4.1 Verification of rated impulse withstand voltage

M.8.4.1.1 General

The MRCD shall comply with the requirements stated in M.7.2.5. The tests shall be carried out in all the auxiliary contact positions.

The tests are made in accordance with 8.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 with the following additions.

M.8.4.1.2 Verification of rated impulse withstand voltage with respect to the monitored circuit

M.8.4.1.2.1 Tests for terminal type MRCD

The test voltage, defined in M.7.2.5, is applied as indicated in 8.3.3.4.1 item 2), of IEC 60947-1:2007/AMD1:2010.

M.8.4.1.2.2 Tests for MRCDs of through-conductor type

The test is carried out on a sensing means through which runs an uninsulated busbar, installed according to the manufacturer's instructions.

The test voltage, defined in M.7.2.5, is applied as follows:

a) between all the conductors of the monitored circuit connected together and the mounting plate if the sensing means are separate;

b) between all the conductors of the monitored circuit connected together and the processing device enclosure or its mounting plate if the sensing means are combined;

c) between each auxiliary circuit and
   - the monitored circuit;
   - the enclosure or mounting plate of the MRCD.

M.8.4.1.3 Verification of rated impulse withstand voltage of the voltage source circuit (if applicable)

If the voltage source circuit is supplied directly from the monitored circuit, the tests are carried out in accordance with M.8.4.1.2.1.

If the voltage source circuit is not supplied by the monitored circuit, the test voltage defined in Table 12 of IEC 60947-1:2007 is applied as follows:

a) between all the supply terminals of the voltage source circuit connected together and the enclosure or mounting plate of the MRCD;

b) between each supply terminal of the voltage source circuit and the other supply terminals connected together and connected to the enclosure or mounting plate of the MRCD.

M.8.4.2 Capability of any circuits connected to the monitored circuit in respect of withstanding d.c. voltages due to insulation measurements

The need for this verification of MRCDs which cannot be disconnected in service is under consideration.

M.8.5 Verification of the operation of the test device at the limits of the rated voltage

Subclause B.8.4 applies, replacing the rated voltage by the rated voltage of the voltage source. The MRCD shall be tested in association with the test equipment specified in M.8.3.1.

M.8.6 Verification of the limiting value of non-operating current under overcurrent conditions, in case of a single phase load

The MRCD is connected according to Figure M.4 a), b) or c), as applicable, paying particular attention to the positioning of the conductors in case of a through-conductor type according to the manufacturer's instructions, the switch S_1 being open. The switch S_a, where applicable, is then closed and the voltage U_s is applied.

The test is made in accordance with B.8.5 at a current of 6 I_n. For MRCDs with separate sensing means, the test shall be made at the lowest residual current setting value declared by the manufacturer.

No change of state of the MRCD shall occur.

M.8.7 Resistance against unwanted tripping due to surge currents resulting from impulse voltages

M.8.7.1 General

For MRCDs with adjustable time-delay, the time-delay shall be set at its minimum.

M.8.7.2 Verification of the resistance to unwanted tripping in case of loading of the network capacitance

Subclause B.8.6.2 applies, replacing Figure B.5 by Figure M.5.

No change of state of the MRCD shall occur.

M.8.7.3 Verification of the resistance to unwanted tripping in case of flashover without follow-on current

Subclause B.8.6.3 applies, replacing Figure B.7 by Figure M.6.

No change of state of the MRCD shall occur.

M.8.8 Verification of the behaviour in case of an earth fault current comprising a d.c. component

M.8.8.1 General

The test conditions of M.8.3.1, M.8.3.2 and M.8.3.3 apply.

M.8.8.2 Type A MRCD

M.8.8.2.1 General

Type A MRCDs shall satisfy the tests from M.8.8.2.2 to M.8.8.2.5.

For MRCDs the operation of which depends on a voltage source the tests are made at 1,1 and 0,85 times the rated voltage of the voltage source (U_s).

M.8.8.2.2 Verification of operation in case of a continuous rise of a residual pulsating direct current

Subclause B.8.7.2.1 applies, replacing Figure B.8 by Figure M.7.

The switches S_1 and S_2, and S_a if applicable, are closed, the MRCD being ready to operate.

M.8.8.2.3 Verification of operation in case of a suddenly appearing residual pulsating direct current

Tests of B.8.7.2.2 apply with the following modifications.

The test circuit shall be in accordance with Figure M.8 or Figure M.9, as applicable.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement instrument indicating the change in status of the output;
– for the second step, the MRCD is connected to a breaking device, specified by the manufacturer, and installed on the monitored circuit. The characteristics of this breaking device shall be given in the test report.

The switches S_1, and S_a if applicable, are in the closed position and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S_2.

The test is carried out at each value of the residual current specified:

– for the first step, none of the operating times measured shall exceed the values indicated by the manufacturer for the response time of the MRCD only;
– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.2.4 Verification of operation with load at the reference temperature

The tests of M.8.8.2.2 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current, the current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure M.7c).

M.8.8.2.5 Verification of operation in case of a residual pulsating direct current superimposed by a smooth direct current of 6 mA

Tests of B.8.7.2.4 apply with the following modifications.

The test circuit shall be in accordance with Figure M.10 a), b) or c), as applicable.

M.8.8.3 Type B MRCD

M.8.8.3.1 General

Additionally to the tests specified in M.8.3.4 and M.8.3.5, type B MRCDs shall comply with the tests from M.8.8.3.2 to M.8.8.3.6. For MRCDs with voltage source, these tests are carried out at 1,1 and 0,85 times the rated voltage of the source voltage.

M.8.8.3.2 Verification of operation in case of a slowly rising residual smooth direct current

The test circuit shall be in accordance with Figure M.11, switches S_1 and S_2, and S_a if applicable, being closed. Each current path is tested twice in position I and twice in position II of switch S_3.

The residual current, starting from zero, shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 2 $I_{\Delta n}$.

M.8.8.3.3 Verification of operation in case of a suddenly appearing residual smooth direct current

The test circuits shall be in accordance with Figure M.12 and Figure M.13.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement apparatus giving the status of the output;

– for the second step, the MRCD is connected to a current breaking device, specified by the manufacturer and installed on the monitored circuit. The characteristics of this breaking device shall be given in the test report.

The circuit being successively calibrated at the values specified hereafter, the auxiliary switch S_1 or S_a, as applicable, being closed and the MRCD being ready to operate, the residual current is suddenly established by closing switch S_2.

The test is carried out at each value of residual current specified in Table B.1, multiplied by two.

Two operating time measurements are performed for each value, the auxiliary switch S_3 being in position I for the first measurement and in position II for the second measurement:

– for the first step, none of the values obtained shall exceed the values indicated by the manufacturer for the actuating time of the MRCD alone,

– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.4 Verification of operation in case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection

The test circuit shall be in accordance with Figure M.14, the switches S_1 and S_2, and S_a if applicable, being in the closed position. The test shall be carried out twice.

For each test, starting from zero, the current shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 2 $I_{\Delta n}$.

M.8.8.3.5 Verification of operation in case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line

The test circuit shall be in accordance with Figure M.15, with switches S_1 and S_2, and S_a if applicable, being in the closed position. The test shall be carried out on all possible combinations of pairs of current paths for the MRCD sensing means.

For each test, starting from zero, the current shall be steadily increased to 1,4 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 1,4 $I_{\Delta n}$.

NOTE 1 To simplify tests for residual currents caused by a fault in a circuit supplied by a two-pulse bridge connection line-to-line or a three-pulse star connection or six-pulse bridge connection, the verification of the operation is carried out only with a residual current slowly rising and a phase control angle of α = 0°.

NOTE 2 To simplify tests for residual currents caused by a fault in a three-phase rectified circuit, the verification of the operation is carried out only for a three-pulse star connection.

M.8.8.3.6 Verification of operation with load at the reference temperature

The tests of M.8.8.3.2, M.8.8.3.4 and M.8.8.3.5 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current.

M.8.9 Verification of the behaviour of MRCDs with separate sensing means in case of a failure of the sensing means connection

M.8.9.1 General

For MRCDs with a range of rated values of the voltage source, tests shall be made for each rated value, according to M.8.9.2 or M.8.9.3, as applicable, according to the manufacturer's instructions.

M.8.9.2 Test method 1

The MRCD shall be connected to the external sensing means and is supplied successively with each rated voltage, as shown in Figure M.16. There shall be no fault current flowing in the sensing means and the test circuit shall not be activated.

The sensing means are disconnected and the MRCD shall operate or provide a signal to indicate such disconnection.

The time interval between the disconnection and the output status change is measured.

Three measurements are carried out; no value shall exceed 5 s.

M.8.9.3 Test method 2

Tests shall be carried out as follows:

a) The test device is activated. The MRCD shall operate.
b) The sensing means are disconnected and the test device is activated. The MRCD shall not operate.

M.8.10 Verification of temperature-rise of terminal type MRCDs

M.8.10.1 General

Unless otherwise specified, the MRCD is connected with the appropriate conductors whose cross-sections are specified in Tables 9, 10 and 11 of IEC 60947-1:2007, and is fixed on a mat black painted plywood board of about 20 mm thickness.

The test shall be carried out in an atmosphere protected against abnormal external heating or cooling.

M.8.10.2 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.8.10.3 Test procedure

The test shall be carried out in accordance with 8.3.3.3.4 of IEC 60947-1:2007, at the rated current I_n.

During this test, temperature-rise shall not exceed the values listed in Table 2 of IEC 60947-1:2007 and Table 3 of IEC 60947-1:2007/AMD2:2014.

M.8.11 Verification of mechanical and electrical endurance

The MRCD output is submitted to mechanical and electrical endurance tests including:

– 500 off-load operations controlled by the test device;

– 500 off-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path;
– 500 on-load operations controlled by the test device;
– 500 on-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path.

The on-load tests are carried out on a circuit corresponding to the output rating given by the manufacturer.

After the tests, the MRCD shall show no damage impairing its further use. The output shall be able to withstand in the open position a voltage equal to twice its maximum rated value given by the manufacturer.

NOTE 1 This verification is not applicable if the output is designed for a specific load and does not have a rated output voltage.

For MRCDs having more than one output rating, two tests shall be made:

– a test at the highest rated current at the corresponding voltage;
– a test at the highest rated voltage at the corresponding current.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2.

NOTE 2 If the MRCD output has an appropriate AC15 rating, according to IEC 60947-5-1, the tests of this subclause are not necessary.

M.8.12 Verification of the behaviour of MRCDs in case of failure of the voltage source for MRCDs classified under M.3.2.2.1

M.8.12.1 General

For adjustable residual operating current MRCDs, the test shall be carried out at the lowest setting.

For adjustable time-delayed MRCDs, the test is carried out at any one of the time-delay settings.

The voltage applied is the rated voltage of the voltage source (U_s).

For MRCDs having a range of rated voltages of the voltage source, the tests shall be made at the maximum and minimum values of the voltage range.

M.8.12.2 Determination of the limiting value of the voltage source

Tests shall be carried out in accordance with B.8.8.2, replacing “line voltage” by “voltage source” and “line terminals” by “voltage source terminals”.

M.8.12.3 Verification of automatic opening in case of voltage source failure

Tests are carried out in accordance with B.8.8.3, replacing “line voltage” by “voltage source” and “line terminals” by “voltage source terminals”, but in this case the time interval between the switching off and the change in status of the output shall be measured.

Three measurements are carried out:

– for instantaneous MRCDs, no value shall exceed 1 s;
– for time delayed MRCDs, no value shall exceed 1 s plus the set time-delay.

M.8.13 Verification of the behaviour of MRCDs with voltage source as classified under M.3.2.2.2 in case of failure of the voltage source

The provisions of B.8.9 apply in the case where the voltage source is the line voltage of the monitored circuit. In the case where the voltage source is other than the line voltage, a test shall be made as follows.

For MRCDs having an adjustable residual operating current, the test shall be made at the lowest setting.

For MRCDs having an adjustable time-delay, the test is made at any one of the time-delay settings.

The MRCD is connected according to Figure M.3 and is supplied with its rated voltage, or in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_a or S_1, as applicable; the MRCD shall not operate.

The switch S_a or S_1, as applicable, is then reclosed and the voltage is reduced to 70 % of the lowest rated voltage. The rated residual current $I_{\Delta n}$ is then applied by closing S_2; the MRCD shall operate.

Test sequence M II

M.8.14 Verification of the behaviour of the MRCD under short-circuit conditions

M.8.14.1 General

Since an MRCD is not a switching device, where it has been tested with a given SCPD according to M.8.14.3 and M.8.14.5, tests with other SCPDs of a lower peak current and lower I^2t are considered to be also covered.

M.8.14.2 General conditions for the test

M.8.14.2.1 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies, replacing Figures 9, 10, 11 and 12 by Figure M.17, Figure M.18 and Figure M.19.

For short-time withstand tests, the SCPD shall be omitted.

M.8.14.2.2 Tolerances on the test quantities

Table 8 of IEC 60947-1:2007 applies.

M.8.14.2.3 Power factor of test circuit

Table 11 applies.

M.8.14.2.4 Power frequency recovery voltage

Subclause 8.3.2.2.3, item a), of IEC 60947-1:2007/AMD2:2014 applies.

M.8.14.2.5 Calibration of the test circuit

The SCPD and the MRCD, if of the terminal type, are replaced by temporary connections of impedance negligible compared with that of the test circuit. For other MRCDs, the conductors through the sensing means are part of the calibrating circuit.

For the test at rated conditional short-circuit current I_{cc}, the resistors R and the reactors L are adjusted so as to obtain, at the test voltage, a current equal to I_{cc}, at the prescribed power factor. The test circuit is energised simultaneously in all poles.

For the tests at rated residual conditional short-circuit current $I_{\Delta c}$, the additional impedance Z is used so as to obtain the required current values.

M.8.14.2.6 Condition of the MRCD for tests

The wiring and the fixing of the MRCD shall be in accordance with the manufacturer's instructions.

This is particularly the case for MRCDs of the through-conductor type for installing conductors that pass through the sensing means.

The MRCD shall be mounted on a metal plate.

M.8.14.2.7 Condition of the MRCD after tests

After each test of M.8.14.3, M.8.14.4 and M.8.14.5, the MRCD shall show no damage impairing its further use and, in case of a terminal type MRCD, shall be capable of withstanding a voltage equal to twice its rated voltage under the conditions of 8.3.3.6.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2 and M.8.12.3, if applicable, and limited to one measurement.

M.8.14.3 Verification of the rated conditional short-circuit current (I_{cc})

M.8.14.3.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated short-time withstand current I_{cw}.

M.8.14.3.2 Test conditions

The negligible impedance connections are replaced by the SCPD and, if applicable, by the terminal type MRCD.

M.8.14.3.3 Test procedure

The rated voltage of the voltage source, if applicable, is applied.

The following sequence of operations is performed:

$$O - t - O$$

M.8.14.3.4 Behaviour of the MRCD during the tests

During the tests the MRCD may operate.

M.8.14.4 Verification of rated short-time withstand current (I_{cw})

Subclause 8.3.4.3 of IEC 60947-1:2007 applies to the primary circuit.

The test may be carried out at any convenient voltage. The SCPD of Figure M.17, Figure M.18 and Figure M.19 shall be omitted for the test.

M.8.14.5 Verification of the rated conditional residual short-circuit current ($I_{\Delta c}$)

M.8.14.5.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated residual short-time withstand current $I_{\Delta w}$.

M.8.14.5.2 Test conditions

The MRCD shall be tested under the conditions prescribed in M.8.14.2.1 but shall be connected so that the short-circuit current is a residual current. For residual short-circuit tests, the connection B, indicated by the dashed line in Figure M.17, Figure M.18 and Figure M.19, replaces the connection through the sensing means, between X and Y.

The test is carried out on one current path.

The negligible impedance connections are replaced by the SCPD and, where applicable, by the MRCD.

M.8.14.5.3 Test procedure

The following sequence is performed without synchronisation with respect to the voltage wave:

$$O - t - O$$

M.8.14.5.4 Behaviour of the MRCD during the tests

During the tests the MRCD may operate.

M.8.14.6 Verification of rated residual short-time withstand current ($I_{\Delta w}$)

Subclause M.8.14.4 applies except that the MRCD shall be connected so that the short-circuit current is a residual current.

Test sequence M III

M.8.15 Verification of effects of environmental conditions

The tests conditions of B.8.11 apply.

At the end of the tests, the MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2.

Test sequence M IV

M.8.16 Verification of electromagnetic compatibility

M.8.16.1 Immunity tests

M.8.16.1.1 General

Subclause B.8.12.1 applies, replacing "CBR" by "MRCD" where necessary, except that the verifications after the tests shall be a measurement of the operating time (see M.2.2.2.1) at $I_{\Delta n}$, which shall not exceed the value declared by the manufacturer (see M.4.2). The test circuit for the verification shall be in accordance with Figure M.3.

M.8.16.1.2 Electrostatic discharges

Subclause B.8.12.1.2 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.3 Radiated RF electromagnetic fields

Subclause B.8.12.1.3 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.4, and Figure M.20 for MRCDs with separate sensing means.

M.8.16.1.4 Electrical fast transients/bursts (EFT/B)

Subclause B.8.12.1.4 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.5 and Figure J.6, and Figure M.21 for MRCDs with separate sensing means.

M.8.16.1.5 Surges

Subclause B.8.12.1.5 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.6 Conducted disturbances induced by RF fields (common mode)

Subclause B.8.12.1.6 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure M.22 for MRCDs with separate sensing means.

An EM clamp may be used when normal functioning cannot be achieved because of the impact of the CDN on the MRCD.

M.8.16.2 Emission tests

Subclause B.8.12.2 applies.

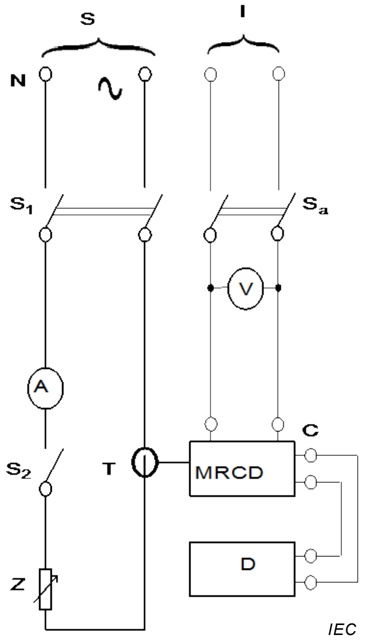


Figure M.1a) – MRCD with separate sensing means

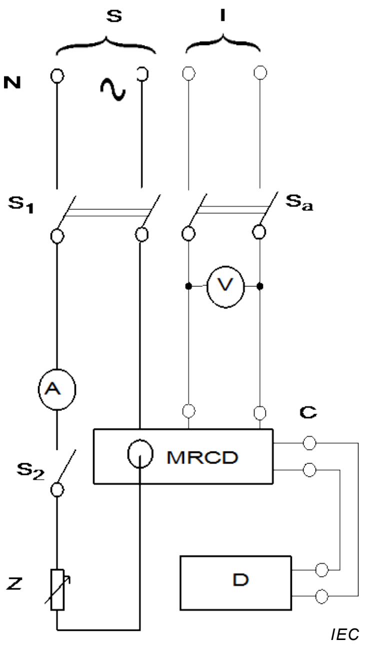


Figure M.1b) – MRCD with integral sensing means

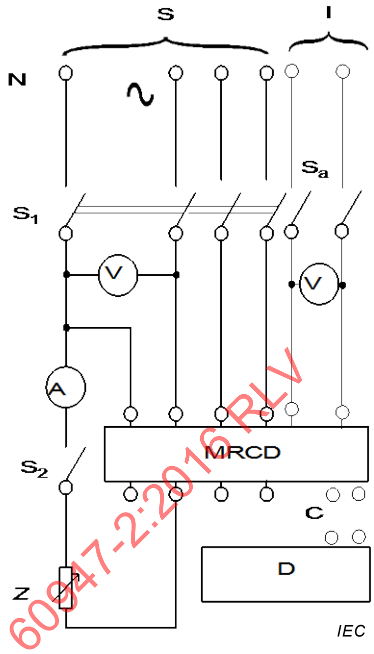


Figure M.1c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current

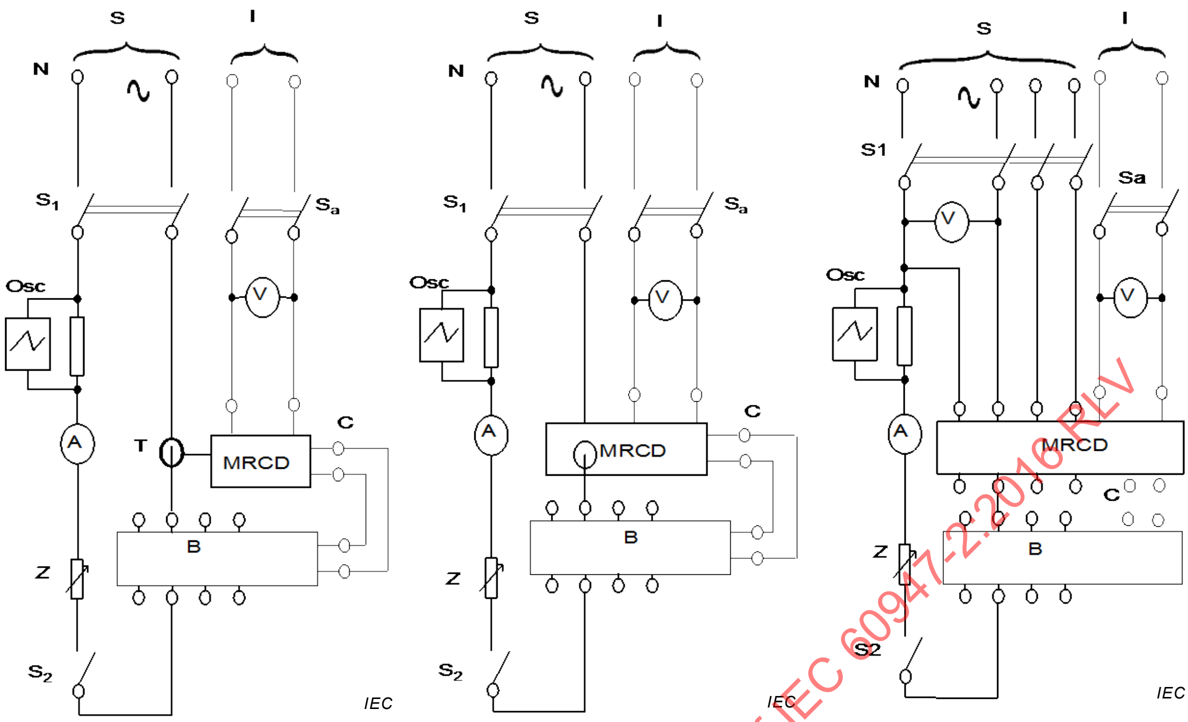


Figure M.2a) – MRCD with separate sensing means

Figure M.2b) – MRCD with integral sensing means

Figure M.2c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

B breaking device

Osc oscilloscope

Figure M.2 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (with breaking device)

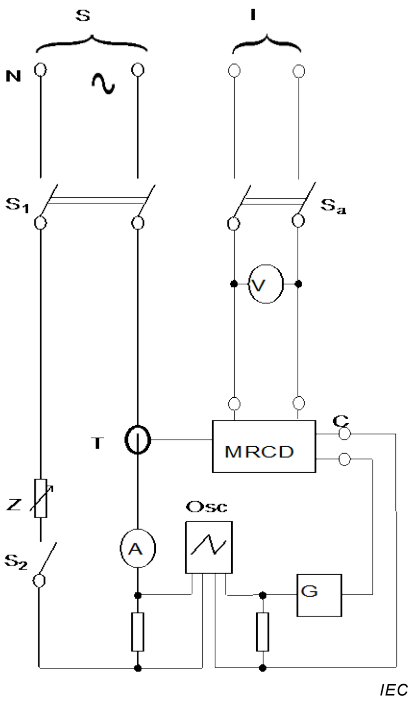


Figure M.3a) – MRCD with separate sensing means

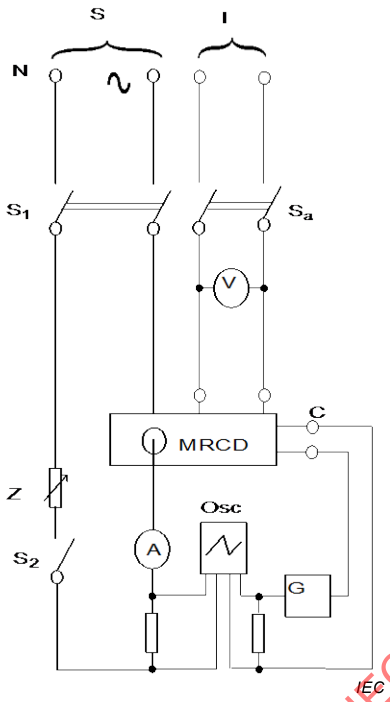


Figure M.3b) – MRCD with integral sensing means

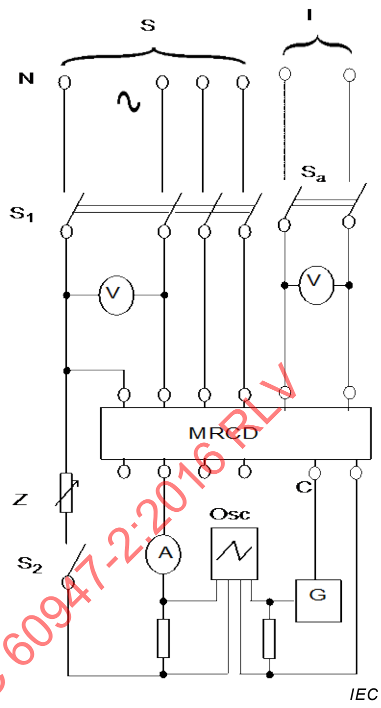


Figure M.3c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope

Figure M.3 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (without breaking device)

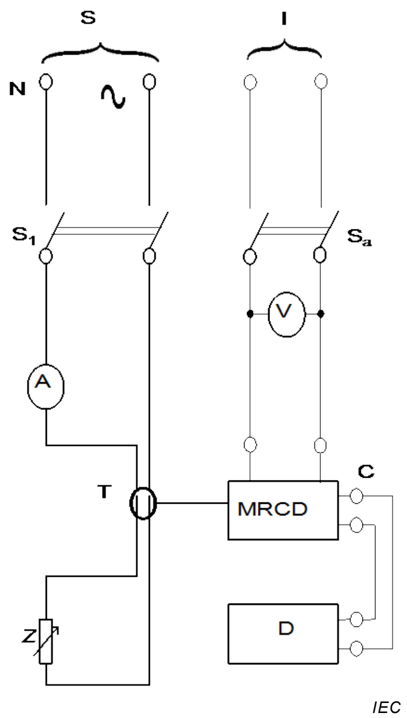


Figure M.4a) – MRCD with separate sensing means

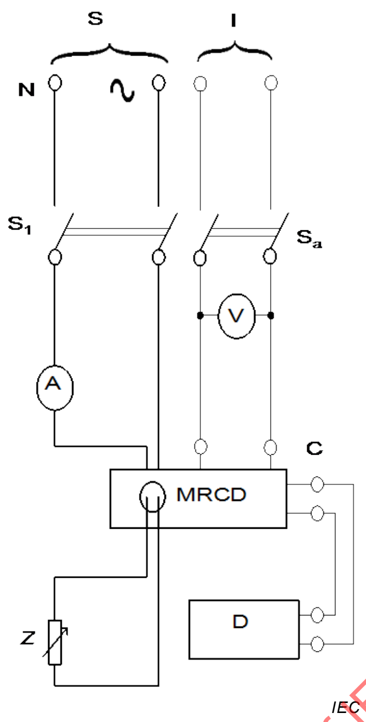


Figure M.4b) – MRCD with integral sensing means

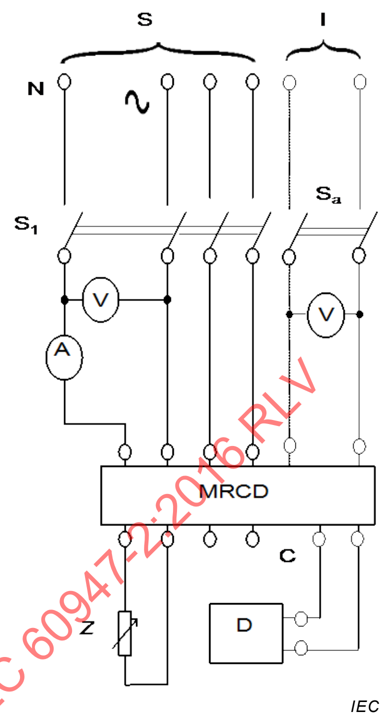


Figure M.4c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.4 – Test circuits for the verification of the limiting value of non-operating current under overcurrent conditions

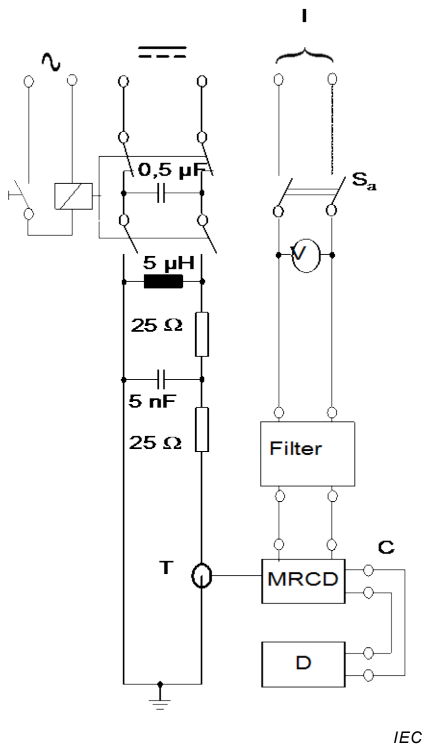


Figure M.5a) – MRCD with separate sensing means

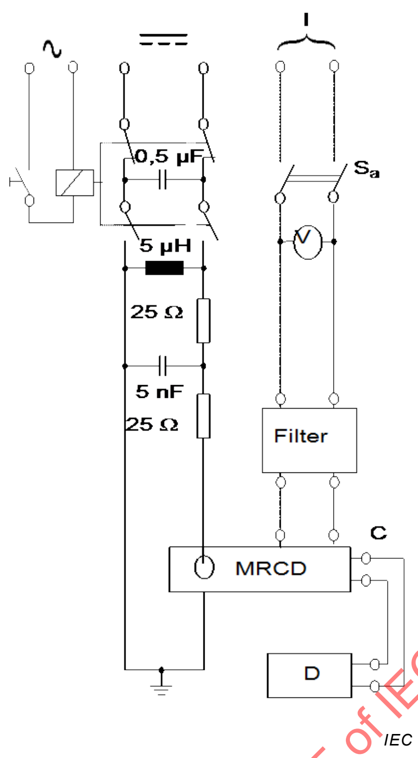


Figure M.5b) – MRCD with integral sensing means

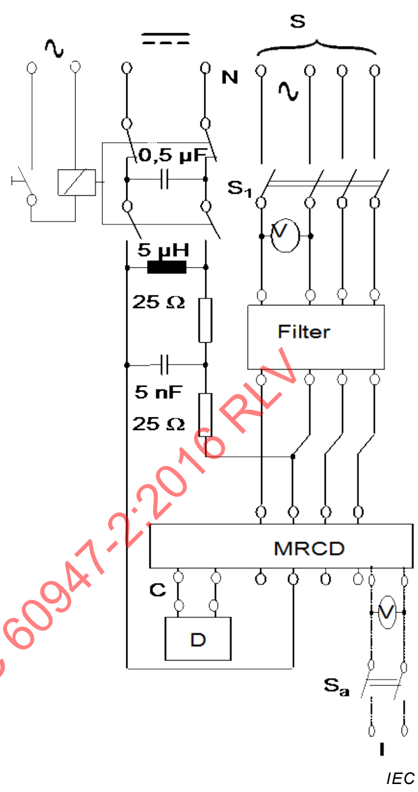


Figure M.5c) – Terminal type MRCD

Key

S power supply

V voltmeter

I separate voltage source, if applicable

S_a auxiliary switch

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance

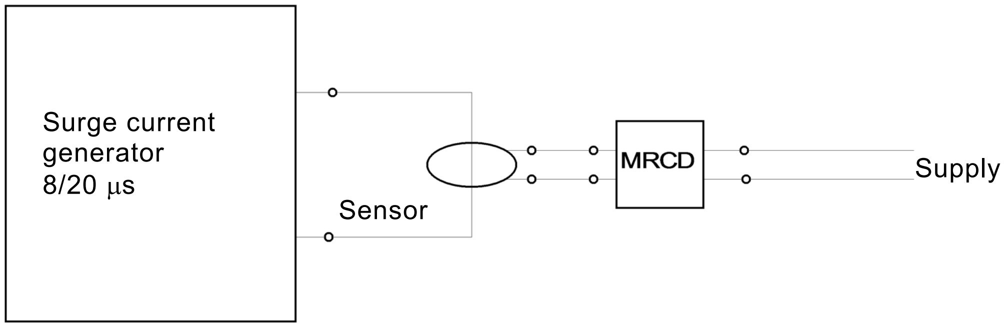


Figure M.6a) MRCD with separate sensing means

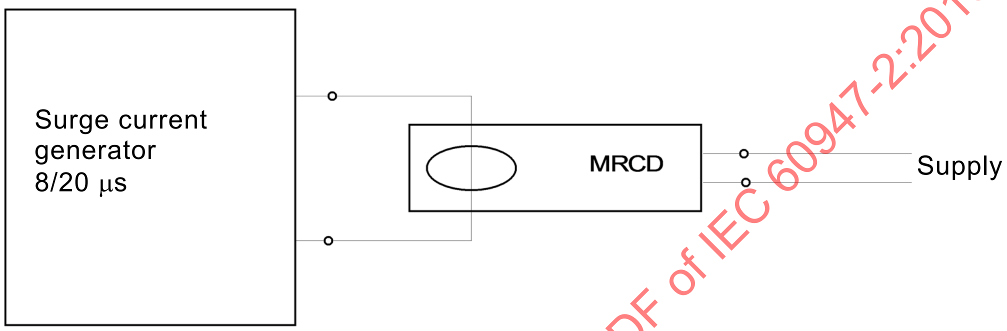


Figure M.6b) MRCD with integral sensing means

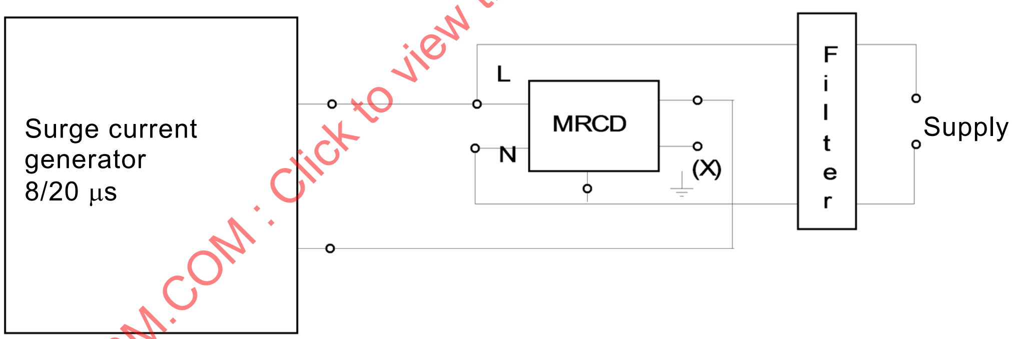


Figure M.6c) Terminals type MRCD

Figure M.6 – Test circuit for the verification of the resistance to unwanted tripping in the case of flashover without follow-on current

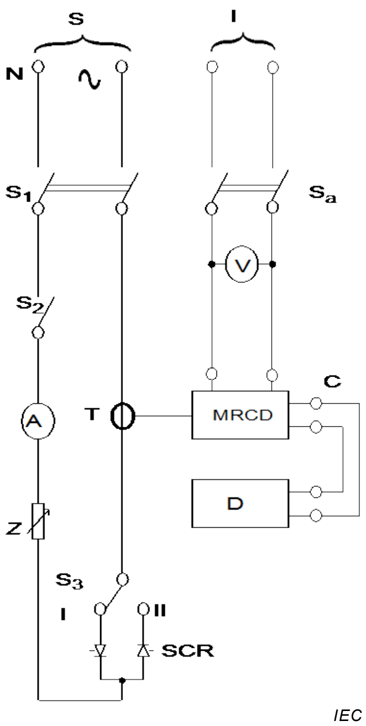


Figure M.7a) – MRCD with separate sensing means

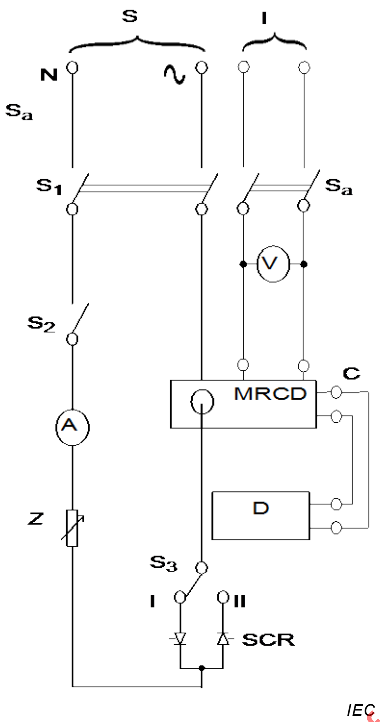


Figure M.7b) – MRCD with integral sensing means

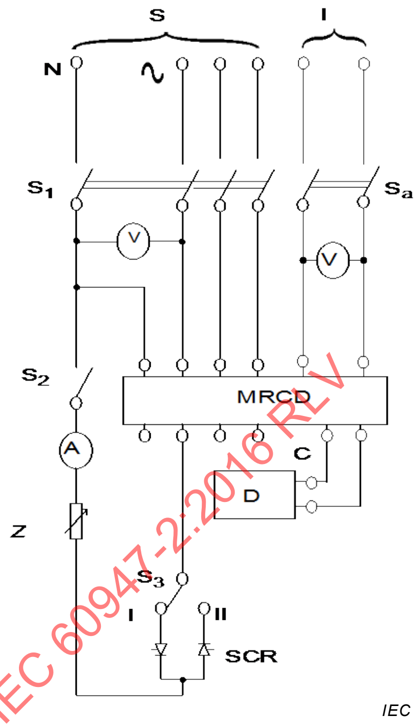


Figure M.7c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	D	instrument indicating the change of status
S_2	single-pole switch	SCR	thyristor
S_3	inverter switch		

Figure M.7 – Test circuits for the verification of operation in the case of a continuous rise of a residual pulsating direct current

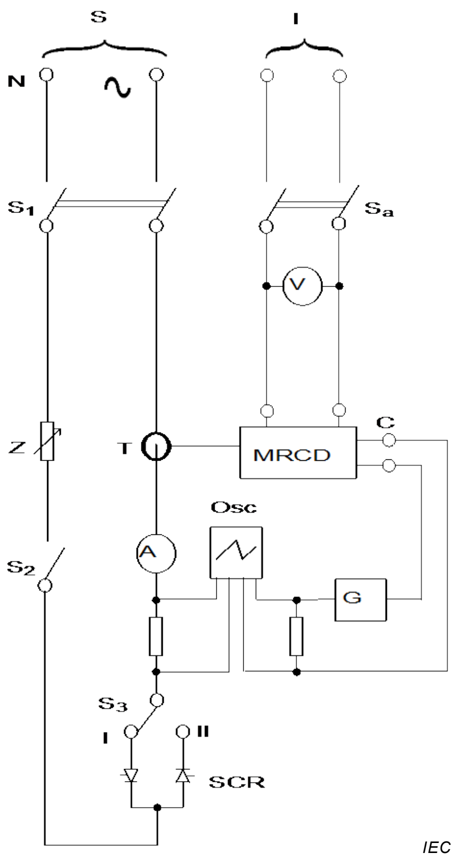


Figure M.8a) – MRCD with separate sensing means

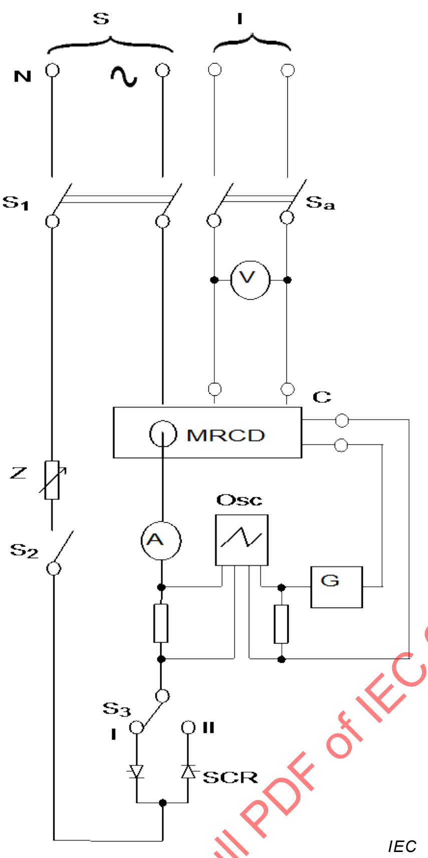


Figure M.8b) – MRCD with integral sensing means

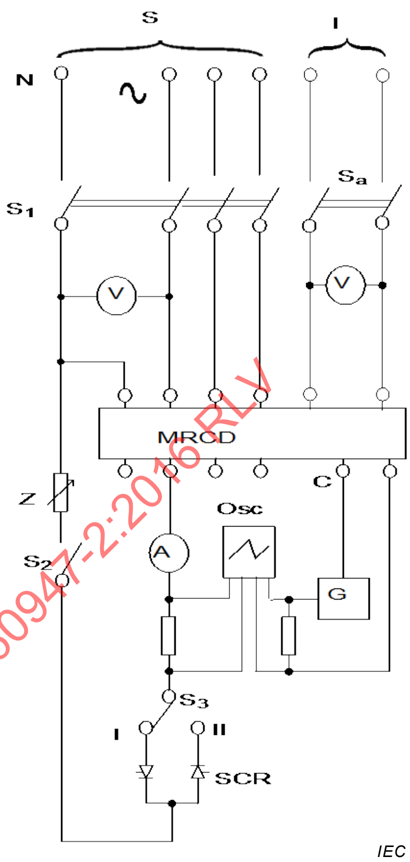


Figure M.8c) – Terminal type MRCD

Key

S	power supply	Sa	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristor

Figure M.8 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (without breaking device)

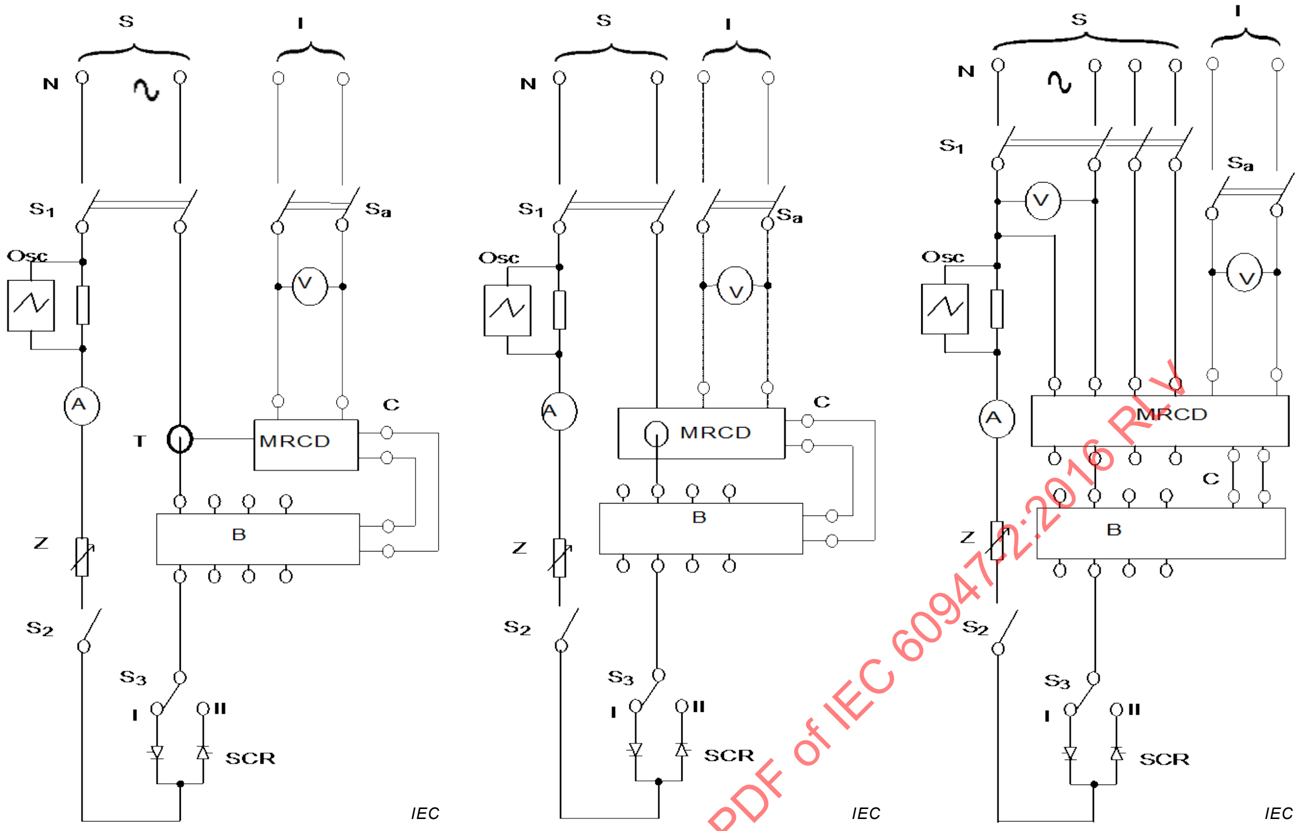


Figure M.9a) – MRCD with separate sensing means

Figure M.9b) – MRCD with integral sensing means

Figure M.9c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multipole switch	B	breaking device
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristor

Figure M.9 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (with breaking device)

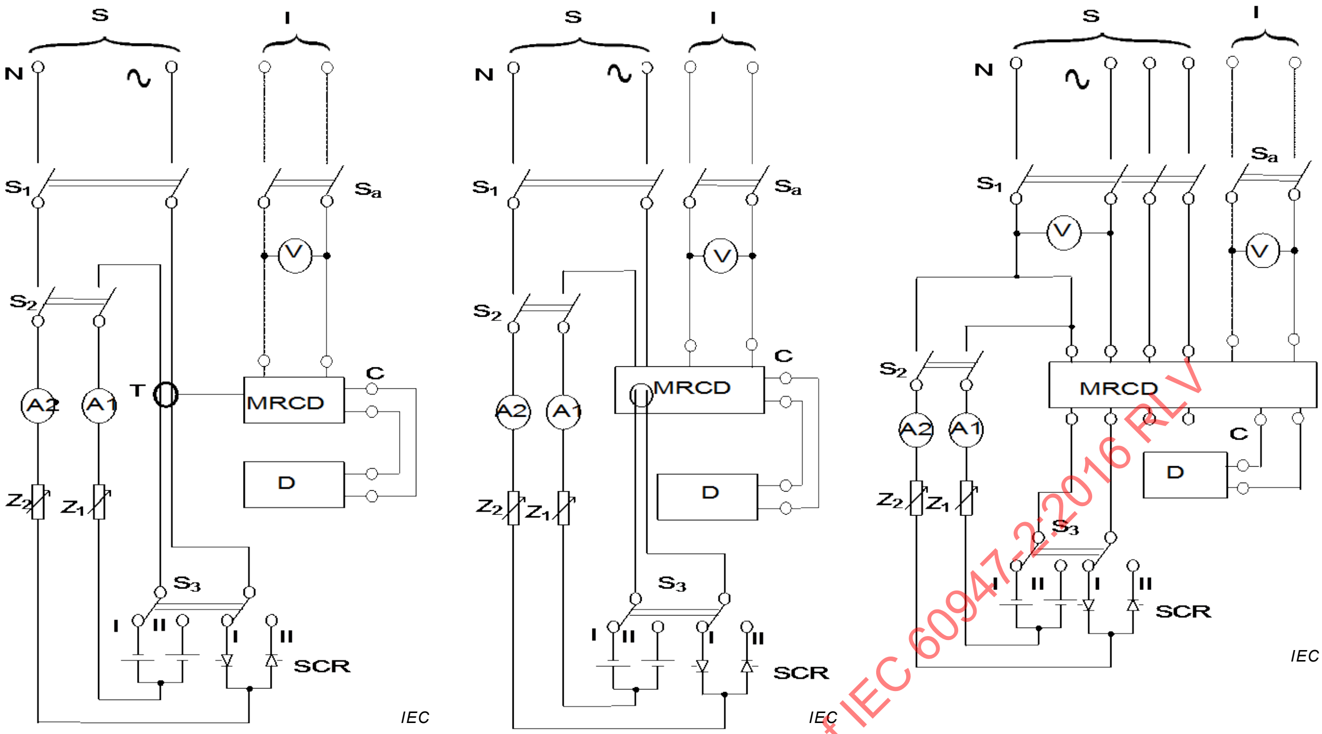


Figure M.10a) – MRCD with separate sensing means

Figure M.10b) – MRCD with integral sensing means

Figure M.10c) – Terminal type MRCD

Key

S	power supply	S_3	double inverter switch
I	separate voltage source if applicable	S_a	auxiliary switch
V	voltmeter	*Z*	variable impedance
A_1	ammeter measuring d.c. current	T	sensing means
A_2	ammeter measuring a.c. r.m.s. current	C	output circuit
S_1	multipole switch	D	instrument indicating the change of status
S_2	two-pole switch	SCR	thyristor

Figure M.10 – Test circuits for the verification of operation in the case of a residual pulsating direct current superimposed by smooth direct current of 6 mA

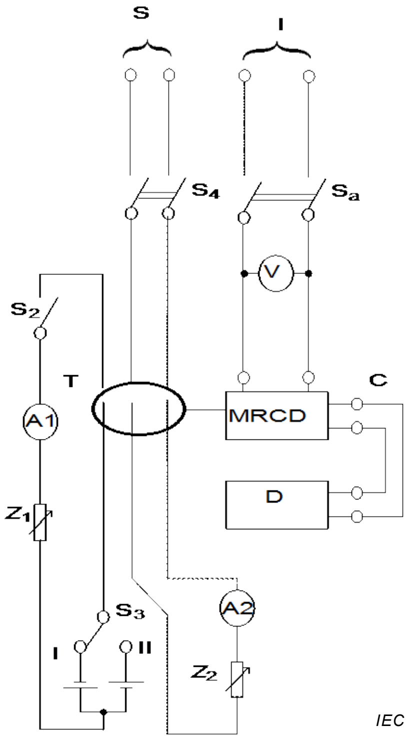


Figure M.11a) – MRCD with separate sensing means

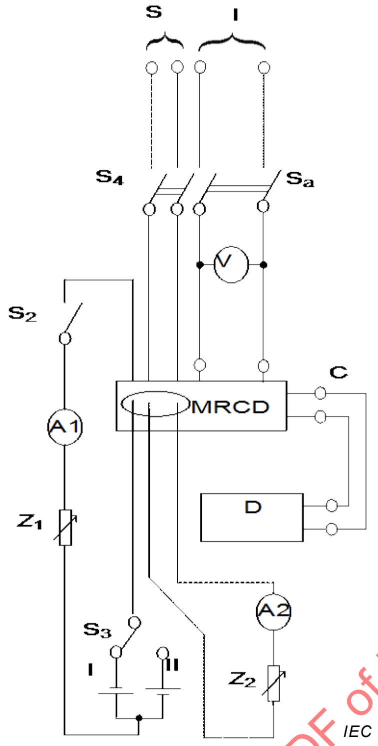


Figure M.11b) – MRCD with integral sensing means

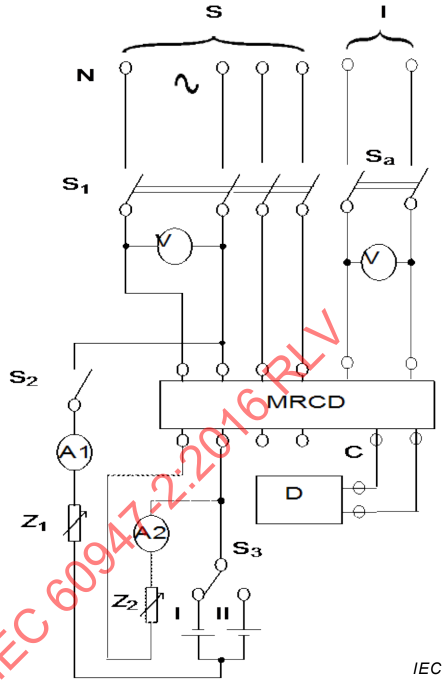


Figure M.11c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A_1 ammeter measuring d.c. current

A_2 ammeter measuring a.c. r.m.s. current

S_1 multipole switch

S_2 single-pole switch

S_3 double inverter switch

S_4 two-pole switch

S_a auxiliary switch

Z_1, Z_2 variable impedances

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.11 – Test circuits for the verification of operation in the case of a slowly rising residual smooth direct current

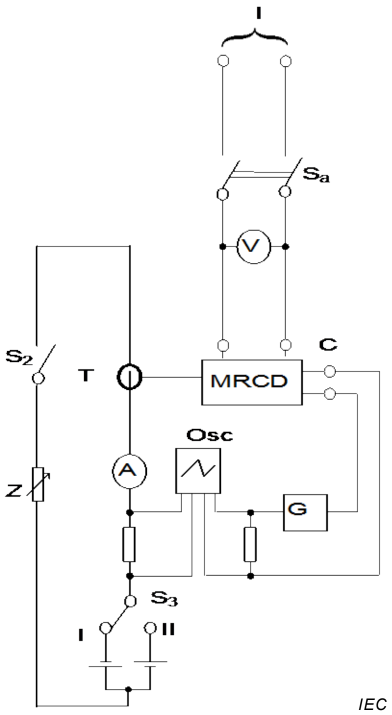


Figure M.12a) – MRCD with separate sensing means

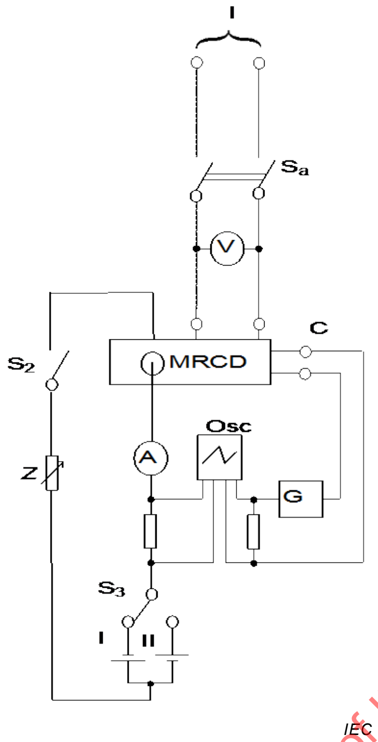


Figure M.12b) – MRCD with integral sensing means

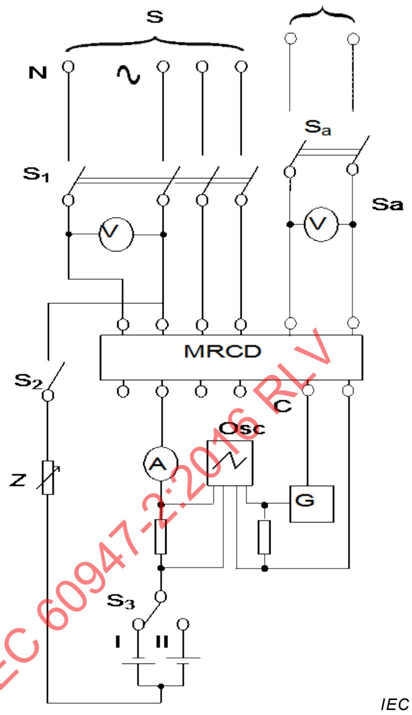


Figure M.12c) – Terminal type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	*Z*	variable impedance
V	voltmeter	T	sensing means
A	ammeter measuring d.c. current	C	output circuit
S_1	multipole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch		

Figure M.12 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (without breaking device)

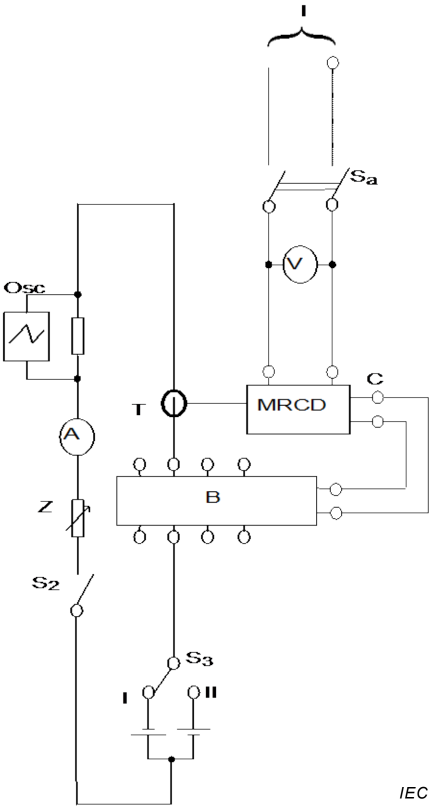


Figure M.13a) – MRCD with separate sensing means

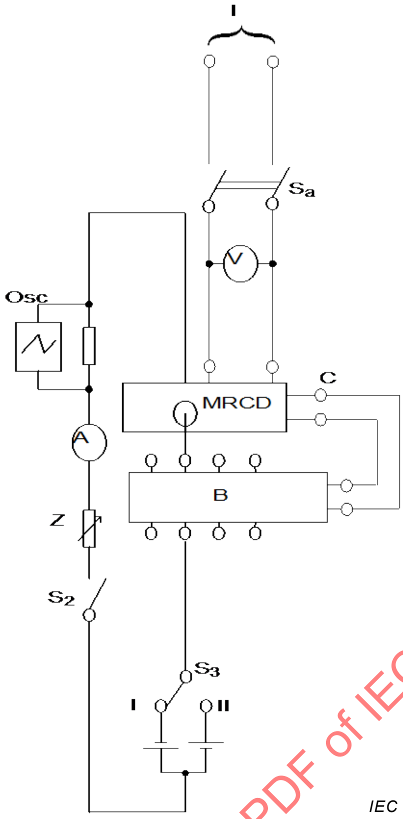


Figure M.13b) – MRCD with integral sensing means

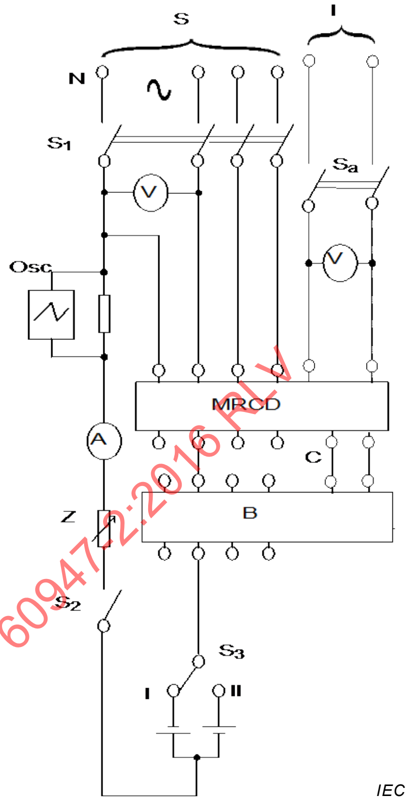


Figure M.13c) – Terminal type MRCD

Key

S power supply

I separate voltage source if applicable

V voltmeter

A ammeter measuring d.c. current

S_1 multipole switch

S_2 single-pole switch

S_3 inverter switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

B breaking device

Osc oscilloscope

Figure M.13 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (with breaking device)

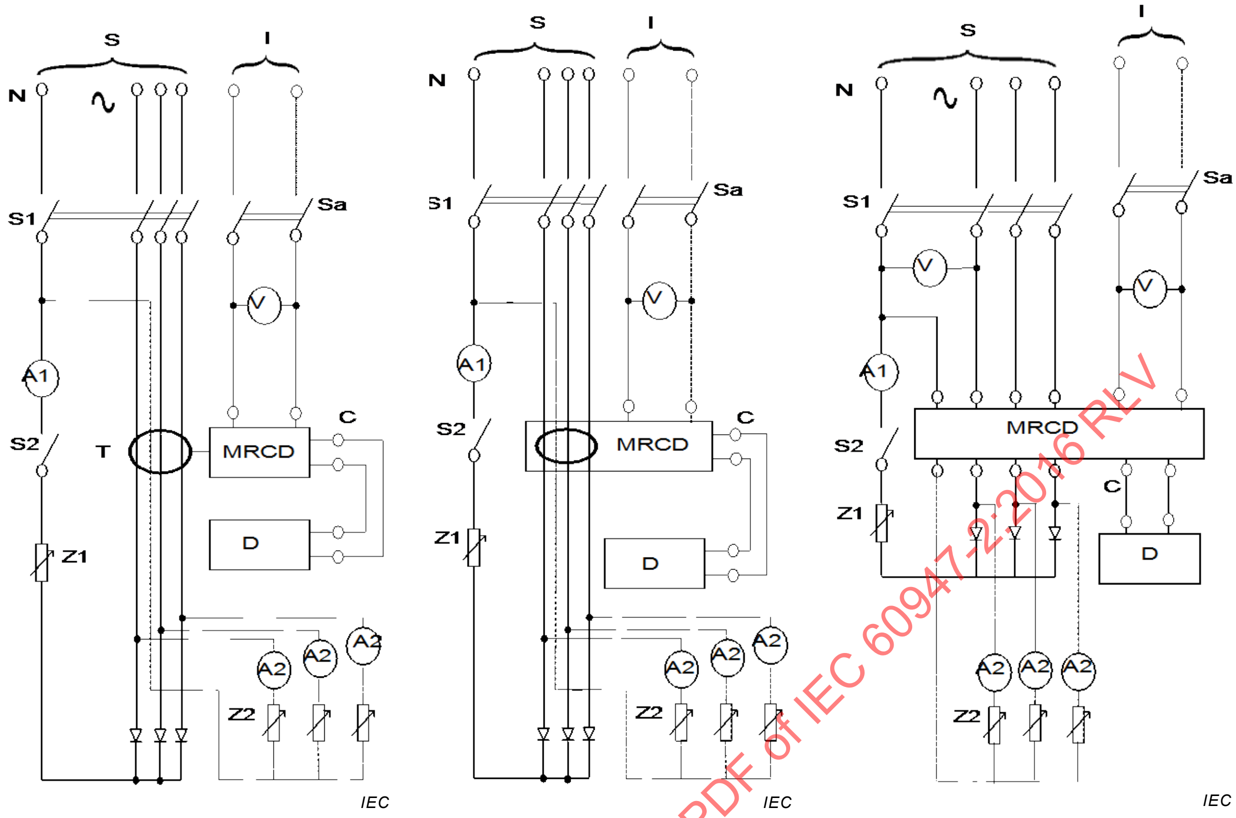


Figure M.14a) – MRCD with separate sensing means

Figure M.14b) – MRCD with integral sensing means

Figure M.14c) – Terminal type MRCD

Key

S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z_1, Z_2	variable impedances
A_1	ammeter measuring r.m.s. current	T	sensing means
A_2	ammeter measuring a.c. current	C	output circuit
S_1	multipole switch	D	instrument indicating the change of status

Figure M.14 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection

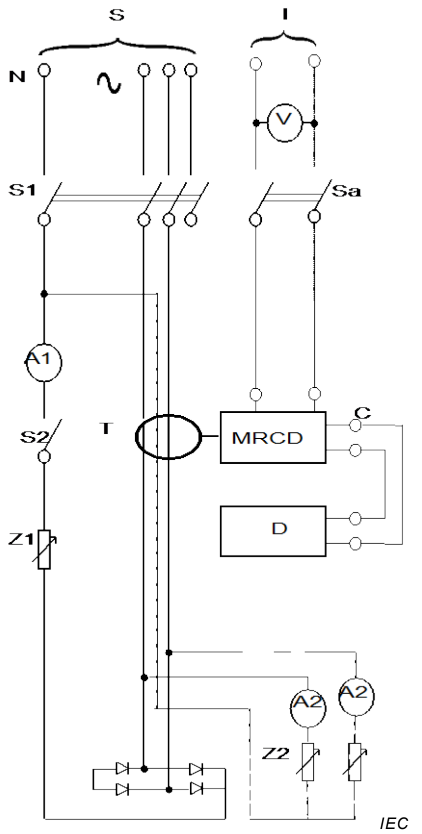


Figure M.15a) – MRCD with separate sensing means

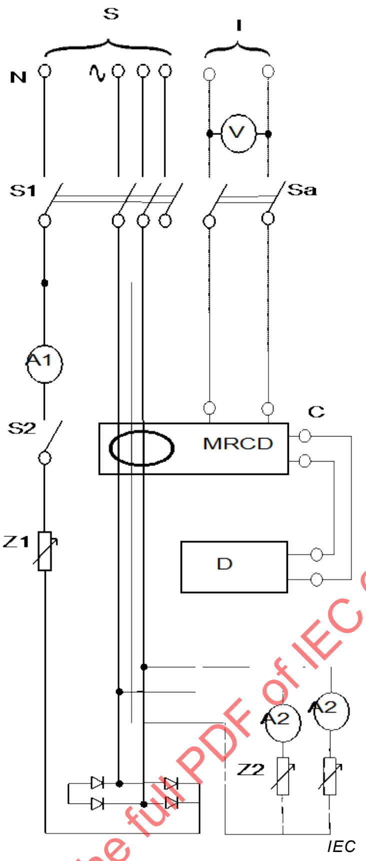


Figure M.15b) – MRCD with integral sensing means

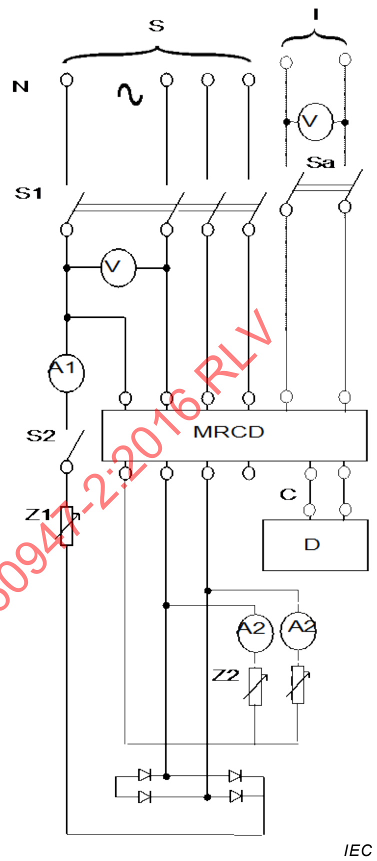
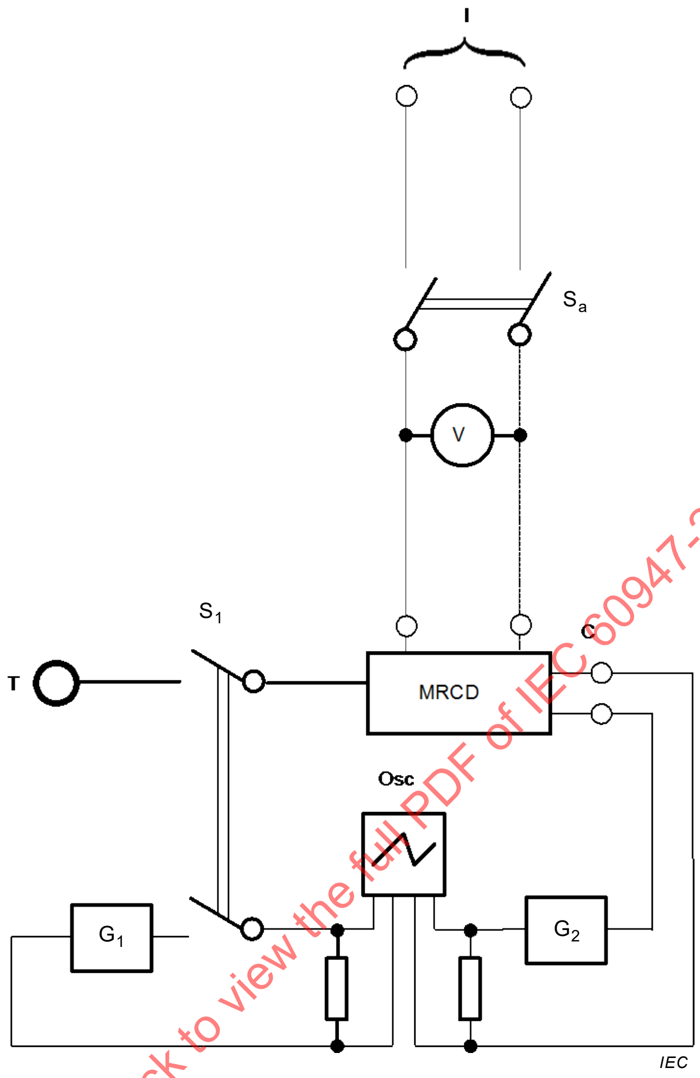


Figure M.15c) – Terminal type MRCD

Key

S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z_1, Z_2	variable impedances
A_1	ammeter measuring r.m.s. current	T	sensing means
A_2	ammeter measuring a.c. current	C	output circuit
S_1	multipole switch	D	instrument indicating the change of status

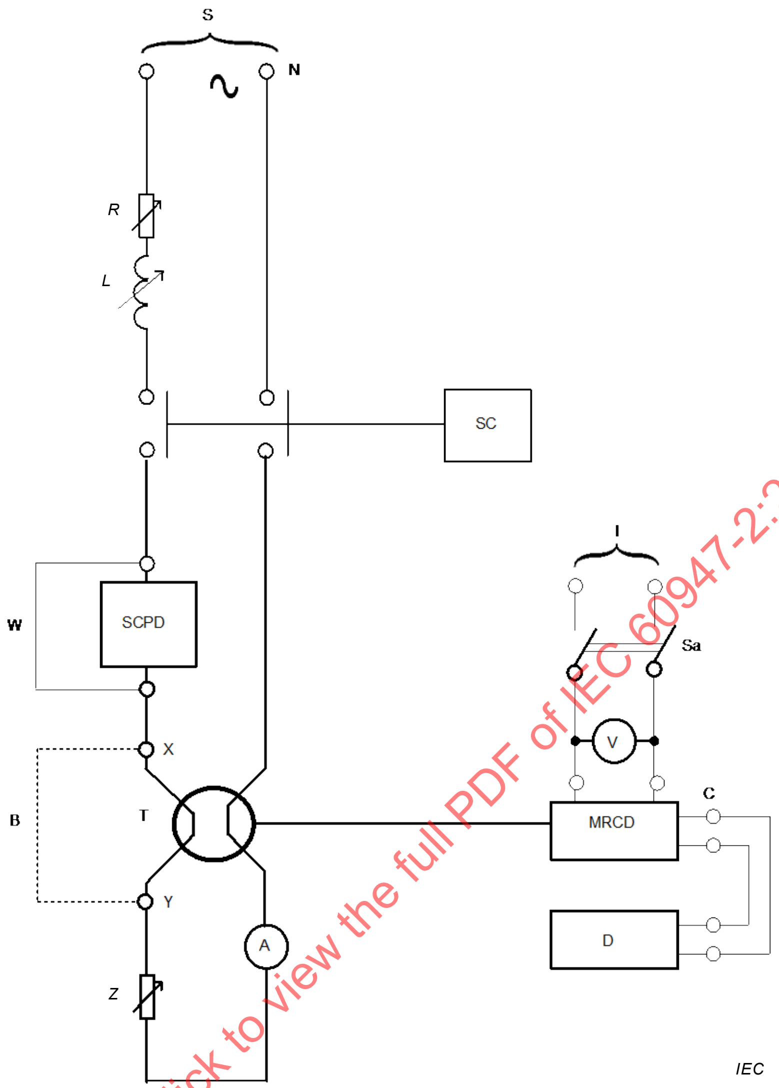
Figure M.15 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line



Key

I	separate voltage source, if applicable	T	sensing means
V	voltmeter	C	output circuit
S_1	multipole switch	G	generator
S_a	auxiliary switch	Osc	oscilloscope

Figure M.16 – Test circuit for the verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensor means connection



Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistance

Z variable impedance

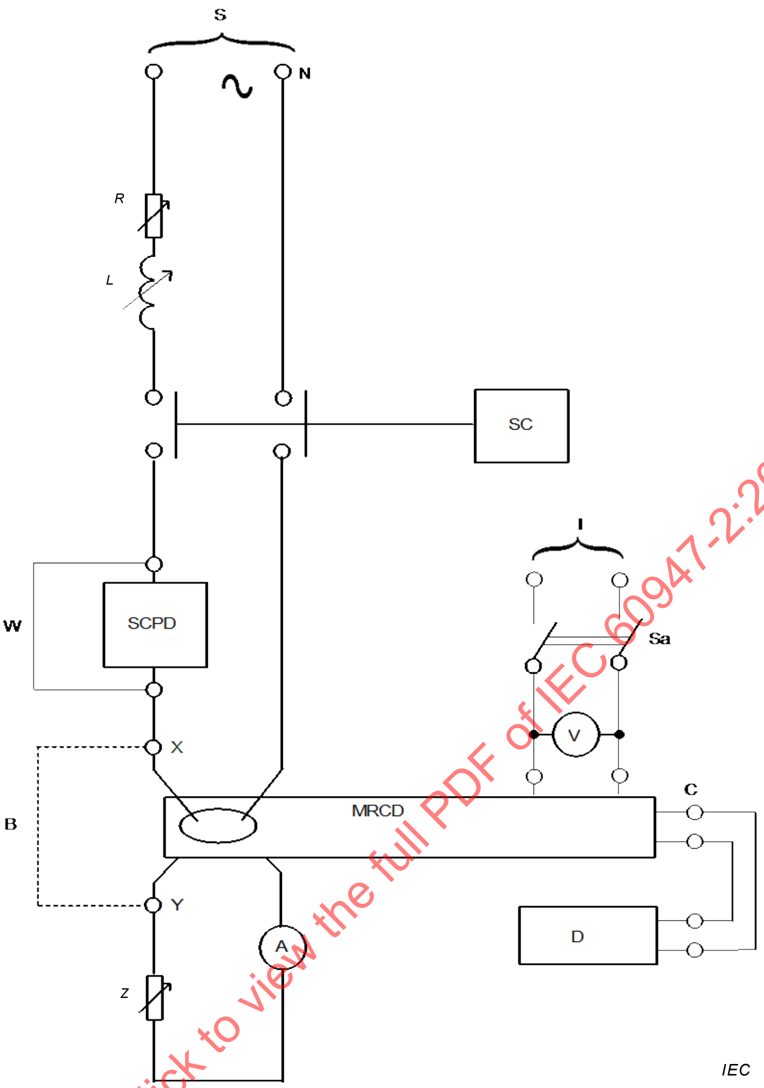
T sensing means

C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

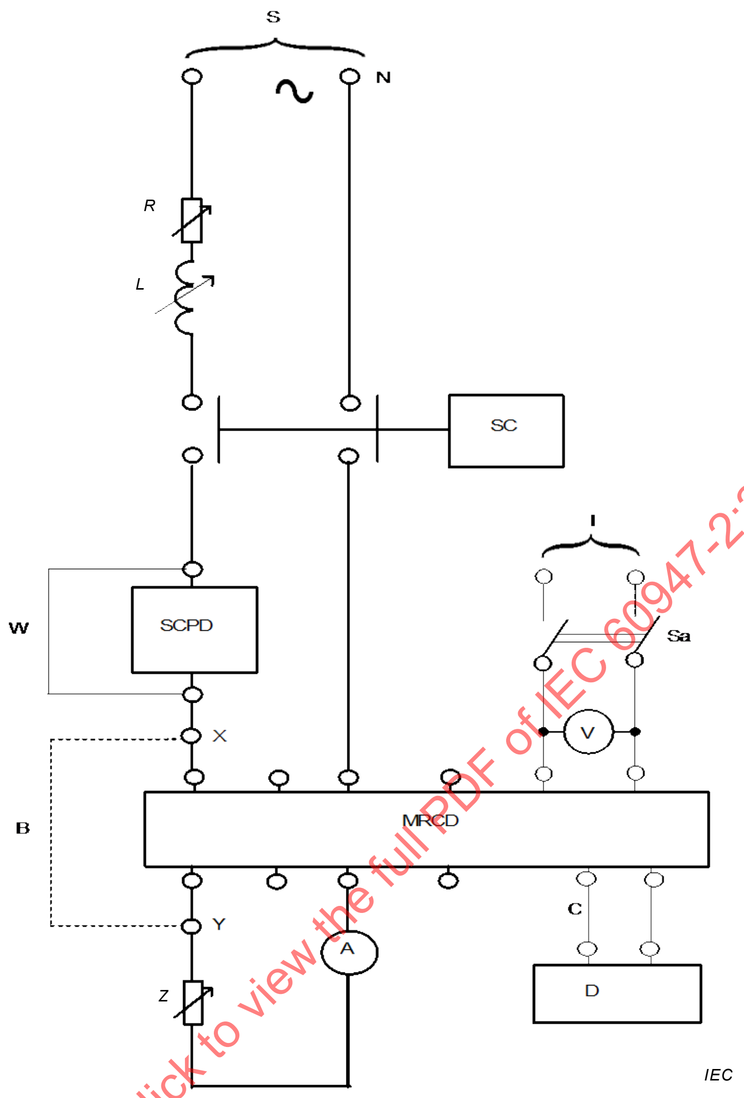
Figure M.17 – Test circuit for the verification of the behaviour of MRCD with separate sensing means under short-circuit conditions



Key

S	power supply	B	connection for residual short-circuit test, replacing the connection through the sensing means
I	separate voltage source, if applicable	*L*	variable reactor
V	voltmeter	*R*	variable resistance
A	ammeter	*Z*	variable impedance
S_a	auxiliary switch	C	output circuit
SC	short-circuit switch	D	instrument indicating the change of status
W	temporary connection	SCPD	short-circuit protective device

Figure M.18 – Test circuit for the verification of the behaviour of MRCD with integral sensing means under short-circuit conditions



Key

S power supply

A ammeter

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistor

Z variable impedance

C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.19 – Test circuit for the verification of the behaviour of terminal type MRCD under short-circuit conditions

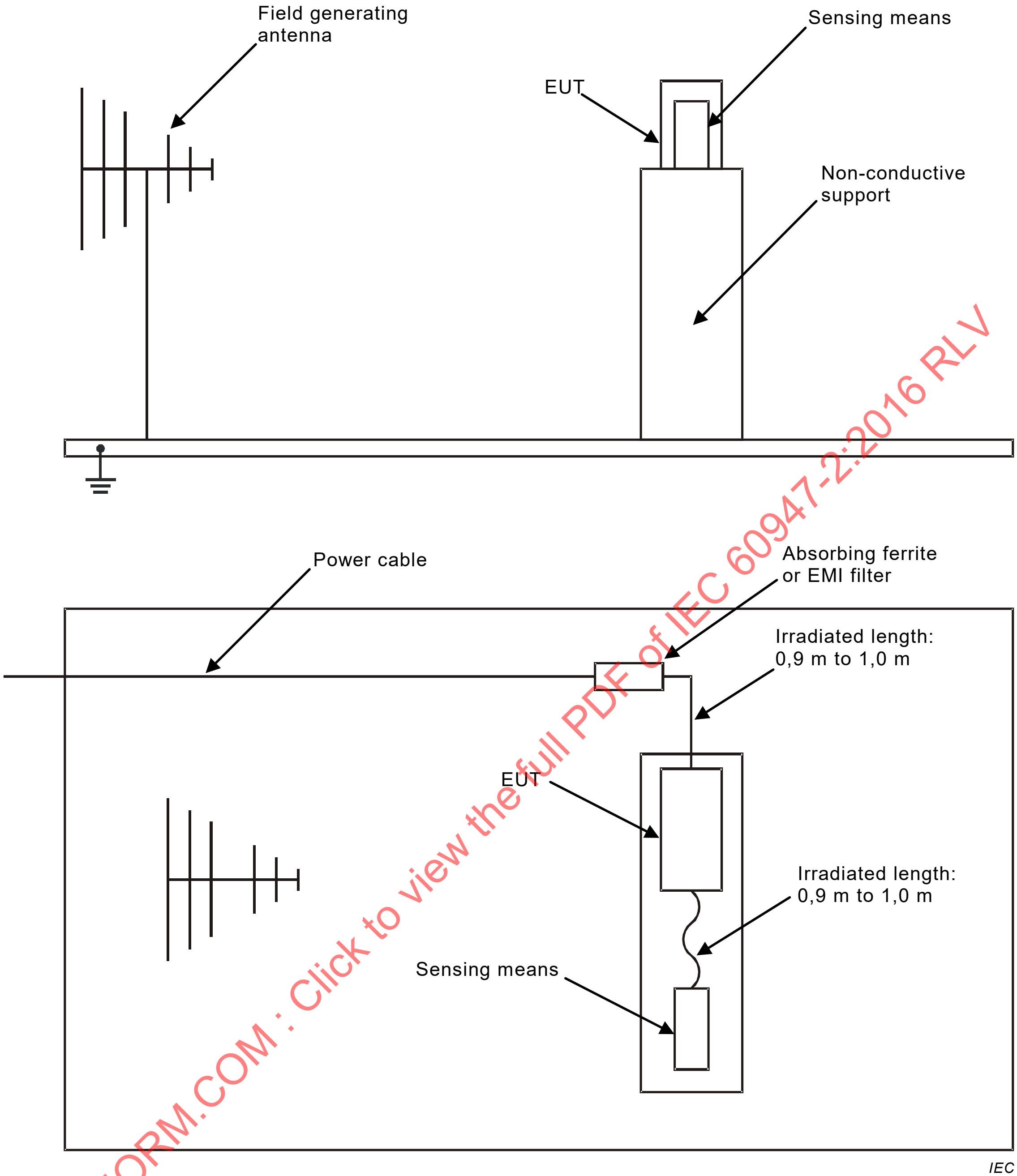


Figure M.20 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCD with separate sensing means (additional to the test of Annex B)

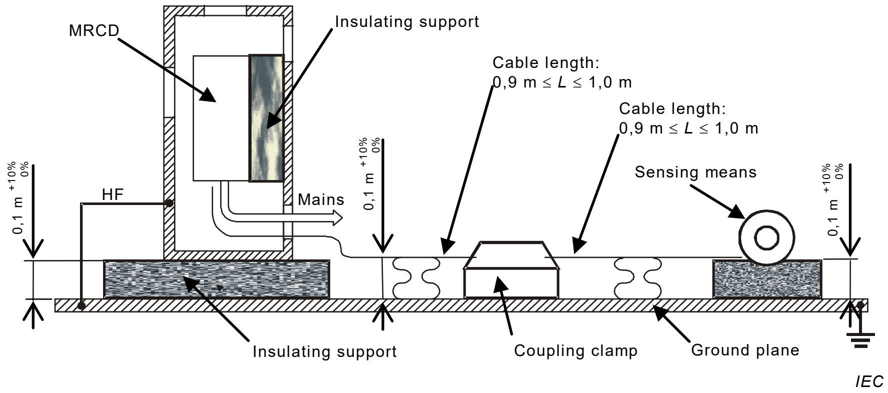


Figure M.21 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (additional to the test of Annex B)

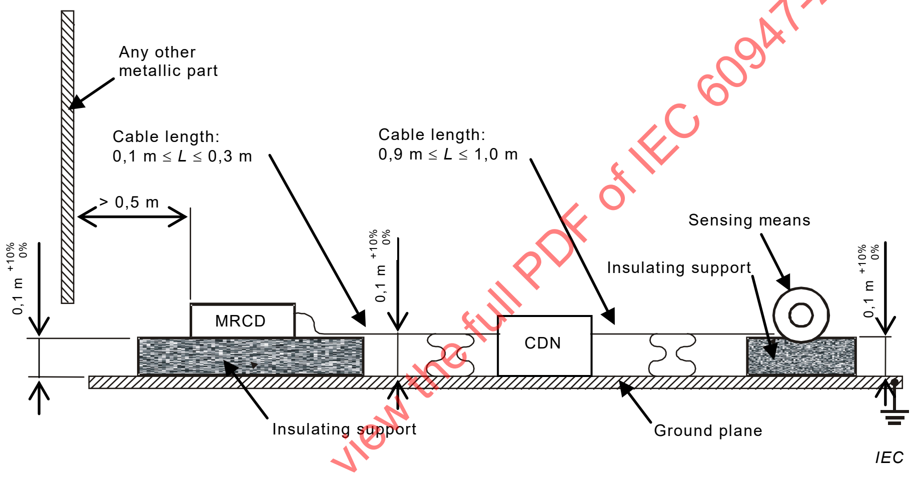


Figure M.22 – Verification of immunity to conducted disturbances induced by RF fields – Test set up for MRCD with separate sensing means (additional to the test of Annex B)

Annex N
(normative)

Electromagnetic compatibility (EMC) – Additional requirements and test methods for devices not covered by Annex B, Annex F and Annex M

N.1 General

N.1.1 General

This annex applies to devices, mounted in or on the circuit-breaker, incorporating electronic circuits (see 7.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014), and not covered by Annex B (circuit-breakers incorporating residual current protection), Annex F (circuit-breakers with electronic overcurrent protection) and Annex M (modular residual current devices).

It covers circuit-breaker auxiliaries such as undervoltage releases, shunt releases, closing coils, motor-operators, remote status indicators, etc. Communication modules are not covered by these requirements.

It supplements Annex J, for test conditions and acceptance criteria specific to these devices.

N.1.2 General test conditions

Tests according to this annex may be performed separately from the test sequences of Clause 8.

A new device may be used for each test, or one device may be used for several tests, at the manufacturer's discretion.

For devices with different voltage supply ratings, one device of each rating shall be tested.

Tests on closing coils are not necessary if their construction (coil and electronic control) is identical to the equivalent shunt trips.

The devices shall be mounted in or on the circuit-breaker, in accordance with the manufacturer's instructions.

Undervoltage releases and power ports intended to be permanently connected to a power supply shall be supplied with the rated voltage. In case of a range of rated voltages, they shall be supplied at any convenient voltage within this range.

Devices rated from 50 Hz to 60 Hz may be tested at either one of the rated frequencies.

N.2 Immunity

N.2.1 General

N.2.1.1 Test conditions

Immunity tests may be performed on a circuit-breaker fitted with different devices, and may be combined with the corresponding tests of Annex B and Annex F, where applicable (e.g. electrostatic discharges, radiated RF electromagnetic fields, etc.).

Devices, except closing coils, shall be tested with the circuit-breaker closed.

Closing coils, if applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

N.2.1.2 Performance criteria

Criterion A: during the test, the status of the circuit-breaker shall not change and the status of the outputs of remote indication modules shall not change.

Criterion B: during the test, the status of the circuit-breaker shall not change while the status of the outputs of remote indication modules may change temporarily, but shall indicate the correct status of the circuit-breaker after the test.

After the tests, the simplified functional verification of N.2.1.3 shall be made.

N.2.1.3 Simplified functional verification

For both criteria, after the test, the operation of the device shall be checked at the rated voltage, or, in the case of a range of rated voltages, at any convenient voltage within this range:

a) An undervoltage release, when energized, shall not prevent the circuit-breaker from being closed; when the voltage is removed, the circuit-breaker shall trip.
b) A shunt trip, when energized, shall trip the circuit-breaker.
c) A closing coil, when energized, shall close the circuit-breaker.
d) A motor-operator, when energized in accordance with the manufacturer's instructions, shall be capable of closing and opening the circuit-breaker.

NOTE This test is intended only to check that the device has not been damaged during the immunity tests. It is not intended to check the full compliance with the requirements of the main body of this standard.

N.2.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

Performance criterion B of N.2.1.2 applies.

N.2.3 Radiated RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test connections shall be in accordance with Figures 5 or 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer’s instructions for installation. The type of cable used shall be stated in the test report.

For step 1 (see J.2.3), the performance criterion A applies.

For step 2 (see J.2.3), at each of the frequencies listed in J.2.3, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figures 11, 12, 13 and 14 of IEC 61000-4-4:2012, taking into consideration the manufacturer’s instructions for installation.

Performance criterion A applies.

N.2.5 Surges

Annex J applies, in particular J.2.5.

The test connections shall be in accordance with Figures 5, 6, 7, 8, 9, 10 or 11 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

N.2.6 Conducted disturbances induced by RF fields (common mode)

Annex J applies, in particular J.2.6.

For step 1 (see J.2.6), the performance criterion A applies.

For step 2 (see J.2.6), at each of the frequencies listed in J.2.6, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.7 Voltage dips and interruptions

These tests are applicable to devices with permanent a.c. power supply only.

Tests shall be performed in accordance with IEC 61000-4-11, at test levels of Table 23 of IEC 60947-1:2007/AMD1:2010.

During the test, the status of the circuit-breaker may change. The status of the outputs of remote indication modules may change, but shall indicate the correct status of the breaker after the test. After the test, the correct operation of the device shall be checked in accordance with N.2.1.3.

N.3 Emission

N.3.1 General

These tests are applicable to devices incorporating electronic circuits with fundamental switching frequencies greater than 9 kHz (see 7.3.3.2.1 of IEC 60947-1:2007/AMD2:2014), and intended for continuous operation (e.g. undervoltage releases).

They are not applicable to shunt trips intended only for use with a clearing switch, either built-in or separate.

They are not applicable to motor-operators not incorporating permanently energized electronic circuits, because these devices are operated at very infrequent intervals and the duration of the operations (closing, opening or resetting) is very short (a few hundreds of milliseconds to a few seconds).

Each device shall be submitted to separate emission tests, these tests shall not be combined with the corresponding tests of Annex B and Annex F.

Closing coils, when applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

Undervoltage releases and closing coils shall be tested with the circuit-breaker closed.

Shunt trips and motor-operators shall be tested with the circuit-breaker open.

Remote status indicators shall be tested with the circuit-breaker closed.

N.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

N.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

Annex J applies, in particular J.3.3.

Annex O
(normative)

Instantaneous trip circuit-breakers (ICB)

O.1 General

This annex covers circuit-breakers which fulfil only the short-circuit portion of overcurrent protection specified in the main part of this standard, hereinafter referred to as ICBs. They comprise instantaneous short-circuit releases which may be adjustable but not overload releases. These devices are generally used in conjunction with other equipment such as motor-starters, overload relays, etc. In combination with specified overload relays, they offer complete overcurrent protection (overload and short-circuit) to both the circuit and specified equipment.

An ICB forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (see O.2.1) by omitting the overload releases and incorporating a short-circuit release, which may be adjustable, designed to provide co-ordinated overcurrent protection when associated with specified motor-starters or overload relays.

O.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

O.2.1
equivalent circuit-breaker
circuit-breaker from which the ICB has been derived, which has been tested according to this standard and which has the same frame size as the ICB

O.3 Rated values

O.3.1 General

The characteristics of Clause 4 apply with the exception of the reference to overload releases and with the following additions.

O.3.2 Rated current (I_n)

The rated current of an ICB shall not exceed the rated current of the equivalent circuit-breaker.

O.3.3 Rated short-circuit making capacity

ICBs may be assigned a rated short-circuit making capacity different to the equivalent circuit-breaker.

NOTE ICBs can be assigned a rated short-circuit making capacity equal to or greater than that of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.3.4 Rated short-circuit breaking capacities

ICBs may be assigned rated short-circuit breaking capacities different to the equivalent circuit-breaker.

NOTE ICBs can be assigned a rated short-circuit breaking capacity equal to or greater than I_{cu} of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.4 Product information

An ICB shall be marked according to 5.2 as relevant.

Rated short-circuit making and breaking capacities shall be marked, where applicable (see O.6.1.1). When the ICB is only rated for short-circuit performance in association with a motor-starter or overload relay (see O.6.2), the short-circuit ratings of the association shall not be marked on the ICB.

In addition the ICB shall be marked as follows:

– for 5.2, item a), add the marking “ICB”;
– for 5.2, item b), add the rated instantaneous short-circuit current settings I_i (see 2.20) (actual values or multiples of rated current).

Manufacturers’ instructions shall draw attention to the fact that, below the rated instantaneous short-circuit current settings, an ICB provides no overcurrent protection to itself or to the circuit. Such protection shall be provided separately.

When an ICB is not associated with a specified protected device (see O.6.2), the manufacturer shall provide data to permit the selection of suitable overload protection, e.g. withstand characteristics of the ICB up to its maximum instantaneous setting.

O.5 Constructional and performance requirements

An ICB, being derived from the equivalent circuit-breaker (see O.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4, item b).

O.6 Tests

O.6.1 Test sequence of the ICB alone

O.6.1.1 General

The tests of this subclause are not required if

– the short-circuit characteristics of the short-circuit releases and the main current paths of the ICB are the same as those of the equivalent circuit-breaker, or
– the ICB is only rated and tested as an association (see O.6.2).

A sample of each of the maximum and minimum values of the rated current I_n of each frame size shall be tested.

In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample shall be tested at the maximum rated current corresponding to each construction.

O.6.1.2 Test sequences

Tests shall be made according to sequences II and III of this standard without the verification of overload releases.

For ICBs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. The other variant(s) shall be submitted to the tests of sequence III only (without the verification of overload releases).

O.6.1.3 Verification of short-circuit releases

Following the test of O.6.1.2, a tripping test is made in accordance with 8.3.3.2.2 on each phase pole in turn, at the maximum setting of the rated instantaneous short-circuit current. The test is made at the value of the tripping current declared by the manufacturer for individual poles. The ICB shall trip.

O.6.2 ICB associated with a specified protected device (i.e. motor-starter or overload relay)

The applicable test requirements for these associations are covered in the relevant sections of IEC 60947-4-1, specifically the following clauses:

– co-ordination with short-circuit protective devices;

– additional requirements for combination starters and protected starters suitable for isolation;

– performance under short-circuit conditions;

– co-ordination at the crossover current between the starter and associated SCPD.

NOTE The symbol SCPD in IEC 60947-4-1 applies to various short-circuit protective devices, including the ICB.

Annex P
(normative)

DC circuit-breakers for use in photovoltaic (PV) applications

P.1 Field of application

This annex applies to d.c. circuit-breakers, rated up to 1 500 V d.c., intended for use with photovoltaic (PV) systems, and hereafter referred to as "PV circuit-breakers".

Circuit-breakers used in PV systems are subjected to electrical, environmental and operational conditions which differ from the general conditions taken into account in the body of this standard.

The requirements have thus been adapted to reflect these conditions of use.

The object of this annex is to state:

– the requirements for circuit-breakers to be used on the d.c. side of PV applications;
– the tests intended to verify the product performances and their maintaining after exposure to the PV service environmental conditions.

P.2 Terms and definitions

Clause 2 applies.

P.3 Classification

Clause 3 applies.

P.4 Characteristics of PV circuit-breakers

Clause 4 applies with the following modification:

A PV circuit-breaker rated for use not only in PV applications shall have only one rated current.

The impulse withstand voltage (U_{imp}) of PV circuit-breakers shall comply with Table P.1.

Table P.1 – Rated impulse withstand levels for PV circuit-breakers

Maximum value of rated operational voltage (V)	Value of rated impulse withstand voltage (V)
300	2 500
600	4 000
1 000	6 000
1 500	8 000
NOTE These values are based on requirements in IEC 60364-7-712 for overvoltage category II, as defined in IEC 60664-1 and IEC/TR 60664-2-1:2011, Annex D.	

P.5 Product information

Subclause 5.2 applies with the following additions:

A PV circuit-breaker shall be marked "IEC 60947-2, Annex P" under the conditions of item 5.2 b).

A circuit-breaker rated for use not only in PV applications shall have the ratings U_e and corresponding I_{cu} / I_{cs} according to this annex clearly separated from the ratings according to the body of this standard.

A PV circuit-breaker shall have method and diagram of series connection of poles (as necessary for each rating) marked under the conditions of item 5.2 c).

P.6 Normal service, mounting and transport conditions

Clause 6 applies with the following addition:

Guidance on de-rating for ambient air temperature up to 70 °C may be provided. In addition guidance on operation at temperature lower than -5 °C may also be given.

P.7 Constructional and performance requirements

P.7.1 Constructional requirements

Subclause 7.1 applies.

P.7.2 Performance requirements

Subclause 7.2 applies with the following modifications:

PV circuit-breakers shall be capable of interrupting any current up to their rated short-circuit breaking capacity, including critical load current, if exists, in both forward and reverse directions.

Compliance with these requirements is checked by the tests of P.8.3.

With reference to 7.2.4.1, such overload conditions do not arise in the case of PV applications. Overcurrent conditions can only result from a short-circuit. Therefore, no tests to this clause are required. Tests for short-circuit performance are given from P.8.3.4 to P.8.3.8.

With reference to 7.2.4.2 for operational performance capability, PV circuit-breakers shall be capable of meeting the requirements of Table P.2.

Table P.2 – Number of operating cycles

Rated current [a] (A)	Number of operating cycles per hour [b]	Number of operating cycles		
		Without current	With current [c]	Total
$I_n \leq 100$	120	9 700	300	10 000
$100 < I_n \leq 315$	120	7 800	200	8 000
$315 < I_n \leq 630$	60	4 800	200	5 000
$630 < I_n \leq 2\ 500$	20	2 900	100	3 000
$2\ 500 < I_n$	10	1 900	100	2 000

[a] This means the maximum rated current for a given frame size.

[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

[c] During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

Due to the installation rules defined in IEC 60364-7-712, the risk of a double fault to earth does not need to be taken in consideration. Therefore, Annex H of this standard is not applicable to PV circuit-breakers.

NOTE The case of a PV circuit-breaker having to interrupt a small fault current on one pole only is under consideration.

P.7.3 Electromagnetic compatibility (EMC)

Subclause 7.3 applies.

P.8 Tests

P.8.1 Kind of tests

Subclause 8.1 applies.

P.8.2 Compliance with constructional requirements

Subclause 8.2 applies.

P.8.3 Type tests

Subclause 8.3 applies with the following modifications:

P.8.3.1 Test sequences

With reference to 8.3.1.2, tests omitted from test sequence I need not be made if the PV circuit-breaker is derived from a circuit-breaker on which identical or more severe tests have already been conducted, except that tripping characteristics conducted in a.c. do not cover d.c. characteristics.

With reference to 8.3.1.4, alternative test programmes do not apply to PV circuit-breakers.

P.8.3.2 General test conditions

For all tests, the series connection of poles of the circuit-breaker shall be in accordance with the manufacturer instructions.

Samples shall be selected and tested according to column "Terminals marked line/load-No" of Table 10.

With reference to 8.3.2.2.5, the time constant for operational performance capability, short-circuit tests and critical d.c. load current test shall be equal to 1 ms. At the discretion of the manufacturer, a higher value may be used. In this case, it shall be stated in the test report.

P.8.3.3 Test sequence I

Subclause 8.3.3 applies with the following modifications:

With reference to 8.3.3.4.3, for operational performance capability without current, the number of operating cycles and the number of cycles per hour are given in Table P.2.

With reference to 8.3.3.4.4, for operational performance capability with current, the number of operating cycles and the number of cycles per hour are given in Table P.2, and the time constant shall comply with P.8.3.2. Half of the operations shall be made with the currents flowing in one direction, the other half with the other direction.

With reference to 8.3.3.5, the overload performance test is not applicable.

P.8.3.4 Test sequence II

Subclause 8.3.4 applies, with the modifications listed in P.8.3.2.

P.8.3.5 Test sequence III

Subclause 8.3.5 applies with the modifications listed in P.8.3.2.

P.8.3.6 Test sequence IV

Subclause 8.3.6 applies with the modifications listed in P.8.3.2.

P.8.3.7 Test sequence V

Subclause 8.3.7 applies with the modifications listed in P.8.3.2.

P.8.3.8 Test sequence VI

Subclause 8.3.8 applies with the modifications listed in P.8.3.2.

P.8.3.9 Critical d.c. load current test

Subclause 8.3.9 applies with the following modifications:

The circuit-breaker shall be closed and opened 10 times on to each of the test currents, 5 times with the current flowing in the forward direction, and 5 times with the current flowing in the reverse direction.

The time constant shall comply with P.8.3.2.

During the operational performance verification, if applicable, the breaker shall be subjected to 100 operations instead of 50.

P.8.3.10 Thermal cycling test

PV circuit-breakers shall be subjected to temperature cycling according to IEC 60068-2-14, test Nb, consisting of 50 cycles, each cycle consisting of 1 h at – 40 °C followed by 1 h at + 85 °C.

Temperature change rate shall be 1 K/min. At the conclusion of the 50 cycles, the devices shall be returned to room temperature of 25 ± 5 °C for a minimum of 3 h.

The device shall then be subjected to:

– a visual inspection to confirm that there is no distortion or damage to parts that will affect normal operation and protection;
– the verification of overload releases according to 8.3.3.2.3;
– a verification of temperature rise at the main terminals in accordance with 8.3.2.5. The temperature rise shall not exceed the values given in Table 7;
– a verification of dielectric withstand according to 8.3.3.6.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I.

P.8.3.11 Climatic test

PV circuit-breakers shall be subjected to the climatic tests of IEC 60947-1:2007/AMD1:2010/AMD2:2014 Annex Q, category B: environment subject to temperature and humidity, except that the dry heat test and the low temperature test are not required, as they are deemed to be covered by the thermal cycling test of P.8.3.10.

Where Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 calls for verification of operational performance capability, this shall be made by carrying out the routine tests to 8.4 of this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I. At the discretion of the manufacturer, this test may be combined with the thermal cycling test and made on the same samples.

P.8.4 Routine tests

Subclause 8.4 applies.

P.8.5 Special tests

Subclause 8.5 applies.

Annex Q

Vacant

Annex R
(normative)

Circuit-breakers incorporating residual current protection with automatic re-closing functions

R.1 General

R.1.1 Preamble

CBRs according to Annex B of this standard are used as protective devices to provide protection against the effects of electric shock hazards.

CBRs according to Annex B need to be manually reset after tripping.

CBRs may be installed at remote, unmanned locations such as telecommunication stations or traffic signaling sites. Where such a CBR is tripped due to a lightning surge or temporary earth leakage there will be a delay and cost in travel to site to effect rectification and restoration of the supply.

The results of this tripping by temporary faults such as the blackout of a mobile telecommunication station or malfunction of a traffic light system could cause inconvenience or danger to life.

CBRs with automatic reclosing functions are intended to improve the efficiency of operating unmanned facilities.

This annex is essentially based on the relevant requirements of Annex B of this standard.

R.1.2 Field of application

This annex applies to CBRs, hereinafter referred to as CBARs, which restore the power supply through automatic reclosing without manual operation, in the case of tripping due to the residual current function.

This annex also applies to automatic reclosing devices supplied separately which, when combined with a CBR, fulfils the requirements of a CBAR. For the purpose of this annex, the term CBAR also covers an automatic reclosing device combined with a CBR.

This annex also covers the requirements for CBARs concerning electromagnetic compatibility (EMC).

This annex applies only to CBARs intended for use in a.c. circuits.

The residual current function of CBARs according to this annex may or may not be functionally dependent on line voltage. CBARs depending on an alternative supply source for the residual current function are not covered by this annex.

The object of this annex is to state:

a) specific features of the automatic reclosing function;
b) specific requirements which shall be complied with by the CBAR:
   – under normal circuit conditions;
   – under abnormal circuit conditions;
   – under temporary fault conditions.

c) tests which shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures;

d) relevant product information.

R.2 Terms and definitions

As a complement to Clause 2 and Clause B.2 of this standard, the following additional terms and definitions apply:

R.2.1
automatic reclosing
operating sequence of a mechanical switching device whereby, following its opening, it closes automatically depending on specific conditions

[SOURCE: IEC 60050-441:1984, 441-16-10, modified – term and supplemented by “depending on specific conditions”]

R.2.2
rated automatic reclosing operating residual current
$\boldsymbol{I_{\Delta ar}}$
maximum value of the residual current at which a type M CBAR recloses automatically under the specified conditions (see R.3.2.1)

R.2.3
selector switch
switch for selecting automatic reclosing or manual reclosing mode

R.2.4
reset time
maximum period of time, declared by the manufacturer, during which consecutive reclosing operations may be made

R.2.5
blocked state
state of the CBAR in which the automatic reclosing function is inhibited and a manual reset is necessary

R.2.6
reclosing time-delay
for type TD CBAR, maximum time between the tripping of the device and the reclosing of the contacts

Note 1 to entry: For definition of type TD CBAR, see R.3.2.2.

R.2.7
reclosing time
for type M CBAR, maximum time between the instant when the reclosing condition is fulfilled and the reclosing of the contacts

Note 1 to entry: For definition of type M CBAR, see R.3.2.1.

R.2.8
monitoring time
for type M CBARs, time during which the monitoring is effective after operation of the residual current tripping function

R.3 Classification

As a complement to Clause 3 and Clause B.3 of this standard, the following additional classifications apply.

R.3.1 According to the method of construction

R.3.1.1 Integral CBAR

CBAR as a single unit comprising an automatic reclosing function integrated by the manufacturer with the circuit-breaker.

R.3.1.2 External automatic reclosing device

An automatic reclosing device externally connected to a CBR without modification of its internal circuits or components.

R.3.2 According to the method of automatic reclosing

R.3.2.1 Earth leakage monitoring type (M)

CBAR, hereafter called "type M", which monitors the downstream circuit to assess the presence of an earth fault, and does not allow reclosing when the assessed earth leakage current exceeds $I_{\Delta ar}$.

The monitoring shall be achieved through the use of the line voltage. It may be either continuous or intermittent.

Type M CBARs with limitation of test voltage monitors the downstream circuit by means of a non-hazardous voltage, hereinafter called "monitoring voltage".

Type M CBARs with limitation of test current monitors the downstream circuit by means of a non-hazardous current, hereinafter called "monitoring current".

R.3.2.2 Time-delay type (TD)

CBAR, hereafter called "type TD", for which the automatic re-closing takes place after a time-delay without consideration of the circuit conditions.

R.4 Characteristics

Clause 4 and Clause B.4 of this standard apply with the following addition.

R.4.1 Rated automatic reclosing operating residual current ($I_{\Delta ar}$)

The value of the rated automatic reclosing operating residual current shall be declared by the manufacturer, without exceeding $I_{\Delta n}$. The manufacturer may declare different values of $I_{\Delta ar}$ for different rated voltages.

R.4.2 Maximum number of consecutive reclosing operations

The reset time and the maximum number of consecutive reclosing operations within the reset time shall be declared by the manufacturer.

R.5 Marking and instructions

As a complement to Clause 5 and Clause B.5 of this standard, the following additional marking shall apply:

a) The following data shall be marked on the device, in addition to the marking specified in 5.2 a) and B.5, and be clearly visible in the installed position:
   – indication of mode selection of the selector switch: "automatic reclosing" and "manual reclosing";

b) The following data shall also be marked externally on the device, as specified in item a), except that they need not be visible when the device is installed. This data shall also be made available in the manufacturer's literature:
   – rated control circuit supply voltage (U_s) of the CBAR, if applicable;
   – rated automatic reclosing operating residual current ($I_{\Delta ar}$);
   – meaning of the indicators (e.g. lamps), if applicable;

c) The following data shall either be marked on the device as specified in item b), or made available in the manufacturer's literature:
   – procedure for replacement of any built-in fuse;
   – procedure for the connection of the earth terminal when necessary for the automatic reclosing function;
   – reset time and corresponding maximum number of reclosing operations;
   – monitoring time and reclosing time for type M CBARs;
   – reclosing time-delay for type TD CBARs.

R.6 Normal service, mounting and transport conditions

Clause 6 applies.

R.7 Design and operating requirements

R.7.1 Design requirements

As a complement to 7.1 and B.7.1 of this standard, the following additional requirements apply:

R.7.1.1 Mode selection

The device shall be equipped with a selector switch (see R.2.3).

Compliance is checked by the tests of R.8.4.4.

R.7.1.2 Indicators

The device shall be provided with an indicator showing the blocked state.

All indicators shall be visible in the installed position.

R.7.1.3 Type M CBARs

It shall be ensured that no hazardous voltage or current is applied to the load terminals. One of the following methods shall be employed:

– The monitoring voltage (see R.3.2.1) shall be supplied by a transformer providing Class II isolation between primary and secondary circuits. The monitoring voltage shall not exceed 25 V a.c. or 60 V d.c.; or

– The monitoring current (see R.3.2.1) shall be supplied from a current-limiting source or a protective impedance device complying with IEC 61140. The steady-state current shall not exceed 1 mA a.c. or 2 mA d.c.

R.7.2 Operating requirements

As a complement to 7.2 and B.7.2 of this standard, the following additional requirements apply:

R.7.2.1 General

CBARs shall only reclose automatically after tripping due to the residual current function. Compliance is checked by the tests of R.8.2.

CBARs shall not reclose automatically after intentional opening of the circuit-breaker. Compliance is checked by the tests of R.8.3.

When the maximum number of automatic reclosing operations within the reset time is reached, the automatic reclosing function shall be blocked until a manual reset is performed.

The reset time shall be not less than 5 s.

R.7.2.2 Type M CBARs

After tripping of the residual current release, if the assessed earth leakage current is lower than $I_{\Delta ar}$, a type M CBAR shall automatically reclose within the reclosing time declared by the manufacturer.

After tripping of the residual current release, if the assessed earth leakage current is higher than $I_{\Delta ar}$, the automatic reclosing shall be inhibited. In this case, the monitoring shall not be effective for a period of time longer than the monitoring time declared by the manufacturer. After this time, the automatic reclosing function shall be blocked.

The monitoring time shall be less than 1 h.

Compliance is checked by the tests of R.8.4.2.

R.7.2.3 Type TD CBAR

After tripping due to the residual current function, a type TD CBAR shall automatically reclose within the reclosing time-delay declared by the manufacturer, unless it has reached the maximum number of consecutive reclosing operations within the reset time.

Compliance is checked by the tests of R.8.4.3.

NOTE A type TD CBAR will not reclose on a phase-to-phase short-circuit, but can potentially reclose on a phase-to-ground fault.

R.7.2.4 Residual short-circuit making and breaking capacity

CBARs shall make, carry for a specified time and break residual short-circuit currents.

Compliance is checked by the tests of R.8.7.

R.7.2.5 Effects of environmental conditions

CBARs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the tests of R.8.8.

R.8 Tests

R.8.1 General conditions

As a complement to Clause 8 and Clause B.8 of this standard, the following additional requirements apply.

Integral CBARs shall meet the test requirements from R.8.2 to R.8.8 except that the tests of R.8.6 only apply to CBARs suitable for isolation.

One sample shall be submitted to the tests of R.8.2, R.8.3 and R.8.4 in sequence.

The tests from R.8.5 to R.8.8 may be made during the test sequences of Clause 8.

External CBARs shall meet the test requirements of R.8.9.

Tests shall be performed in automatic reclosing mode, unless otherwise stated, the CBAR being supplied with the maximum rated voltage and the rated control circuit supply voltage, if applicable.

The CBAR shall be connected as per the manufacturer's instructions.

EMC tests of B.8.12 shall be performed in both automatic re-closing mode and manual re-closing mode.

R.8.2 Verification of the non-reclosing after tripping under over-current conditions

R.8.2.1 Tripping under short-circuit conditions

The circuit-breaker shall be tripped through its short-circuit release by applying a test current higher or equal to 120 % of the short-circuit current setting on one combination of two poles in series chosen at random (see 8.3.3.2.2). In case of adjustable current setting, the test shall be performed at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker short-circuit release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

R.8.2.2 Tripping under overload conditions

The circuit-breaker shall be tripped through its overload release by applying a test current higher than 130 % of the overload current setting and lower than 80 % of the short circuit current setting. This test may be performed at any ambient temperature and in case of adjustable current setting, at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker overload release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

R.8.3 Verification of the non-reclosing after intentional opening

The selector switch being in the "automatic reclosing" position and the control circuit supply voltage normally applied, the circuit-breaker is opened manually. The device shall not reclose automatically after opening. The test duration shall be twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

This test shall be repeated for opening through shunt trip or undervoltage release as applicable, using any convenient rated control voltage variant.

R.8.4 Verification of the automatic reclosing function after tripping on earth fault

R.8.4.1 General

The devices shall be installed as in normal use.

The test circuit shall be in accordance with Figure R.1.

R.8.4.2 Verification of the correct operation of type M CBARs

R.8.4.2.1 In case of continuous residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

The switch S_2 shall be maintained in the closed position for the monitoring time declared by the manufacturer (see R.7.2.2).

The monitoring voltage or current shall comply with the requirements of R.7.1.3.

The CBAR shall not reclose automatically.

At the end of the monitoring time, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

R.8.4.2.2 In case of temporary residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.The CBAR shall trip.

After tripping, the residual current is reduced to the value of $I_{\Delta ar}$ corresponding to the applied voltage.

The CBAR shall reclose automatically within the reclosing time declared by the manufacturer.

The test is repeated as many times as necessary to verify the maximum number of consecutive reclosing operations within the reset time, as declared by the manufacturer. At the end of the test, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

R.8.4.3 Verification of the correct operation of type TD CBARs

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay (Δt) as applicable.

The test circuit being calibrated at 2 × $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall reclose automatically within the reclosing time-delay, repeated for the maximum number of consecutive reclosings within the reset time, as declared by the manufacturer.

At the end of the test, the CBAR shall be in the blocked state.

R.8.4.4 Verification of the correct operation of the selector switch

The test is made on one pole only chosen at random, with the selector switch in the "manual reclosing" position, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit being calibrated at 2 × $I_{\Delta n}$, and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

Immediately after tripping, the switch S_2 is re-opened; the CBAR shall not reclose automatically within twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

R.8.5 Verification of mechanical endurance

R.8.5.1 External automatic reclosing device combined with a CBR previously tested to Annex B or CBAR previously tested to Annex B

The test circuit is in accordance with Figure R.1.

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit is calibrated at 2 × $I_{\Delta n}$. With the switch S_1 and the CBAR in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall be reclosed automatically.

The test shall be repeated for one-third of the number of "operations with current" specified in Table 8. No failure to trip or to reclose shall be permitted.

NOTE Depending on the reset time and corresponding maximum number of consecutive reclosing operations, it may be necessary to manually reset the CBAR or inhibit the blocking function.

R.8.5.2 CBAR not previously tested to Annex B

The test of R.8.5.1 may be carried out separately or during the operational performance test of B.8.1.1.1, replacing the operations performed by applying a residual current.

R.8.6 Verification of the isolation function

R.8.6.1 General

This verification only applies to CBARs suitable for isolation.

The tests of R.8.6.2 and R.8.6.3 shall be performed in all positions of the selector switch and in the blocked state.

R.8.6.2 Leakage current between open contacts

The following requirements apply:

a) Following the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA.

b) Following the test of 8.3.3.6 (Test sequence I, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.

c) Following the test of 8.3.4.4 (Test sequence II, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.

d) If applicable, following the test of 8.3.5.4 (Test sequence III, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 6 mA.

R.8.6.3 Impulse voltage between open contacts

During the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the test voltage shall be applied between the line terminals being connected together and load terminals being connected together of CBARs with the contacts in the open position and its value shall be as specified in Table 14 of IEC 60947-1:2007.

There shall be no unintentional disruptive discharge during the tests.

R.8.7 Verification of residual short-circuit making and breaking capacity

B.8.10 applies, with the following additional requirements:

The tests shall be performed in automatic reclosing mode, if applicable, with the line voltage (i.e. control circuit supply voltage) connected to the CBAR.

The following additional requirements shall be met after test:

– The CBAR shall comply with the test of B.8.10.4.2 regardless of the operation of the protection devices (fuse, etc.);

– In case of operation of the protection devices (fuse, etc.), this operation shall be shown by the appropriate indication means, if provided. If no indication mean is provided, it shall not be possible to reclose the CBAR, even manually, when the protection devices have operated.

R.8.8 Verification of the automatic reclosing function after the test sequences of Clause B.8

Following each of the verifications of B.8.1.1.2 (verification of the withstand capability to short-circuit currents), a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

Following each of the test sequences B I to B IV of Annex B, a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

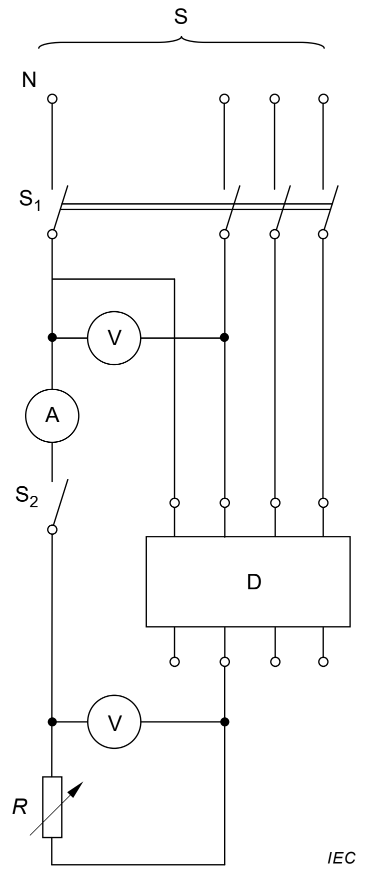
R.8.9 Test items for external type automatic reclosing devices

The following test sequences shall be performed on CBARs classified under R.3.1.2, in accordance with Figure R.1.

These tests are applicable to an automatic reclosing device assembled to a CBR and do not replace the tests of Clause B.8 made on the CBR.

Table R.1 – Test sequences for external type automatic re-closing devices

Sequence (sample)	Test	Subclause
1	Verification of the non-reclosing after tripping under over-current conditions	R.8.2
	Verification of the non-reclosing after intentional opening	R.8.3
	Verification of the automatic reclosing function after tripping on earth faults	R.8.4
	Verification of mechanical endurance	R.8.5
	Verification of the isolation function	R.8.6
2	Verification of the residual short-circuit making and breaking capacity	R.8.7
3	Rated ultimate short-circuit breaking capacity	8.3.5
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
4	Verification of the effects of environmental conditions	B.8.11
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
5	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Verification of electromagnetic compatibility	B.8.12
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8



Key:

S = power supply

N = neutral connection

S_1 = multipole switch

S_2 = single-pole switch

V = voltmeter

A = r.m.s. ammeter

D = CBAR under test

R = adjustable resistor

Figure R.1 – Test circuit for the verification of the automatic reclosing functions

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IEC 61008-1:2010/AMD2:2013

2 This publication was withdrawn.

3 "DB" refers to the IEC on-line database.

4 "DB" refers to the IEC on-line database.

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

AVANT-PROPOS

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8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets et de ne pas avoir signalé leur existence.

La Norme internationale IEC 60947-2 a été établie par le sous-comité 121A: Appareillages à basse tension, du comité d'études 121 de l'IEC: Appareillage et ensembles d'appareillages basse tension.

Cette cinquième édition annule et remplace la quatrième édition parue en 2006, l'Amendement 1:2009 et l'Amendement 2:2013. Cette édition constitue une révision technique.

Cette édition inclut les additions techniques majeures suivantes par rapport à l'édition précédente:

- essais pour la vérification de la sélectivité dans l'Annexe A (voir A.5.3),
- essais de courants de charge critiques pour disjoncteurs à courant continu (voir 8.3.9),

- nouvelle Annexe P relative aux disjoncteurs pour utilisation dans des applications photovoltaïques,
- nouvelle Annexe R relative aux disjoncteurs de courant différentiel résiduel avec fonctions de refermeture automatique.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
121A/71/FDIS	121A/83/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60947, publiées sous le titre général *Appareillage à basse tension*, peut être consultée sur le site web de l'IEC.

Cette Norme internationale doit être utilisée conjointement avec l'IEC 60947-1:2007 et ses Amendement 1:2010 et Amendement 2:2014.

Les dispositions des règles générales qui font l'objet de l'IEC 60947-1 sont applicables à la présente norme lorsque celle-ci le précise. Les articles, paragraphes, tableaux, figures et annexes des règles générales qui sont ainsi applicables sont identifiés par référence à l'IEC 60947-1 et ses amendements le cas échéant, par exemple: 1.2.3 de l'IEC 60947-1:2007, Tableau 4 de l'IEC 60947-1:2007/AMD1:2010, ou Annexe A de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

Le contenu du corrigendum de novembre 2016 a été pris en considération dans cet exemplaire.

IMPORTANT – Le logo «colour inside» qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

1 Généralités

1.1 Domaine d'application et objet

La présente partie de la série IEC 60947 est applicable aux disjoncteurs dont les contacts principaux sont destinés à être reliés à des circuits dont la tension assignée ne dépasse pas 1 000 V en courant alternatif ou 1 500 V en courant continu; elle contient aussi des exigences supplémentaires pour les disjoncteurs à fusibles incorporés.

Les disjoncteurs de caractéristiques assignées supérieures à 1 000 V en courant alternatif mais ne dépassant pas 1 500 V en courant alternatif peuvent également être soumis à essai selon la présente norme.

Elle est applicable quels que puissent être les courants assignés, les méthodes de construction et l'emploi prévu des disjoncteurs.

Les exigences pour les disjoncteurs qui sont aussi prévus pour assurer une protection contre les courants différentiels résiduels font l'objet de l'Annexe B.

Les exigences supplémentaires pour les disjoncteurs à protection électronique contre les surintensités font l'objet de l'Annexe F.

Les exigences supplémentaires relatives aux disjoncteurs pour réseaux IT font l'objet de l'Annexe H.

Les exigences et les méthodes d'essai pour la compatibilité électromagnétique des disjoncteurs font l'objet de l'Annexe J.

Les exigences pour les disjoncteurs ne satisfaisant pas aux exigences concernant les protections contre les surintensités font l'objet de l'Annexe L.

Les exigences pour les appareils modulaires à courant différentiel résiduel (non intégrés à un appareil de coupure de courant) font l'objet de l'Annexe M.

Les exigences et les méthodes d'essai pour la compatibilité électromagnétique des auxiliaires de disjoncteurs font l'objet de l'Annexe N.

Les exigences et les méthodes d'essai pour les disjoncteurs à courant continu utilisables dans les applications photovoltaïques (PV) font l'objet de l'Annexe P.

Les exigences et les méthodes d'essai pour les disjoncteurs incorporant une protection par courant différentiel résiduel avec fonctions de refermeture automatique font l'objet de l'Annexe R.

Les exigences supplémentaires pour les disjoncteurs utilisés comme démarreurs directs sont données dans l'IEC 60947-4-1, applicable aux contacteurs et aux démarreurs à basse tension.

Les exigences concernant les disjoncteurs destinés à la protection des installations électriques des bâtiments et à des emplois analogues et prévus pour être utilisés par des personnes non averties figurent dans l'IEC 60898.

Les exigences relatives aux disjoncteurs pour le matériel (par exemple pour les appareils électriques) figurent dans l'IEC 60934.

Des exigences particulières ou complémentaires peuvent être nécessaires pour certaines applications spécifiques (par exemple: traction, laminoirs, service à bord des navires).

NOTE Les disjoncteurs, objet de la présente norme, peuvent être munis d'appareils provoquant l'ouverture automatique dans des conditions prédéterminées autres que la surintensité et la chute de tension, telles que, par exemple, l'inversion de la puissance ou du courant. La présente norme ne traite pas de la vérification du fonctionnement dans de telles conditions prédéterminées.

La présente norme a pour objet de fixer:

a) les caractéristiques des disjoncteurs;
b) les conditions auxquelles doivent répondre les disjoncteurs concernant:
   1) leur fonctionnement et leur tenue en service normal;
   2) leur fonctionnement et leur tenue en cas de surcharge et en cas de court-circuit, y compris la coordination en service (sélectivité et protection d'accompagnement);
   3) leurs propriétés diélectriques;
c) les essais destinés à vérifier si ces conditions sont remplies et les méthodes à adopter pour ces essais;
d) les informations à marquer sur les appareils ou à fournir avec ceux-ci.

1.2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-14, *Essais d'environnement – Partie 2-14: Essais – Essai N: Variation de température*

IEC 60068-2-30, *Essais d'environnement – Partie 2-30: Essais – Essai Db: Essai cyclique de chaleur humide (cycle de 12 h + 12 h)*

IEC 60269-1:2006, *Fusibles basse tension – Partie 1: Exigences générales*

IEC 60364 (toutes les parties), *Installations électriques à basse tension*

IEC 60664-1:2007, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60947-1:2007, *Appareillage à basse tension – Partie 1: Règles générales*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1, *Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques*

IEC 61000-3-2, *Compatibilité électromagnétique (CEM) – Partie 3-2: Limites – Limites pour les émissions de courant harmonique (courant appelé par les appareils ≤ 16 A par phase)*

IEC 61000-3-3, *Compatibilité électromagnétique (CEM) – Partie 3-3: Limites – Limitation des variations de tension, des fluctuations de tension et du papillotement dans les réseaux publics d'alimentation basse tension, pour les matériels ayant un courant assigné ≤16 A par phase et non soumis à un raccordement conditionnel*

IEC 61000-4-2, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3:2006, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61000-4-5:2014, *Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc*

IEC 61000-4-6:2013, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques*

IEC 61000-4-11, *Compatibilité électromagnétique (CEM) – Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension*

IEC 61140, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 62475:2010, *Techniques des essais à haute intensité – Définitions et exigences relatives aux courants d'essai et systèmes de mesure*

CISPR 11, *Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure*

CISPR 22, *Appareils de traitement de l'information – Caractéristiques des perturbations radioélectriques – Limites et méthodes de mesure*

2 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60947-1 ainsi que les suivants s'appliquent.

NOTE Lorsque ces définitions sont identiques à celles du *Vocabulaire Electrotechnique International (VEI)*, IEC 60050-441, la référence à cette publication est donnée entre crochets.

2.1
disjoncteur
appareil mécanique de connexion capable d'établir, de supporter et d'interrompre des courants dans les conditions normales du circuit, ainsi que d'établir, de supporter pendant une durée spécifiée et d'interrompre des courants dans des conditions anormales spécifiées du circuit telles que celles du court-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20]

2.1.1
taille
terme désignant un groupe de disjoncteurs dont les dimensions extérieures physiques sont communes à une plage de courants assignés

Note 1 à l'article: La taille est exprimée en ampères correspondant au courant assigné le plus élevé du groupe.

Note 2 à l'article: Dans une taille, la largeur de l'appareil peut varier selon le nombre de pôles.

Note 3 à l'article: Cette définition n'implique pas de normalisation dimensionnelle.

2.1.2
différence de construction
différence significative de construction entre des disjoncteurs d'une taille donnée, nécessitant d'effectuer des essais supplémentaires de type

2.2
disjoncteur à fusibles incorporés
combinaison en un seul appareil d'un disjoncteur et de fusibles, un fusible étant placé en série avec chaque pôle du disjoncteur destiné à être relié à un conducteur de phase

[SOURCE: IEC 60050-441:1984, 441-14-22]

2.3
disjoncteur à limitation du courant
disjoncteur qui, à l'intérieur d'une plage de courants spécifiée, empêche le courant coupé limité d'atteindre la valeur crête présumée et qui limite l'énergie limitée (I^2t) à une valeur inférieure à l'énergie limitée d'une demi-période du courant présumé symétrique

Note 1 à l'article: Il peut être fait référence à la valeur crête présumée symétrique ou asymétrique du courant coupé limité.

Note 2 à l'article: Le courant coupé limité (let-through current) est aussi nommé «cut-off current» (voir IEC 60050-441:1984, 441-17-12).

Note 3 à l'article: Les modèles de représentation graphique des caractéristiques de courant coupé limité et d'énergie limitée sont illustrés de la Figure K.2 à la Figure K.5 et les exemples d'utilisation des modèles de la Figure K.6 à la Figure K.7.

2.4
disjoncteur enfichable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts permettant le retrait du disjoncteur

Note 1 à l'article: Certains disjoncteurs peuvent être de type enfichable sur le côté d'alimentation uniquement, les bornes de sortie étant les bornes utilisées habituellement pour le raccordement par conducteurs.

2.5
disjoncteur débrochable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts de sectionnement lui permettant d'être retiré du circuit principal et, en position débrochée, de présenter une distance de sectionnement conforme à des exigences spécifiées

2.6
disjoncteur en boitier moulé
disjoncteur dont le châssis et l'enveloppe sont en matériau isolant moulé et font partie intégrante du disjoncteur

[SOURCE: IEC 60050-441:1984, 441-14-24]

2.7
disjoncteur à air
disjoncteur dont les contacts s'ouvrent et se ferment dans l'air à la pression atmosphérique

[SOURCE: IEC 60050-441:1984, 441-14-27]

2.8
disjoncteur à vide
disjoncteur dont les contacts s'ouvrent et se ferment dans une enceinte où règne un vide poussé

[SOURCE: IEC 60050-441:1984, 441-14-29]

2.9
disjoncteur à gaz
disjoncteur dont les contacts s'ouvrent et se ferment dans un gaz autre que l'air à une pression égale ou supérieure à la pression atmosphérique

2.10
déclencheur sous courant de fermeture
déclencheur qui permet l'ouverture d'un disjoncteur sans retard intentionnel, pendant une manœuvre de fermeture, si le courant établi dépasse une valeur prédéterminée, et qui est rendu inopérant lorsque le disjoncteur est en position fermée

2.11
déclencheur de court-circuit
déclencheur à maximum de courant destiné à la protection contre les courts-circuits

2.12
déclencheur de court-circuit à retard de courte durée
déclencheur à maximum de courant prévu pour fonctionner au bout d'un retard de courte durée

2.13
interrupteur de défaut
interrupteur auxiliaire ne fonctionnant que lors du déclenchement du disjoncteur auquel il est associé

2.14
disjoncteur à fermeture empêchée
disjoncteur dont chacun des contacts mobiles est empêché de se fermer suffisamment pour être capable de laisser passer le courant si l'ordre de fermeture est donné alors que demeurent maintenues des conditions spécifiées

2.15
pouvoir de coupure (ou de fermeture) en court-circuit
pouvoir de coupure (ou de fermeture) pour lequel les conditions spécifiées comprennent un court-circuit

2.15.1
pouvoir de coupure ultime en court-circuit
pouvoir de coupure pour lequel les conditions spécifiées suivant une séquence d'essai spécifiée ne comprennent pas l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

2.15.2
pouvoir de coupure de service en court-circuit
pouvoir de coupure pour lequel les conditions spécifiées suivant une séquence d'essai spécifiée comprennent l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

2.16
durée d'ouverture
intervalle de temps entre l'instant spécifié de début de la manoeuvre d'ouverture et l'instant de la séparation des contacts d'arc sur tous les pôles

Note 1 à l'article:

– dans le cas d'un disjoncteur actionné directement, l'instant de début de la durée d'ouverture est l'instant de début d'un courant assez fort pour provoquer la manœuvre du disjoncteur;
– dans le cas d'un disjoncteur actionné par toute forme d'énergie auxiliaire, l'instant de début de la durée d'ouverture est l'instant de début de l'application ou du retrait de l'énergie auxiliaire au déclencheur d'ouverture.

Note 2 à l'article: Pour les disjoncteurs, la «durée d'ouverture» est couramment appelée «durée de déclenchement», bien que, à proprement parler, la durée de déclenchement comprenne le délai entre l'instant où commence la durée d'ouverture et celui où la commande de l'ouverture devient irréversible.

[SOURCE: IEC 60947-1:2007, 2.5.39, modifiée – ajout de Notes à l'article.]

2.17
coordination de la protection contre les surintensités

2.17.1
sélectivité lors d'une surintensité
coordination entre les caractéristiques de fonctionnement de plusieurs appareils de protection à maximum de courant de telle façon qu'à l'apparition de surintensités comprises dans des limites données, l'appareil prévu pour fonctionner dans ces limites fonctionne, tandis que le ou les autres ne fonctionnent pas

2.17.2
sélectivité totale
sélectivité lors d'une surintensité dans laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval assure la protection sans provoquer le fonctionnement de l'autre appareil de protection

2.17.3
sélectivité partielle
sélectivité lors d'une surintensité dans laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval assure la protection jusqu'à un niveau donné de surintensité sans provoquer le fonctionnement de l'autre appareil de protection

2.17.4
courant limite de sélectivité
I_s
valeur de courant correspondant à l'intersection de la caractéristique totale temps-courant de l'appareil de protection placé en aval avec la caractéristique temps-courant de préarc (pour les fusibles) ou de déclenchement (pour les disjoncteurs) de l'autre appareil de protection

Note 1 à l'article: Le courant limite de sélectivité (voir Figure A.1) est une valeur limite de courant:

– en dessous de laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval achève sa manœuvre de coupure en temps voulu pour empêcher l'autre appareil de protection d'amorcer sa manœuvre (c'est-à-dire que la sélectivité est assurée);
– au-dessus de laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval peut ne pas achever sa manœuvre de coupure en temps voulu pour empêcher l'autre appareil de protection d'amorcer sa manœuvre (c'est-à-dire que la sélectivité n'est pas assurée).

2.17.5
courant d'intersection
***I*B**
coordonnée du courant correspondant à l'intersection des courbes donnant les caractéristiques de la durée maximale de coupure en fonction du courant pour deux appareils de protection à maximum de courant placés en série

Note 1 à l'article: Cela s'applique à deux appareils de protection à maximum de courant placés en série pour des durées de fonctionnement ≥ 0,05 s. Pour des durées de fonctionnement < 0,05 s, les deux appareils à maximum de courant placés en série sont considérés comme une association (voir Annexe A).

2.18
caractéristique I^2t d'un disjoncteur
information (généralement une courbe) donnant les valeurs maximales de I^2t correspondant à la durée de coupure en fonction du courant présumé (valeur efficace de la composante périodique en courant alternatif) jusqu'à la valeur maximale du courant présumé correspondant au pouvoir assigné de coupure en court-circuit à la tension correspondante

2.19
durée de réarmement
temps écoulé entre le déclenchement du disjoncteur provoqué par une surintensité et l'instant où les conditions sont atteintes pour qu'il puisse être refermé

2.20
courant assigné instantané de réglage de court-circuit
I_i
valeur assignée du courant provoquant le fonctionnement d'un déclencheur sans retard intentionnel

2.21
courant de réglage de surcharge
I_r
courant de réglage pour un déclencheur de surcharge réglable

Note 1 à l'article: Dans le cas d'un déclencheur de surcharge non réglable, cette valeur est égale au courant assigné I_n.

2.22
automate programmable
AP
système électronique numérique conçu pour un usage en environnement industriel et utilisant une mémoire programmable destinée au stockage interne d'instructions orientées utilisateur pour réaliser des fonctions particulières telles que la logique, le séquencement, le décompte du temps, le comptage et l'arithmétique afin de commander, au moyen d'entrées et de sorties analogiques ou numériques, différents types de machines ou de processus. Un AP ainsi que ses périphériques associés sont conçus de sorte qu'ils peuvent aisément être intégrés dans un système de commande industriel et employés dans toutes leurs fonctions prévues

[SOURCE: IEC 61131-1:2003, 3.5, modifiée – suppression de la note.]

3 Classification

Les disjoncteurs peuvent être classés:

3.1 Suivant leur catégorie de sélectivité, A ou B (voir 4.4)

3.2 Suivant le milieu de coupure, par exemple:

– coupure à air,

– coupure sous vide,
– coupure à gaz.

3.3 Suivant le type de conception, par exemple:

– construction ouverte,
– construction en boîtier moulé.

3.4 Suivant le mode de commande du mécanisme de manœuvre, c'est-à-dire:

– manœuvre dépendante à main,
– manœuvre indépendante à main,
– manœuvre dépendante à source d'énergie extérieure,
– manœuvre indépendante à source d'énergie extérieure,
– manœuvre à accumulation d'énergie.

3.5 Suivant l'aptitude au sectionnement:

– apte au sectionnement,
– inapte au sectionnement.

3.6 Suivant les possibilités d'entretien:

– conçu pour être entretenu,
– non conçu pour être entretenu.

3.7 Suivant le mode d'installation, par exemple:

– fixe,
– enfichable,
– débrochable.

3.8 Suivant le degré de protection procuré par l'enveloppe (voir 7.1.12 de l'IEC 60947-1:2007).

4 Caractéristiques des disjoncteurs

4.1 Enumération des caractéristiques

Les caractéristiques d'un disjoncteur doivent, selon le cas, être indiquées de la façon suivante:

– type du disjoncteur (4.2),
– valeurs assignées et valeurs limites du circuit principal (4.3),
– catégories de sélectivité (4.4),
– circuits de commande (4.5),
– circuits auxiliaires (4.6),
– déclencheurs (4.7),
– fusibles incorporés (disjoncteurs à fusibles incorporés) (4.8).

4.2 Type du disjoncteur

Les éléments suivants doivent être indiqués:

– le nombre de pôles,

– la nature du courant (courant alternatif ou courant continu) et, dans le cas du courant alternatif, le nombre de phases et la fréquence assignée.

4.3 Valeurs assignées et valeurs limites du circuit principal

4.3.1 Généralités

Les valeurs assignées relatives à un disjoncteur doivent être indiquées conformément aux 4.3.2 à 4.4, mais il n'est pas nécessaire de spécifier toutes les valeurs assignées énumérées.

4.3.2 Tensions assignées

4.3.2.1 Tension d'emploi assignée (U_e)

Le paragraphe 4.3.1.1 de l'IEC 60947-1:2007 est applicable avec le développement suivant:

– Disjoncteurs répondant au point a) de la Note 2 (de l'IEC 60947-1 :2007):

U_e est généralement exprimée par la tension entre phases.

NOTE 1 Au Canada et aux Etats-Unis, la tension assignée d'emploi U_e est exprimée par:

a) la tension entre phases et la terre, ainsi que par la tension entre phases (par exemple 277 V/480 V) pour des réseaux triphasés à quatre fils et neutre mis à la terre,

b) la tension entre phases (par exemple 480 V) pour des réseaux triphasés, à trois fils, non reliés à la terre ou reliés à la terre par une impédance.

Les disjoncteurs pour systèmes non reliés à la terre ou pour systèmes reliés à la terre par une impédance requièrent des essais supplémentaires conformément à l'Annexe H.

– Disjoncteurs répondant au point b) de la Note 2:

Ces disjoncteurs demandent des essais supplémentaires conformément à l'Annexe C.

U_e doit s'exprimer par la tension entre phases, précédée de la lettre C.

NOTE 2 Dans la pratique actuelle au Canada et aux Etats-Unis, les disjoncteurs répondant au point b) de la Note 2 (de l'IEC 60947-1 :2007) ne sont identifiés que par la tension entre phases.

4.3.2.2 Tension d'isolement assignée (U_i)

Le paragraphe 4.3.1.2 de l'IEC 60947-1:2007 est applicable.

4.3.2.3 Tension assignée de tenue aux chocs (U_{imp})

Le paragraphe 4.3.1.3 de l'IEC 60947-1:2007 est applicable.

4.3.3 Courants

4.3.3.1 Courant thermique conventionnel à l'air libre (I_{th})

Le paragraphe 4.3.2.1 de l'IEC 60947-1:2007 est applicable.

4.3.3.2 Courant thermique conventionnel sous enveloppe (I_{the})

Le paragraphe 4.3.2.2 de l'IEC 60947-1:2007 est applicable.

4.3.3.3 Courant assigné (I_n)

Pour les disjoncteurs, le courant assigné est le courant assigné ininterrompu (I_u) (voir 4.3.2.4 de l'IEC 60947-1:2007) et a la même valeur que le courant thermique conventionnel à l'air libre (I_{th}).

4.3.3.4 Courant assigné des disjoncteurs tétrapolaires

Le paragraphe 7.1.9 de l'IEC 60947-1:2007 est applicable.

4.3.4 Fréquence assignée

Le paragraphe 4.3.3 de l'IEC 60947-1:2007 est applicable.

4.3.5 Service assigné

Les services assignés considérés comme normaux sont:

– le service de huit heures (voir le 4.3.4.1 de l'IEC 60947-1:2007),
– le service ininterrompu (voir le 4.3.4.2 de l'IEC 60947-1:2007).

4.3.6 Caractéristiques de court-circuit

4.3.6.1 Pouvoir assigné de fermeture en court-circuit (I_{cm})

Le pouvoir assigné de fermeture en court-circuit d'un disjoncteur est la valeur de pouvoir de fermeture en court-circuit fixée pour ce disjoncteur par le fabricant pour la tension assignée d'emploi, à la fréquence assignée et pour un facteur de puissance spécifié en courant alternatif, ou une constante de temps spécifiée en courant continu. Il s'exprime par la valeur maximale de crête du courant présumé.

En courant alternatif, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur ne doit pas être inférieur au produit de son pouvoir assigné de coupure ultime en court-circuit multiplié par le facteur *n* figurant au Tableau 2 (voir 4.3.6.3).

En courant continu, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur ne doit pas être inférieur à son pouvoir assigné de coupure ultime en court-circuit.

Un pouvoir assigné de fermeture en court-circuit implique que le disjoncteur doit être capable d'établir le courant correspondant à ce pouvoir assigné pour une tension appliquée appropriée à la tension assignée d'emploi.

4.3.6.2 Pouvoirs assignés de coupure en court-circuit

4.3.6.2.1 Généralités

Les pouvoirs assignés de coupure en court-circuit d'un disjoncteur sont les valeurs de pouvoir de coupure en court-circuit assignées par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans des conditions spécifiées.

Un pouvoir assigné de coupure en court-circuit exige que le disjoncteur doit pouvoir couper tout courant de court-circuit de valeur inférieure ou égale à ce pouvoir assigné de coupure, à une tension de rétablissement à fréquence industrielle correspondant aux valeurs spécifiées pour la tension d'essai et:

– en courant alternatif, à tout facteur de puissance supérieur ou égal à celui du Tableau 11 (voir 8.3.2.2.4),
– en courant continu, à toute constante de temps inférieure ou égale à celle du Tableau 11 (voir 8.3.2.2.5).

Aucun pouvoir de coupure en court-circuit n'est garanti pour des tensions de rétablissement à fréquence industrielle supérieures aux valeurs spécifiées pour la tension d'essai (voir 8.3.2.2.6).

En courant alternatif, le disjoncteur doit être capable de couper un courant présumé correspondant à son pouvoir assigné de coupure en court-circuit et le facteur de puissance correspondant donné au Tableau 11, quelle que soit la valeur de la composante continue correspondante, en admettant que la composante périodique est constante.

Les pouvoirs assignés de coupure en court-circuit sont définis comme suit:

– pouvoir assigné de coupure ultime en court-circuit,
– pouvoir assigné de coupure de service en court-circuit.

4.3.6.2.2 Pouvoir assigné de coupure ultime en court-circuit (I_{cu})

Le pouvoir assigné de coupure ultime en court-circuit d'un disjoncteur est la valeur du pouvoir de coupure ultime en court-circuit (voir 2.15.1) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans les conditions spécifiées en 8.3.5. Il est exprimé comme valeur du courant de coupure présumé, en kA (valeur efficace de la composante alternative dans le cas du courant alternatif).

4.3.6.2.3 Pouvoir assigné de coupure de service en court-circuit (I_{cs})

Le pouvoir assigné de coupure de service en court-circuit d'un disjoncteur est la valeur du pouvoir de coupure de service en court-circuit (voir 2.15.2) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans les conditions spécifiées en 8.3.4. Il est exprimé comme valeur du courant de coupure présumé, en kA, ou comme pourcentage de I_{cu} (par exemple I_{cs} = 25 % I_{cu}).

I_{cs} doit être au moins égal à 25 % de I_{cu}.

Tableau 1 (vide)

4.3.6.3 Relation normale entre les pouvoirs de fermeture et de coupure en court-circuit des disjoncteurs à courant alternatif et les facteurs de puissance correspondants

La relation normale entre le pouvoir de coupure en court-circuit et le pouvoir de fermeture en court-circuit est donnée par le Tableau 2.

Tableau 2 – Rapport *n* entre le pouvoir de fermeture en court-circuit et le pouvoir de coupure en court-circuit et le facteur de puissance correspondant (pour les disjoncteurs à courant alternatif)

Pouvoir de coupure en court-circuit kA eff	Facteur de puissance	Valeur minimale exigée de *n* $n = \frac{\text{pouvoir de fermeture en court-circuit}}{\text{pouvoir de coupure en court-circuit}}$
$I \leq 1{,}5$	0,95	1,41
$1{,}5 < I \leq 3$	0,9	1,42
$3 < I \leq 4{,}5$	0,8	1,47
$4{,}5 < I \leq 6$	0,7	1,53
$6 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

Les pouvoirs assignés de fermeture et de coupure en court-circuit ne sont valables que si le disjoncteur est manœuvré selon les exigences de 7.2.1.1 et 7.2.1.2.

Pour des exigences spéciales, le fabricant peut fixer une valeur de pouvoir assigné de fermeture en court-circuit supérieure à celle exigée dans le Tableau 2. Les essais de vérification de ces valeurs assignées doivent faire l'objet d'un accord entre le fabricant et l'utilisateur.

4.3.6.4 Courant assigné de courte durée admissible (I_{cw})

Le courant assigné de courte durée admissible d'un disjoncteur est la valeur de courant de courte durée admissible fixée pour ce disjoncteur par le fabricant dans les conditions d'essai spécifiées en 8.3.6.3.

En courant alternatif, la valeur de ce courant est la valeur efficace de la composante périodique du courant présumé de court-circuit, étant par hypothèse constante pendant le retard de courte durée.

Le retard de courte durée associé au courant assigné de courte durée admissible doit être d'au moins 0,05 s, les valeurs préférentielles étant les suivantes:

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

Le courant assigné de courte durée admissible ne doit pas avoir une valeur moindre que les valeurs figurant au Tableau 3.

Tableau 3 – Valeurs minimales du courant assigné de courte durée admissible

Courant assigné I_n A	Courant assigné de courte durée admissible I_{cw} – Valeurs minimales kA
$I_n \leq 2\,500$	12 I_n ou 5 kA, selon la valeur la plus élevée
$I_n > 2\,500$	30 kA

4.4 Catégories de sélectivité

Les disjoncteurs conformes à la présente norme sont divisés en deux catégories de sélectivité:

– **catégorie de sélectivité B** comprenant les disjoncteurs assurant la sélectivité en ayant un courant assigné de courte durée admissible et un retard de courte durée associé conformes à 4.3.6.4.

  La sélectivité des disjoncteurs de catégorie de sélectivité B n'est pas nécessairement assurée jusqu'au pouvoir de coupure ultime en court-circuit (par exemple, en cas de fonctionnement d'un déclencheur instantané), mais elle l'est au moins jusqu'à la valeur spécifiée au Tableau 3.

– **catégorie de sélectivité A** comprenant tous les autres disjoncteurs.

  Ces disjoncteurs peuvent assurer la sélectivité dans des conditions de court-circuit par d'autres moyens.

  Un disjoncteur de catégorie de sélectivité A peut avoir un retard de courte durée intentionnel avec un courant de courte durée admissible inférieur à celui spécifié en 4.3.6.4. Dans ce cas, les essais comprennent la séquence d'essai IV (voir 8.3.6) au courant assigné de courte durée admissible.

L'attention est attirée sur les différences entre les essais s'appliquant aux deux catégories de sélectivité (voir Tableau 9 et 8.3.4, 8.3.5, 8.3.6 et 8.3.8).

Tableau 4 (vide)

4.5 Circuits de commande

4.5.1 Circuits de commande électriques

Le paragraphe 4.5.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable, avec le complément suivant:

Si la tension assignée d'alimentation de commande est différente de celle du circuit principal, il est recommandé de choisir sa valeur parmi celles du Tableau 5.

Tableau 5 – Valeurs préférentielles de la tension assignée d'alimentation de commande si elle est différente de celle du circuit principal

Courant continu V	Courant alternatif monophasé V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230

4.5.2 Circuits de commande à air comprimé (pneumatiques ou électropneumatiques)

Le paragraphe 4.5.2 de l'IEC 60947-1:2007 est applicable.

4.6 Circuits auxiliaires

Le paragraphe 4.6 de l'IEC 60947-1:2007 est applicable.

4.7 Déclencheurs

4.7.1 Types

Pour les besoins de la présente norme, les types suivants de déclencheurs sont considérés:

1) déclencheur shunt,
2) déclencheur à maximum de courant:
   a) instantané,
   b) à retard indépendant,
   c) à temps inverse:
      – indépendant de la charge préalable,
      – dépendant de la charge préalable (par exemple: déclencheur du type thermique).

   NOTE 1 Le terme «déclencheur de surcharge» est employé pour désigner des déclencheurs à maximum de courant destinés à la protection contre les surcharges (voir 2.4.30 de l'IEC 60947-1:2007). Le terme «déclencheur de court-circuit» est employé pour désigner des déclencheurs à maximum de courant destinés à la protection contre les courts-circuits (voir 2.11).

   NOTE 2 Le terme «déclencheur réglable», utilisé dans la présente norme, comprend aussi les déclencheurs interchangeables.
3) déclencheur à minimum de tension (déclencheur d'ouverture),
4) autres déclencheurs.

4.7.2 Caractéristiques

Les caractéristiques suivantes doivent être considérées:

1) déclencheur shunt et déclencheur à minimum de tension (déclencheurs d'ouverture):
   – tension assignée du circuit de commande (U_c),

– nature du courant,
– fréquence assignée, dans le cas du courant alternatif.

2) déclencheur à maximum de courant:
– courant assigné (I_n),
– nature du courant,
– fréquence assignée, dans le cas du courant alternatif,
– courant de réglage (ou plage de réglage),
– temps de réglage (ou plage de réglage) le cas échéant.

Le courant assigné d'un déclencheur à maximum de courant est la valeur du courant (valeur efficace dans le cas du courant alternatif) correspondant au courant de réglage maximal qu'il doit être capable de supporter dans les conditions d'essai spécifiées en 8.3.2.5 sans que l'échauffement dépasse les valeurs spécifiées au Tableau 7.

4.7.3 Courant de réglage des déclencheurs à maximum de courant

Pour les disjoncteurs équipés de déclencheurs réglables (voir Note 2 de 4.7.1, point 2)), le courant de réglage (ou la plage des courants de réglage, le cas échéant) doit être marqué ou affiché sur le déclencheur ou sur son échelle de réglage. L'indication ou l'affichage peut être donné(e) soit directement en ampères, soit en multiples de la valeur du courant. Des moyens doivent être disponibles auprès du fabricant pour lire l'affichage indépendamment de l'état du disjoncteur.

Pour les disjoncteurs équipés de déclencheurs non réglables, l'indication peut figurer sur le disjoncteur. Si les caractéristiques de fonctionnement du déclencheur de surcharge satisfont aux exigences du Tableau 6, il suffit d'indiquer sur le disjoncteur son courant assigné (I_n).

Pour les déclencheurs indirects fonctionnant à l'aide d'un transformateur de courant, les indications peuvent se rapporter soit au courant au primaire du transformateur de courant qui les alimente, soit au courant de réglage du déclencheur de surcharge. Dans l'un et l'autre cas, le rapport de transformation du transformateur de courant doit être indiqué.

Sauf spécification contraire,

– la valeur de fonctionnement des déclencheurs de surcharge autres que ceux du type thermique est indépendante de la température de l'air ambiant dans les limites de – 5 °C à + 40 °C;
– pour les déclencheurs du type thermique, les valeurs indiquées correspondent à une température de référence de + 30 °C ± 2 °C. Le fabricant doit être en mesure de préciser l'influence des variations de la température de l'air ambiant (voir 7.2.1.2.4, point b)).

4.7.4 Réglage du temps de déclenchement des déclencheurs à maximum de courant

Le temps de déclenchement doit être défini comme suit, selon le type de déclencheur à maximum de courant:

1) Déclencheurs à maximum de courant à retard défini

   Le retard de ces déclencheurs est indépendant de la surintensité. Le réglage du temps de déclenchement doit être défini comme égal à la valeur en secondes de la durée d'ouverture du disjoncteur si le retard n'est pas réglable, ou aux valeurs extrêmes de la durée d'ouverture si le retard est réglable.

2) Déclencheurs à maximum de courant à temps inverse

   Le retard de ces déclencheurs dépend de la surintensité.

   Les caractéristiques temps/courant doivent être données sous forme de courbes fournies par le fabricant. Celles-ci doivent indiquer comment la durée d'ouverture, à partir de l'état froid, varie en fonction du courant dans la plage de fonctionnement du déclencheur. Le fabricant doit indiquer, par des moyens convenables, les tolérances applicables à ces courbes.

Ces courbes doivent être données pour chacune des valeurs extrêmes du courant de réglage et, si le temps de réglage donné est réglable, il est recommandé qu'elles soient également données pour chacune des valeurs extrêmes du temps de réglage.

Il est recommandé de porter le courant en abscisses et le temps en ordonnées, en utilisant des échelles logarithmiques. De plus, en vue de faciliter l'étude de la coordination des divers types de protection contre les surintensités, il est recommandé de porter le courant en multiples du courant de réglage et le temps en secondes en utilisant les échelles normalisées données dans les feuilles de courbe normale décrites en 5.6.1 de l'IEC 60269-1:2006.

4.8 Fusibles incorporés (disjoncteurs à fusibles incorporés)

Le paragraphe 4.8 de l'IEC 60947-1:2007/AMD1:2010 est applicable.

Le fabricant doit fournir les informations nécessaires.

5 Informations sur le matériel

5.1 Nature des informations

Le paragraphe 5.1 de l'IEC 60947-1:2007 est applicable, dans la mesure où il est approprié pour un modèle particulier.

En supplément le fabricant doit, sur demande, fournir les informations concernant la puissance dissipée typique pour les différentes tailles (voir 2.1.1). Voir Annexe G.

5.2 Marquage

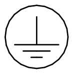
Chaque disjoncteur doit être marqué de façon indélébile.

a) Les indications suivantes doivent se trouver sur le disjoncteur lui-même ou sur une ou plusieurs plaques signalétiques fixées au disjoncteur, et ces marques doivent être à un endroit tel qu'elles soient visibles et lisibles lorsque le disjoncteur est en place;

- courant assigné (I_n);
- aptitude au sectionnement, s'il y a lieu, avec le symbole ;
- indications des positions d'ouverture et de fermeture, respectivement par ○ et | si des symboles sont utilisés (voir 7.1.6.1 de l'IEC 60947-1:2007).

b) Les indications suivantes doivent également être marquées sur le disjoncteur, comme spécifié au point a), excepté qu'il n'est pas nécessaire qu'elles soient visibles lorsque le disjoncteur est en place:

- nom du fabricant ou marque de fabrique;
- désignation du type ou numéro de série;
- IEC 60947-2 si le fabricant déclare la conformité à la présente norme;
- catégorie de sélectivité;
- tension(s) assignée(s) d'emploi U_e (voir 4.3.2.1 et le cas échéant, l'Annexe H);
- tension assignée de tenue aux chocs (U_{imp});
- valeur (ou plage) de la fréquence assignée (par exemple 50 Hz) et/ou indication «courant continu» (ou le symbole ⎓);
- pouvoir assigné de coupure de service en court-circuit (I_{cs}) à la tension assignée correspondante (U_e);

- pouvoir assigné de coupure ultime en court-circuit (I_{cu}) à la tension assignée correspondante (U_e);
- courant assigné de courte durée admissible (I_{cw}) et retard de courte durée correspondant pour la catégorie de sélectivité B;
- bornes d'entrée et de sortie, à moins que leur raccordement soit indifférent;
- bornes du pôle neutre, le cas échéant, par la lettre N;
- borne de terre de protection, le cas échéant, par le symbole  (voir 7.1.10.3 de l'IEC 60947-1:2007);
- température de référence pour les déclencheurs thermiques non compensés, si elle est différente de 30 °C;
- plage de courant de réglage (I_r) du déclencheur de surcharge réglable;
- plage du courant assigné de court-circuit instantané (I_i), pour les déclencheurs réglables.

Le cas échéant, les plages I_r et I_i peuvent être affichées au lieu d'être marquées sur le disjoncteur.

c) Les indications suivantes doivent soit être marquées sur le disjoncteur comme spécifié au point b), soit figurer dans les catalogues ou notices du fabricant:

- pouvoir assigné de fermeture en court-circuit (I_{cm}), s'il est supérieur à celui spécifié en 4.3.6.1;
- tension assignée d'isolement (U_i), si elle est supérieure à la tension assignée d'emploi maximale;
- degré de pollution s'il est autre que 3;
- courant thermique conventionnel sous enveloppe (I_{the}), s'il est différent du courant assigné;
- code IP, le cas échéant (voir Annexe C de l'IEC 60947-1:2007/AMD1:2010);
- taille minimale de l'enveloppe et, s'il y a lieu, données concernant la ventilation, auxquelles s'appliquent les caractéristiques assignées marquées;
- distance minimale entre le disjoncteur et les parties métalliques reliées à la terre pour les disjoncteurs destinés à être utilisés sans enveloppe;
- aptitude à l'environnement A ou l'environnement B, suivant le cas;
- détection sensible à la valeur efficace, le cas échéant, conformément à F.4.1.1;
- section minimale du câble, si différente de la valeur donnée dans le Tableau 9 de l'IEC 60947-1:2007, pour les calibres ≤ 20 A en fonction du pouvoir assigné de coupure ultime en court-circuit I_{cu};
- valeurs du couple de serrage pour les bornes du disjoncteur.

d) Les indications suivantes concernant les dispositifs d'ouverture et de fermeture du disjoncteur doivent figurer, soit sur leurs propres plaques signalétiques, soit sur la plaque signalétique du disjoncteur; si l'espace disponible est insuffisant, elles doivent figurer dans les catalogues ou notices du fabricant:

- tension assignée du circuit de commande de l'appareil de fermeture (voir 7.2.1.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014) et fréquence assignée dans le cas du courant alternatif;
- tension assignée du circuit de commande du déclencheur shunt (voir 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014) et/ou du déclencheur à minimum de tension (ou du déclencheur à manque de tension) (voir 7.2.1.3 de l'IEC 60947-1:2007), et fréquence assignée dans le cas du courant alternatif;
- courant assigné des déclencheurs indirects à maximum de courant;

- nombre et type des contacts auxiliaires ainsi que nature du courant, fréquence assignée (en cas de courant alternatif) et tensions assignées, si elles diffèrent de celles du circuit principal.

e) Marquage des bornes

Le paragraphe 7.1.8.4 de l'IEC 60947-1:2007 est applicable (voir aussi le point b) ci-dessus).

5.3 Instructions d'installation, de fonctionnement et d'entretien

Le paragraphe 5.3 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

6 Conditions normales de service, de montage et de transport

L'Article 6 de l'IEC 60947-1:2007/AMD2:2014 est applicable, avec le complément suivant:

Degré de pollution (voir 6.1.3.2 de l'IEC 60947-1:2007).

Sauf spécification contraire du fabricant, un disjoncteur est prévu pour être installé dans les conditions d'environnement du degré de pollution 3.

7 Exigences relatives à la construction et au fonctionnement

7.1 Exigences relatives à la construction

7.1.1 Généralités

Le paragraphe 7.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable. Lorsque, dans le paragraphe 7.1.2.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, la température d'essai est à spécifier, la température d'essai exigée par la présente norme est de 960 °C.

7.1.2 Disjoncteur débrochables

En position débrochée, les contacts de sectionnement du circuit principal et, s'il y a lieu, des circuits auxiliaires des disjoncteurs débrochables doivent avoir des distances de sectionnement répondant aux exigences spécifiées pour la fonction de sectionnement, en tenant compte des tolérances de fabrication et des modifications dimensionnelles causées par l'usure.

Le mécanisme de débrochage doit être équipé d'un dispositif d'indication sûr et robuste indiquant sans équivoque les positions des contacts de sectionnement.

Le mécanisme de débrochage doit être équipé de dispositifs de verrouillage ne permettant au disjoncteur d'être débroché (ou embroché) qu'après l'ouverture des contacts principaux.

En outre, le mécanisme de débrochage doit être équipé de dispositifs de verrouillage ne permettant la fermeture des contacts principaux que:

– lorsque les contacts de sectionnement sont complètement fermés, ou
– lorsque la distance de sectionnement spécifiée est obtenue entre les parties fixes et les parties mobiles des contacts de sectionnement (position débrochée).

Lorsque le disjoncteur est en position débrochée, il doit comporter des dispositifs permettant de s'assurer que les distances spécifiées de sectionnement entre les contacts de sectionnement ne puissent pas être réduites par inadvertance.

7.1.3 Exigences complémentaires pour les disjoncteurs aptes au sectionnement

Pour des exigences supplémentaires concernant le fonctionnement, voir 7.2.7.

Le paragraphe 7.1.7 de l'IEC 60947-1:2007/AMD1:2010 est applicable avec le complément suivant:

Si la position de déclenchement n'est pas la position d'ouverture indiquée, il convient de l'identifier sans ambiguïté.

7.1.4 Distances d'isolement et lignes de fuite

Les valeurs minimales sont données dans le Tableau 13 de l'IEC 60947-1:2007 et dans le Tableau 15 de l'IEC 60947-1:2007/AMD1:2010.

Pour les valeurs de U_{imp} dépassant les valeurs données dans le Tableau 13 de l'IEC 60947-1:2007, les distances d'isolement doivent être prises dans le Tableau F.2 de l'IEC 60664-1:2007.

7.1.5 Exigences pour la sécurité de l'opérateur

Il ne doit pas y avoir de passage ou d'ouverture permettant aux particules incandescentes de s'échapper de la zone où se trouvent les organes de commande.

La conformité est vérifiée selon les indications données en 8.3.2.6.1, point b).

7.1.6 Liste des différences de construction

Des disjoncteurs d'une taille donnée sont considérés comme ayant une différence de construction (voir 2.1.2) si l'une des caractéristiques suivantes n'est pas la même:

– matériau, revêtement et dimensions des parties internes transmettant le courant, en admettant cependant les différences citées en a), b), c), f) et g) ci-après;
– dimensions, matériau, configuration et mode de fixation des contacts principaux;
– tout mécanisme de manœuvre manuelle intégré, ses matériaux et caractéristiques physiques;
– matériaux moulés et isolants;
– principe de fonctionnement, matériaux et construction du système d'extinction de l'arc;
– conception de base des appareils de déclenchement aux surintensités en admettant, cependant, les différences détaillées en a), b) et c) ci-après.

Les différences suivantes ne constituent pas une différence de construction:

a) les dimensions des bornes, si les distances d'isolement et les lignes de fuites ne sont pas réduites;
b) dans le cas de déclencheurs thermiques et magnétiques, les dimensions et matériaux des composants du déclencheur, y compris les connexions flexibles, qui déterminent le courant assigné;
c) les enroulements du secondaire des déclencheurs avec transformateurs de courant;
d) les moyens de manœuvre externes supplémentaires aux moyens intégrés de manœuvre;
e) la désignation du type et/ou les particularités purement esthétiques (par exemple les étiquettes);
f) dans le cas de variantes bipolaires et tétrapolaires, le remplacement du dispositif de déclenchement d'un pôle par une liaison, pour obtenir un neutre non protégé;
g) la création d'un disjoncteur bipolaire à partir d'un disjoncteur tripolaire en supprimant la ligne de courant du pôle central;

h) une différence dans le logiciel embarqué (micrologiciel) dans les déclencheurs électroniques, n'ayant aucune incidence sur les caractéristiques de fonctionnement exigées, notamment la fonction de déclenchement;

i) le matériel des déclencheurs électroniques, dans le cas d'omission de composants sur des circuits imprimés de configuration identique (par exemple, bouton tournant, affichage, etc.).

7.1.7 Exigences supplémentaires pour les disjoncteurs munis d'un pôle neutre

Le paragraphe 7.1.9 de l'IEC 60947-1:2007 s'applique avec le complément suivant:

Si un pôle ayant un pouvoir de fermeture et de coupure approprié est utilisé comme pôle neutre, alors tous les pôles, y compris le pôle neutre, peuvent fonctionner sensiblement ensemble.

7.1.8 Entrées et sorties numériques à l'usage des automates programmables (AP)

L'Annexe S de l'IEC 60947-1:2007 s'applique. Pour les besoins de la présente norme, cette exigence ne s'applique pas aux entrées et sorties numériques dédiées à des appareils autres que les automates programmables.

7.2 Exigences relatives au fonctionnement

7.2.1 Conditions de fonctionnement

7.2.1.1 Fermeture

7.2.1.1.1 Généralités

Pour qu'un disjoncteur soit fermé avec sécurité lorsqu'il établit un courant correspondant à son pouvoir assigné de fermeture en court-circuit, il convient pour l'essentiel qu'il soit manœuvré avec la même vitesse et la même force qu'au cours des essais de type de vérification du pouvoir de fermeture en court-circuit.

7.2.1.1.2 Fermeture dépendante manuelle

Pour un disjoncteur muni d'un mécanisme de fermeture dépendante manuelle, il n'est pas possible de fixer une valeur de pouvoir assigné de fermeture en court-circuit sans tenir compte des conditions de manœuvre mécanique.

Il convient de ne pas utiliser un tel disjoncteur dans des circuits pour lesquels la valeur de crête du courant établi présumé dépasse 10 kA.

Cependant, ceci ne s'applique pas dans le cas d'un disjoncteur muni d'un mécanisme de fermeture dépendante manuelle comportant un déclencheur d'ouverture incorporé à action rapide qui fait couper le disjoncteur de façon sûre, quelles que soient la vitesse et la force avec lesquelles il est fermé, à des valeurs de crête de courant présumé supérieures à 10 kA; dans ce cas, un pouvoir assigné de fermeture en court-circuit peut être fixé.

7.2.1.1.3 Fermeture indépendante manuelle

Dans le cas d'un disjoncteur muni d'un mécanisme de fermeture indépendante manuelle, un pouvoir assigné de fermeture en court-circuit peut être fixé sans tenir compte des conditions de manœuvre mécanique.

7.2.1.1.4 Fermeture dépendante à source d'énergie extérieure

Le dispositif de fermeture, y compris, s'il y a lieu, les relais intermédiaires de commande, doit être capable d'assurer la fermeture du disjoncteur dans tous les cas, depuis le fonctionnement à vide jusqu'à celui correspondant au pouvoir assigné de fermeture, quand la valeur de la tension d'alimentation, mesurée pendant la manœuvre de fermeture, demeure dans les limites de 110 % et 85 % de la tension assignée d'alimentation de commande et, dans le cas du courant alternatif, à la fréquence assignée.

A 110 % de la tension assignée d'alimentation de commande, la manœuvre de fermeture, lorsqu'elle est effectuée à vide, ne doit causer aucune détérioration au disjoncteur.

A 85 % de la tension assignée d'alimentation de commande, la manœuvre de fermeture doit être assurée lorsque le courant établi par le disjoncteur est égal à son pouvoir assigné de fermeture dans les limites permises par le fonctionnement de ses relais ou déclencheurs et, si une valeur maximale est indiquée pour la durée de fermeture, en un temps n'excédant pas cette valeur maximale.

7.2.1.1.5 Fermeture indépendante à source d'énergie extérieure

Un disjoncteur à manœuvre de fermeture indépendante à source d'énergie extérieure peut avoir un pouvoir assigné de fermeture en court-circuit sans tenir compte des conditions de fermeture.

Les organes moteurs des mécanismes d'accumulation, ainsi que les organes de commande de fermeture, doivent pouvoir fonctionner suivant les spécifications du fabricant.

7.2.1.1.6 Fermeture par accumulation d'énergie

Ce type de mécanisme de fermeture doit pouvoir assurer la fermeture du disjoncteur dans toute condition entre le fonctionnement à vide et son pouvoir assigné de fermeture.

Lorsque l'énergie est accumulée dans le disjoncteur, un appareil indiquant que le mécanisme d'accumulation d'énergie est complètement armé doit être prévu.

Les organes moteurs des mécanismes d'accumulation, ainsi que les organes de commande de fermeture, doivent être capables de fonctionner lorsque leur tension d'alimentation auxiliaire est comprise entre 85 % et 110 % de la valeur de la tension assignée d'alimentation de commande.

Les contacts mobiles ne doivent pas pouvoir s'écarter de la position d'ouverture sans que l'énergie soit suffisante pour effectuer entièrement la manœuvre de fermeture de façon satisfaisante.

Lorsque le mécanisme d'accumulation d'énergie est à commande manuelle, le sens dans lequel s'effectue cette manœuvre doit être indiqué.

Cette dernière exigence ne s'applique pas aux disjoncteurs ayant une manœuvre de fermeture indépendante manuelle.

7.2.1.2 Ouverture

7.2.1.2.1 Généralités

Les disjoncteurs dont l'ouverture est automatique doivent être à déclenchement libre (voir 2.4.23 de l'IEC 60947-1:2007) et, sauf accord contraire entre le fabricant et l'utilisateur, l'énergie nécessaire à leur déclenchement doit être emmagasinée automatiquement avant l'achèvement de la manœuvre de fermeture.

7.2.1.2.2 Ouverture par déclencheurs à minimum de tension

Le paragraphe 7.2.1.3 de l'IEC 60947-1:2007 est applicable.

7.2.1.2.3 Ouverture par déclencheurs shunt

Le paragraphe 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014 s'applique.

7.2.1.2.4 Ouverture par déclencheurs à maximum de courant

a) Ouverture dans des conditions de court-circuit

Le déclencheur de court-circuit doit provoquer le déclenchement du disjoncteur avec une tolérance de ±20 % de la valeur réglée, pour toutes les valeurs de réglage du déclencheur de courant de court-circuit.

Si cela est nécessaire pour la coordination relative aux surintensités (voir 2.17), le fabricant doit fournir des informations (habituellement des courbes) indiquant:

– la valeur maximale de crête du courant coupé limité (voir 2.5.19 de l'IEC 60947-1:2007) en fonction du courant présumé (valeur efficace périodique),

– les caractéristiques I^2t (voir 2.18) pour les disjoncteurs de catégorie de sélectivité A et, le cas échéant, de catégorie B pour les disjoncteurs à commande instantanée (voir note de 8.3.5.1).

La conformité à ces informations peut être vérifiée au cours des essais de type pertinents des séquences d'essai II et III (voir 8.3.4 et 8.3.5).

NOTE 1 Il est possible de fournir d'autres sortes de données pour vérifier les caractéristiques de coordination des disjoncteurs, par exemple des essais portant sur des combinaisons d'appareils de protection contre les courts-circuits.

b) Ouverture dans des conditions de surcharge

1) Fonctionnement instantané ou à retard indépendant

Le déclencheur doit fonctionner avec une tolérance de ±10 % de la valeur réglée pour toutes les valeurs de réglage du déclencheur de surcharge.

2) Fonctionnement à temps inverse

Les valeurs conventionnelles de fonctionnement à temps inverse figurent au Tableau 6.

A la température de référence (voir 4.7.3) et à 1,05 fois le courant de réglage (voir 2.4.37 de l'IEC 60947-1:2007), c'est-à-dire au courant conventionnel de non-déclenchement (voir 2.5.30 de l'IEC 60947-1:2007), le déclencheur d'ouverture étant alimenté sur tous les pôles de phase, le déclenchement ne doit pas se produire en un laps de temps inférieur au temps conventionnel (voir 2.5.30 de l'IEC 60947-1:2007) à partir de l'état froid, c'est-à-dire avec le disjoncteur à la température de référence.

De plus, quand, à l'expiration du temps conventionnel, la valeur du courant est immédiatement portée à 1,30 fois le courant de réglage, c'est-à-dire au courant conventionnel de déclenchement (voir 2.5.31 de l'IEC 60947-1:2007), le déclenchement doit se produire dans un laps de temps inférieur au temps conventionnel.

NOTE 2 La température de référence est la température ambiante sur laquelle est fondée la caractéristique temps/courant du disjoncteur.

Tableau 6 – Caractéristiques d'ouverture des déclencheurs d'ouverture à maximum de courant à temps inverse à la température de référence

Tous les pôles en charge		Temps conventionnel h
Courant conventionnel de non-déclenchement	Courant conventionnel de déclenchement	
1,05 fois le courant de réglage	1,30 fois le courant de réglage	2 [a]

[a] 1 h quand $I_n \leq 63$ A

Si le fabricant déclare qu'un déclencheur est essentiellement indépendant de la température ambiante, les valeurs de courant du Tableau 6 doivent s'appliquer à l'intérieur du domaine de températures annoncé par le fabricant, avec une tolérance ne dépassant pas 0,3 %/K.

L'étendue du domaine de températures doit être au moins égale à 10 K de part et d'autre de la température de référence.

7.2.2 Echauffement

7.2.2.1 Limites d'échauffement

Les échauffements des différents organes d'un disjoncteur, mesurés dans les conditions spécifiées en 8.3.2.5, ne doivent pas dépasser les valeurs limites indiquées dans le Tableau 7, au cours des essais effectués conformément à 8.3.3.7. Les échauffements des bornes ne doivent pas dépasser les valeurs limites figurant dans le Tableau 7 durant les essais effectués conformément aux 8.3.4.5 et 8.3.6.4.

7.2.2.2 Température de l'air ambiant

Les limites d'échauffement indiquées au Tableau 7 ne sont valables que si la température de l'air ambiant reste entre les limites indiquées au 6.1.1 de l'IEC 60947-1:2007/AMD2:2014.

7.2.2.3 Circuit principal

Le circuit principal d'un disjoncteur, y compris les déclencheurs à maximum de courant pouvant lui être associés, doit pouvoir supporter son courant assigné I_n, dans les conditions de l'Article 8, sans que les échauffements dépassent les limites spécifiées au Tableau 7.

7.2.2.4 Circuits de commande

Les circuits de commande, y compris les appareils pour circuits de commande, utilisés pour les manœuvres de fermeture et d'ouverture d'un disjoncteur, doivent permettre de réaliser le service assigné prévu en 4.3.5 ainsi que d'effectuer les essais d'échauffement dans les conditions spécifiées en 8.3.2.5, sans que les échauffements dépassent les limites spécifiées au Tableau 7.

Les exigences de ce paragraphe doivent être vérifiées sur un disjoncteur neuf. Ou bien, si le fabricant le souhaite, la vérification peut être effectuée pendant l'essai d'échauffement du 8.3.3.7.

7.2.2.5 Circuits auxiliaires

Les circuits auxiliaires, y compris les appareils auxiliaires, doivent pouvoir supporter leur courant thermique conventionnel, sans que les échauffements dépassent les limites spécifiées au Tableau 7 lorsqu'ils sont soumis à essai selon les exigences de 8.3.2.5.

Tableau 7 – Limites d'échauffement des bornes et des parties accessibles

Description de l'organe [a]	Limites d'échauffement [b] K
– Bornes de raccordement à des connexions extérieures	80
– Organes de manœuvre manuels:	
métalliques	25
non métalliques	35
– Parties destinées à être touchées mais pas à être tenues à la main:	
métalliques	40
non métalliques	50
– Parties pouvant ne pas être touchées en service normal:	
métalliques	50
non métalliques	60

[a] Aucune valeur n'est précisée pour les pièces autres que celles énumérées ci-dessus, mais il convient qu'aucun dommage ne soit occasionné aux pièces voisines en matériau isolant.

[b] Les limites d'échauffement spécifiées ne sont pas celles qui s'appliquent à un échantillon à l'état neuf, mais celles qui s'appliquent aux vérifications de l'échauffement au cours des séquences d'essai appropriées spécifiées à l'Article 8.

7.2.3 Propriétés diélectriques

7.2.3.1 Généralités

Les paragraphes 7.2.3 a) et 7.2.3 b) de l'IEC 60947-1:2007 sont applicables.

Les essais de type doivent être effectués conformément à 8.3.3.3.

La vérification de la tenue diélectrique au cours de toutes les séquences d'essai doit être effectuée conformément à 8.3.3.6.

Les essais individuels de série doivent être effectués conformément à 8.4.6.

7.2.3.2 Tension de tenue aux chocs

Le paragraphe 7.2.3.1 de l'IEC 60947-1:2007 est applicable.

Pour les disjoncteurs de caractéristiques assignées supérieures à 1 000 V en courant alternatif, la tension de tenue aux chocs doit être convenue entre le fabricant et l'utilisateur mais ne doit pas être inférieure aux valeurs correspondant à 1 000 V en courant alternatif.

7.2.3.3 Tension de tenue à fréquence industrielle des circuits principaux, auxiliaires et de commande

Les essais à fréquence industrielle sont utilisés dans les cas suivants:

– essais diélectriques considérés comme essais de type pour la vérification de l'isolation solide,

– vérification de la tenue diélectrique comme critère de défaut après les essais de type de manœuvre ou de court-circuit,

– essais individuels de série.

7.2.3.4 Distance d'isolement

Le paragraphe 7.2.3.3 de l'IEC 60947-1:2007/AMD2:2014 s'applique.

7.2.3.5 Lignes de fuite

Le paragraphe 7.2.3.4 de l'IEC 60947-1:2007 est applicable.

7.2.3.6 Isolation solide

L'isolation solide doit être vérifiée soit par des essais à fréquence industrielle, selon 8.3.3.4.1, point 3) de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, soit par des essais en courant continu (les tensions d'essai pour les essais en courant continu sont à l'étude).

Pour les besoins de la présente norme, les circuits comprenant des appareils à semi-conducteurs doivent être déconnectés pour les essais.

7.2.3.7 Espacements entre circuits distincts

Le paragraphe 7.2.3.6 de l'IEC 60947-1:2007 est applicable.

7.2.4 Aptitude à l'établissement et à la coupure à vide, en charge normale et en surcharge

7.2.4.1 Fonctionnement en surcharge

Cette exigence ne s'applique qu'aux disjoncteurs de courant assigné ne dépassant pas 630 A.

Le disjoncteur doit être capable d'effectuer le nombre de cycles de manœuvres dans les conditions d'essai de 8.3.3.5, le courant dans le circuit principal étant supérieur à son courant assigné.

Chaque cycle de manœuvre consiste en une manœuvre de fermeture suivie d'une manœuvre de coupure.

7.2.4.2 Aptitude au fonctionnement en service

Le paragraphe 7.2.4.2 de l'IEC 60947-1:2007 est applicable avec les compléments suivants:

Le disjoncteur doit être capable de satisfaire aux exigences du Tableau 8:

– pour l'essai de fonctionnement en service sans courant dans le circuit principal dans les conditions d'essai précisées en 8.3.3.4.3,
– pour l'essai de fonctionnement en service avec courant dans le circuit principal dans les conditions d'essai précisées en 8.3.3.4.4.

Chaque cycle de manœuvre consiste, soit en une manœuvre de fermeture suivie d'une manœuvre d'ouverture (essai de fonctionnement en service sans courant), soit en une manœuvre d'établissement suivie d'une manœuvre de coupure (essai de fonctionnement en service avec courant).

Tableau 8 – Nombre de cycles de manœuvres

1	2	3	4	5
Courant assigné [a]	**Nombre de cycles de manœuvres par heure** [b]	**Nombre de cycles de manœuvres**		
A		**Sans courant**	**Avec courant** [c]	**Total**
$I_n \leq 100$	120	8 500	1 500	10 000
$100 < I_n \leq 315$	120	7 000	1 000	8 000
$315 < I_n \leq 630$	60	4 000	1 000	5 000
$630 < I_n \leq 2\,500$	20	2 500	500	3 000
$2\,500 < I_n$	10	1 500	500	2 000

[a] Indique le courant assigné maximal pour une taille donnée.

[b] La colonne 2 indique la fréquence de manœuvre minimale. Cette fréquence peut être augmentée avec l'accord du fabricant; dans ce cas, la fréquence utilisée doit être indiquée dans le rapport d'essai.

[c] Au cours de chaque cycle de manœuvres, le disjoncteur doit rester fermé pendant un temps suffisant pour assurer l'établissement complet du courant mais ne dépassant pas 2 s.

7.2.5 Aptitude à l'établissement et à la coupure en condition de court-circuit

Le paragraphe 7.2.5 de l'IEC 60947-1:2007 est applicable avec les développements suivants:

Le pouvoir assigné de fermeture en court-circuit doit être conforme aux 4.3.6.1 et 4.3.6.3.

Le pouvoir assigné de coupure en court-circuit doit être conforme à 4.3.6.2.

Le courant assigné de courte durée admissible doit être conforme à 4.3.6.4.

NOTE Le fabricant a la responsabilité d'assurer que la caractéristique de déclenchement du disjoncteur est compatible avec l'aptitude de celui-ci à supporter les contraintes thermiques et électrodynamiques inhérentes.

7.2.6 Disponible

7.2.7 Exigences complémentaires pour les disjoncteurs aptes au sectionnement

Le paragraphe 7.2.7 de l'IEC 60947-1:2007 est applicable et les essais doivent être effectués conformément à 8.3.3.3, 8.3.3.6, 8.3.3.10, 8.3.4.4, 8.3.5.4 et 8.3.7.8, selon le cas.

7.2.8 Exigences particulières pour les disjoncteurs à fusibles incorporés

NOTE Pour la coordination des disjoncteurs et des fusibles séparés associés dans un même circuit, voir 7.2.9.

Un disjoncteur à fusibles incorporés doit être conforme à la présente norme à tous égards jusqu'au pouvoir assigné de coupure ultime en court-circuit. En particulier, il doit répondre aux exigences de la séquence d'essai V (voir 8.3.7).

Le disjoncteur doit fonctionner, sans provoquer le fonctionnement des fusibles, en présence de surintensités ne dépassant pas le courant limite de sélectivité I_s déclaré par le fabricant.

Pour toutes les surintensités jusqu'à et y compris le pouvoir assigné de coupure ultime en court-circuit attribué à l'ensemble, le disjoncteur doit s'ouvrir lorsqu'un ou plusieurs fusibles fonctionnent (pour éviter l'alimentation sur une seule phase). Si le fabricant déclare que le disjoncteur est à fermeture empêchée (voir 2.14), il ne doit pas être possible de refermer le disjoncteur tant que n'auront pas été remplacés, soit les éléments de remplacement fondus, soit tout élément de remplacement manquant, ou bien que les dispositifs de verrouillage n'auront pas été réarmés.

7.2.9 Coordination entre un disjoncteur et un autre appareil de protection contre les courts-circuits

Pour la coordination entre un disjoncteur et un autre appareil de protection contre les courts-circuits, voir l'Annexe A.

7.3 Compatibilité électromagnétique (CEM)

Les exigences et les méthodes d'essai sont données à l'Annexe J.

8 Essais

8.1 Nature des essais

8.1.1 Généralités

Le paragraphe 8.1 de l'IEC 60947-1:2007 est applicable avec les compléments suivants:

Les essais destinés à vérifier les caractéristiques des disjoncteurs sont:

– les essais de type (voir 8.3),
– les essais individuels de série (voir 8.4),
– les essais spéciaux (voir 8.5).

8.1.2 Essais de type

Les essais de type comprennent les essais suivants:

Essai	Paragraphe
Echauffement	8.3.2.5
Limites et caractéristiques de déclenchement	8.3.3.2
Propriétés diélectriques	8.3.3.3
Aptitude au fonctionnement en service	8.3.3.4
Fonctionnement en surcharge (le cas échéant)	8.3.3.5
Pouvoirs de coupure en court-circuit	8.3.4 et 8.3.5
Courant de courte durée admissible (le cas échéant)	8.3.6
Fonctionnement des disjoncteurs à fusibles incorporés	8.3.7
Courant continu critique de charge	8.3.9

Les essais de type doivent être effectués par le fabricant dans ses ateliers ou dans un laboratoire approprié de son choix.

8.1.3 Essais individuels de série

Les essais individuels de série comprennent les essais énumérés en 8.4.

8.2 Conformité aux exigences de construction

Le paragraphe 8.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable.

8.3 Essais de type

Pour éviter la répétition de textes identiques concernant les différentes séquences d'essai, les conditions générales d'essai ont été groupées au début du présent paragraphe sous trois titres:

– conditions d'essai applicables à toutes les séquences (8.3.3 à 8.3.8),
– conditions d'essai applicables aux essais d'échauffement (8.3.2.5),
– conditions d'essai applicables aux essais de court-circuit (8.3.2.6).

Dans la mesure du possible, ces conditions générales d'essai se réfèrent aux règles générales de l'IEC 60947-1 ou sont fondées sur celles-ci.

Chaque séquence d'essai se réfère aux conditions générales d'essai qui sont applicables. Cela demande l'emploi de références, mais permet de présenter chaque séquence d'essai sous une forme très simplifiée.

Le terme «essai» est utilisé dans toute cette section pour chaque essai à effectuer; il convient d'interpréter le terme «vérification» dans le sens de «essai de vérification» et ce terme est utilisé lorsqu'il s'agit de vérifier l'état du disjoncteur après un essai au cours d'une séquence d'essai où le disjoncteur aurait pu être endommagé.

Un index alphabétique est donné en 8.3.1.3 pour situer plus facilement une condition d'essai ou un essai. Cet index comprend les termes qui seront le plus vraisemblablement employés (pas forcément les termes exacts qui figurent dans le titre des paragraphes correspondants).

8.3.1 Séquences d'essai

8.3.1.1 Généralités

Les essais de type sont regroupés dans plusieurs séquences, comme indiqué au Tableau 9.

Pour chaque séquence, les essais doivent être réalisés dans l'ordre indiqué, sauf spécification contraire dans la présente norme.

8.3.1.2 Essais omis de la séquence I et réalisés séparément

En référence à 8.1.1 de l'IEC 60947-1:2007, les essais suivants de la séquence d'essai I (voir 8.3.3) peuvent être omis de la séquence et réalisés sur des échantillons séparés:

– limites et caractéristiques de déclenchement (8.3.3.2); auquel cas l'échantillon (ou les échantillons) en essai dans la séquence doi(ven)t être soumis aux essais de 8.3.3.2.3, uniquement sur les pôles des phases et au réglage maximal, à la température ambiante de la pièce et sans l'essai supplémentaire du point b) destiné à vérifier la caractéristique temps-courant;
– essai des propriétés diélectriques (8.3.3.3);
– essai des déclencheurs à minimum de tension de 8.3.3.4.2.3 et 8.3.3.4.3, afin de vérifier les exigences de 7.2.1.3 de l'IEC 60947-1:2007, et essais des déclencheurs à minimum de tension aux fréquences alternatives (voir 8.3.2.1);
– essai des déclencheurs shunt de 8.3.3.4.2.4 et 8.3.3.4.3, afin de vérifier les exigences de 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014, et essais des déclencheurs shunt aux fréquences alternatives (voir 8.3.2.1);
– essais supplémentaires d'aptitude au fonctionnement en service sans courant pour les disjoncteurs débrochables (8.3.3.4.5).

8.3.1.3 Applicabilité des séquences selon la relation entre les caractéristiques assignées de court-circuit

L'applicabilité des séquences d'essai en fonction de la relation entre I_{cs}, I_{cu} et I_{cw} est donnée au Tableau 9a.

Index alphabétique des essais

Tableau 9 – Schéma d'ensemble des séquences d'essai [a]

Séquence d'essai	Validité	Essais
I Caractéristiques générales de fonctionnement (8.3.3)	Tous les disjoncteurs	Limites et caractéristiques de déclenchement Propriétés diélectriques Fonctionnement mécanique et aptitude au fonctionnement en service Fonctionnement en surcharge (le cas échéant) Vérification de la tenue diélectrique Vérification de l'échauffement Vérification des déclencheurs de surcharge Vérification des déclencheurs à minimum de tension et des déclencheurs shunt (le cas échéant) Vérification de la position des contacts principaux (le cas échéant)
II Pouvoir assigné de coupure de service en court-circuit (8.3.4)	Tous les disjoncteurs [b]	Pouvoir assigné de coupure de service en court-circuit Vérification de l'aptitude au fonctionnement Vérification de la tenue diélectrique Vérification de l'échauffement Vérification des déclencheurs de surcharge
III Pouvoir assigné de coupure ultime en court-circuit (8.3.5)	Tous les disjoncteurs [c] de catégorie de sélectivité A et les disjoncteurs de catégorie de sélectivité B à commande instantanée [d]	Vérification des déclencheurs de surcharge Pouvoir assigné de coupure ultime en court-circuit Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge
IV Courant assigné de courte durée admissible (8.3.6)	Disjoncteurs de catégorie de sélectivité B [b] et disjoncteurs de catégorie de sélectivité A avec un courant assigné de courte durée admissible (voir 4.4)	Vérification des déclencheurs de surcharge Courant assigné de courte durée admissible Vérification de l'échauffement Pouvoir de coupure en court-circuit au courant maximal de courte durée admissible Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge

V
Fonctionnement des disjoncteurs à fusibles incorporés
(8.3.7)
	Phase 1 {
	Disjoncteurs à fusibles incorporés
	Phase 2 {
		Court-circuit au courant limite de sélectivité
		Vérification de l'échauffement
		Vérification de la tenue diélectrique
		Vérification des déclencheurs de surcharge
		Court-circuit à 1,1 fois le courant d'intersection
		Court-circuit au pouvoir assigné de coupure ultime en court-circuit
		Vérification de la tenue diélectrique
		Vérification des déclencheurs de surcharge

VI Séquence d'essai combinée (8.3.8)	Disjoncteurs de catégorie de sélectivité B: avec $I_{cw} = I_{cs}$ (remplace les séquences d'essai II et IV) avec $I_{cw} = I_{cs} = I_{cu}$ (remplace les séquences d'essai II, III et IV)	Vérification des déclencheurs de surcharge Courant assigné de courte durée admissible Pouvoir assigné de coupure de service en court-circuit Aptitude au fonctionnement en service Vérification de la tenue diélectrique Vérification de l'échauffement Vérification des déclencheurs de surcharge
Courant continu critique de charge (8.3.9)	Disjoncteurs à caractéristiques assignées à courant continu	Essais de courant continu critique de charge
Séquence d'essai en court-circuit sur un pôle séparément (Annexe C)	Disjoncteur pour emploi sur des réseaux avec liaison phase-terre	Pouvoir de coupure en court-circuit sur un pôle séparément (I_{su}) Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge
Séquence d'essai pour les disjoncteurs pour réseaux IT (Annexe H)	Disjoncteur pour emploi sur réseaux IT	Pouvoir de coupure en court-circuit sur un pôle séparément (I_{IT}) Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge

[a] Pour le choix des disjoncteurs pour les essais et les différentes séquences d'essai applicables en fonction de la relation entre I_{cs}, I_{cu} et I_{cw}, voir le Tableau 9a.

[b] Sauf lorsque la séquence VI est appliquée.

[c] Sauf

– lorsque $I_{cs} = I_{cu}$ (mais voir 8.3.5),
– lorsque la séquence VI est appliquée,
– pour les disjoncteurs à fusibles incorporés.

[d] Voir la note de 8.3.5.1

Tableau 9a – Applicabilité des séquences d'essai en fonction de la relation entre I_{cs}, I_{cu} et I_{cw} [a]

Relation entre I_{cs}, I_{cu} et I_{cw}	Séquence d'essai	Catégorie de sélectivité			
		A	A Fusibles incorporés	B	B Fusibles incorporés
CAS 1	I	X	X	X	X
	II	X	X	X	X
$I_{cs} \neq I_{cu}$ pour la catégorie de sélectivité A	III	X		X [b]	
$I_{cs} \neq I_{cu} \neq I_{cw}$ pour la catégorie de sélectivité B	IV	X [d]		X	X
	V		X		X
CAS 2	I			X	X
$I_{cs} = I_{cw} \neq I_{cu}$ pour la catégorie de sélectivité B	II			X	X
	III			X [b]	
	IV			X	X
	V				X
	VI (combinée)			X [c]	X [c]
CAS 3	I	X	X	X	X
	II	X	X	X	X
$I_{cs} = I_{cu}$ pour la catégorie de sélectivité A	III				
$I_{cs} = I_{cu} \neq I_{cw}$ pour la catégorie de sélectivité B	IV	X [d]		X	X
	V		X		X
CAS 4	I			X	
	II			X	
$I_{cs} = I_{cu} = I_{cw}$ pour la catégorie de sélectivité B	III				
	IV			X	
	V				
	VI (combinée)			X [c]	

[a] Tableau applicable à chacune des valeurs de U_e. Dans le cas de valeurs assignées multiples de U_e, le tableau s'applique à chaque valeur de U_e. La séquence d'essai applicable est indiquée par X dans la case correspondante.

[b] Essai applicable uniquement si $I_{cu} > I_{cw}$.

[c] A la discrétion du fabricant ou avec son accord, cette séquence d'essai peut être appliquée aux disjoncteurs de la catégorie de sélectivité B et, dans ce cas, elle remplace les séquences d'essai II et IV.

[d] La séquence d'essai IV s'applique seulement aux disjoncteurs à courant assigné de courte durée admissible (voir 4.4).

8.3.1.4 Programmes d'essais alternatifs pour disjoncteurs à courant alternatif comportant différents nombres de pôles

Ces programmes d'essai alternatifs peuvent uniquement être appliqués aux caractéristiques assignées en courant alternatif et lorsque toutes les caractéristiques assignées sont identiques ou inférieures à celles de la variante soumise au programme complet du Tableau 9, et les différences de construction sont les mêmes pour toutes les variantes. Dans le cas de disjoncteurs unipolaires, les tensions assignées doivent être inférieures ou égales à la tension phase-neutre de la variante soumise au programme complet du Tableau 9. Il n'est pas nécessaire de soumettre à l'essai un disjoncteur bipolaire obtenu en supprimant la ligne de courant centrale d'un disjoncteur tripolaire soumis à essai selon le programme 1 ou le programme 2 du présent paragraphe, car il est considéré comme couvert par les essais de la variante tripolaire.

La conformité aux exigences d'essais est satisfaite en réalisant l'un des programmes alternatifs 1 ou 2 suivants:

– Programme 1: Les séquences d'essai applicables selon le Tableau 9 doivent être effectuées sur la variante tripolaire. De plus, le cas échéant, les essais ou les séquences d'essai énumérés dans le Tableau 9b doivent être effectués sur les autres variantes.
– Programme 2: Les séquences d'essai applicables selon le Tableau 9 doivent être effectuées sur la variante tétrapolaire. De plus, le cas échéant, les essais ou les séquences d'essai énumérés dans le Tableau 9c doivent être effectués sur les autres variantes.

Le principe d'application des programmes d'essais alternatifs est illustré ci-après:

	Programme 1				**Programme 2**			
	unipolaire	bipolaire	tripolaire	tétrapolaire	unipolaire	bipolaire	tripolaire	tétrapolaire
Construction 1[a]	□	□	■	□	○	○	○	■
Construction 2	–	–	■	□	–	–	–	■
Construction 3	–	–	■	□	–	–	–	■
…	–	–	■	□	–	–	–	■
Construction *n*	–	–	■	□	–	–	–	■
Légende	■ soumis à essai entièrement selon le Tableau 9 □ soumis à essai selon le Tableau 9b ○ soumis à essai selon le Tableau 9c – pas d'essai exigé							
[a] La construction 1 est celle qui couvre la caractéristique assignée maximale.								

Tableau 9b – Applicabilité des essais ou des séquences d'essai aux disjoncteurs unipolaires, bipolaires et tétrapolaires selon le programme alternatif 1 de 8.3.1.4

Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tétrapolaire[f, h]	Applicabilité aux variantes unipolaires ou bipolaires[g]
I	8.3.3.2	Essai des limites et des caractéristiques de déclenchement		
	8.3.3.2.1	Généralités	X	X
	8.3.3.2.2	Déclencheurs de court-circuit	X[a]	X[e]
	8.3.3.2.3 a)[k] ou 8.3.3.2.3 b)[k] (suivant le cas)	Déclencheurs de surcharge: – instantanés/à retard indépendant – à temps inverse	X X	X[e]
	8.3.3.2.4	Essai supplémentaire pour les déclencheurs à retard indépendant:		
	8.3.3.3	Propriétés diélectriques	X	X
	8.3.3.4	Fonctionnement mécanique et aptitude au fonctionnement en service		
	8.3.3.4.1	Généralités	X	X
	8.3.3.4.2	Dispositions de construction et fonctionnement mécanique	X[d]	X[d, e]
	8.3.3.4.3	Aptitude au fonctionnement en service sans courant	X	X
	8.3.3.4.4	Aptitude au fonctionnement en service avec courant	X	X
	8.3.3.4.5	Disjoncteur débrochables	X	
	8.3.3.5	Fonctionnement en surcharge	X	X
	8.3.3.6	Vérification de la tenue diélectrique	X	X
	8.3.3.7	Vérification de l'échauffement	X	X
	8.3.3.8	Vérification des déclencheurs de surcharge		
	8.3.3.9	Vérification des déclencheurs à minimum de tension et des déclencheurs shunt	X	X
	8.3.3.10	Vérification de la position des contacts principaux	X	X
II	8.3.4	Pouvoir assigné de coupure de service en court-circuit		
III	8.3.5[b, c]	Pouvoir assigné de coupure ultime en court-circuit	X	X
IV	8.3.6	Courant assigné de courte durée admissible	X 4ème pôle et pôle adjacent uniquement (voir 8.3.2.6.4)	
V	8.3.7	Fonctionnement des disjoncteurs à fusibles incorporés	X	X
VI	8.3.8	Séquence d'essai combinée		
Annexe C		Séquence d'essai en court-circuit sur un pôle séparément		
Annexe H		Séquence d'essai pour les disjoncteurs pour réseaux IT		

NOTE L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case appropriée.

a	Un essai sur une paire de pôles de phase choisis au hasard. Dans le cas d'une unité de déclenchement électronique, cet essai peut être réalisé sur un pôle choisi au hasard.
b	Cette séquence d'essai s'applique aussi lorsque, pour les essais de disjoncteurs tripolaires, la séquence III sur la variante tripolaire est remplacée par la séquence II ou la séquence VI (voir le Tableau 9).
c	Un seul échantillon, de courant assigné maximal seulement, soumis à essai aux valeurs assignées correspondant au maximum de kVA ($I_{cu} \times U_e$ correspondant).
d	Sans les essais de vérification des déclencheurs à manque de tension (8.3.3.4.2.3) et des déclencheurs shunt (8.3.3.4.2.4).
e	Applicable uniquement à la variante unipolaire; non exigé pour les variantes bipolaires.
f	Dans le cas d'appareils tétrapolaires avec différents niveaux de protection du neutre (par exemple 60 % ou 100 %), seule la variante comportant le niveau le plus élevé est à soumettre à l'essai selon le Tableau 9b.
g	Un seul échantillon, de courant assigné maximal seulement, pour chaque séquence d'essai.
h	Un échantillon de courant assigné maximal pour chaque séquence d'essai; dans le cas d'une ou plusieurs différences de construction (voir 2.1.2 et 7.1.6) dans la taille, un échantillon supplémentaire est soumis à l'essai au courant assigné maximal correspondant à chaque construction.
i	Disponible.
j	Disponible.
k	Cet essai n'est pas exigé pour les unités de déclenchement électroniques.

Tableau 9c – Applicabilité des essais ou des séquences d'essai aux disjoncteurs unipolaires, bipolaires et tripolaires selon le programme alternatif 2 de 8.3.1.4

Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tripolaire[g]	Applicabilité aux variantes unipolaires ou bipolaires[g]
I	8.3.3.2	Essai des limites et des caractéristiques de déclenchement		
	8.3.3.2.1	Généralités		X
	8.3.3.2.2	Déclencheurs de court-circuit		X [e]
	8.3.3.2.3 a)[k] ou 8.3.3.2.3 b)[k] (suivant le cas)	Déclencheurs de surcharge: – instantanés/à retard indépendant – à temps inverse		X[e]
	8.3.3.2.4	Essai supplémentaire des déclencheurs à retard indépendant		
	8.3.3.3	Propriétés diélectriques	X	X
	8.3.3.4	Fonctionnement mécanique et aptitude au fonctionnement en service		
	8.3.3.4.1	Généralités	X	X
	8.3.3.4.2	Dispositions de construction et fonctionnement mécanique		X[d, e]
	8.3.3.4.3	Aptitude au fonctionnement en service sans courant	X	X
	8.3.3.4.4	Aptitude au fonctionnement en service avec courant	X	X
	8.3.3.4.5	Disjoncteur débrochables		
	8.3.3.5	Fonctionnement en surcharge	X	X
	8.3.3.6	Vérification de la tenue diélectrique	X	X
	8.3.3.7	Vérification de l'échauffement	X	X
	8.3.3.8	Vérification des déclencheurs de surcharge		
	8.3.3.9	Vérification des déclencheurs à minimum de tension et des déclencheurs shunt	X	X
	8.3.3.10	Vérification de la position des contacts principaux	X	X
II	8.3.4	Pouvoir assigné de coupure de service en court-circuit		

Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tripolaire[g]	Applicabilité aux variantes unipolaires ou bipolaires[g]
III	8.3.5[b, c]	Pouvoir assigné de coupure ultime en court-circuit	X	X
IV	8.3.6	Courant assigné de courte durée admissible		
V	8.3.7	Fonctionnement des disjoncteurs à fusibles incorporés	X	X
VI	8.3.8	Séquence d'essai combinée		
Annexe C		Séquence d'essai en court-circuit sur un pôle séparément		
Annexe H		Séquence d'essai pour les disjoncteurs pour réseaux IT		

NOTE L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case appropriée.

[a] Disponible.

[b] Cette séquence d'essai s'applique aussi lorsque, pour les essais de disjoncteurs tétrapolaires, la séquence III sur la variante tétrapolaire est remplacée par la séquence II ou la séquence VI (voir le Tableau 9).

[c] Un seul échantillon, de courant assigné maximal seulement, soumis à essai aux valeurs assignées correspondant au maximum de kVA ($I_{cu} \times U_e$ correspondant).

[d] Sans les essais de vérification des déclencheurs à manque de tension (8.3.3.4.2.3) et des déclencheurs shunt (8.3.3.4.2.4).

[e] Applicable uniquement à la variante unipolaire; non exigé pour les variantes bipolaires.

[f] Disponible.

[g] Un seul échantillon, de courant assigné maximal seulement, pour chaque séquence d'essai.

[h] Disponible.

[i] Disponible.

[j] Disponible.

[k] Cet essai n'est pas exigé pour les unités de déclenchement électroniques.

8.3.2 Conditions générales d'essai

NOTE Les essais selon les exigences de cette norme n'excluent pas la nécessité d'effectuer des essais supplémentaires concernant les disjoncteurs incorporés dans des ensembles, par exemple des essais selon la série IEC 61439.

8.3.2.1 Exigences générales

Sauf accord contraire du fabricant, chaque séquence d'essai doit être effectuée sur un échantillon de disjoncteurs (ou un jeu d'échantillons) à l'état neuf et propre.

Le nombre d'échantillons à soumettre à essai pour chaque séquence d'essai et les conditions d'essai (par exemple: réglage des déclencheurs de surcharge, raccordement des bornes) suivant les paramètres du disjoncteur, sont indiqués au Tableau 10 ou, le cas échéant, pour les programmes d'essais alternatifs, dans le Tableau 9b et le Tableau 9c (voir 8.3.1.4).

Lorsque cela est nécessaire, des informations complémentaires sont données aux paragraphes correspondants.

Sauf spécification contraire, les essais sont à effectuer sur un disjoncteur ayant le courant maximal assigné pour une taille donnée et sont considérés comme couvrant tous les courants assignés de cette taille.

Dans le cas d'une ou de plusieurs différences de construction (voir 2.1.2 et 7.1.6) dans la taille considérée, des échantillons supplémentaires doivent être soumis à essai conformément au Tableau 9b et/ou au Tableau 10, suivant le cas.

Sauf spécification contraire, les déclencheurs de court-circuit doivent être réglés au maximum (temps et courant) pour tous les essais.

Les disjoncteurs à soumettre à essai doivent être conformes dans tous leurs détails essentiels au plan du type qu'ils représentent.

Sauf indication contraire, les essais doivent être effectués avec un courant de même nature et, dans le cas du courant alternatif, de même fréquence assignée et avec le même nombre de phases que pour le service auquel le disjoncteur est destiné. Les essais réalisés à la fréquence de 50 Hz couvrent les applications à 60 Hz et vice-versa, à l'exception du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt (voir 7.2.2 de l'IEC 60947-1:2007/AMD2:2010 et 7.2.2.6 de l'IEC 60947-1:2007).

Si le mécanisme est à commande électrique, il doit être alimenté à la tension minimale spécifiée en 7.2.1.1.4. En outre, les mécanismes à commande électrique doivent être alimentés par les circuits de commande appropriés du disjoncteur complet, avec leurs appareils de connexion. Il doit être vérifié que le disjoncteur fonctionne correctement à vide lorsqu'il est manœuvré dans les conditions ci-dessus.

Dans le cas de disjoncteurs à manœuvre dépendante manuelle (voir 2.4.12 de l'IEC 60947-1:2007), le disjoncteur doit être manœuvré à une vitesse de 0,1 m/s ± 25 %, cette vitesse étant mesurée à l'endroit où l'organe de manœuvre de l'appareil d'essai touche l'organe de manœuvre du disjoncteur en essai. Pour les poignées tournantes, la vitesse angulaire doit correspondre essentiellement aux conditions ci-dessus en référence à la vitesse de l'organe de manœuvre (à ses extrémités) du disjoncteur en essai.

Le disjoncteur à soumettre à essai doit être monté complet sur son propre support ou un support équivalent.

Les disjoncteurs doivent être soumis à essai à l'air libre.

Lorsqu'un disjoncteur peut être utilisé dans des enveloppes individuelles spécifiées et qu'il a été soumis à essai à l'air libre, il doit en plus être soumis à essai dans la plus petite des enveloppes déclarées par le fabricant, en utilisant un nouvel échantillon pour chacun des essais suivants:

a) Un essai de court-circuit selon 8.3.5, à U_e max et à la valeur correspondante de I_{cu}, avec les réglages du déclencheur au maximum (voir note de bas de tableau a du Tableau 10).
b) Un essai d'échauffement selon les conditions générales de 8.3.2.5 réalisé sur un disjoncteur ayant une valeur maximale de I_{th} au courant thermique assigné conventionnel sous enveloppe I_{the} (voir 4.3.3.2). Les échauffements doivent satisfaire aux exigences de 7.2.2 à l'exception du fait que l'échauffement des bornes ne doit pas dépasser 70 K.

Les détails concernant ces essais, y compris les dimensions de l'enveloppe, doivent être consignés dans le rapport d'essai.

NOTE Une enveloppe individuelle est une enveloppe conçue et dimensionnée pour ne contenir qu'un seul disjoncteur.

Cependant, si un disjoncteur peut être utilisé dans des enveloppes individuelles spécifiées et est soumis à essai dans la plus petite de ces enveloppes déclarées par le fabricant, il n'est pas nécessaire d'effectuer les essais à l'air libre pourvu qu'une telle enveloppe soit en métal nu, sans isolation. Les détails, y compris les dimensions de l'enveloppe doivent être consignés dans le rapport d'essai.

Pour les essais à l'air libre, pour les essais relatifs au fonctionnement en surcharge (8.3.3.5), au court-circuit (8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.6, 8.3.7.7 et 8.3.8.4), ainsi qu'à la tenue au courant de courte durée admissible (8.3.6.3 et 8.3.8.3), suivant le cas, un écran métallique doit être placé sur toutes les faces du disjoncteur conformément aux instructions du fabricant. Les détails, y compris les distances du disjoncteur par rapport à l'écran métallique doivent être consignés dans le rapport d'essai.

Les caractéristiques de l'écran métallique doivent être les suivantes:

- structure: écran à fils entrelacés, ou
  métal perforé, ou
  métal expansé,
- surface des trous par rapport à la surface totale: 0,45 à 0,65;
- surface de chaque trou: ne dépassant pas 30 mm^2;
- finition: sans revêtement (nu) ou revêtement conducteur;
- résistance: doit être comprise dans le calcul du courant présumé de défaut dans le circuit de l'élément fusible (voir 8.3.4.1.2, point d), de l'IEC 60947-1:2007) et mesurée à partir du point le plus éloigné de l'écran métallique susceptible d'être atteint par les émissions d'arc.

Les couples de serrage appliqués aux vis des bornes doivent être conformes aux instructions du fabricant (voir 5.2 e)).

L'entretien ou le remplacement de pièces n'est pas autorisé.

Si, pour faciliter un essai, il apparaît utile d'en augmenter la sévérité (par exemple adopter une fréquence de manœuvres plus élevée pour réduire la durée de l'essai), cela ne doit pas être effectué sans le consentement du fabricant.

Pour les essais en courant monophasé sur les pôles individuels des disjoncteurs multipolaires pour alimentation d'un circuit où une phase est reliée à la terre, voir l'Annexe C.

Pour les essais supplémentaires des disjoncteurs pour les réseaux (IT) non reliés à la terre ou reliés à la terre par une impédance, voir l'Annexe H.

Tableau 10 – Nombre d'échantillons pour les essais *(1 de 2)*

Séquence d'essai	Nombre de caractéristiques assignées U_e marquées			Bornes repérées Alimentation/charge		Nombre d'échantillons	Echantillon N°	Courant de réglage [a]		Tension d'essai	Courant d'essai		Vérification de l'échauffement	Notes
	1	2	Plus	Oui	Non			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	Voir 8.3.3		X	g
II (I_{cs}) et VI (combinée)	X			X		2	1		X	U_e	X		X	h
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X		X	h
							2	X		U_e	X			b
							3		X	U_e	X		X	j
		X		X	X	3	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e max	X		X	k
			X	X	X	4	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e interméd.	X		X	e
							4		X	U_e max	X		X	k
III (I_{cu})	X			X		2	1		X	U_e	X			g
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X			g
							2	X		U_e	X			b
							3		X	U_e	X			c
		X		X	X	3	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e max	X			d
			X	X	X	4	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e interméd.	X			e
							4		X	U_e max	X			d

Tableau 10 *(2 de 2)*

Séquence d'essai	Nombre de caractéris-tiques assignées U_e marquées			Bornes repérées Alimentation/charge		Nombre d'échantillons	Echantillon N°	Courant de réglage [a]		Tension d'essai	Courant d'essai		Retard		Vérification de l'échauffement	Notes
	1	2	Plus	Oui	Non			Min.	Max.		Corr.	Max.	Corr.	Max.		
IV (I_{cw}) [l]	X			X	X	2	1		X	U_e max		X		X	X	[g]
							2		X	U_e max		X		X	X	[m]
			X	X	X	3	1		X	U_e max corr.		X	X		X	[g]
							2		X	U_e max corr.	X		X		X	[i]
							3		X	U_e max	X		X		X	[n, d]
V Fusibles incorporés (I_{cu})	X	X	X	X	X	2	1		X	U_e max	X				X	[f, g]
							2	X		U_e max	X					[b]
Pôle individuel (Annexe C) (I_{su})	X	X	X	X	X	2	1		X	U_e max	I_{su}					[g]
							2	X		U_e max	I_{su}					–
Pôle individuel (Annexe H) (I_{IT})	X	X	X	X	X	1	1		X	U_e max	I_{IT}					[g]

Légende

Plus = plusieurs (>2), Corr. = correspondant, Interméd. = intermédiaire

NOTE 1 Le Tableau 10 s'applique aux programmes d'essai du Tableau 9. Dans le cas des programmes d'essais alternatifs (voir 8.3.1.4), le Tableau 9b ou le Tableau 9c est applicable.

NOTE 2 L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case appropriée.

[a] Min signifie l'I_n minimum d'une taille donnée; dans le cas de déclencheurs de surcharge réglables, cela signifie le réglage minimal du I_n minimum. Max signifie le maximum de I_n pour une taille donnée.

[b] Cet échantillon est omis dans les cas suivants:

- –un disjoncteur ayant un seul courant de réglage non ajustable pour une taille donnée,
- –un disjoncteur équipé seulement d'un déclencheur shunt (c'est-à-dire sans déclencheur de surintensité intégré),
- –un disjoncteur à protection électronique contre les surintensités, d'une taille donnée, ayant un courant assigné réglable seulement par des moyens électroniques (c'est-à-dire sans changer de capteurs de courant).

[c] Connexions inversées.

[d] Connexions inversées si les bornes ne sont pas repérées.

[e] Suivant accord à conclure entre le laboratoire d'essais et le fabricant.

[f] Si les bornes ne sont pas repérées, un échantillon supplémentaire doit être soumis à essai avec les connexions inversées.

[g] Dans le cas d'une ou plusieurs différences de construction (voir 2.1.2 et 7.1.6) pour une taille donnée, un autre échantillon est soumis à essai au courant maximal assigné correspondant à chaque construction dans les conditions applicables à l'échantillon 1.

[h] L'exigence de la note g est applicable à la séquence VI (combinée) et aussi à la séquence II lorsque $I_{cs} = I_{cu}$.

[i] Cet échantillon est sélectionné sur la base de la valeur la plus élevée de l'énergie thermique ($I_{cw}^2 t$; où «*t*» est le retard de courte durée correspondant, voir 4.3.6.4). Cet échantillon est omis si la condition d'énergie thermique maximale est remplie par l'échantillon 1 ou 3.

[j] Cet échantillon, avec les connexions inversées, est uniquement exigé si la séquence III est remplacée par la séquence II (I_{cu}= I_{cs}, voir 8.3.5).

[k] Connexions inversées, si bornes non repérées, lorsque la séquence III est remplacée par la séquence II ($I_{cu} = I_{cs}$, voir 8.3.5) ou si la séquence VI remplace les séquences II, III et IV ($I_{cu} = I_{cs} = I_{cw}$, voir 8.3.8), autrement cet échantillon est soumis à essai avec une connexion dans le sens direct.

[l] S'applique uniquement aux disjoncteurs à courant assigné de courte durée admissible (voir 4.4).

[m] Cet échantillon, avec les connexions inversées, est uniquement exigé avec les bornes non repérées si la séquence III est remplacée par la séquence IV ($I_{cu} = I_{cw}$, voir 8.3.5).

[n] Cet échantillon est uniquement exigé lorsque la séquence III est remplacée par la séquence IV ($I_{cu} = I_{cw}$, voir 8.3.5).

8.3.2.2 Grandeurs d'essai

8.3.2.2.1 Valeurs des grandeurs d'essai

Le paragraphe 8.3.2.2.1 de l'IEC 60947-1:2007 est applicable.

8.3.2.2.2 Tolérances sur les grandeurs d'essai

Le paragraphe 8.3.2.2.2 de l'IEC 60947-1:2007 est applicable.

8.3.2.2.3 Fréquence du circuit d'essai en courant alternatif

Tous les essais doivent être effectués à la fréquence assignée du disjoncteur. Pour tous les essais de court-circuit, si le pouvoir de coupure assigné dépend essentiellement de la valeur de la fréquence, la tolérance ne doit pas dépasser ±5 %.

Si le fabricant indique que le pouvoir de coupure assigné est notablement indépendant de la valeur de la fréquence, la tolérance ne doit pas dépasser ±25 %.

8.3.2.2.4 Facteur de puissance du circuit d'essai

Le paragraphe 8.3.4.1.3 de l'IEC 60947-1:2007 est applicable avec la modification suivante:

Le Tableau 16 de l'IEC 60947-1:2007 est remplacé par le Tableau 11 de la présente norme.

Tableau 11 – Valeurs des facteurs de puissance et des constantes de temps en fonction des courants d'essai

Courant d'essai *I* kA	Facteur de puissance			Constante de temps ms		
	Court-circuit	Aptitude au fonctionnement en service	Surcharge	Court-circuit	Aptitude au fonctionnement en service	Surcharge
$I \leq 3$	0,9	0,8	0,5	5	2	2,5
$3 < I \leq 4,5$	0,8			5		
$4,5 < I \leq 6$	0,7			5		
$6 < I \leq 10$	0,5			5		
$10 < I \leq 20$	0,3			10		
$20 < I \leq 50$	0,25			15		
$50 < I$	0,2			15		

8.3.2.2.5 Constante de temps du circuit d'essai

Le paragraphe 8.3.4.1.4 de l'IEC 60947-1:2007 est applicable avec la modification suivante:

Le Tableau 16 de l'IEC 60947-1:2007 est remplacé par le Tableau 11 de la présente norme.

8.3.2.2.6 Tension de rétablissement à fréquence industrielle

Le point a) du 8.3.2.2.3 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

8.3.2.2.7 Ondulation du courant d'essai en courant continu

Le courant d'essai doit satisfaire aux exigences de 6.3.1 de l'IEC 62475:2010.

8.3.2.3 Interprétation des résultats d'essai

L'état du disjoncteur après les essais doit être contrôlé par les vérifications spécifiées pour chaque séquence.

Un disjoncteur est réputé avoir satisfait aux exigences de la présente norme s'il répond aux exigences de chaque séquence à laquelle il est soumis.

Le boîtier ne doit pas présenter de cassure, mais les fissures fines sont acceptables.

NOTE Les fissures fines sont la conséquence de la pression élevée du gaz ou de contraintes thermiques dues aux arcs lors de l'interruption de courants de défaut très élevés, et sont de nature superficielle. En conséquence, elles ne se propagent pas dans toute l'épaisseur de l'enveloppe moulée de l'appareil.

8.3.2.4 Rapports d'essai

Le paragraphe 8.3.2.4 de l'IEC 60947-1:2007 est applicable.

8.3.2.5 Conditions d'essai pour les essais d'échauffement

Le disjoncteur doit répondre aux exigences de 7.2.2.

Le paragraphe 8.3.3.3 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable, à l'exception de 8.3.3.3.6, avec le complément suivant:

Le disjoncteur doit être monté selon 8.3.2.1.

Pendant l'essai d'échauffement de la séquence I (voir 8.3.3.7), les bobines des déclencheurs à minimum de tension doivent (le cas échéant) être alimentées à une fréquence assignée et sa tension correspondante, choisies au hasard. Des essais supplémentaires pour vérifier les bobines à d'autres fréquences et tensions assignées doivent être réalisés en dehors de la séquence.

Pour les disjoncteurs tétrapolaires, un essai doit d'abord être effectué sur les trois pôles munis de déclencheurs à maximum de courant. Un essai complémentaire doit être effectué sur les disjoncteurs de courant assigné ne dépassant pas 63 A en faisant passer le courant d'essai par le quatrième pôle et le pôle adjacent. Pour les valeurs supérieures de courant assigné, la méthode d'essai doit faire l'objet d'un accord séparé entre le fabricant et l'utilisateur.

8.3.2.6 Conditions d'essai pour les essais de court-circuit

8.3.2.6.1 Exigences générales

Le paragraphe 8.3.4.1.1 de l'IEC 60947-1:2007 est complété comme suit:

a) Le disjoncteur doit être monté selon 8.3.2.1.
b) A moins qu'il ne puisse être montré que, les moyens de manœuvre manuelle étant dans n'importe quelle position, il n'y a pas d'ouverture autour des moyens de manœuvre manuelle par laquelle une corde à piano de 0,26 mm de diamètre peut être introduite jusqu'à la chambre d'arc, les dispositions d'essai suivantes doivent s'appliquer.

   Pour les manœuvres d'ouverture seulement, une feuille de polyéthylène à basse densité, transparente, d'une épaisseur égale à 0,05 mm ± 0,01 mm et de dimension 100 mm × 100 mm positionnée comme indiqué sur la Figure 1, est fixée et tendue de façon raisonnable sur un cadre et placée à une distance de 10 mm:

   – de la position la plus débordante de l'organe de fermeture manuelle d'un disjoncteur dont l'organe de fermeture ne se trouve pas dans un renfoncement;
   – ou du bord du renfoncement pour un disjoncteur dont l'organe de fermeture manuelle se trouve dans un renfoncement.

La feuille de polyéthylène doit avoir les caractéristiques physiques suivantes:

- densité à 23 °C: 0,92 g/cm^3 ± 0,05 g/cm^3,
- point de fusion: 110 °C à 120 °C.

Sur le côté opposé au disjoncteur, il doit y avoir un renfort convenable afin d'éviter une déchirure de la feuille de polyéthylène due à l'onde de pression qui peut survenir pendant l'essai de court-circuit (voir Figure 1).

Pour les essais autres que ceux dans une enveloppe individuelle, un écran, qui peut être en matériau isolant ou en métal, est placé entre l'écran métallique et la feuille de polyéthylène (voir Figure 1).

NOTE Le dispositif d'essai s'applique aux manœuvres O seulement étant donné qu'il est difficile d'effectuer les manœuvres CO et il est accepté que les manœuvres O ne sont pas moins graves que les manœuvres CO (voir 8.3.2.6.4).

c) Le disjoncteur doit être manœuvré au cours des essais de manière à reproduire aussi fidèlement que possible les conditions de service.

Un disjoncteur à manœuvre dépendante par source d'énergie extérieure doit se fermer au cours des essais avec une alimentation de commande (tension ou pression) égale à 85 % de sa valeur assignée.

Un disjoncteur à manœuvre indépendante par source d'énergie extérieure doit se fermer au cours des essais avec le mécanisme de manœuvre chargé à la valeur maximale fixée par le fabricant.

Un disjoncteur à manœuvre par accumulation d'énergie doit se fermer au cours des essais avec le dispositif de manœuvre alimenté à 85 % de la tension assignée de l'alimentation auxiliaire.

d) Si un disjoncteur est muni de déclencheurs réglables à maximum de courant, le réglage de ces déclencheurs doit être comme spécifié pour chaque séquence d'essai.

Dans le cas des disjoncteurs non équipés de déclencheurs à maximum de courant mais équipés d'un déclencheur shunt, celui-ci doit être alimenté sous une tension égale à 70 % de la tension assignée d'alimentation de commande de ce déclencheur (voir 7.2.1.2.3), appliquée au plus tôt au début du court-circuit et au plus tard 10 ms après le début de celui-ci.

e) Pour tous ces essais, le côté source du circuit d'essai doit être raccordé aux bornes correspondantes du disjoncteur telles qu'elles ont été repérées par le fabricant. En l'absence de tels repères, les connexions d'essai doivent être comme spécifiées au Tableau 10.

8.3.2.6.2 Circuit d'essai

Le paragraphe 8.3.4.1.2 de l'IEC 60947-1:2007/AMD1:2010 est applicable.

8.3.2.6.3 Etalonnage du circuit d'essai

Le paragraphe 8.3.4.1.5 de l'IEC 60947-1:2007 est applicable.

8.3.2.6.4 Mode opératoire d'essai

8.3.2.6.4.1 Généralités

Le paragraphe 8.3.4.1.6 de l'IEC 60947-1:2007 est applicable, avec le complément suivant.

8.3.2.6.4.2 Essais sur disjoncteurs unipolaires, bipolaires et tripolaires

Après étalonnage du circuit d'essai, conformément à 8.3.2.6.3, les connexions provisoires sont remplacées par le disjoncteur en essai et ses câbles de raccordement, le cas échéant.

Les essais de vérification du fonctionnement en condition de court-circuit doivent être effectués conformément aux séquences du Tableau 9 (voir 8.3.1).

Pour les disjoncteurs dont le courant assigné ne dépasse pas 630 A, un câble d'au plus 75 cm de longueur, et de section correspondant au courant thermique conventionnel (voir 8.3.3.3.4, Tableaux 9 et 10 de l'IEC 60947-1:2007) doit être inséré, comme suit:

– environ 50 cm côté source,
– environ 25 cm côté charge.

Pour les caractéristiques assignées ≤ 20 A, le fabricant peut spécifier une section plus grande, auquel cas cette dernière doit être utilisée pour tous les essais de court-circuit applicables, et être indiquée dans le rapport d'essai. De plus, une vérification des déclencheurs à temps inverse selon 8.3.3.2.3 b) doit être réalisée avec ladite section.

La séquence de manœuvres doit être celle applicable à chaque séquence d'essai, comme spécifié en 8.3.4.2, 8.3.5.3, 8.3.6.5 et 8.3.7.7.

Des programmes d'essais alternatifs pour les disjoncteurs disposant de variantes à trois pôles et quatre pôles sont indiqués en 8.3.1.4.

8.3.2.6.4.3 Essais de disjoncteurs tétrapolaires

Les exigences de 8.3.2.6.4.2 s'appliquent.

Des séquences de manœuvres supplémentaires doivent être réalisées sur un ou plusieurs échantillons nouveaux, conformément au Tableau 10, sur le quatrième pôle et le pôle adjacent, conformément à la séquence III ou V, suivant le cas, et à la séquence IV le cas échéant. Cette exigence s'applique même lorsque la séquence III est remplacée par la séquence II (I_{cu} = I_{cs}) ou lorsque la séquence IV est remplacée par la séquence VI (I_{cw} = I_{cs}).

En variante, à la demande du fabricant, ces essais peuvent être combinés avec les essais en tripolaire de 8.3.2.6.4.2 et réalisés sur les mêmes échantillons, auquel cas l'essai dans chaque séquence d'essai appropriée doit comprendre

– l'essai des trois pôles adjacents de phase,
– l'essai du quatrième pôle et du pôle adjacent.

Les essais sur le quatrième pôle et le pôle adjacent sont réalisés sous une tension appliquée de $U_e/\sqrt{3}$, dans le circuit représenté à la Figure 12 de l'IEC 60947-1:2007/AMD1:2010 avec les connexions C1 et C2 retirées. Le courant d'essai doit faire l'objet d'un accord entre le fabricant et l'utilisateur, mais ne doit pas être inférieur à 60 % de I_{cu} ou de I_{cw} suivant le cas.

Des programmes d'essais alternatifs pour les disjoncteurs disposant de variantes à trois pôles et quatre pôles sont indiqués en 8.3.1.4.

8.3.2.6.4.4 Manœuvres d'essai

Les symboles suivants sont utilisés pour définir la séquence de manœuvres:

O représente une manœuvre de coupure;

CO représente une manœuvre d'établissement suivie d'une manœuvre de coupure, après la durée d'ouverture appropriée;

t représente l'intervalle de temps entre deux manœuvres en court-circuit successives, qui doit être aussi court que possible, en tenant compte de la durée de réarmement du disjoncteur (voir 2.19), mais pas inférieure à 3 min. La valeur réelle de *t* doit être spécifiée dans le rapport d'essai.

La durée de réarmement maximale doit être de 15 min ou une durée plus longue pouvant être déclarée par le fabricant, mais sans dépasser 1 h, durant laquelle le disjoncteur ne doit pas être déplacé. Les tentatives de refermeture du disjoncteur pendant la durée de réarmement doivent être espacées d'au moins 1 min.

La valeur maximale de I^2t (voir 2.5.18 de l'IEC 60947-1:2007) notée durant ces essais peut être consignée dans le rapport d'essai (voir 7.2.1.2.4, point a)).

8.3.2.6.5 Comportement du disjoncteur pendant les essais de fermeture et de coupure en court-circuit

Le paragraphe 8.3.4.1.7 de l'IEC 60947-1:2007 est applicable.

8.3.2.6.6 Interprétation des enregistrements

Le paragraphe 8.3.4.1.8 de l'IEC 60947-1:2007 est applicable.

8.3.2.6.7 Vérification après les essais de court-circuit

Après les manœuvres d'ouverture des essais de pouvoir de coupure et de fermeture en court-circuit de 8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.7, 8.3.8.4, suivant le cas, les conditions suivantes doivent être remplies:

– l'isolant des câbles utilisés pour raccorder l'appareil ne doit présenter aucune dégradation;
– la feuille de polyéthylène, le cas échéant, ne doit pas présenter de trous visibles à l'œil nu ou avec vision corrigée sans grossissement supplémentaire. Les trous minuscules dont le diamètre est inférieur à 0,26 mm peuvent être ignorés;
– le boîtier ne doit pas présenter de cassure, mais les fissures fines sont acceptables.

NOTE Les fissures fines sont la conséquence de la pression élevée du gaz ou de contraintes thermiques dues aux arcs lors de l'interruption de courants de défaut très élevés, et sont de nature superficielle. En conséquence, elles ne se propagent pas dans toute l'épaisseur de l'enveloppe moulée de l'appareil.

Ensuite, après les essais de court-circuit, le disjoncteur doit satisfaire aux vérifications spécifiées pour chaque séquence d'essai s'il y a lieu.

8.3.3 Séquence d'essai I: Caractéristiques générales de fonctionnement

8.3.3.1 Généralités

Cette séquence d'essai s'applique à tous les disjoncteurs et comprend les essais suivants:

Essai	Paragraphe
Limites et caractéristiques de déclenchement	8.3.3.2
Propriétés diélectriques	8.3.3.3
Fonctionnement mécanique et aptitude au fonctionnement en service	8.3.3.4
Fonctionnement en surcharge (le cas échéant)	8.3.3.5
Vérification de la tenue diélectrique	8.3.3.6
Vérification de l'échauffement	8.3.3.7
Vérification des déclencheurs de surcharge	8.3.3.8
Vérification des déclencheurs à minimum de tension et des déclencheurs shunt (le cas échéant)	8.3.3.9
Vérification de la position des contacts principaux (pour disjoncteurs aptes au sectionnement)	8.3.3.10

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

Voir 8.3.1 pour les essais qui peuvent être omis de la séquence et effectués sur des échantillons séparés.

8.3.3.2 Essai des limites et des caractéristiques de déclenchement

8.3.3.2.1 Généralités

Le paragraphe 8.3.3.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est développé comme suit:

La température de l'air ambiant doit être mesurée comme lors des essais d'échauffement (voir 8.3.2.5).

Quand le déclencheur d'ouverture à maximum de courant est normalement monté comme partie intégrante du disjoncteur, il doit être vérifié dans le disjoncteur correspondant.

Tout déclencheur séparé doit être monté approximativement comme dans les conditions normales de service. Le disjoncteur complet doit être monté selon 8.3.2.1. Le matériel à l'essai doit être protégé contre des échauffements ou des refroidissements anormaux dus à des causes extérieures.

Les connexions du déclencheur séparé, le cas échéant, ou du disjoncteur complet doivent être réalisées de la même façon que pour le service normal avec des conducteurs de section correspondant au courant assigné (I_n) (voir 8.3.3.3.4, Tableaux 9 et 10 de l'IEC 60947-1:2007), et de longueur conforme au 8.3.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

Pour les disjoncteurs munis de déclencheurs à maximum de courant réglables, les essais doivent être effectués aux :

a) courant de réglage minimal et au réglage minimal de la temporisation, suivant le cas, et

b) courant de réglage maximal et au réglage maximal de la temporisation, suivant le cas,

dans chaque cas avec des conducteurs correspondant au courant assigné I_n (voir 4.7.2).

Pour les essais pour lesquels la caractéristique de déclenchement est indépendante de la température des bornes (par exemple les déclencheurs électroniques de surcharge, les déclencheurs magnétiques), les données relatives au raccordement (type, section, longueur) peuvent être différentes de celles exigées en 8.3.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014. Il convient que les raccordements soient compatibles avec le courant d'essai et les contraintes thermiques induites.

Pour les disjoncteurs ayant un pôle neutre équipé d'un déclencheur de surcharge, la vérification de ce déclencheur de surcharge doit être effectuée sur le pôle neutre seul.

Les essais peuvent être effectués à toute tension convenable.

8.3.3.2.2 Déclencheurs de court-circuit

Le fonctionnement des déclencheurs de court-circuit (voir 4.7.1) doit être vérifié à 80 % et à 120 % du courant de réglage de court-circuit du déclencheur. Pour les essais en courant alternatif, le courant d'essai ne doit pas présenter d'asymétrie. Pour les essais en courant continu, le courant ne doit présenter aucun dépassement au démarrage et la constante de temps doit être inférieure à 10 ms.

Pour une valeur du courant d'essai égale à 80 % du courant de réglage de court-circuit, le déclencheur ne doit pas fonctionner, le courant étant maintenu:

– pendant 0,2 s dans le cas de déclencheurs instantanés (voir 2.20),
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour une valeur de courant d'essai égale à 120 % du courant de réglage de court-circuit, le déclencheur doit fonctionner:

– en 0,2 s dans le cas de déclencheurs instantanés (voir 2.20);
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour les disjoncteurs munis d'un déclencheur de surintensité électronique, le fonctionnement des déclencheurs de court-circuit doit être vérifié par seulement un essai sur chaque pôle individuellement.

Pour les disjoncteurs munis de déclencheurs de surintensité électromagnétiques, le fonctionnement des déclencheurs multipolaires de court-circuit doit être vérifié par seulement un essai sur chaque combinaison de deux pôles de phase en série. Pour les disjoncteurs possédant un pôle neutre identifié muni d'un déclencheur de court-circuit, le pôle neutre doit être soumis à essai en série avec un pôle de phase choisi au hasard. De plus, le fonctionnement des déclencheurs de court-circuit doit être vérifié une fois sur chaque pôle individuellement, à 120 % de la valeur déclarée par le fabricant pour les pôles individuels ou de la valeur de réglage du courant de court-circuit (si aucune valeur n'est déclarée pour les pôles individuels), et le fonctionnement à cette valeur doit s'effectuer:

– en 0,2 s dans le cas de déclencheurs instantanés (voir 2.20);
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Les déclencheurs à retard indépendant doivent, en outre, satisfaire aux exigences de 8.3.3.2.4.

8.3.3.2.3 Déclencheurs de surcharge

a) Déclencheurs instantanés ou à retard indépendant

Le fonctionnement des déclencheurs de surcharge instantanés ou à retard indépendant (voir Note 1 de 4.7.1) doit être vérifié à 90 % et à 110 % du courant de réglage de surcharge du déclencheur. Pour les essais en courant alternatif, le courant d'essai ne doit pas présenter d'asymétrie. Pour les essais en courant continu, le courant ne doit présenter aucun dépassement au démarrage et la constante de temps doit être inférieure à 10 ms. Le fonctionnement des déclencheurs de surcharge multipolaires doit être vérifié avec tous les pôles de phase alimentés simultanément par le courant d'essai.

Les déclencheurs à retard indépendant doivent, en outre, satisfaire aux exigences de 8.3.3.2.4.

A un courant d'essai d'une valeur égale à 90 % du courant de réglage, le déclencheur ne doit pas fonctionner, le courant étant maintenu

– pendant 0,2 s dans le cas de déclencheurs instantanés (voir 2.20),
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

A un courant d'essai d'une valeur égale à 110 % du courant de réglage, le déclencheur doit fonctionner

– en 0,2 s dans le cas de déclencheurs instantanés (voir 2.20),
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour les disjoncteurs ayant un pôle neutre identifié équipé d'un déclencheur de surcharge (voir 8.3.3.2.3), le courant d'essai pour ce déclencheur doit avoir une valeur égale à 1,2 fois 110 % du courant de réglage.

b) Déclencheurs à temps inverse

Les caractéristiques de fonctionnement des déclencheurs de surcharge à temps inverse doivent être vérifiées selon les exigences de 7.2.1.2.4, point b) 2).

Pour les disjoncteurs ayant un pôle neutre identifié équipé d'un déclencheur de surcharge (voir 8.3.3.2.4), les courants d'essai pour ce déclencheur doivent être choisis dans le Tableau 6 excepté que le courant d'essai au courant conventionnel de déclenchement doit être multiplié par le facteur 1,2.

Pour les déclencheurs sensibles à la température de l'air ambiant, les caractéristiques de fonctionnement doivent être vérifiées à la température de référence (voir 4.7.3 et point b) de 5.2), le déclencheur étant alimenté sur tous les pôles de phase.

Si l'essai est effectué à une température différente de la température de l'air ambiant, une correction doit être effectuée conformément aux caractéristiques température/courant fournies par le fabricant.

Pour les déclencheurs magnétothermiques déclarés insensibles à la température de l'air ambiant par le fabricant, les caractéristiques de fonctionnement doivent être vérifiées par deux mesurages, l'un à 30 °C ± 2 °C, l'autre à 20 °C ± 2 °C ou à 40 °C ± 2 °C, le déclencheur étant alimenté sur tous les pôles de phase.

Pour les déclencheurs électroniques, les caractéristiques de fonctionnement doivent être vérifiées à la température ambiante du local d'essai (voir 6.1.1 de l'IEC 60947-1:2007/AMD2:2014), le déclencheur étant alimenté sur tous les pôles de phase.

Un essai supplémentaire, à une valeur de courant devant faire l'objet d'un accord entre le fabricant et l'utilisateur, doit être effectué en vue de vérifier que les caractéristiques temps/courant du déclencheur correspondent (dans les limites des tolérances indiquées) aux courbes fournies par le fabricant.

NOTE En plus des essais décrits dans ce paragraphe, les déclencheurs des disjoncteurs sont également vérifiés sur chaque pôle séparément au cours des séquences d'essai III, IV V et VI (voir 8.3.5.2, 8.3.5.5, 8.3.6.2, 8.3.6.7, 8.3.7.5, 8.3.7.9, 8.3.8.2 et 8.3.8.8).

8.3.3.2.4 Essais supplémentaires des déclencheurs à retard indépendant

Les déclencheurs à retard indépendant doivent être soumis à essai pour vérifier les valeurs du retard et de la durée de non-déclenchement

a) Retard

Cet essai est effectué à un courant égal à 1,5 fois le courant de réglage:

– dans le cas de déclencheurs de surcharge, tous les pôles de phase étant chargés;
– pour les disjoncteurs ayant un pôle neutre identifié équipé d'un déclencheur de surcharge (voir 8.3.3.2.1), le courant d'essai pour ce déclencheur doit être égal à 1,5 fois le courant de réglage;
– dans le cas de déclencheurs de court-circuit électromagnétiques, avec deux pôles en série parcourus par le courant d'essai, en utilisant successivement toutes les combinaisons possibles de pôles de phase munis d'un déclencheur de court-circuit.
– dans le cas de déclencheurs de court-circuit électroniques, sur un pôle choisi au hasard.

Le retard mesuré doit se trouver entre les limites fixées par le fabricant.

Si le courant d'essai chevauche une autre caractéristique de déclenchement (par exemple une caractéristique de déclenchement instantané), le réglage du déclenchement (par exemple I_{sd}, voir Figure K.1) et le courant d'essai doivent être réduits autant que nécessaire pour empêcher un déclenchement prématuré. Ces valeurs doivent être enregistrées dans le rapport d'essai.

b) Durée de non-déclenchement

Cet essai est effectué dans les mêmes conditions que pour l'essai du point a) ci-dessus pour les déclencheurs de surcharge et pour les déclencheurs de court-circuit:

Un courant d'essai égal à 1,5 fois le courant de réglage est d'abord maintenu pendant un intervalle de temps égal à la durée de non-déclenchement fixée par le fabricant; puis le courant est réduit à la valeur correspondant au courant de réglage de surcharge (I_r) et il est maintenu à cette valeur pendant un intervalle de temps égal au double du retard fixé par le fabricant. Le disjoncteur ne doit pas déclencher.

8.3.3.3 Essai des propriétés diélectriques

Le paragraphe 8.3.3.4.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable, à l'exception du point 5), avec les compléments suivants:

(i) en référence à 8.3.3.4.1, point 2) c) i) et ii), de l'IEC 60947-1:2007: les positions normales de service comprennent la position de déclenchement, le cas échéant;

(ii) en référence à 8.3.3.4.1, point 3 c), de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014: pour les besoins de la présente norme, les circuits comprenant des appareils à semi-conducteurs reliés au circuit principal doivent être déconnectés pour l'essai;

(iii) les disjoncteurs non déclarés comme aptes au sectionnement doivent être soumis à essai avec la tension d'essai appliquée à travers les pôles du circuit principal, les bornes amont étant reliées entre elles et les bornes aval étant reliées entre elles. La tension d'essai doit être en conformité au Tableau 12 de l'IEC 60947-1:2007;

(iv) pour les disjoncteurs aptes au sectionnement (voir 3.5) et ayant une tension d'emploi supérieure à 50 V, le courant de fuite, mesuré à travers chaque pôle avec les contacts en position d'ouverture, à une tension d'essai égale à 1,1 U_e, ne doit pas dépasser 0,5 mA;

(v) les disjoncteurs ayant une tension d'isolement assignée supérieure à 1 000 V en courant alternatif doivent être soumis à essai à une tension de U_i + 1 200 V en courant alternatif (valeur efficace) ou 2 U_i selon la plus grande des deux valeurs;

(vi) les disjoncteurs débrochables (voir 7.1.2) doivent faire l'objet d'une vérification de la tension de tenue aux chocs, selon 8.3.3.4.1, point 2) b) de l'IEC 60947-1:2007. La tension d'essai doit être choisie dans le Tableau 14 de l'IEC 60947-1:2007, et elle doit être appliquée entre les contacts principaux des unités débrochables et leurs contacts fixes correspondantes, en position déconnectée. Les critères d'acceptation sont ceux de 8.3.3.4.1, point 2) d) de l'IEC 60947-1:2007.

8.3.3.4 Essais de fonctionnement mécanique et d'aptitude au fonctionnement en service

8.3.3.4.1 Conditions générales d'essai

Le disjoncteur doit être monté comme indiqué en 8.3.2.1, mis à part que, pour ces essais, il peut être monté sur un châssis métallique. Le disjoncteur doit être protégé contre tout échauffement ou refroidissement extérieur excessif.

Les essais doivent être effectués à la température ambiante du local d'essai.

La tension d'alimentation de commande de chaque circuit de commande doit être mesurée à ses bornes sous le courant assigné.

Toutes les résistances ou impédances faisant partie de l'appareil de commande doivent être en circuit. Cependant, aucune impédance supplémentaire ne doit être insérée entre la source de courant et les bornes de l'appareil.

Les essais de 8.3.3.4.2, 8.3.3.4.3 et 8.3.3.4.4 doivent être effectués sur le même disjoncteur, mais l'ordre dans lequel ces essais sont effectués est facultatif. Cependant pour les essais des déclencheurs à minimum de tension et les déclencheurs shunt, les essais de 8.3.3.4.2 et 8.3.3.4.3 peuvent être effectués, à la place, sur un échantillon neuf.

S'il est souhaité, dans le cas des disjoncteurs pouvant être entretenus, qu'un nombre de manœuvres supérieur à celui spécifié au Tableau 8 soit effectué, ces manœuvres supplémentaires doivent être effectuées d'abord, suivies par des opérations d'entretien conformes aux instructions du fabricant et, ensuite, par le nombre de manœuvres prévu au Tableau 8, sans qu'aucune autre opération d'entretien soit permise au cours du restant de cette séquence d'essai.

Pour la commodité de l'essai, il est admis de diviser chacun de ces essais en deux périodes ou plus. Il convient cependant qu'aucune de ces périodes ne soit inférieure à 3 h.

8.3.3.4.2 Dispositions constructives et fonctionnement mécanique

8.3.3.4.2.1 Construction

Un disjoncteur débrochable doit être vérifié suivant les exigences de 7.1.2.

La conformité à 7.2.1.1.6 d'un disjoncteur à manœuvre par accumulation d'énergie doit être vérifiée en ce qui concerne l'indication de la charge et le sens de manœuvre du mécanisme manuel d'accumulation d'énergie.

8.3.3.4.2.2 Fonctionnement mécanique

Les essais doivent être effectués comme spécifié en 8.3.3.4.1 en vue de:

- vérifier le déclenchement satisfaisant du disjoncteur, l'appareil de fermeture étant alimenté;
- vérifier le comportement satisfaisant du disjoncteur lorsque la manœuvre de fermeture est provoquée, l'appareil de déclenchement étant en action;
- vérifier que la mise en action d'un appareil à commande par source d'énergie extérieure, lorsque le disjoncteur est déjà fermé, ne doit provoquer aucun dommage au disjoncteur ni mettre en danger l'opérateur.

Le fonctionnement mécanique d'un disjoncteur peut être vérifié à vide.

Un disjoncteur à manœuvre dépendante à source d'énergie extérieure doit satisfaire aux exigences de 7.2.1.1.4.

Un disjoncteur à manœuvre dépendante à source d'énergie extérieure doit fonctionner avec son mécanisme de manœuvre chargé aux limites minimale et maximale fixées par le fabricant.

Un disjoncteur à manœuvre par accumulation d'énergie doit être conforme aux exigences de 7.2.1.1.6 avec une tension d'alimentation auxiliaire égale à 85 % et à 110 % de la tension assignée d'alimentation de commande. Il doit être aussi vérifié que les contacts mobiles ne peuvent pas s'écarter de la position d'ouverture lorsque la charge du mécanisme de manœuvre est légèrement inférieure à la pleine charge mise en évidence par l'appareil indicateur.

Les contacts d'un disjoncteur à déclenchement libre ne doivent pas pouvoir être maintenus en contact ou en position de fermeture lorsque le déclencheur est en position de déclenchement.

Si les durées de fermeture et d'ouverture d'un disjoncteur sont indiquées par le fabricant, leurs valeurs doivent être conformes à ces indications.

8.3.3.4.2.3 Déclencheurs à minimum de tension

Les déclencheurs à minimum de tension doivent satisfaire aux exigences de 7.2.1.3 de l'IEC 60947-1:2007. Pour cela, le déclencheur doit être adapté à un disjoncteur ayant le courant maximal assigné pour lequel le déclencheur convient.

i) Tension de retombée

   Il doit être aussi vérifié que le déclencheur fonctionne pour ouvrir le disjoncteur entre les limites de tension spécifiées.

   La tension doit être réduite en partant de la tension assignée d'alimentation de commande pour atteindre 0 V en 30 s environ.

L'essai pour la limite inférieure est effectué sans courant dans le circuit principal et sans préchauffage préalable de la bobine du déclencheur.

Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation de commande, cet essai est effectué à la tension maximale de la plage.

L'essai pour la limite supérieure est effectué en partant d'une température constante correspondant à l'application de la tension assignée d'alimentation de commande au déclencheur et au courant assigné dans les pôles principaux du disjoncteur. Cet essai peut être combiné avec l'essai d'échauffement de 8.3.3.7.

Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation de commande, cet essai est effectué aux deux tensions assignées minimale et maximale d'alimentation de commande.

ii) Essai pour les limites de fonctionnement

En démarrant avec le disjoncteur ouvert, à la température du local d'essai et avec la tension d'alimentation égale à 30 % de la tension assignée maximale d'alimentation de commande, il doit être vérifié que le disjoncteur ne peut pas être fermé en manœuvrant l'organe de commande. Lorsque la tension d'alimentation est augmentée jusqu'à 85 % de la tension assignée minimale d'alimentation de commande, il doit être vérifié que le disjoncteur peut être fermé en manœuvrant l'organe de commande.

iii) Fonctionnement dans des conditions de maximum de tension

Le disjoncteur étant fermé sans courant dans le circuit principal, il doit être vérifié que le déclencheur à minimum de tension supporte l'application d'une tension égale à 110 % de la tension assignée d'alimentation de commande pendant 4 h sans altérer ses performances.

8.3.3.4.2.4 Déclencheurs shunt

Les déclencheurs à minimum de tension doivent satisfaire aux exigences de 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014. Pour cela, le déclencheur doit être adapté à un disjoncteur ayant le courant maximal assigné pour lequel le déclencheur convient.

Il doit être vérifié que le déclencheur fonctionne pour ouvrir le disjoncteur à 70 % de la tension assignée d'alimentation de commande, celui-ci étant soumis à essai à une température ambiante de + 55 °C ± 2 °C sans courant dans les pôles principaux du disjoncteur. Dans le cas d'un déclencheur ayant une plage de tensions assignées d'alimentation de commande, la tension d'essai doit correspondre à 70 % de la tension minimale assignée d'alimentation de commande.

8.3.3.4.3 Aptitude au fonctionnement en service sans courant

Ces essais doivent être effectués dans les conditions spécifiées en 8.3.2.1. Le nombre de cycles de manœuvres à effectuer sur le disjoncteur est indiqué dans la colonne 3 du Tableau 8; le nombre de cycles de manœuvres par heure est indiqué dans la colonne 2 de ce tableau.

Les essais doivent être effectués sans courant dans le circuit principal du disjoncteur.

Pour les disjoncteurs qui peuvent être équipés de déclencheurs shunt, 10 % du nombre total de cycles de manœuvres doivent être des manœuvres de fermeture/déclenchement, c'est-à-dire avec le déclencheur shunt alimenté à la tension maximale assignée d'alimentation de commande.

Pour les disjoncteurs qui peuvent être équipés de déclencheurs à minimum de tension, 10 % du nombre total de cycles de manœuvres doivent être des manœuvres de fermeture/déclenchement à la tension minimale assignée d'alimentation de commande, cette tension étant retirée du déclencheur après chaque manœuvre de fermeture, afin de déclencher le disjoncteur.

Dans chaque cas, la moitié du nombre de cycles de manœuvres doit être effectuée au début des essais et l'autre moitié à la fin des essais.

Pour les disjoncteurs équipés de déclencheurs à minimum de tension, avant l'essai de fonctionnement en service, le déclencheur à minimum de tension non alimenté, il doit être vérifié que le disjoncteur ne peut pas être fermé en essayant 10 fois de le fermer.

Les essais doivent être réalisés sur un disjoncteur muni de son propre mécanisme de fermeture. Dans le cas de disjoncteurs munis d'un appareil électrique ou pneumatique de fermeture, cet appareil doit être alimenté à sa tension assignée d'alimentation de commande ou à sa pression assignée. Des précautions doivent être prises pour éviter que les échauffements des organes électriques ne dépassent pas les limites indiquées au Tableau 7.

Les disjoncteurs manœuvrés à la main doivent être manœuvrés comme en usage normal.

8.3.3.4.4 Aptitude au fonctionnement en service avec courant

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 8.3.2.1, le circuit d'essai étant conforme au 8.3.3.5.2 de l'IEC 60947-1:2007.

Le nombre et la fréquence des cycles de manœuvres à effectuer sont donnés dans les colonnes 2 et 4 du Tableau 8.

Le fonctionnement du disjoncteur doit être tel qu'il établisse et qu'il coupe son courant assigné sous sa tension assignée d'emploi maximale, fixée par le fabricant, avec un facteur de puissance ou une constante de temps, suivant le cas, conforme au Tableau 11, les tolérances étant telles qu'indiquées en 8.3.2.2.2.

Les essais sur les disjoncteurs à courant assigné alternatif doivent être effectués à une fréquence comprise entre 45 Hz et 62 Hz.

Pour les disjoncteurs munis de déclencheurs réglables, les essais doivent être effectués avec les déclencheurs réglés à leur valeur de réglage maximale en surcharge et minimale en court-circuit.

Les essais doivent être réalisés sur un disjoncteur muni de son propre mécanisme de fermeture. Dans le cas de disjoncteurs munis d'un appareil électrique ou pneumatique de fermeture, cet appareil doit être alimenté à sa tension assignée d'alimentation de commande ou à sa pression assignée. Des précautions doivent être prises pour s'assurer que les échauffements des organes électriques n'excèdent pas les valeurs indiquées au Tableau 7.

Les disjoncteurs manœuvrés à la main doivent être manœuvrés comme en usage normal.

8.3.3.4.5 Essai supplémentaire d'aptitude au fonctionnement en service sans courant pour les disjoncteurs débrochables

Un essai d'aptitude au fonctionnement en service sans courant doit être effectué sur le mécanisme de débrochage et les dispositifs de verrouillage associés des disjoncteurs débrochables.

Le nombre de cycles de manœuvres doit être 100.

Après cet essai, les contacts de sectionnement, le mécanisme de débrochage et les dispositifs de verrouillage doivent pouvoir assurer leur fonction. La vérification doit être effectuée par inspection.

8.3.3.5 Fonctionnement en surcharge

Cet essai s'applique aux disjoncteurs de courant assigné inférieur ou égal à 630 A.

NOTE 1 Sur demande du fabricant, cet essai peut aussi être effectué sur des disjoncteurs de courant assigné supérieur à 630 A.

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 8.3.2.1, et le circuit d'essai doit être conforme au 8.3.3.5.2 de l'IEC 60947-1:2007.

L'essai doit être effectué à une tension correspondant à la valeur maximale d'emploi $U_{e\ max}$ assignée par le fabricant au disjoncteur, en prenant en compte l'exigence relative à la tension de rétablissement du Tableau 12 (voir également 8.3.2.2.3 a) de l'IEC 60947-1:2007/AMD2:2014).

Pour les disjoncteurs munis de déclencheurs réglables, cet essai doit être effectué avec les déclencheurs réglés à leur valeur de réglage maximale.

Le disjoncteur doit être ouvert neuf fois à la main et trois fois de façon automatique par l'action d'un déclencheur de surcharge, sauf dans le cas de disjoncteurs ayant un déclencheur de court-circuit dont le réglage maximal est inférieur au courant d'essai, pour lesquels toutes les 12 manœuvres doivent être automatiques.

Si le moyen d'essai ne résiste pas au passage de l'énergie apparaissant pendant le fonctionnement automatique, l'essai peut être effectué de la façon suivante, avec l'accord du fabricant:

– 12 manœuvres manuelles;
– trois manœuvres supplémentaires avec une ouverture automatique, réalisées sous toute tension appropriée.

Au cours de chacun des cycles manuels, le disjoncteur doit rester fermé pendant une durée suffisante pour assurer l'établissement complet du courant, mais ne dépassant pas 2 s.

Le nombre de cycles de manœuvres par heure doit être comme spécifié dans la colonne 2 du Tableau 8. Si le disjoncteur ne se verrouille pas à la fréquence spécifiée, cette fréquence peut être réduite suffisamment pour permettre au disjoncteur de se fermer après l'établissement complet du courant.

Si les conditions de l'installation d'essai ne permettent pas de réaliser les essais à la fréquence de manœuvre spécifiée au Tableau 8, une fréquence plus faible peut être adoptée, mais ce fait doit être mentionné dans le rapport d'essai.

Les valeurs du courant et de la tension de rétablissement d'essai doivent être conformes au Tableau 12, avec le facteur de puissance ou la constante de temps, le cas échéant, conforme au Tableau 11, les tolérances étant telles qu'indiquées en 8.3.2.2.2.

NOTE 2 Avec l'accord du fabricant, cet essai peut être effectué dans des conditions plus sévères que celles spécifiées.

Tableau 12 – Caractéristiques du circuit d'essai pour le fonctionnement en surcharge

	Courant alternatif	Courant continu
Courant	6 I_n	2,5 I_n
Tension de rétablissement	1,05 $U_{e\ max}$	1,05 $U_{e\ max}$
$U_{e\ max}$ = tension d'emploi maximale du disjoncteur.		

Les essais sur les disjoncteurs à courant assigné alternatif doivent être effectués à une fréquence comprise entre 45 Hz et 62 Hz.

Le courant présumé aux bornes d'alimentation du disjoncteur doit être au moins égal à la plus petite des deux valeurs suivantes: 10 fois la valeur du courant d'essai ou au moins 50 kA.

8.3.3.6 Vérification de la tenue diélectrique

8.3.3.6.1 Généralités

L'essai doit être effectué sur le disjoncteur restant monté tel qu'il l'était pour l'essai précédent. Si ce montage n'est pas possible, il peut être déconnecté et retiré du circuit d'essai, mais alors des mesures doivent être prises pour s'assurer que cela n'influence pas les résultats de l'essai.

8.3.3.6.2 Tension d'essai

Le paragraphe 8.3.3.4.1, point 3) b), de l'IEC 60947-1:2007/AMD1:2010 est applicable.

La valeur de la tension d'essai doit être égale à 2 U_e avec un minimum de 1 000 V en valeur efficace, ou 1 415 V en courant continu si une tension alternative ne peut pas être appliquée. La valeur de U_e à considérer est celle à laquelle les essais de manœuvre et/ou de court-circuit précédents ont été effectués.

8.3.3.6.3 Application de la tension d'essai

La tension d'essai doit être appliquée pendant 5 s conformément à 8.3.3.4.1, points 2) c) i), ii) et iii), de l'IEC 60947-1:2007 et, en complément, entre les bornes d'entrée et de sortie de chaque pôle, le disjoncteur étant ouvert. L'utilisation de la feuille métallique telle que spécifiée en 8.3.3.4.1, point 1), de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 n'est pas exigée. Pour les besoins de la présente norme, les circuits comprenant des appareils à semi-conducteurs reliés au circuit principal doivent être déconnectés pour les essais. Les positions normales de service comprennent la position de déclenchement, le cas échéant.

Pour les disjoncteurs aptes au sectionnement, le courant de fuite doit être mesuré selon 8.3.3.3, point (iv), excepté que le courant de fuite ne doit pas dépasser 2 mA.

8.3.3.6.4 Critères d'acceptation

Le paragraphe 8.3.3.4.1, point 3) d), de l'IEC 60947-1:2007 est applicable.

8.3.3.7 Vérification de l'échauffement

A la suite de l'essai de 8.3.3.6, un essai d'échauffement doit être effectué au courant thermique conventionnel, conformément à 8.3.2.5. A la fin de l'essai, les valeurs des échauffements ne doivent pas dépasser celles spécifiées au Tableau 7.

8.3.3.8 Vérification des déclencheurs de surcharge

Immédiatement après l'essai effectué conformément à 8.3.3.7, le fonctionnement des déclencheurs de surcharge doit être vérifié à 1,45 fois la valeur de leur courant de réglage, à la température de référence (voir 7.2.1.2.4, point b) 2)).

Tous les pôles doivent être reliés en série pour cet essai. En variante, cet essai peut être effectué avec une alimentation triphasée.

Cet essai peut être effectué sous toute tension convenable.

La durée de fonctionnement ne doit pas dépasser la durée conventionnelle de déclenchement.

Avec l'accord du fabricant, un délai entre les essais de 8.3.3.7 et 8.3.3.8 est admissible.

En variante, cet essai peut être effectué à la température de l'air ambiant, à un courant d'essai modifié conformément aux caractéristiques température/courant fournies par le fabricant, pour les déclencheurs sensibles à la température ambiante.

8.3.3.9 Vérification des déclencheurs à minimum de tension et des déclencheurs shunt

Les disjoncteurs équipés de déclencheurs à minimum de tension doivent être soumis à l'essai de 8.3.3.4.2.3 i), excepté que les essais pour les limites supérieures et inférieures doivent être effectués à la température du local d'essai sans courant dans le circuit principal. Le déclencheur ne doit pas fonctionner à 70 % de la tension minimale d'alimentation de commande et doit fonctionner à 35 % de la tension maximale assignée d'alimentation de commande.

Les disjoncteurs équipés de déclencheurs shunt doivent être soumis à l'essai de 8.3.3.4.2.4, excepté que l'essai peut être effectué à la température du local d'essai. Le déclencheur doit fonctionner à 70 % de la tension minimale assignée d'alimentation de commande.

8.3.3.10 Vérification de la position des contacts principaux

Pour les disjoncteurs aptes au sectionnement (voir 3.5), après la vérification de 8.3.3.8, un essai doit être effectué afin de vérifier l'efficacité de l'indication de la position des contacts principaux selon 8.2.5 de l'IEC 60947-1:2007/AMD1:2010.

8.3.4 Séquence d'essai II: Pouvoir assigné de coupure de service en court-circuit

8.3.4.1 Généralités

Sauf dans les cas où s'applique la séquence d'essai VI (combinée) (voir 8.3.8), cette séquence d'essai s'applique à tous les disjoncteurs et comprend les essais suivants:

Essai	Paragraphe
Pouvoir assigné de coupure de service en court-circuit	8.3.4.2
Vérification de l'aptitude au fonctionnement	8.3.4.3
Vérification de la tenue diélectrique	8.3.4.4
Vérification de l'échauffement	8.3.4.5
Vérification des déclencheurs de surcharge	8.3.4.6

Pour le cas où $I_{cs} = I_{cu}$, voir 8.3.5.

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.4.2 Essai du pouvoir assigné de coupure de service en court-circuit

Un essai de court-circuit est effectué dans les conditions générales de 8.3.2, la valeur du courant présumé I_{cs} déclarée par le fabricant étant conforme à 4.3.6.2.3.

Le facteur de puissance pour cet essai doit être conforme au Tableau 11, pour le courant d'essai approprié.

La séquence de manœuvres doit être:

$$O - t - CO - t - CO$$

Dans le cas des disjoncteurs à fusibles incorporés, tout fusible fondu doit être remplacé après chaque manœuvre. Il peut être nécessaire d'augmenter pour cela l'intervalle de temps t.

8.3.4.3 Vérification de l'aptitude au fonctionnement

Après l'essai selon 8.3.4.2, l'aptitude au fonctionnement doit être vérifiée selon 8.3.3.4.4, excepté que cette vérification doit être effectuée à la même tension assignée d'emploi utilisée pour l'essai de 8.3.4.2 et que le nombre de manœuvres doit être égal à 5 % du nombre donné dans la colonne 4 du Tableau 8.

Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.4.2 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge tel que spécifié au Tableau 10.

8.3.4.4 Vérification de la tenue diélectrique

Après l'essai selon 8.3.4.3, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

Pour les disjoncteurs aptes au sectionnement, le courant de fuite doit être mesuré selon 8.3.3.6.

8.3.4.5 Vérification de l'échauffement

Après l'essai selon 8.3.4.4, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.2.5. L'échauffement ne doit pas dépasser les valeurs données au Tableau 7.

Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.4.2 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge.

8.3.4.6 Vérification des déclencheurs de surcharge

Immédiatement après l'essai de 8.3.4.5, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.3.8.

Avec l'accord du fabricant, un délai entre les essais de 8.3.4.5 et 8.3.4.6 est admissible.

8.3.5 Séquence d'essai III: Pouvoir assigné de coupure ultime en court-circuit

8.3.5.1 Généralités

Sauf dans les cas où s'applique la séquence d'essai VI (combinée) (voir 8.3.8), cette séquence d'essai s'applique aux disjoncteurs de catégorie de sélectivité A et à ceux de catégorie de sélectivité B dont le pouvoir assigné de coupure ultime en court-circuit est supérieur au courant assigné de courte durée admissible.

NOTE Pour ce type de disjoncteurs de catégorie de sélectivité B, le déclencheur instantané fonctionne à des valeurs de courant supérieures à celles indiquées dans la colonne 2 du Tableau 3 (4.3.6.4); ce type de déclencheur peut être appelé «commande instantanée».

Il n'est pas nécessaire d'effectuer cette séquence d'essai sur les disjoncteurs de catégorie de sélectivité B dont le courant assigné de courte durée admissible est égal au pouvoir assigné de coupure ultime en court-circuit car, dans ce cas, le pouvoir de coupure ultime en court-circuit est vérifié au cours de la séquence d'essai IV.

Pour les disjoncteurs à fusibles incorporés, la séquence d'essai V s'applique à la place de cette séquence.

Lorsque $I_{cs} = I_{cu}$, cette séquence d'essai peut ne pas être réalisée, et dans ce cas des essais de différences de construction sont exigés en séquence II (voir le Tableau 10) et les vérifications suivantes doivent être faites en plus dans la séquence d'essai II:

– la vérification de 8.3.5.2 au début de la séquence d'essai,
– la vérification de 8.3.5.5 à la fin de la séquence d'essai.

Cette séquence d'essai comprend les essais suivants:

Essai	Paragraphe
Vérification des déclencheurs de surcharge	8.3.5.2
Pouvoir assigné de coupure ultime en court-circuit	8.3.5.3
Vérification de la tenue diélectrique	8.3.5.4
Vérification des déclencheurs de surcharge	8.3.5.5

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.5.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié à deux fois la valeur de leur courant de réglage sur chaque pôle séparément. Cet essai peut être effectué sous toute tension convenable.

Si la température ambiante est différente de la température de référence, la valeur du courant d'essai doit être corrigée conformément aux caractéristiques température/courant fournies par le fabricant, pour les déclencheurs sensibles à la température ambiante.

Pour les essais pour lesquels la caractéristique de déclenchement est indépendante de la température des bornes (par exemple les déclencheurs électroniques de surcharge, les déclencheurs magnétiques), les données relatives au raccordement (type, section, longueur) peuvent être différentes de celles exigées en 8.3.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014. Il convient que les raccordements soient compatibles avec le courant d'essai et les contraintes thermiques induites.

La durée de fonctionnement ne doit pas dépasser la valeur maximale fixée par le fabricant pour le double du courant de réglage à la température de référence, sur un pôle séparément.

8.3.5.3 Essai de pouvoir assigné de coupure ultime en court-circuit

Après l'essai de 8.3.5.2, un essai de pouvoir de coupure en court-circuit est effectué avec un courant présumé de valeur égale au pouvoir assigné de coupure ultime en court-circuit déclaré par le fabricant, dans les conditions générales conformes à celles de 8.3.2.

La séquence de manœuvres doit être:

$$O – t – CO$$

8.3.5.4 Vérification de la tenue diélectrique

Après l'essai selon 8.3.5.3, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6. Pour les disjoncteurs aptes au sectionnement, le courant de fuite ne doit pas dépasser 6 mA.

8.3.5.5 Vérification des déclencheurs de surcharge

Après l'essai selon 8.3.5.4, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2, excepté que le courant d'essai doit être de valeur égale à 2,5 fois celle de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

8.3.6 Séquence d'essai IV: Courant assigné de courte durée admissible

8.3.6.1 Généralités

Sauf lorsque la séquence d'essai VI (combinée) s'applique (voir 8.3.8), cette séquence d'essai s'applique aux disjoncteurs à courant assigné de courte durée admissible (voir 4.4); elle comprend les essais suivants:

Essai	Paragraphe
Vérification des déclencheurs de surcharge	8.3.6.2
Courant assigné de courte durée admissible	8.3.6.3
Vérification de l'échauffement	8.3.6.4
Pouvoir de coupure en court-circuit au courant maximal de courte durée admissible	8.3.6.5
Vérification de la tenue diélectrique	8.3.6.6
Vérification des déclencheurs de surcharge	8.3.6.7

Les disjoncteurs à fusibles incorporés de catégorie de sélectivité B doivent satisfaire aux exigences de cette séquence.

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.6.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2.

8.3.6.3 Essai du courant assigné de courte durée admissible

Le paragraphe 8.3.4.3 de l'IEC 60947-1:2007 est applicable, avec le complément suivant:

Pour les besoins de cet essai seulement, tout déclencheur à maximum de courant, y compris la commande instantanée, s'il y a lieu, susceptible de fonctionner au cours de l'essai, doit être rendu inopérant.

8.3.6.4 Vérification de l'échauffement

Après l'essai de 8.3.6.3, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.2.5. L'échauffement ne doit pas dépasser la valeur indiquée au Tableau 7.

Avec l'accord du fabricant, la vérification de l'échauffement peut être faite après la vérification de la tenue diélectrique (8.3.6.6). Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.7.3 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge.

8.3.6.5 Essai de pouvoir de coupure en court-circuit au courant maximal de courte durée admissible

Après l'essai de 8.3.6.4, un essai en court-circuit doit être effectué avec la séquence de manœuvres suivante:

$$O - t - CO$$

dans les conditions générales de 8.3.2, avec un courant présumé de valeur égale à celle de l'essai de tenue au courant de courte durée admissible (voir 8.3.6.3) et sous la tension la plus élevée applicable au courant assigné de courte durée admissible.

Le disjoncteur doit rester fermé pendant la courte durée associée à la durée maximale de réglage possible du déclencheur de court-circuit de courte durée, et la commande instantanée, le cas échéant, ne doit pas fonctionner. Si le disjoncteur a un déclencheur sous courant de fermeture (voir 2.10), cette exigence ne s'applique pas à la manœuvre CO si le courant présumé dépasse la valeur prédéterminée, puisqu'il va fonctionner.

8.3.6.6 Vérification de la tenue diélectrique

Après l'essai selon 8.3.6.5, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

8.3.6.7 Vérification des déclencheurs de surcharge

Après l'essai selon 8.3.6.6, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2, excepté que le courant d'essai doit être de valeur égale à 2,5 fois celle de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

8.3.7 Séquence d'essai V: Fonctionnement des disjoncteurs à fusibles incorporés

8.3.7.1 Généralités

Cette séquence d'essai s'applique aux disjoncteurs à fusibles incorporés. Elle remplace la séquence d'essai III et comprend les essais suivants:

	Essai	Paragraphe
Phase 1	Court-circuit au courant limite de sélectivité	8.3.7.2
	Vérification de l'échauffement	8.3.7.3
	Vérification de la tenue diélectrique	8.3.7.4
Phase 2	Vérification des déclencheurs de surcharge	8.3.7.5
	Court-circuit à 1,1 fois le courant d'intersection	8.3.7.6
	Court-circuit au pouvoir assigné de coupure ultime en court-circuit	8.3.7.7
	Vérification de la tenue diélectrique	8.3.7.8
	Vérification des déclencheurs de surcharge	8.3.7.9

Cette séquence d'essai est divisée en deux phases:

– La phase 1 comprend les essais de 8.3.7.2 à 8.3.7.4;
– La phase 2 comprend les essais de 8.3.7.5 à 8.3.7.9.

Ces deux phases peuvent être effectuées:

– sur deux disjoncteurs distincts, ou
– sur le même disjoncteur, avec des opérations d'entretien entre elles, ou
– sur le même disjoncteur, sans aucun entretien; auquel cas l'essai de 8.3.7.4 peut être omis.

L'essai selon 8.3.7.3 ne doit être effectué que si $I_{cs} > I_s$.

Les essais selon 8.3.7.2, 8.3.7.6 et 8.3.7.7 doivent être effectués à la tension maximale d'emploi du disjoncteur.

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.7.2 Court-circuit au courant limite de sélectivité

Un essai de court-circuit est effectué dans les conditions générales de 8.3.2, avec un courant présumé de valeur égale à celle du courant limite de sélectivité déclarée par le fabricant (voir 2.17.4).

Pour cet essai, les fusibles appropriés doivent être en place.

Cet essai doit consister en une manœuvre «O» à l'issue de laquelle les fusibles doivent demeurer intacts.

8.3.7.3 Vérification de l'échauffement

NOTE Cette vérification de l'échauffement est effectuée car les fusibles peuvent avoir fondu au cours de l'essai de court-circuit de la séquence d'essai II, 8.3.4.2, auquel cas l'essai de 8.3.7.2 est plus sévère.

Après l'essai selon 8.3.7.2, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.2.5.

L'échauffement ne doit pas dépasser la valeur indiquée au Tableau 7.

8.3.7.4 Vérification de la tenue diélectrique

Après l'essai selon 8.3.7.3, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

8.3.7.5 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2.

8.3.7.6 Court-circuit à 1,1 fois le courant d'intersection

Après l'essai selon 8.3.7.5, un essai de court-circuit est effectué dans les mêmes conditions générales que celles de 8.3.7.2, avec un courant présumé de valeur égale à 1,1 fois celle du courant d'intersection déclarée par le fabricant (voir 2.17.5).

Pour cet essai, les fusibles appropriés doivent être en place.

Cet essai doit consister en une manœuvre «O», à l'issue de laquelle au moins deux des fusibles doivent avoir fondu.

8.3.7.7 Court-circuit au pouvoir assigné de coupure ultime en court-circuit

Après l'essai de 8.3.7.6, un essai de court-circuit est effectué dans les mêmes conditions générales que celles de 8.3.7.2, avec un courant présumé de valeur égale au pouvoir de coupure ultime en court-circuit I_{cu} déclaré par le fabricant.

Pour cet essai, un nouveau jeu de fusibles doit être mis en place.

La séquence de manœuvres doit être:

$$O - t - CO$$

un autre nouveau jeu de fusibles étant mis en place au cours de l'intervalle de temps t, qui peut être allongé pour cette raison.

8.3.7.8 Vérification de la tenue diélectrique

Après l'essai selon 8.3.7.7 et avec un nouveau jeu de fusibles adaptés, la tenue diélectrique doit être vérifiée selon 8.3.5.4.

8.3.7.9 Vérification des déclencheurs de surcharge

Après l'essai selon 8.3.7.8, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2, excepté que le courant d'essai doit être de valeur égale à 2,5 fois celle de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

8.3.8 Séquence d'essai VI: séquence d'essai combinée

8.3.8.1 Généralités

A la discrétion du fabricant ou en accord avec celui-ci, cette séquence d'essai peut s'appliquer aux disjoncteurs de catégorie de sélectivité B:

a) lorsque le courant assigné de courte durée admissible et le pouvoir assigné de coupure de service en court-circuit ont la même valeur ($I_{cw} = I_{cs}$); dans ce cas, elle remplace les séquences d'essai II et IV;

b) lorsque le courant assigné de courte durée admissible, le pouvoir assigné de coupure de service en court-circuit et le pouvoir assigné de coupure ultime en court-circuit ont la même valeur ($I_{cw} = I_{cs} = I_{cu}$); dans ce cas, elle remplace les séquences d'essai II, III et IV.

Cette séquence d'essai comprend les essais suivants:

Essai	Paragraphe
Vérification des déclencheurs de surcharge	8.3.8.2
Courant assigné de courte durée admissible	8.3.8.3
Pouvoir assigné de coupure de service en court-circuit*	8.3.8.4
Vérification de l'aptitude au fonctionnement	8.3.8.5
Vérification de la tenue diélectrique	8.3.8.6
Vérification de l'échauffement	8.3.8.7
Vérification des déclencheurs de surcharge	8.3.8.8
* Pour les disjoncteurs répondant au cas de 8.3.8.1 b) ci-dessus, il s'agit également du pouvoir assigné de coupure ultime en court-circuit.	

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.8.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2.

8.3.8.3 Essai du courant assigné de courte durée admissible

Après l'essai selon 8.3.8.2, un essai doit être effectué au courant assigné de courte durée admissible conformément à 8.3.6.3.

Il n'est pas nécessaire d'effectuer cet essai sur l'échantillon de I_n minimum spécifié dans le Tableau 10.

8.3.8.4 Essai du pouvoir assigné de coupure de service en court-circuit

Après l'essai selon 8.3.8.3, un essai doit être effectué au pouvoir assigné de coupure de service en court-circuit, conformément à 8.3.4.2, à la tension la plus élevée applicable au courant assigné de court-circuit admissible. Le disjoncteur doit rester fermé pendant la courte durée correspondant à la durée maximale de réglage possible du déclencheur de court-circuit de courte durée.

Au cours de cet essai, la commande instantanée (le cas échéant) ne doit pas fonctionner et le déclencheur sous courant de fermeture (le cas échéant) doit fonctionner.

8.3.8.5 Vérification de l'aptitude au fonctionnement

Après l'essai selon 8.3.8.4, l'aptitude au fonctionnement doit être vérifiée selon 8.3.4.3.

8.3.8.6 Vérification de la tenue diélectrique

Après l'essai selon 8.3.8.5, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

Pour les disjoncteurs aptes au sectionnement, le courant de fuite doit être mesuré selon 8.3.3.6.

8.3.8.7 Vérification de l'échauffement

Après l'essai selon 8.3.8.6, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.4.5.

L'échauffement ne doit pas dépasser la valeur indiquée au Tableau 7.

Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.8.4 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge.

8.3.8.8 Vérification des déclencheurs de surcharge

Après refroidissement suivant l'essai de 8.3.8.7, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.3.8.

Le fonctionnement des déclencheurs de surcharge doit ensuite être vérifié sur chaque pôle individuellement selon 8.3.5.2, excepté que le courant d'essai doit être égal à 2,5 fois la valeur de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

8.3.9 Essai de courant continu critique de charge

Cet essai s'applique uniquement aux disjoncteurs ayant des valeurs assignées en courant continu.

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 8.3.2.1, et le circuit d'essai doit être conforme au 8.3.3.5.2 de l'IEC 60947-1:2007 excepté que l'écran métallique et l'élément fusible ne doivent pas être utilisés.

Les échantillons à soumettre à essai doivent être sélectionnés selon le Tableau 10 – séquence I, excepté que pour l'application de la note g, les différences de construction relatives aux appareils de déclenchement aux surintensités ne doivent pas être prises en compte.

L'essai doit être effectué à la tension continue maximale d'emploi (U_e max) assignée par le fabricant au disjoncteur.

Pour les disjoncteurs munis de déclencheurs réglables, l'essai doit être effectué avec les déclencheurs réglés à leur valeur maximale.

Le disjoncteur doit être fermé et ouvert 5 fois à chacun des courants d'essai énumérés ci-dessous. Si le sens de passage du courant est spécifié par le fabricant, l'essai doit être effectué en faisant passer le courant dans le sens spécifié, tel qu'indiqué par la polarité et le marquage amont/aval. Dans le cas contraire, cinq manœuvres doivent être effectuées dans le sens direct et cinq dans le sens inverse.

Au cours de chaque cycle de fermeture-ouverture, le disjoncteur doit rester fermé pendant une durée suffisante pour assurer l'établissement complet du courant, sans dépasser 2 s.

La constante de temps doit être conforme à la valeur indiquée dans le Tableau 11 comme pour le fonctionnement en service. A la discrétion du fabricant, une valeur plus élevée peut être utilisée, auquel cas cette valeur doit être indiquée dans le rapport d'essai.

Le nombre de cycles de manœuvres par heure doit être comme spécifié dans le Tableau 8.

La durée d'arc pendant l'essai doit être consignée et ne doit pas dépasser 1 s.

Les valeurs du courant d'essai doivent être: 4 A, 8 A, 16 A, 32 A et 63 A en courant continu, avec une tolérance de ± 10 %, sans toutefois dépasser le courant assigné. La valeur critique est déterminée en considérant la durée d'arc moyenne maximale, pour chaque sens de passage du courant le cas échéant. Les valeurs les plus élevées et les plus basses du courant d'essai doivent présenter des durées d'arc moyennes plus courtes que pour la valeur critique. Si nécessaire, pour déterminer la valeur critique, la plage des courants d'essai doit être étendue à la hausse ou à la baisse en appliquant un rapport de 2 autant de fois que nécessaire, sans toutefois dépasser la valeur du courant assigné. Si aucune valeur critique du courant n'est trouvée dans les limites de ces critères, aucun autre essai conformément à ce paragraphe n'est nécessaire.

Les tolérances applicables aux grandeurs d'essai autres que celles du courant doivent être conformes à 8.3.2.2.2.

A l'issue de cet essai, le même échantillon doit faire l'objet d'une vérification de fonctionnement en service de 50 manœuvres, dans les mêmes conditions, au courant et dans le sens correspondant à la valeur critique. Après cet essai, la tenue diélectrique doit être vérifiée selon 8.3.3.6 avec une tension d'essai en courant continu.

8.4 Essais individuels de série

8.4.1 Généralités

Pour la définition des essais individuels de série, voir 2.6.2 et 8.1.3 de l'IEC 60947-1:2007.

Les essais suivants sont applicables:

– fonctionnement mécanique (8.4.2),
– vérification de l'étalonnage des déclencheurs de surintensité (8.4.3),
– vérification du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt (8.4.4),
– essais supplémentaires pour les DPR selon l'Annexe B (8.4.5),
– essais diélectriques (voir note) (8.4.6),
– vérification des distances d'isolement (8.4.7).

NOTE Si, par le contrôle des matériaux et des procédés de fabrication, l'intégrité des propriétés diélectriques a été prouvée, ces essais peuvent être remplacés par des essais sur prélèvement selon le plan d'échantillonnage reconnu (voir l'IEC 60410).[1]

Cependant, le fonctionnement du disjoncteur pendant la fabrication et/ou un autre essai individuel de série peut prendre la place des essais cités ci-dessus pourvu que les mêmes conditions soient applicables et que le nombre de manœuvres ne soit pas inférieur à celui spécifié.

Les essais de 8.4.3, 8.4.4 et 8.4.5 doivent être effectués avec les déclencheurs équipant le disjoncteur ou avec un matériel d'essai approprié simulant le comportement du disjoncteur.

Dans le contexte des essais de 8.4.2, 8.4.3, 8.4.4, 8.4.6 et 8.4.7, le terme «disjoncteurs» englobe les DPR, le cas échéant.

8.4.2 Essais de fonctionnement mécanique

Les essais suivants doivent être effectués sans courant dans le circuit principal, sauf si cela est exigé pour le fonctionnement des déclencheurs. Pendant les essais, aucun réglage ne doit être effectué et le fonctionnement doit être satisfaisant.

Les essais suivants doivent être effectués sur les disjoncteurs manœuvrés manuellement:

– deux manœuvres de fermeture-ouverture,
– deux manœuvres à déclenchement libre.

NOTE Pour la définition d'un appareil mécanique de connexion à déclenchement libre, voir 2.4.23 de l'IEC 60947-1:2007.

Les essais suivants doivent être effectués sur les disjoncteurs alimentés à 110 % de la tension assignée maximale d'alimentation de commande et/ou de la pression d'alimentation assignée et à 85 % de la tension assignée minimale d'alimentation de commande et/ou de la pression d'alimentation assignée:

– deux manœuvres de fermeture-ouverture,
– deux manœuvres à déclenchement libre,
– pour les disjoncteurs à refermeture automatique, deux manœuvres de refermeture automatique.

1 Cette publication a été supprimée.

8.4.3 Vérification de l'étalonnage des déclencheurs de surintensité

8.4.3.1 Déclencheurs à temps inverse

La vérification de l'étalonnage des déclencheurs à temps inverse doit être effectuée à un multiple du courant de réglage pour vérifier que le temps de déclenchement est conforme (avec des tolérances) à la courbe fournie par le fabricant.

Cette vérification peut être faite à toute température convenable, une correction devant être apportée pour toute différence de température par rapport à la température de référence (voir 4.7.3).

8.4.3.2 Déclencheurs instantanés et à retard indépendant

La vérification de l'étalonnage des déclencheurs instantanés et à retard indépendant doit permettre de s'assurer du non-fonctionnement et du fonctionnement des déclencheurs aux valeurs de courant données en 8.3.3.2.2 ou 8.3.3.2.3, point a), suivant le cas, aucun mesurage de la durée de coupure n'étant exigé.

Les essais peuvent être effectués en alimentant deux pôles en série avec le courant d'essai, en utilisant toutes les combinaisons possibles de pôles équipés de déclencheurs ou en alimentant avec le courant d'essai chaque pôle équipé individuellement d'un déclencheur.

Une méthode pour déterminer le niveau de déclenchement consiste à appliquer un courant d'essai augmentant lentement partant d'une valeur en dessous de la limite inférieure jusqu'à ce que le déclenchement du disjoncteur survienne. Le déclenchement doit se produire entre les limites inférieure et supérieure du courant d'essai.

8.4.4 Vérification du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt

8.4.4.1 Déclencheurs à minimum de tension

Des essais doivent être effectués pour vérifier que le déclencheur fonctionne selon 7.2.1.3 de l'IEC 60947-1:2007 comme suit:

a) Tension de maintien

   Le déclencheur doit fermer à une tension correspondant à 85 % de la tension assignée minimale d'alimentation de commande.

b) Tension de retombée

   Le déclencheur doit ouvrir lorsque la tension est réduite à une valeur comprise dans la plage correspondant à 70 % et 35 % de la tension assignée d'alimentation de commande, réglée afin de tenir compte de la nécessité de fonctionner dans les conditions spécifiées en 8.3.3.4.2.3 i). Dans le cas de déclencheurs ayant une plage de tensions assignées d'alimentation de commande, la limite supérieure doit correspondre au minimum de la plage et la limite inférieure au maximum de la plage.

8.4.4.2 Déclencheurs shunt (pour l'ouverture)

Un essai doit être effectué pour vérifier que le déclencheur fonctionne selon 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014. L'essai peut être effectué à toute température convenable pourvu que la tension d'essai soit réduite afin de tenir compte de la nécessité pour le déclencheur de fonctionner dans les conditions spécifiées en 8.3.3.4.2.4. Dans le cas d'un déclencheur ayant une plage de tensions assignées d'alimentation de commande, la tension d'essai doit correspondre à 70 % de la tension assignée minimale d'alimentation de commande.

8.4.5 Essais supplémentaires pour les DPR

Les essais supplémentaires suivants doivent être effectués sur les DPR ou les unités c.r.

a) Fonctionnement de l'appareil d'essai

Le DPR doit être soumis à deux manœuvres de fermeture-déclenchement ou, dans le cas d'unités c.r., à deux manœuvres de réarmement-déclenchement, avec un déclenchement par la manœuvre manuelle de l'appareil d'essai avec le DPR alimenté à la tension assignée la plus basse d'emploi.

b) Vérification de l'étalonnage de l'appareil de déclenchement par courant résiduel du DPR

En utilisant un courant résiduel sinusoïdal alternatif, il doit être vérifié que

– le DPR ne déclenche pas avec un courant résiduel égal à 0,5 fois $I_{\Delta n}$ dans chaque pôle séparément, au réglage minimal de $I_{\Delta n}$ s'il est réglable;

– le DPR déclenche avec un courant résiduel égal à $I_{\Delta n}$ dans chaque pôle séparément, au réglage minimal de $I_{\Delta n}$ s'il est réglable.

8.4.6 Essais diélectriques

Les conditions d'essai doivent être conformes à 8.3.3.4.1, point 1), de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, excepté que l'usage d'une feuille métallique n'est pas exigé. La tension d'essai doit être appliquée comme suit:

– le disjoncteur étant en position d'ouverture, entre chaque paire de bornes qui sont électriquement raccordées lorsque le disjoncteur est fermé;

– pour les disjoncteurs ne comprenant pas de circuits électroniques reliés aux pôles principaux, avec le disjoncteur en position de fermeture, entre chaque pôle et le ou les pôles adjacents et entre chaque pôle et le cadre, le cas échéant;

– pour les disjoncteurs comprenant des circuits électroniques reliés aux pôles principaux, avec le disjoncteur en position d'ouverture, entre chaque pôle et le ou les pôles adjacents et entre chaque pôle et le cadre, le cas échéant, soit sur le côté entrée, soit sur le côté sortie selon la position des composants électroniques.

  En variante, la déconnexion des circuits électroniques reliés aux pôles principaux est permise, auquel cas la tension d'essai doit être appliquée avec le disjoncteur en position fermée, entre chaque pôle et le ou les pôles adjacents, et entre chaque pôle et le cadre, le cas échéant.

La méthode d'essai doit être celle de a), de b) ou de c) ci-dessous, au choix du fabricant:

a) Deux essais doivent être effectués:

   1) Tension de tenue aux chocs

   La tension d'essai ne doit pas être inférieure à la plus grande des deux valeurs suivantes: 30 % de la tension assignée de tenue aux chocs (sans facteur de correction d'altitude) ou la valeur de crête correspondant à 2 U_i, et

   2) Tension de tenue à fréquence industrielle

   Le dispositif d'essai doit être le même que celui indiqué en 8.3.3.4.1, point 3) b), de l'IEC 60947-1:2007/AMD1:2010, excepté que la surintensité de déclenchement doit être réglée à 25 mA. Cependant, le fabricant peut, pour des raisons de sécurité, utiliser un dispositif d'essai de puissance inférieure ou de réglage de déclenchement plus bas mais le courant de court-circuit du dispositif d'essai doit être au moins égal à huit fois le réglage de déclenchement du relais de surintensité; par exemple, pour un transformateur avec un courant de court-circuit de 40 mA, le réglage de déclenchement maximal du relais de surintensité doit être 5 mA ± 1 mA.

   La valeur efficace de la tension d'essai doit être 2 U_e max, avec un minimum de 1 000 V, appliquée pendant au moins 1 s. Le relais de surintensité ne doit pas déclencher.

b) Un seul essai à fréquence industrielle conformément au point a) 2) ci-dessus à une tension d'essai telle que la valeur de crête de l'onde sinusoïdale corresponde à la plus grande des valeurs de crête des valeurs suivantes: 30 % de U_{imp}, 2 U_i, 2 U_e max ou 1 000 V eff.

c) Un essai de résistance d'isolement à 500 V en courant continu. La résistance d'isolement ne doit pas être inférieure à 1 MΩ en tout point.

Si les propriétés diélectriques sont vérifiées conformément à un plan d'échantillonnage selon la note de 8.4.1, un essai de tenue à fréquence industrielle doit être effectué conformément à 8.4.6, point a) 2) de ce paragraphe, mais avec une tension d'essai selon le Tableau 12A de l'IEC 60947-1:2007/AMD2:2010. Les disjoncteurs ayant une tension d'isolement assignée supérieure à 1 000 V en courant alternatif doivent être soumis à essai à une tension de U_i + 1 200 V en courant alternatif (valeur efficace) ou 2 U_i selon la plus grande des deux valeurs.

8.4.7 Essai pour la vérification des distances d'isolement inférieures à celles correspondant au Tableau 13, cas A, de l'IEC 60947-1:2007

Le paragraphe 8.3.3.4.3 de l'IEC 60947-1:2007 est applicable excepté que, pour les besoins de la présente norme, cet essai doit être un essai individuel de série.

NOTE Le cas des distances d'isolement supérieures ou égales au cas A du Tableau 13 de l'IEC 60947-1:2007 est couvert par les essais de 8.4.6.

8.5 Essais spéciaux – Chaleur humide, brouillard salin, vibrations et chocs

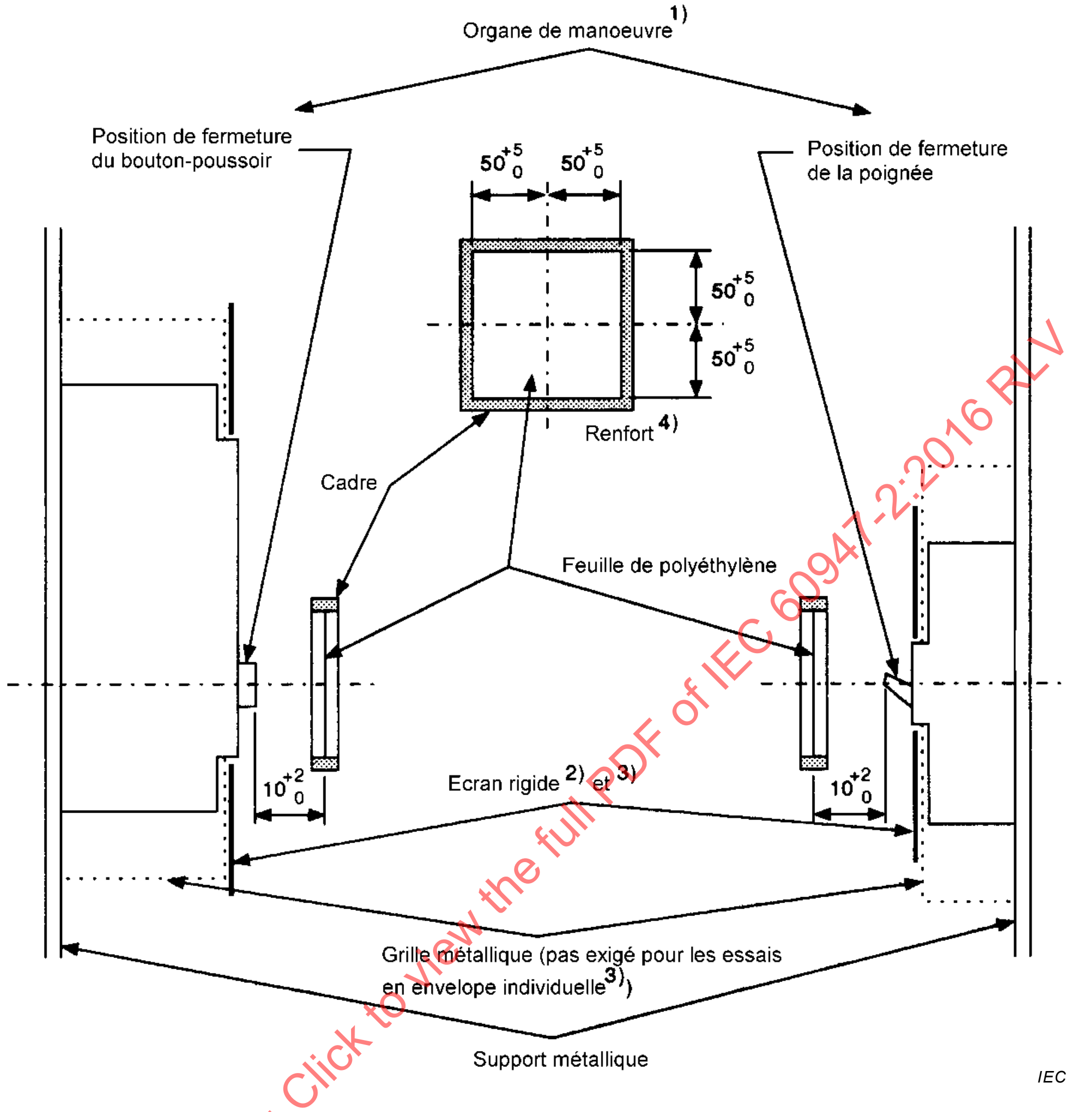
Les essais spéciaux suivants doivent être réalisés soit à la discrétion du fabricant soit selon l'accord établi entre le fabricant et l'utilisateur (voir 2.6.4 de l'IEC 60947-1:2007). En tant qu'essais spéciaux, sauf indication spécifique, ces essais supplémentaires ne sont pas obligatoires et il n'est pas nécessaire pour un disjoncteur de satisfaire à l'un quelconque de ces essais pour être conforme à la présente norme.

L'Annexe Q de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 s'applique.

Au cours des séquences d'essai réalisées selon le Tableau Q.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, seule la vérification finale de l'aptitude au fonctionnement est exigée. Elle doit être effectuée en réalisant les essais individuels de série de 8.4 de la présente norme, à l'exception des essais diélectriques de 8.4.6, lesquels sont couverts par les essais du Tableau Q.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

En référence à la note e) de bas de page du Tableau Q.1 de l'IEC 60947-1:2007 concernant l'essai de chaleur sèche, le disjoncteur ne doit pas être parcouru par le courant. Lorsqu'un déclencheur à minimum de tension est installé, il doit être alimenté sous sa tension assignée. Le disjoncteur doit être manœuvré selon le 8.4.2 pendant la dernière heure de l'essai.

En référence à la note g) de bas de page du Tableau Q.1 de l'IEC 60947-1:2007, pendant l'essai de chaleur humide, l'essai fonctionnel doit comprendre les manœuvres mécaniques du 8.4.2 de la présente norme. Lorsque seuls des organes de manœuvre manuels sont disponibles, cet essai peut être réalisé au cours du début de la période froide suivante.



Cas d'un disjoncteur avec bouton-poussoir de fermeture Cas d'un disjoncteur avec poignée de fermeture

Dimensions en millimètres

1) L'organe de manœuvre comprend toute extension normalement utilisée pour la manœuvre de fermeture.

2) L'écran rigide a pour but d'éviter que des projections issues de zones autres que celles de la poignée ou du bouton-poussoir n'atteignent la feuille de polyéthylène (cela n'est pas exigé pour les essais en enveloppe individuelle).

3) L'écran rigide et la façade de la grille (ou de l'écran) métallique peuvent être combinés en une seule plaque métallique conductrice.

4) Fait en matériau rigide convenable afin d'éviter le déchirement de la feuille de polyéthylène.

Figure 1 – Installation d'essai (câbles de raccordement non représentés) pour essais de court-circuit

Annexe A
(normative)

Coordination entre un disjoncteur et un autre appareil de protection contre les courts-circuits associés dans le même circuit

A.1 Généralités

Pour assurer la coordination entre un disjoncteur (C_1) et un autre appareil de protection contre les courts-circuits (DPCC) associés dans le même circuit, il est nécessaire d'examiner les caractéristiques de chacun de ces deux appareils ainsi que leur comportement dynamique en tant qu'association.

NOTE Un DPCC peut comprendre des dispositifs de protection supplémentaires, par exemple des déclencheurs de surcharge.

Le DPCC peut être un fusible (ou un jeu de fusibles) – voir Figure A.1 – ou un autre disjoncteur (C_2) (voir Figure A.2 et Figure A.3).

La comparaison des caractéristiques individuelles de fonctionnement de chacun de ces deux appareils associés peut ne pas être suffisante lorsqu'il est nécessaire de faire référence au comportement de ces deux appareils fonctionnant en série, car leurs impédances ne sont pas toujours négligeables. Il convient de tenir compte de ce fait. Pour les courants de court-circuit, il est recommandé de faire référence à I^2t plutôt qu'au temps. Les modèles préférentiels pour la représentation des caractéristiques du courant coupé limité et de l'énergie limitée (I^2t) sont indiqués à l'Annexe K.

C_1 est fréquemment raccordé en série avec un autre DPCC, soit du fait de la méthode de distribution de puissance adoptée pour l'installation, soit parce que le pouvoir de coupure en court-circuit du disjoncteur C_1 seul peut être insuffisant pour l'emploi envisagé. Dans de tels cas, le DPCC peut être monté dans des emplacements éloignés de C_1. Le DPCC peut protéger une ligne d'alimentation comportant plusieurs disjoncteurs C_1 ou simplement un seul disjoncteur.

Dans de telles applications, l'utilisateur ou spécificateur peut avoir à décider, en se basant sur des études théoriques, comment le niveau optimal de coordination peut être réalisé. La présente annexe est destinée à donner des lignes directrices pour cette décision ainsi que pour le type d'information qu'il convient que le fabricant du disjoncteur mette à disposition.

Elle donne aussi des lignes directrices en ce qui concerne les exigences d'essai lorsque de tels essais sont jugés nécessaires à l'emploi envisagé.

Le terme «coordination» englobe à la fois l'examen de la sélectivité (voir 2.5.23 de l'IEC 60947-1:2007/AMD2:2014 ainsi que 2.17.2 et 2.17.3 et celui de la protection d'accompagnement (voir 2.5.24 de l'IEC 60947-1:2007).

L'examen de la sélectivité peut être effectué soit par des études théoriques, soit par un essai (voir A.5), alors que la vérification de la protection d'accompagnement nécessite normalement d'avoir recours à des essais (voir A.6).

Lors de l'étude du pouvoir de coupure en court-circuit, il peut être fait référence, soit au pouvoir assigné de coupure ultime en court-circuit (I_{cu}), soit au pouvoir assigné de coupure de service en court-circuit (I_{cs}), suivant le critère souhaité.

A.2 Domaine d'application et objet

La présente annexe donne des lignes directrices et fournit les exigences pour la coordination des disjoncteurs avec d'autres DPCC associés dans le même circuit, aussi bien en ce qui concerne la sélectivité que la protection d'accompagnement.

La présente annexe a pour objet de spécifier:

– les exigences générales relatives à la coordination d'un disjoncteur avec un autre DPCC;
– les méthodes et les essais (s'ils sont jugés nécessaires) destinés à vérifier que les conditions de la coordination ont été remplies.

A.3 Exigences générales de coordination d'un disjoncteur avec un autre DPCC

A.3.1 Généralités

D'une manière idéale, il convient que la coordination soit telle qu'un disjoncteur (C_1) seul fonctionne pour toutes les valeurs de surintensité jusqu'à la limite de son pouvoir assigné de coupure en court-circuit I_{cu}.

NOTE 1 Si la valeur du courant présumé de défaut au point d'installation est inférieure au pouvoir assigné de coupure ultime en court-circuit de C_1, il peut être pris pour hypothèse que le DPCC n'est placé dans le circuit que pour des raisons autres que la protection d'accompagnement.

Dans la pratique, les considérations suivantes sont applicables:

a) si la valeur du courant limite de sélectivité I_s (voir 2.17.4) est trop basse, il y a risque de perte inutile de sélectivité.
b) si la valeur du courant présumé de défaut au point d'installation est supérieure au pouvoir assigné de coupure ultime en court-circuit de C_1, le DPCC doit être choisi de telle manière que le comportement de C_1 soit conforme à A.3.3 et que le courant d'intersection I_B (voir 2.17.5), le cas échéant, réponde aux exigences de A.3.2.

Chaque fois que possible, le DPCC doit être placé sur le côté source de C_1. Si le DPCC est placé sur le côté charge, il est essentiel que le raccordement entre C_1 et le DPCC soit réalisé de manière à réduire le plus possible tout risque de court-circuit.

NOTE 2 Dans le cas de déclencheurs interchangeables, ces conditions s'appliquent à chaque déclencheur concerné.

A.3.2 Courant d'intersection

Pour la protection d'accompagnement, le courant d'intersection I_B ne doit pas être supérieur au pouvoir assigné de coupure ultime en court-circuit I_{cu} de C_1 seul (voir Figure A.3a)).

A.3.3 Comportement de C_1 en association avec un autre DPCC

Pour toutes les valeurs de surintensité inférieures ou égales au pouvoir de coupure en court-circuit de l'association, C_1 doit répondre aux exigences de 7.2.5 de l'IEC 60947-1:2007 et l'association doit répondre aux exigences de 7.2.1.2.4, point a).

A.4 Type et caractéristiques du DPCC associé

Sur demande, le fabricant du disjoncteur doit donner des informations sur le type et les caractéristiques du DPCC à employer avec C_1 et sur le courant présumé de court-circuit maximal pour lequel l'association est valable sous la tension d'emploi déclarée.

Les informations détaillées concernant le DPCC utilisé pour tout essai conforme à la présente annexe, c'est-à-dire nom du fabricant, désignation du type, tension assignée, courant assigné et pouvoir de coupure en court-circuit doivent figurer dans le rapport d'essai.

Le courant de court-circuit conditionnel maximal (voir 2.5.29 de l'IEC 60947-1:2007) ne doit pas être supérieur au pouvoir assigné de coupure ultime en court-circuit du DPCC.

Si le DPCC associé est un disjoncteur, il doit répondre aux exigences de la présente norme ou de toute autre norme applicable.

Si le DPCC associé est un fusible, il doit être conforme à la norme de fusibles appropriée.

A.5 Vérification de la sélectivité

A.5.1 Généralités

La sélectivité peut normalement être étudiée par le fabricant sur le seul plan théorique, c'est-à-dire en comparant les caractéristiques de fonctionnement de C_1 et du DPCC associé (voir A.5.2). La sélectivité peut également être déterminée par essais (voir A.5.3).

Dans certains cas, des essais sur l'association montrent qu'un niveau de I_s plus élevé que dans l'étude théorique est obtenu, par exemple:

– lorsque C_1 est du type limiteur et que C_2 n'a pas de retard intentionnel;
– lorsque le temps d'ouverture du DPCC est inférieur au temps correspondant à une demi-période.

Pour obtenir une sélectivité améliorée lorsque le DPCC associé est un disjoncteur, C_2 est parfois muni d'un retard de courte durée intentionnel.

La sélectivité peut être partielle (voir Figure A.3a)) ou totale jusqu'au pouvoir assigné de coupure ultime en court-circuit I_{cu} de C_1.

Deux exemples de sélectivité totale sont représentés à la Figure A.2a) et la Figure A.2b).

A.5.2 Examen de la sélectivité par étude théorique

A.5.2.1 Sélectivité dans la zone de surcharge

Deux cas sont considérés ci-après, selon que le DPCC est un disjoncteur ou un fusible

a) Disjoncteurs en série (C_1 et C_2) – détermination de la sélectivité par comparaison des caractéristiques

   La sélectivité dans la zone de surintensité retardée est vérifiée par comparaison des caractéristiques temps/courant. La séparation des caractéristiques selon l'axe du temps et l'axe du courant permet un fonctionnement sélectif de C_1 par rapport à C_2 dans cette zone. Une tolérance s'applique aux caractéristiques, et il convient d'en tenir compte. Il convient que les données du fabricant présentent une bande de tolérance ou indiquent autrement la tolérance applicable, comme l'exige la présente norme.

b) Disjoncteurs (C_1) avec fusible comme DPCC – détermination de la sélectivité par comparaison des caractéristiques

   La sélectivité dans la zone de surcharge est déterminée par comparaison des caractéristiques temps/courant. La séparation des caractéristiques selon l'axe du temps et l'axe du courant permet un fonctionnement sélectif de C_1 par rapport au fusible, dans cette zone. Une tolérance s'applique aux caractéristiques, et il convient d'en tenir compte. Il convient que les données du fabricant présentent une bande de tolérance, ou indiquent autrement la tolérance applicable, comme l'exigent les normes du produit.

A.5.2.2 Détermination de la sélectivité dans la zone de courant de défaut (court-circuit)

La détermination de la sélectivité entre deux disjoncteurs dans la zone de courant de défaut (court-circuit) (voir Figure A.2a)) à partir des caractéristiques temps/courant est limitée au cas où C_2 est muni d'un déclencheur électronique avec fonction de déclenchement de court-circuit temporisée.

a) Disjoncteurs en série (C_1 et C_2) – détermination de la sélectivité par examen du courant coupé limité

Lorsque le déclenchement instantané de C_2 dépend d'un effet électromagnétique (c'est-à-dire disjoncteur magnétothermique ou disjoncteur magnétique seulement) ou dans le cas d'une unité de déclenchement électronique à déclencheur instantané, le niveau minimal de sélectivité entre deux disjoncteurs dans la zone de courant de défaut peut être déterminé comme suit:

La sélectivité est assurée jusqu'au niveau de courant de défaut pour lequel le courant coupé limité de C_1 est inférieur à la valeur de crête correspondant au réglage de courant de court-circuit instantané (I_i) de C_2, en tenant compte de la tolérance.

NOTE 1 Exemple de calcul de sélectivité

C_2 = disjoncteur 800 A; I_i = 8 kA eff – 12 kA eff (réglage 10 kA ± 20 %); C_1 = disjoncteur 125 A.

Le niveau de déclenchement minimal de C_2 est 8 × 1,414 = 11,3 kA de crête.

Le courant coupé limité de C_1 au courant présumé 15 kA eff, dû à la limitation de courant de C_1, est 11 kA de crête, sur la base des données d'essai.

Par conséquent, le système est sélectif jusqu'à au moins un courant présumé de 15 kA eff.

NOTE 2 La limite de sélectivité obtenue avec cette méthode est basse, et la limite réelle déterminée par essai est sensiblement plus élevée dans la plupart des cas.

b) Disjoncteurs (C_1) avec fusible comme DPCC

La sélectivité dans la zone de courant de défaut (court-circuit) (voir Figure A.1) est déterminée à partir des caractéristiques I^2t. Le courant limite de sélectivité I_s est la valeur maximale à laquelle la caractéristique limitée I^2t du disjoncteur est inférieure à la caractéristique de préarc I^2t du fusible. En l'absence de courbe réelle, la valeur de la caractéristique de préarc I^2t indiquée par le fabricant pour le fusible est prise en compte.

c) Fusible (C_1) avec disjoncteur comme DPCC

La sélectivité dans la zone de court-circuit de déclenchement instantané est déterminée à partir du courant coupé limité du fusible.

Le courant limite de sélectivité I_s est la valeur maximale à laquelle le courant coupé limité du fusible est inférieur à la valeur de crête correspondant au niveau de déclenchement instantané (I_i) du disjoncteur, en tenant compte de la tolérance.

A.5.2.3 Détermination du courant limite de sélectivité pour des conditions d'installation spécifiques

Les données relatives aux limites de sélectivité peuvent être fournies sous forme de tableaux, de graphiques ou sur support logiciel. Les données obtenues par étude théorique ou par des essais, conformément à la présente norme, sont basées sur le niveau de courant de défaut présumé au niveau de l'appareil amont (C_2) et prennent pour hypothèse que les appareils coordonnés sont proches l'un de l'autre. Dans la pratique, la limite de sélectivité est influencée par l'impédance entre les deux appareils. Par conséquent, en pratique, tenir compte du courant de défaut présumé au niveau du disjoncteur aval donne une valeur plus précise pour la limite de sélectivité.

A.5.3 Sélectivité déterminée par essai

Un exemple de schéma du circuit d'essai est donné à la Figure A.5, où:

– C_1 peut être un disjoncteur conforme à la présente norme ou une autre norme IEC ou un fusible conforme à la norme IEC appropriée;
– les réglages de C_1 et C_2 sont fixés au réglage instantané maximal, le cas échéant.

Les essais avec d'autres réglages des déclencheurs peuvent être réalisés à la discrétion du fabricant, auquel cas les réglages des déclencheurs doivent être consignés dans le rapport d'essai.

Les câbles de raccordement doivent être inclus, comme spécifié en 8.3.2.6.4, hormis le fait que la longueur totale des câbles peut être répartie entre le côté source et le côté charge de C_1 et C_2 selon ce qui convient.

Chaque essai doit consister en une manœuvre O – t – CO, la manœuvre CO étant réalisée en fermant l'appareil aval C_1. Si l'appareil aval est un fusible, la manœuvre doit être réalisée en fermant C_2.

L'essai est effectué au niveau de courant présumé pour lequel l'association de C_1 et C_2 est déclarée sélective par le fabricant.

Résultats à obtenir:

– Le paragraphe 8.3.4.1.7 de l'IEC 60947-1:2007 s'applique;
– Pendant chaque manœuvre, C_1 doit fonctionner et C_2 ne doit pas déclencher. Si les contacts de C_2 se séparent momentanément durant les manœuvres, le temps entre le début du court-circuit et la fin de la séparation des contacts de C_2 doit être inférieur ou égal à 30 ms. La valeur réelle doit être indiquée dans le rapport d'essai.
– De plus, il doit être vérifié que les contacts de C_2 peuvent être ouverts au moyen des organes de manœuvre normaux.

A.6 Vérification de la protection d'accompagnement

A.6.1 Détermination du courant d'intersection

La conformité aux exigences de A.3.2 peut être vérifiée en comparant les caractéristiques de fonctionnement de C_1 et celles du DPCC associé pour tous les réglages de C_1 et, le cas échéant, pour tous les réglages de C_2.

A.6.2 Vérification de la protection d'accompagnement

La protection d'accompagnement peut être vérifiée par des essais ou par la comparaison des caractéristiques.

a) Vérification par des essais

La conformité aux exigences de A.3.3 se vérifie normalement par des essais conformément à A.6.3. Dans ce cas, toutes les conditions d'essai doivent être comme spécifié en 8.3.2.6, les résistances et bobines d'inductance réglables pour les essais de court-circuit étant placées du côté source de l'association.

b) Vérification par comparaison des caractéristiques

Dans quelques cas pratiques et lorsque le DPCC est un disjoncteur (voir Figure A.3a) et Figure A.3b)), il peut être suffisant que le fabricant compare les caractéristiques de fonctionnement de C_1 et du DPCC associé, en portant une attention particulière aux points suivants:

  – valeurs de l'intégrale de Joule de C_1 à son I_{cu} et du DPCC au courant présumé de l'association,
  – influence sur C_1 (par exemple de l'énergie d'arc, du courant de crête maximal, du courant coupé limité) à la valeur de crête du courant de fonctionnement du DPCC.

La validité de l'association peut être évaluée en examinant la caractéristique I^2t de fonctionnement totale maximale du DPCC sur la plage allant du pouvoir assigné de coupure en court-circuit I_{cu} de C_1 au courant de court-circuit présumé de l'emploi envisagé, mais ne dépassant pas la valeur maximale de la caractéristique limitée I^2t de C_1 à son pouvoir assigné de coupure en court-circuit ou une autre valeur limite plus basse précisée par le fabricant.

NOTE Lorsque le DPCC associé est un fusible, l'étude théorique n'est valable que jusqu'à I_{cu} de C_1.

A.6.3 Essais de vérification de la protection d'accompagnement

Si C_1 est équipé de déclencheurs d'ouverture réglables à maximum de courant, les caractéristiques de fonctionnement doivent être celles correspondant à la durée et au courant de réglage minimaux.

Si C_1 peut être équipé de déclencheurs instantanés d'ouverture à maximum de courant, les caractéristiques de fonctionnement à utiliser doivent être celles correspondant à C_1 équipé de tels déclencheurs.

Si le DPCC associé est un disjoncteur (C_2) équipé de déclencheurs d'ouverture réglables à maximum de courant, les caractéristiques de fonctionnement à utiliser doivent être celles correspondant à la durée et au courant de réglage maximaux.

Lorsque le DPCC associé est un jeu de fusibles, chaque essai doit être effectué en utilisant un nouveau jeu de fusibles, même si certains fusibles utilisés pendant un essai précédent n'ont pas fondu.

S'il y a lieu, les câbles de raccordement doivent être inclus comme spécifié en 8.3.2.6.4, excepté que si le DPCC associé est un disjoncteur (C_2), la longueur totale (75 cm) du câble associé à ce disjoncteur peut être située côté source (voir Figure A.4).

Chaque essai doit consister en une séquence de manœuvres O – t – CO effectuée conformément à 8.3.5, la manœuvre CO étant effectuée sur C1.

Un essai est effectué au courant présumé maximal pour l'emploi proposé. Ce courant ne doit pas être supérieur au courant assigné de court-circuit conditionnel (voir 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014).

Un essai supplémentaire doit être effectué à une valeur de courant présumé égale au pouvoir assigné de coupure en court-circuit I_{cu} (ou I_{cs}) de C_1; pour cet essai, un nouvel échantillon de C_1 peut être utilisé et, si le DPCC associé est un disjoncteur, un nouvel échantillon de C_2 peut aussi être utilisé.

Au cours de chaque manœuvre:

a) si le DPCC associé est un disjoncteur (C_2):

- soit C_1 et C_2 doivent déclencher aux deux courants d'essai, aucun autre essai n'étant alors exigé.

  C'est le cas général qui n'assure que la protection d'accompagnement.

- soit C_1 doit déclencher et C_2 doit être en position fermée à la fin de chaque manœuvre aux deux courants d'essai, aucun essai complémentaire n'étant alors exigé.

  Les contacts de C_2 sont autorisés à se séparer momentanément au cours de chaque manœuvre. Dans ce cas, le rétablissement de l'alimentation est assuré en plus de la protection d'accompagnement (voir Note 1 de la Figure A.3a)). La durée de séparation des contacts de C_2, le cas échéant, doit être enregistrée au cours de ces essais.

- soit C_1 doit déclencher au courant d'essai le plus faible, et C_1 et C_2 doivent déclencher tous deux au courant d'essai le plus élevé.

Les contacts de C_2 sont autorisés à se séparer momentanément au courant d'essai le plus faible. Des essais supplémentaires doivent être effectués à des valeurs de courants intermédiaires pour déterminer la valeur la plus faible du courant à laquelle C_1 et C_2 déclenchent tous les deux et jusqu'à laquelle le rétablissement de l'alimentation est assuré. La durée de séparation des contacts de C_2, le cas échéant, doit être enregistrée au cours de ces essais.

b) lorsque le DPCC associé est un fusible (ou un jeu de fusibles):

– dans le cas d'un circuit monophasé, un fusible au moins doit fondre;

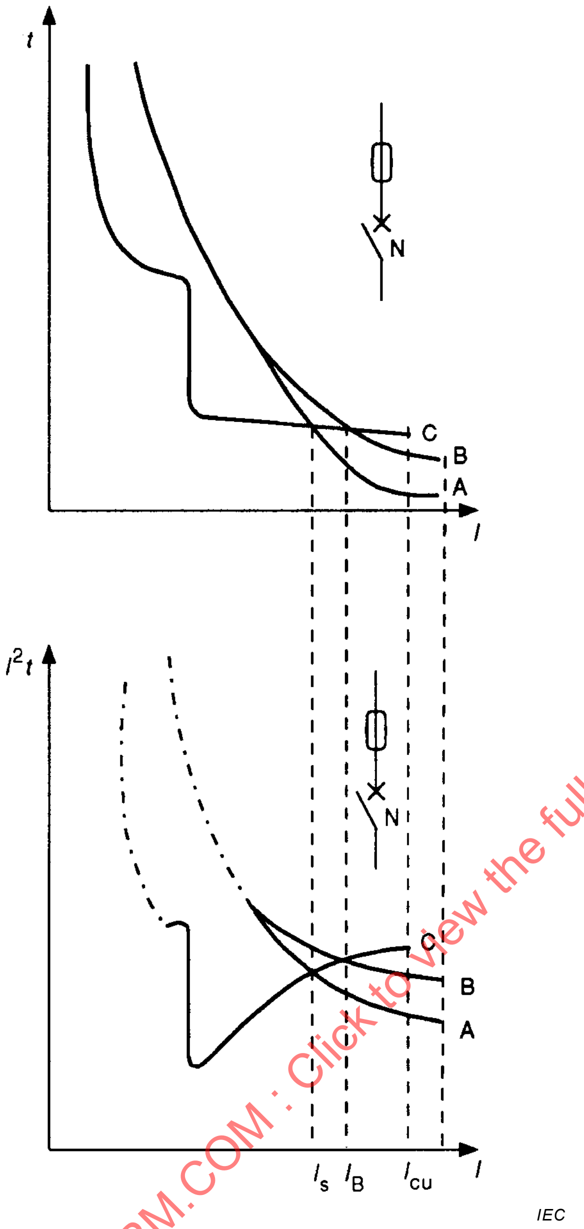
– dans le cas d'un circuit à plusieurs phases, au moins deux fusibles doivent fondre ou bien un fusible doit fondre et C_1 doit déclencher.

A.6.4 Résultats à obtenir

Le paragraphe 8.3.4.1.7 de l'IEC 60947-1:2007 et le paragraphe 8.3.2.6.7 premier alinéa de la présente norme sont applicables, avec le complément suivant:

Après les essais, si C_1 est un disjoncteur, il doit se conformer aux 8.3.5.4 et 8.3.5.5; si C_1 est un fusible, il doit se conformer aux exigences applicables de l'IEC 60269-1.

De plus, si le DPCC associé est un disjoncteur (C_2), il doit être vérifié par une manœuvre manuelle ou tout autre moyen approprié que les contacts de C_2 ne sont pas soudés.



I = Courant de court-circuit présumé

I_{cu} = Pouvoir assigné de coupure ultime en court-circuit (4.3.6.2.2)

I_s = Courant limite de sélectivité (2.17.4)

I_B = Courant d'intersection (2.17.5)

A = Caractéristique de préarc du fusible

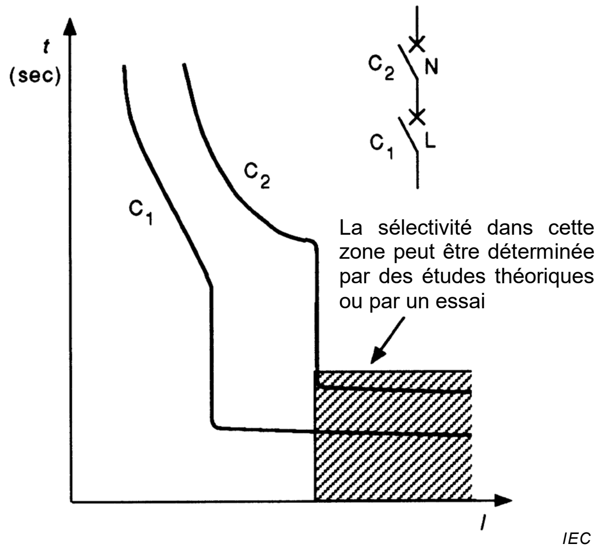
B = Caractéristique de fonctionnement du fusible

C = Caractéristique de fonctionnement du disjoncteur, non-limiteur de courant (N) (durée de coupure/courant et I^2t /courant)

NOTE 1 A est estimé être la limite inférieure; B et C sont estimés être les limites supérieures.

NOTE 2 Zone non adiabatique pour I^2t repérée en ligne discontinue.

Figure A.1 – Coordination pour la surintensité entre un disjoncteur et un fusible ou protection d'accompagnement par un fusible: caractéristiques de fonctionnement

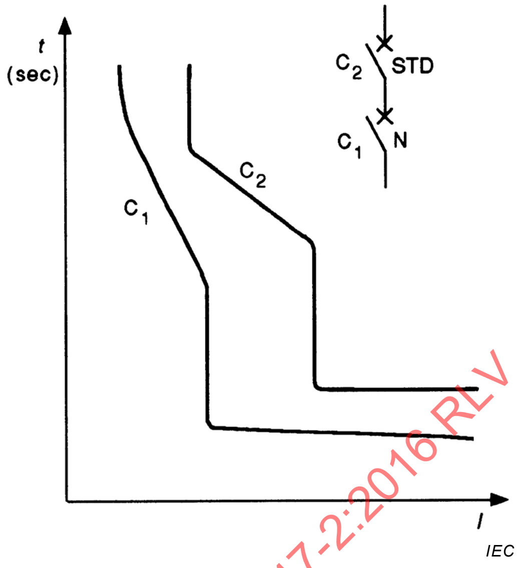


C_1 = Disjoncteur à limitation de courant (L) (caractéristique de durée de coupure)

C_2 = Disjoncteur limiteur de courant ou non-limiteur de courant (N) (caractéristique de déclenchement)

Les valeurs de I_{cu} ne sont pas indiquées.

Figure A.2a) – Disjoncteur aval limiteur de courant

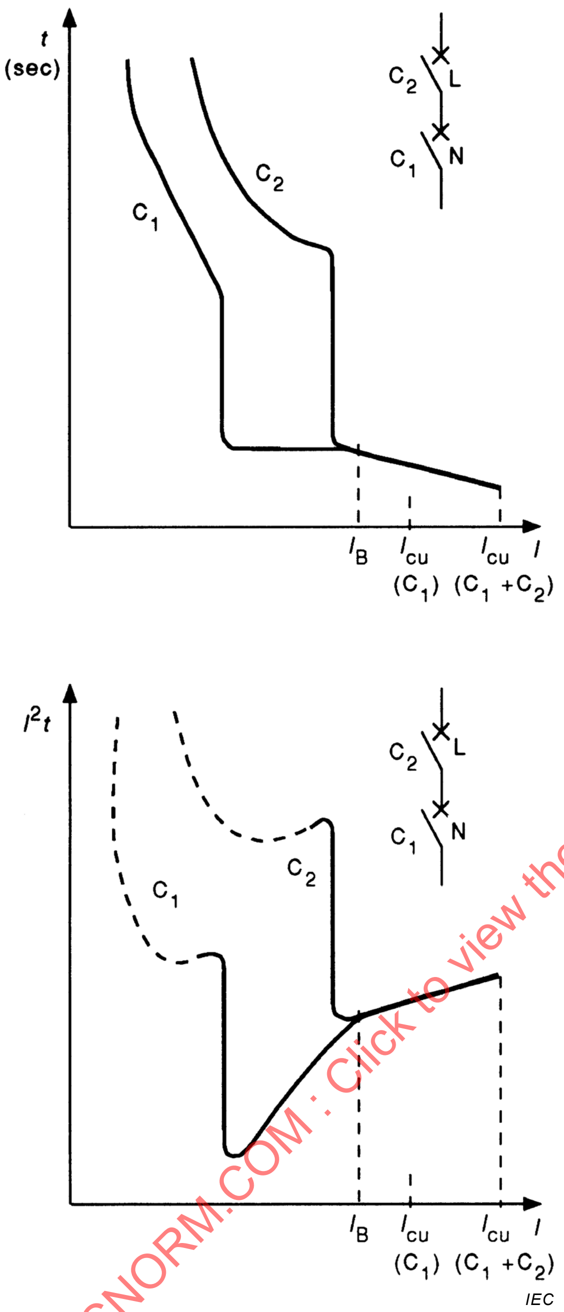


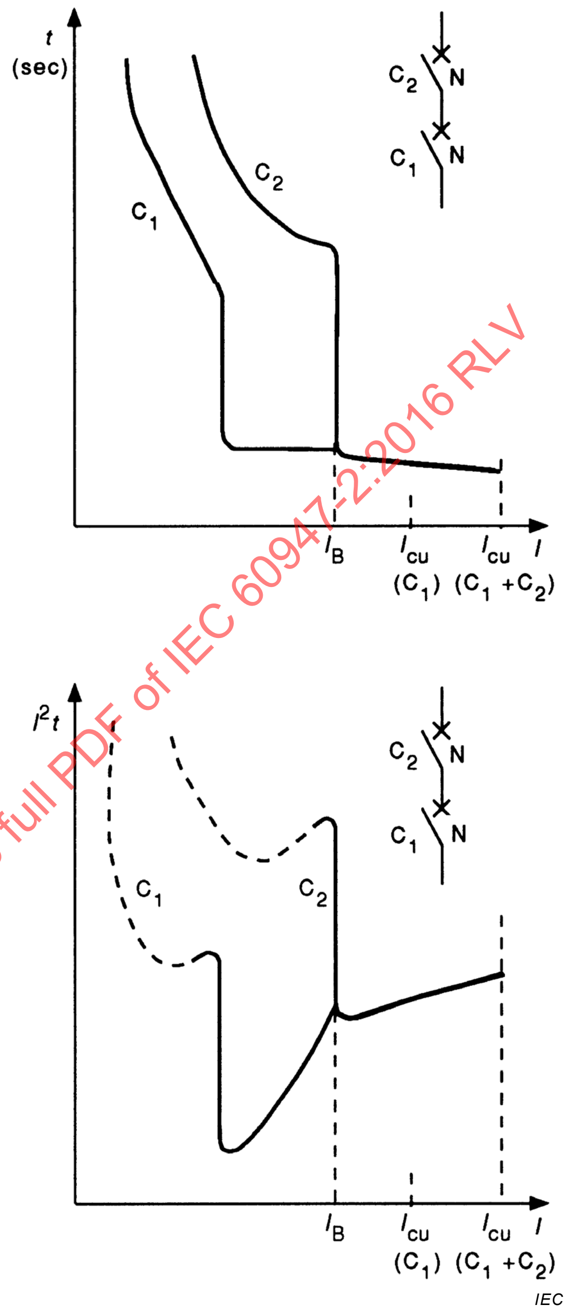
C_1 = Disjoncteur non-limiteur de courant (N) (caractéristique de durée de coupure)

C_2 = Disjoncteur avec retard intentionnel de courte durée (STD) (caractéristique de déclenchement)

Figure A.2b) – Disjoncteur aval non-limiteur de courant

Figure A.2 – Sélectivité totale entre deux disjoncteurs





C_1 = Disjoncteur non-limiteur de courant (N)

C_2 = Disjoncteur limiteur de courant (L)

C_1, C_2 = Disjoncteur non-limiteur de courant (N)

I_B = Courant d'intersection

NOTE 1 Le cas échéant, le rétablissement de l'alimentation a lieu par C_2.

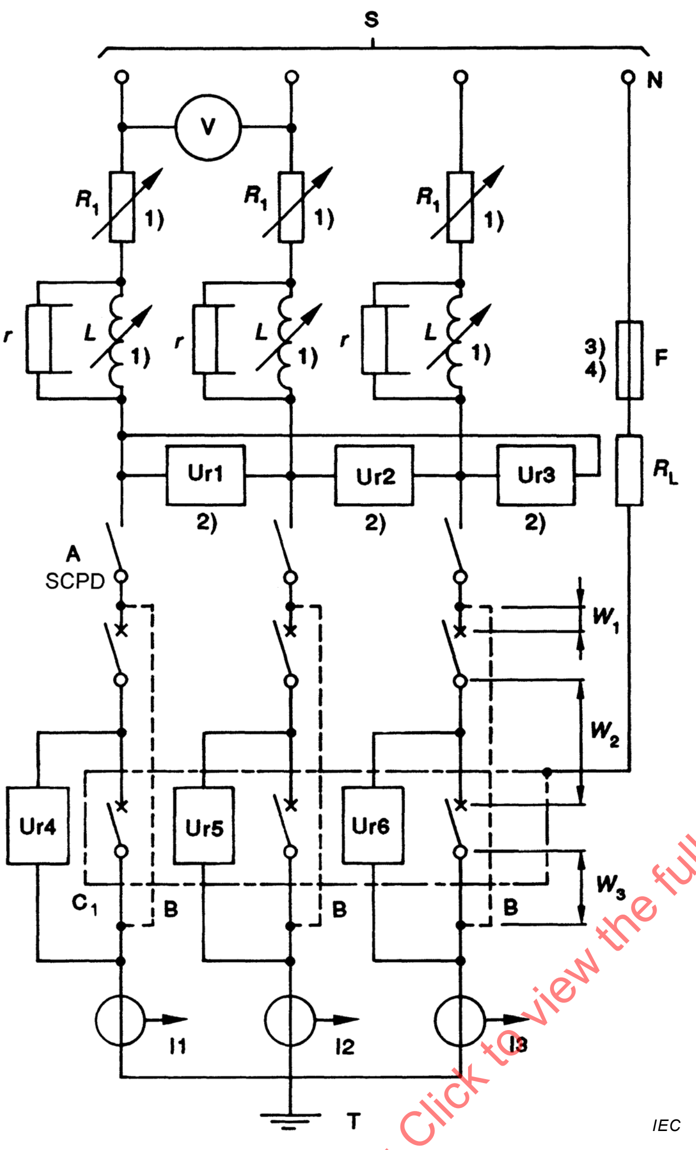
NOTE 2 I_{cu} (C_1 + C_2) ≤ I_{cu} (C_2)

NOTE 3 Pour les valeurs de $I > I_B$, la courbe est celle de l'association (montrée en gras), pour laquelle les données sont obtenues par des essais.

Figure A.3a) – Disjoncteur amont limiteur de courant

Figure A.3b) – Disjoncteur amont non-limiteur de courant

Figure A.3 – Protection d'accompagnement par un disjoncteur – Caractéristiques de fonctionnement



S	=	Alimentation
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6	=	Capteurs de tension
V	=	Appareil de mesure de tension
A	=	Appareil de fermeture
R_1	=	Résistance réglable
N	=	Neutre de la source (ou neutre artificiel)
F	=	Elément fusible (8.3.4.1.2, point d) de l'IEC 60947-1:2007)
L	=	Bobines d'inductance réglables
R_L	=	Résistance de limitation du courant de défaut
B	=	Connexions provisoires d'étalonnage
I1, I2, I3	=	Appareils d'enregistrement des courants
T	=	Terre; un seul point de terre (côté charge ou côté source)
r	=	Résistance shunt (8.3.4.1.2, point b) de l'IEC 60947-1:2007)
W_1	=	75 cm de câble de courant assigné pour le DPCC
W_2	=	50 cm de câble de courant assigné pour C_1
W_3	=	25 cm de câble de courant assigné pour C_1
SCPD	=	Disjoncteur C_2 ou jeu de 3 fusibles
C_1	=	Disjoncteur en essai

Les charges réglables *L* et R_1 peuvent être disposées, soit dans la partie haute tension, soit dans la partie basse tension du circuit d'alimentation, l'appareil d'enclenchement A étant disposé dans la partie basse tension.

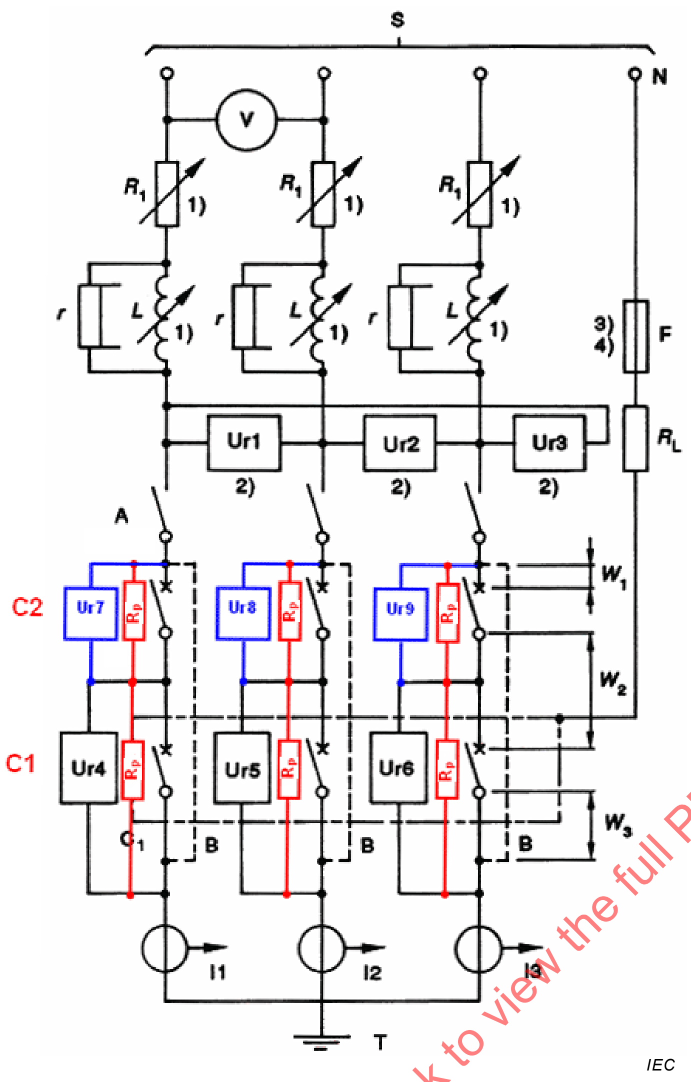
Ur1, Ur2, Ur3 peuvent, en variante, être raccordés entre phase et neutre.

Dans le cas d'appareils destinés à être employés dans un réseau dont une phase est reliée à la terre, F doit être raccordé à une phase de l'alimentation.

Aux Etats-Unis et au Canada (voir notes du 4.3.2.1), F doit être relié:

– à une phase de l'alimentation pour les matériels marqués d'une seule valeur de U_e,
– au neutre pour les matériels marqués d'une double valeur de U_e.

Figure A.4 – Exemple de circuit d'essai pour les essais de pouvoir de coupure en court-circuit conditionnel montrant les connexions d'un disjoncteur triphasé (C_1)



S	=	Alimentation
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 Ur7, Ur8, Ur9	=	Capteurs de tension
V	=	Appareil de mesure de tension
A	=	Appareil de fermeture
R_1	=	Résistance réglable
N	=	Neutre de la source (ou neutre artificiel)
F	=	Elément fusible (8.3.4.1.2, point d) de l'IEC 60947-1:2007)
L	=	Bobines d'inductance réglables
R_L	=	Résistance de limitation du courant de défaut
R_p	=	Résistance de polarisation facultative
B	=	Connexions provisoires d'étalonnage
I1, I2, I3	=	Appareils d'enregistrement des courants
T	=	Terre:– un seul point de terre (côté charge ou côté source)
r	=	Résistance shunt (8.3.4.1.2, point b) de l'IEC 60947-1:2007)
W_1	=	75 cm de câble de courant assigné pour C_2
$W_2 + W_3$	=	75 cm de câble de courant assigné pour C_1 (voir A.5.2)
C_1, C_2	=	Disjoncteurs en essai

Les charges réglables *L* et R_1 peuvent être disposées, soit dans la partie haute tension, soit dans la partie basse tension du circuit d'alimentation, l'appareil d'enclenchement A étant disposé dans la partie basse tension.

Ur1, Ur2, Ur3 peuvent, en variante, être raccordés entre phase et neutre.

Dans le cas d'appareils destinés à être employés dans un réseau dont une phase est reliée à la terre, F doit être raccordé à une phase de l'alimentation.

NOTE 1 Aux Etats-Unis et au Canada (voir notes du 4.3.2.1), F doit être relié:

– à une phase de l'alimentation pour les matériels marqués d'une seule valeur de U_e,
– au neutre pour les matériels marqués d'une double valeur de U_e.

NOTE 2 Les résistances de polarisation permettent de déterminer la durée d'ouverture des contacts pour les deux appareils en série, la valeur étant suffisamment élevée pour ne pas influencer les appareils en essai.

Figure A.5 – Exemple de circuit d'essai pour la vérification de la sélectivité

Annexe B
(normative)

Disjoncteurs à protection incorporée par courant différentiel résiduel

B.1 Généralités

B.1.1 Préambule

Pour assurer la protection contre les dangers occasionnés par les chocs électriques, des appareils agissant sous l'effet des courants différentiels résiduels sont utilisés comme mesure de protection. Ces appareils sont fréquemment utilisés en conjonction avec un disjoncteur ou comme partie intégrante de celui-ci pour répondre à un double objectif, c'est-à-dire:

– assurer la protection des installations contre les surcharges et contre les courants de court-circuit,
– assurer la protection des personnes contre les contacts indirects, c'est-à-dire les augmentations dangereuses du potentiel à la terre dues à une isolation défectueuse.

Les appareils à courant différentiel résiduel peuvent assurer également une protection supplémentaire contre les dangers d'incendie ou autres dangers qui peuvent se développer à la suite d'un défaut à la terre de nature persistante ne pouvant pas être détecté par l'appareil de protection contre les surintensités.

Les appareils à courant différentiel résiduel dont le courant différentiel résiduel assigné ne dépasse pas 30 mA sont également utilisés comme moyens de protection supplémentaires contre les contacts directs en cas de défaillance des dispositifs de protection prévus.

Les exigences pour l'installation de tels appareils sont spécifiées dans les différentes sections de la série IEC 60364.

La présente annexe est fondée principalement sur les exigences correspondantes des IEC 60755, IEC 61008-1 et IEC 61009-1.

B.1.2 Domaine d'application et objet

La présente annexe est applicable aux disjoncteurs assurant la protection par courant différentiel résiduel (DPR). Elle contient les exigences pour les appareils qui assurent à la fois la détection des courants différentiels résiduels, comparent ces mesurages à une valeur réglée au préalable et provoquent la coupure du circuit protégé lorsque cette valeur est dépassée.

La présente annexe est applicable:

– aux disjoncteurs conformes à la présente norme et dont la fonction de courant différentiel résiduel constitue une partie intégrée (désignés ci-après DPR intégrés);
– aux DPR combinant un appareil à courant différentiel résiduel (désignés ci-après unités c.r.) et un disjoncteur conforme à la présente norme; ils peuvent être combinés, mécaniquement et électriquement, soit en usine, soit sur le site par l'utilisateur, suivant les instructions du fabricant.

Cette annexe couvre également les exigences pour les DPR concernant la compatibilité électromagnétique (CEM).

NOTE Les moyens de détection du courant du neutre peuvent, le cas échéant, être extérieurs au disjoncteur ou à la combinaison suivant le cas.

La présente annexe n'est applicable qu'aux DPR destinés à être utilisés dans des circuits à courant alternatif.

La fonction «courant différentiel résiduel» des DPR visés par la présente annexe peut ou non dépendre fonctionnellement de la tension d'alimentation. Les DPR dépendant d'une autre source d'alimentation ne sont pas visés par cette annexe.

Cette annexe n'est pas applicable aux matériels dont les dispositifs de détection du courant (à l'exception des dispositifs de détection du courant du neutre) ou l'appareil de traitement sont montés séparément du disjoncteur.

Les exigences pour de tels appareils sont données à l'Annexe M.

La présente annexe a pour objet de spécifier:

a) les caractéristiques spécifiques de la fonction de courant différentiel résiduel;
b) les exigences spécifiques auxquelles doivent répondre les DPR
   – dans les conditions normales du circuit;
   – dans les conditions anormales du circuit, qu'elles se rapportent ou non au courant différentiel résiduel;
c) les essais qui doivent être effectués pour vérifier la conformité aux exigences du point b) ci-dessus, ainsi que les modes opératoires d'essai appropriés;
d) les informations correspondantes sur le matériel.

B.2 Termes et définitions

En complément de l'Article 2 de la présente norme, les définitions suivantes s'appliquent:

B.2.1 Termes et définitions relatifs aux courants circulant entre les parties actives et la terre

B.2.1.1
courant de défaut à la terre
courant qui s'écoule à la terre lors d'un défaut d'isolement

[SOURCE: IEC 60050-442:1998, 442-01-23]

B.2.1.2
courant de fuite à la terre
courant qui s'écoule des parties actives de l'installation à la terre, en l'absence de tout défaut d'isolement

[SOURCE: IEC 60050-442:1998, 442-01-24]

B.2.2 Termes et définitions relatives à l'alimentation d'un DPR

B.2.2.1
grandeur d'alimentation
grandeur électrique qui, seule ou en combinaison avec d'autres grandeurs électriques, doit être appliquée à un DPR pour qu'il puisse fonctionner dans des conditions spécifiées

B.2.2.2
grandeur d'alimentation d'entrée
grandeur d'alimentation par laquelle le DPR est mis en action, lorsqu'elle est appliquée dans des conditions spécifiées

Note 1 à l'article: Ces conditions peuvent prévoir, par exemple, l'alimentation de certains organes auxiliaires.

[SOURCE: IEC 60050-442:1998, 442-05-58, modifiée – adapté aux DPR]

B.2.2.3
courant différentiel résiduel
I_{Δ}
somme vectorielle des courants qui circulent dans le circuit principal du DPR, exprimée en valeur efficace

[SOURCE: IEC 60050-442:1998, 442-05-19, modifiée– adapté aux DPR]

B.2.2.4
courant différentiel résiduel de fonctionnement
$I_{\Delta n}$
valeur du courant différentiel résiduel qui fait fonctionner le DPR dans des conditions spécifiées

[SOURCE: IEC 60050-442:1998, 442-05-20, modifiée– adapté aux DPR]

B.2.2.5
courant différentiel résiduel de non-fonctionnement
$I_{\Delta no}$
valeur du courant différentiel résiduel pour laquelle (et au-dessous de laquelle) le DPR ne fonctionne pas dans des conditions spécifiées

[SOURCE: IEC 60050-442:1998, 442-05-21, modifiée – symbole introduit et adapté aux DPR]

B.2.3 Termes et définitions relatifs au fonctionnement et aux fonctions des DPR

B.2.3.1
disjoncteur à protection par courant différentiel résiduel incorporée
DPR
disjoncteur (voir 2.1) conçu pour provoquer l'ouverture des contacts lorsque le courant différentiel résiduel atteint une valeur donnée dans des conditions spécifiées

B.2.3.2
DPR fonctionnellement indépendant de la tension d'alimentation
DPR pour lequel les fonctions de détection et d'évaluation et le moyen de déclenchement (voir B.2.3.6) ne dépendent pas de la tension d'alimentation

B.2.3.3
DPR fonctionnellement dépendant de la tension d'alimentation
DPR pour lequel les fonctions de détection et/ou d'évaluation et/ou le moyen de déclenchement (voir B.2.3.6) dépendent de la tension d'alimentation

Note 1 à l'article: Il est entendu que la tension d'alimentation pour la détection, l'évaluation ou l'interruption est celle appliquée au DPR.

B.2.3.4
détection (d'un courant différentiel résiduel)
fonction consistant à détecter la présence d'un courant différentiel résiduel

Note 1 à l'article: Cette fonction peut être remplie, par exemple, par un transformateur intégrant la somme vectorielle des courants.

[SOURCE: IEC 60050-442:1998, 442-05-24]

B.2.3.5
évaluation
fonction consistant à donner au DPR la possibilité de fonctionner quand le courant différentiel résiduel détecté dépasse une valeur de référence spécifiée

[SOURCE: IEC 60050-442:1998, 442-05-25, modifiée – sans «(d'un courant différentiel résiduel)» et adapté aux DPR]

B.2.3.6
coupure
fonction consistant à amener automatiquement les contacts principaux du DPR de la position de fermeture à la position d'ouverture, interrompant ainsi le ou les courants qui les traversent

[SOURCE: IEC 60050-442:1998, 442-05-26, modifiée – sans «(pour un dispositif de coupure différentiel)» et adapté aux DPR]

B.2.3.7
temps limite de non-réponse
temps maximal pendant lequel une valeur de courant différentiel résiduel supérieure à la valeur assignée du courant différentiel résiduel de non-fonctionnement peut être appliquée au DPR, sans provoquer son fonctionnement

[SOURCE: IEC 60050-442:1998, 442-05-23, modifiée – ajout de «assigné» et adapté aux DPR]

B.2.3.8
DPR à retard
DPR spécialement conçu pour atteindre une valeur prédéterminée du temps limite de non-réponse correspondant à une valeur donnée du courant différentiel résiduel

Note 1 à l'article: La caractéristique courant différentiel résiduel/temporisation peut ou non être à temps/courant inverse.

[SOURCE: IEC 60050-442:1998, 442-05-05, modifiée – adapté aux DPR et ajout d'une Note 1 à l'article]

B.2.3.9
DPR de réinitialisation
DPR muni d'une unité c.r. qu'il est nécessaire de réarmer intentionnellement par des moyens différents des moyens de manœuvre du DPR, à la suite d'un courant différentiel résiduel, avant que celui-ci puisse se refermer

[SOURCE: IEC 60050-442:1998, 442-05-10, modifiée – adapté aux DPR]

B.2.3.10
appareil d'essai
appareil destiné à vérifier, en simulant un courant différentiel résiduel, que le DPR fonctionne

B.2.4 Termes et définitions relatifs aux valeurs et aux plages des grandeurs d'alimentation

B.2.4.1
valeur limite de surintensité de non-fonctionnement dans le cas d'une charge monophasée
valeur maximale de surintensité dans un circuit monophasé qui, en l'absence de courant différentiel résiduel, peut circuler dans un DPR (quel que soit le nombre de pôles) sans provoquer la manœuvre de celui-ci

Note 1 à l'article: Voir B.7.2.7.

B.2.4.2
valeur limite de courant de non-fonctionnement dans le cas d'une charge équilibrée
valeur maximale du courant qui, en l'absence de défaut au bâti ou à la terre ou de courant de fuite à la terre, peut circuler dans le circuit surveillé par le DPR avec une charge équilibrée (quel que soit le nombre de pôles) sans provoquer la manœuvre de celui-ci

B.2.4.3
pouvoir de fermeture et de coupure différentiel résiduel en court-circuit
valeur de la composante alternative d'un courant différentiel résiduel de court-circuit présumé qu'un DPR est capable d'établir, de supporter pendant son temps de déclenchement et d'interrompre dans des conditions spécifiées d'utilisation et de comportement

B.3 Classification

B.3.1 Classification selon le mode de fonctionnement de la fonction de courant différentiel résiduel

B.3.1.1 DPR fonctionnellement indépendant de la tension d'alimentation (voir B.2.3.2)

B.3.1.2 DPR fonctionnellement dépendant de la tension d'alimentation (voir B.2.3.3 et B.7.2.11)

B.3.1.2.1 S'ouvrant automatiquement en cas de défaillance de la tension d'alimentation avec ou sans retard.

B.3.1.2.2 Ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation.

Ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation, mais capable de déclencher dans des conditions spécifiées en cas de défaut à la terre apparaissant lors d'une défaillance de la tension d'alimentation.

NOTE Les cas indiqués dans ce paragraphe comprennent les DPR incapables de s'ouvrir automatiquement lorsqu'il n'existe pas de situation dangereuse.

B.3.2 Classification selon la possibilité de réglage du courant différentiel résiduel de fonctionnement

B.3.2.1 DPR à courant différentiel résiduel de fonctionnement unique

B.3.2.2 DPR à réglages multiples de courant différentiel résiduel de fonctionnement (voir note de B.4.1.1)

Un DPR peut avoir plusieurs réglages de courant différentiel résiduel de fonctionnement, soit par échelons soit par variation continue.

B.3.3 Classification selon la temporisation de la fonction de courant différentiel résiduel

B.3.3.1 DPR sans temporisation: type non temporisé

B.3.3.2 DPR avec temporisation: type temporisé (voir B.2.3.8)

B.3.3.2.1 DPR à temporisation non réglable

B.3.3.2.2 DPR à temporisation réglable

Un DPR peut avoir une temporisation réglable, soit par échelons soit par variation continue.

B.3.4 Classification selon le comportement en présence d'une composante continue

B.3.4.1 DPR de type AC (voir B.4.4.1)

B.3.4.2 DPR de type A (voir B.4.4.2)

B.4 Caractéristiques des DPR pour leur fonction de courant différentiel résiduel

B.4.1 Valeurs assignées

B.4.1.1 Courant différentiel de fonctionnement assigné ($I_{\Delta n}$)

Valeur efficace d'un courant sinusoïdal différentiel résiduel de fonctionnement (voir B.2.2.4) assignée par le fabricant au DPR, à laquelle celui-ci doit fonctionner dans des conditions spécifiées.

NOTE Pour un DPR à réglages multiples de courant différentiel résiduel de fonctionnement, le réglage le plus élevé pour désigner ses caractéristiques assignées est utilisé. Voir cependant l'Article B.5 concernant le marquage.

B.4.1.2 Courant différentiel de non-fonctionnement assigné ($I_{\Delta no}$)

Valeur efficace du courant sinusoïdal différentiel résiduel de non-fonctionnement (voir B.2.2.5) assignée par le fabricant, à laquelle le DPR ne fonctionne pas dans des conditions spécifiées.

B.4.1.3 Pouvoir de fermeture et de coupure différentiel résiduel de court-circuit assigné ($I_{\Delta m}$)

Valeur efficace de la composante alternative du courant différentiel résiduel de court-circuit présumé (voir B.2.4.3), assignée au DPR par le fabricant, que le DPR peut fermer, véhiculer et couper dans des conditions spécifiées.

B.4.2 Valeurs préférentielles et valeurs limites

B.4.2.1 Valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné ($I_{\Delta n}$)

Les valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné sont

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A

Des valeurs plus élevées peuvent être spécifiées.

$I_{\Delta n}$ peut s'exprimer en pourcentage du courant assigné.

B.4.2.2 Valeur minimale du courant différentiel résiduel de non-fonctionnement assigné ($I_{\Delta no}$)

La valeur minimale du courant différentiel résiduel de non-fonctionnement assigné est 0,5 $I_{\Delta n}$.

B.4.2.3 Valeur limite de la surintensité de non-fonctionnement dans le cas d'une charge monophasée

La valeur limite de la surintensité de non-fonctionnement dans le cas d'une charge monophasée doit être conforme à B.7.2.7.

B.4.2.4 Caractéristiques de fonctionnement

B.4.2.4.1 Type non temporisé

La caractéristique de fonctionnement pour un type non temporisé est donnée au Tableau B.1.

Tableau B.1 – Caractéristique de fonctionnement pour le type non temporisé

Courant différentiel résiduel	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	10 $I_{\Delta n}$ [b]
Durée maximale de coupures en s	0,3	0,15	0,04	0,04

[a] Pour les DPR avec $I_{\Delta n} \leq$ 30 mA, 0,25 A peut être utilisé à la place de 5 $I_{\Delta n}$.

[b] 0,5 A si 0,25 A est utilisé conformément à la note de bas de page a.

Les DPR avec $I_{\Delta n} \leq$ 30 mA doivent être du type non temporisé.

B.4.2.4.2 Type temporisé

B.4.2.4.2.1 Temps limite de non-réponse (voir B.2.3.7)

Pour un type temporisé, le temps limite de non-réponse est défini à 2 $I_{\Delta n}$ et doit être déclaré par le fabricant.

Le temps limite de non-réponse minimal à 2 $I_{\Delta n}$ est 0,06 s.

Les valeurs préférentielles de temps limite de non-réponse à 2 I_{Δ} sont

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

B.4.2.4.2.2 Caractéristique de fonctionnement

Pour les DPR avec un temps limite de non-réponse supérieur à 0,06 s, le fabricant doit déclarer les durées de coupure maximales pour $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ et 10 $I_{\Delta n}$.

Pour les DPR avec un temps limite de non-réponse de 0,06 s, les caractéristiques de fonctionnement sont données au Tableau B.2.

Tableau B.2 – Caractéristique de fonctionnement pour le type temporisé ayant un temps limite de non-réponse de 0,06 s

Courant différentiel résiduel	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	10 $I_{\Delta n}$
Durée maximale de coupure en s	0,5	0,2	0,15	0,15

Dans le cas d'un DPR à caractéristique temps/courant inverse, le fabricant doit déclarer la caractéristique courant différentiel résiduel/durée de coupure.

B.4.3 Valeur du pouvoir de coupure et de fermeture différentiel résiduel assigné ($I_{\Delta m}$) en court-circuit

La valeur minimale de $I_{\Delta m}$ est 25 % de I_{cu}.

Des valeurs supérieures peuvent être soumises à essai et déclarées par le fabricant.

B.4.4 Caractéristiques de fonctionnement dans le cas d'un courant de défaut à la terre avec ou sans composante continue

B.4.4.1 DPR du type AC

DPR pour lequel le déclenchement est assuré pour des courants alternatifs sinusoïdaux différentiels résiduels, sans composante continue, appliqués soudainement ou de façon progressive.

B.4.4.2 DPR du type A

DPR pour lequel le déclenchement est assuré pour des courants alternatifs sinusoïdaux différentiels résiduels en présence de courants continus pulsés différentiels résiduels spécifiés, avec ou sans un niveau spécifié de courant continu superposé, appliqués soudainement ou de façon progressive.

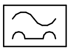
B.5 Marquage

Chaque DPR doit être marqué de façon indélébile:

a) Les indications suivantes doivent être marquées sur les DPR intégrés (voir B.1.1) en plus des marquages spécifiés en 5.2 et être distinctement visibles après l'installation:

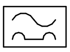
- courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$;
- réglages du courant différentiel résiduel de fonctionnement, le cas échéant;
- temps limite de non-réponse à 2 $I_{\Delta n}$, pour le type temporisé, par le symbole Δt suivi du temps limite de non-réponse en ms; en variante, dans le cas où le temps limite de non-réponse est 0,06 s, ce symbole peut être S (S dans un carré);
- l'organe de manœuvre de l'appareil d'essai, par la lettre T (voir aussi B.7.2.6);
- caractéristique de fonctionnement en présence de courants différentiels résiduels avec ou sans composantes continues:

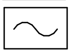
pour les DPR de type AC avec le symbole 

pour les DPR de type A avec le symbole 

b) Les indications suivantes doivent être marquées sur les unités c.r. et être distinctement visibles après l'installation:

- tension(s) assignée(s) si elle(s) diffère(nt) de celle(s) du disjoncteur;
- valeur (ou plage de valeurs) de la fréquence assignée si elle diffère de celle du disjoncteur;
- l'indication $I_n \leq$ ...A (I_n étant le courant assigné maximal du disjoncteur auquel l'unité c.r. peut être associée);
- courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$;
- réglages du courant différentiel résiduel de fonctionnement, le cas échéant;
- temps limite de non-réponse, comme spécifié au point a);
- organe de manœuvre de l'appareil d'essai, comme spécifié au point a);
- caractéristique de fonctionnement en présence de courants différentiels résiduels avec ou sans composantes continues:

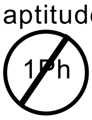
pour les DPR de type A avec le symbole 

pour les DPR de type AC avec le symbole 

c) Les indications suivantes doivent être marquées sur les unités c.r. et être distinctement visibles après l'assemblage avec le disjoncteur:

- nom du fabricant ou marque de fabrique;
- désignation du type ou numéro de série;

– identification du (des) disjoncteur(s) avec le(s)quel(s) l'unité c.r. peut être assemblée, sauf si un assemblage incorrect (rendant la protection inopérante) est impossible du fait de sa conception;
– IEC 60947-2;
– aptitude à une utilisation avec une alimentation triphasée seulement, avec le symbole



d) Les indications suivantes doivent être marquées sur les DPR intégrés ou les unités c.r., suivant le cas, ou figurer dans la documentation du fabricant:
   – pouvoir assigné de fermeture et de coupure différentiel résiduel en court-circuit $I_{\Delta m}$ s'il est supérieur à 25 % de I_{cu} (voir B.4.3);
   – schéma des connexions, y compris celles du circuit d'essai et, le cas échéant, celles de la ligne pour les DPR dépendant de la tension d'alimentation;
   – valeur du courant différentiel résiduel de non-fonctionnement assigné $I_{\Delta no}$ s'il est supérieur à 0,5 $I_{\Delta n}$.
e) Les indications suivantes doivent être disponibles dans la documentation du fabricant:
   – aptitude à une utilisation dans des:
     • circuits triphasés seulement, ou
     • circuits triphasés et monophasés.

B.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable.

B.7 Exigences relatives à la conception et au fonctionnement

B.7.1 Exigences relatives à la conception

Il ne doit pas être possible de modifier la caractéristique de fonctionnement d'un DPR par des moyens autres que ceux spécifiquement destinés au réglage du courant différentiel résiduel de fonctionnement assigné ou de la temporisation définie.

Les DPR combinant une unité c.r. appropriée et un disjoncteur associé doivent être conçus et réalisés de manière telle que:

– l'assemblage de l'unité c.r. adaptable et du disjoncteur associé n'exige aucune liaison mécanique et/ou électrique pouvant être nuisible à l'installation ou présentant des risques pour l'utilisateur;
– l'adjonction de l'unité c.r. adaptable ne compromet en aucune manière le fonctionnement normal ou les performances du disjoncteur;
– l'unité c.r. n'est pas endommagée de façon permanente à la suite des courants de court-circuit au cours des séquences d'essai.

B.7.2 Exigences relatives au fonctionnement

B.7.2.1 Fonctionnement en cas de courant différentiel résiduel

Le DPR doit s'ouvrir automatiquement lors de l'apparition de tout courant de fuite ou de courant de défaut à la terre égal ou supérieur au courant différentiel résiduel de fonctionnement assigné pendant une durée supérieure au temps limite de non-réponse.

La manœuvre du DPR doit être conforme aux exigences de durée spécifiées en B.4.2.4. La conformité doit être vérifiée par les essais de B.8.1.1.

B.7.2.2 Pouvoir de fermeture et de coupure différentiel résiduel de court-circuit assigné $I_{\Delta m}$

Les DPR doivent satisfaire aux exigences d'essai de B.8.10.

B.7.2.3 Aptitude au fonctionnement en service

Les DPR doivent satisfaire aux essais de B.8.1.1.1.

B.7.2.4 Effets des conditions d'environnement

Les DPR doivent fonctionner de manière satisfaisante, compte tenu des effets des conditions d'environnement.

La conformité est vérifiée par l'essai de B.8.11.

B.7.2.5 Propriétés diélectriques

Les DPR doivent satisfaire aux essais de B.8.3.

B.7.2.6 Appareil d'essai

Les DPR doivent être munis d'un appareil d'essai permettant à l'appareil de détection d'être traversé par un courant simulant un courant différentiel résiduel, afin de permettre de vérifier périodiquement par essai l'aptitude au fonctionnement des DPR.

L'appareil d'essai doit satisfaire aux essais de B.8.4.

Aucune tension ne doit apparaître sur le conducteur de protection, lorsqu'il existe, lors du fonctionnement du dispositif de contrôle.

Il ne doit pas être possible d'alimenter le circuit protégé par la manœuvre de l'appareil d'essai lorsque le DPR est en position d'ouverture.

L'appareil d'essai ne doit pas être le seul moyen d'effectuer la manœuvre d'ouverture et n'est pas prévu pour cette fonction.

L'organe de manœuvre de l'appareil d'essai doit être désigné par la lettre T et sa couleur ne doit être ni rouge ni verte; il convient d'employer, de préférence, une couleur claire.

NOTE L'appareil d'essai est seulement destiné à vérifier la fonction de déclenchement, et non la valeur à laquelle cette fonction s'accomplit, par rapport au courant assigné différentiel résiduel de fonctionnement et à la durée de la coupure.

B.7.2.7 Valeur du courant de surcharge de non-fonctionnement pour un circuit de charge monophasé

Les DPR doivent supporter sans déclencher la plus faible des deux valeurs suivantes de surintensité:

– 6 I_n,
– 80 % du courant maximal de réglage du déclencheur de court-circuit.

La conformité est vérifiée par l'essai de B.8.5.

Cet essai n'est toutefois pas nécessaire dans le cas de DPR de catégorie de sélectivité B puisque les exigences de ce paragraphe sont vérifiées pendant la séquence d'essai IV (ou la séquence d'essai VI (combinée)).

NOTE Les essais pour les circuits de charge polyphasés en régime équilibré ne sont pas nécessaires car ils sont estimés être satisfaits par les exigences de ce paragraphe.

B.7.2.8 Résistance des DPR aux déclenchements intempestifs dus à des courants de choc causés par des tensions de choc

B.7.2.8.1 Résistance aux déclenchements intempestifs dans le cas de charge de capacité de réseau

Les DPR doivent satisfaire à l'essai de B.8.6.2.

B.7.2.8.2 Résistance aux déclenchements intempestifs dans le cas d'amorçage sans courant de suite

Les DPR doivent satisfaire à l'essai de B.8.6.3.

B.7.2.9 Comportement des DPR du type A en cas de courant de défaut à la terre comprenant une composante continue

Le comportement des DPR en cas de courant de défaut à la terre comprenant une composante continue doit être tel que les durées maximales de coupure définies dans le Tableau B.1 et le Tableau B.2, suivant le cas, doivent également être respectées, les valeurs du courant d'essai spécifiées étant cependant multipliées :

– par le facteur 1,4 pour les DPR ayant $I_{\Delta n} > 0{,}015$ A,
– par le facteur 2 pour les DPR ayant $I_{\Delta n} \leq 0{,}015$ A (ou 0,03 A, selon celle qui est la plus élevée).

La conformité est vérifiée par les essais de B.8.7.

B.7.2.10 Conditions de fonctionnement des DPR à réarmement

Il ne doit pas être possible de remettre en position de fermeture, après déclenchement dû à un courant différentiel résiduel, les DPR à réarmement (voir B.2.3.9) s'ils n'ont pas été réarmés.

La conformité est vérifiée pendant l'essai de 8.3.3.4.4 selon B.8.1.1.1.

B.7.2.11 Exigences supplémentaires relatives aux DPR fonctionnellement dépendants de la tension d'alimentation

Les DPR fonctionnellement dépendants de la tension d'alimentation doivent fonctionner correctement à toute valeur de la tension d'alimentation comprise entre 0,85 et 1,1 fois sa valeur assignée.

La conformité est vérifiée par les essais de B.8.2.3.

Lorsqu'un DPR a plus d'une fréquence assignée ou une plage de fréquences assignées, le DPR doit être capable de fonctionner selon ce paragraphe à toutes les fréquences.

La conformité est vérifiée en effectuant les essais de B.8.2 et B.8.4.

Suivant leur classification, les DPR fonctionnellement dépendants de la tension d'alimentation doivent satisfaire aux exigences figurant au Tableau B.3.