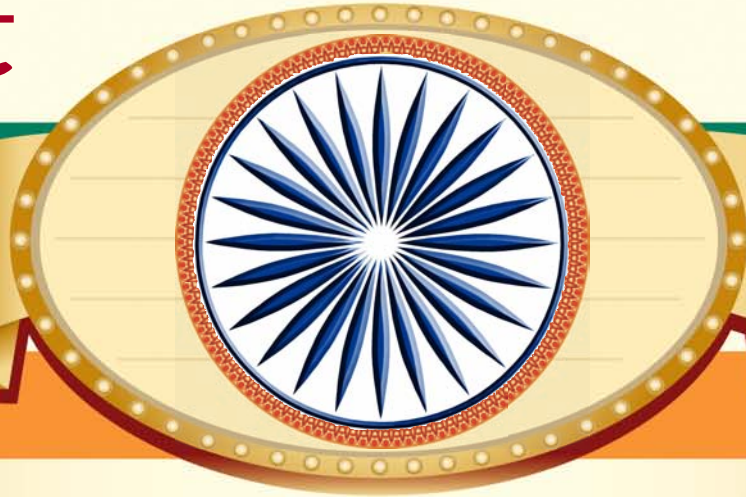


इंटरनेट

मानक



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Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

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Mazdoor Kisan Shakti Sangathan

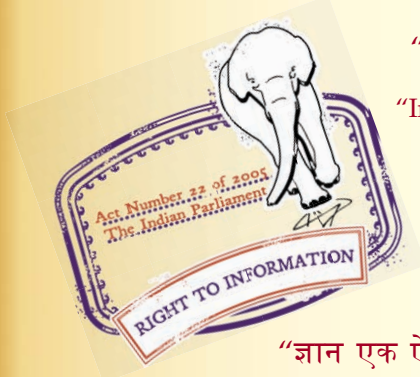
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“पुराने को छोड़ नये के तरफ”

Jawaharlal Nehru

“Step Out From the Old to the New”

IS/IEC 60947-2 (2003): Low-Voltage Switchgear and Controlgear, Part 2: Circuit Breakers [ETD 7: Low Voltage Switchgear and Controlgear]



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“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”





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भारतीय मानक  
निम्न-वोल्टता के स्विचगियर और नियंत्रणगियर  
भाग 2 परिपथ वियोजक

*Indian Standard*  
**LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR**  
**PART 2 CIRCUIT BREAKERS**

ICS 29.130.20

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**BUREAU OF INDIAN STANDARDS**  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

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## NATIONAL FOREWORD

This Indian Standard (Part 2) which is identical with IEC 60947-2 : 2003 'Low-voltage switchgear and controlgear — Part 2: Circuit breakers' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Low-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

This standard supersedes IS 13947 (Part 2) : 1993 'Specification for low-voltage switchgear and controlgear: Part 2 Circuit breakers'.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
- b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60050 (441) (1984) International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear, controlgear and fuses	IS 1885 (Part 17) : 1979 Electrotechnical vocabulary: Part 17 Switchgear and controlgear ( <i>first revision</i> )	Technically Equivalent
IEC 60051 (all parts) Direct acting indicating analogue electrical measuring instruments and their accessories	IS 1248 : 2003 (all parts) Direct acting indicating analogue electrical measuring instruments and their accessories	do
IEC 60068-2-14 (1984) Environmental testing — Part 2-14: Tests — Test N Change of temperature	IS 9000 (Part 14/Sec 1 to 3) : 1988 Basic Environmental testing procedures for electronic and electrical items: Part 14 Test N: Change of temperature ( <i>first revision</i> )	do
IEC 60068-2-30 (1980) Environmental testing — Part 2-30: Tests — Test Db and guidance: Damp heat, cyclic (12+12 hour cycle)	IS 9000 (Part 5/Sec 1 and 2) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 5 Damp heat (cyclic) test	do
IEC 60364-4-41 (1982) Electric installations of buildings — Part 4: Protection for safety — Chapter 41: Protection against shock	SP 30 : 1985 National electrical code	do

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60898 (1995) Circuit-breakers for over-current protection for household and similar installations	IS 8828 : 1996 Circuit-breakers for overcurrent protection for household and similar installations	Identical
IEC 60947-1 (1999) <sup>1)</sup> Low-voltage switchgear and controlgear — Part 1: General rules	IS/IEC 60947-1 : 2004 Low-voltage switchgear and controlgear: Part 1 General rules	Technically Equivalent
IEC 60947-4-1 (2000) <sup>2)</sup> Low-voltage switchgear and controlgear — Part 4: Contactors and motor-starters — Section 1: Electromechanical contactors and motor-starters	IS/IEC 60947-4-1 : 2002 Low-voltage switchgear and controlgear: Part 4 Contactors and motor-starters, Section 1 Electromechanical contactors and motor-starters	do
IEC 61000-3-2 (2000) Electromagnetic compatibility (EMC) — Part 3: Limits — Section 2: Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	IS 14700 (Part 3/Sec 2) : 1999 Electromagnetic compatibility (EMC): Part 3 Limits, Section 2 Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	do
IEC 61000-3-3 (1994) Electromagnetic compatibility (EMC) — Part 3: Limits — Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A	IS 14700 (Part 3/Sec 3) : 1999 Electromagnetic compatibility (EMC): Part 3 Limits, Section 3 Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A	Identical
IEC 61000-4-2 (1995) Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 2: Electrostatic discharge immunity test	IS 14700 (Part 4/Sec 2) : 1999 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section, 2 Electrostatic discharge immunity test	do
IEC 61000-4-3 (2002) Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated, radio-frequency, electromagnetic field immunity test	IS 14700 (Part 4/Sec 3) : 2005 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 3 Radiated, radio-frequency, electromagnetic field immunity test	do
IEC 61000-4-4 (1995) Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 4: Electrical fast transient/burst immunity test	IS 14700 (Part 4/Sec 4) : 1999 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 4 Electrical fast transient/burst immunity test	do
IEC 61008-1 (1990) Residual current operated circuit-breakers without integral over-current protection for household and similar uses (RCCB's) — Part 1: General rules	IS 12640 (Part 1) : 2000 Residual current operated circuit-breaker for household and similar uses: Part 1 Circuit-breakers without integral over-current protection (RCCB's)	do
IEC 61009-1 (1991) Residual current operated circuit-breakers with integral over-current protection for household and similar uses (RCBO's) — Part 1: General rules	IS 12640 (Part 2) : 2001 Residual current operated circuit-breaker for household and similar uses: Part 2 Circuit-breakers with integral over-current protection (RCBO's)	do

<sup>1)</sup> Since revised in 2004.

<sup>2)</sup> Since revised in 2002.

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
CISPR 11(1997) Industrial, scientific and medical (ISM) radio-frequency equipment — Electromagnetic disturbance characteristics — Limits and methods of measurement	IS 6873 (Part 4) : 1999 Limits and methods of measurement of radio disturbance characteristics: Part 4 Industrial, scientific and medical (ISM) radio-frequency equipment ( <i>first revision</i> )	Identical
CISPR 22 (1997) Information technology equipment — Radio disturbance characteristics — Limits and methods of measurement	IS 6873 (Part 7) : 1999 Limits and methods of measurement of radio disturbance characteristics: Part 7 Information technology equipment ( <i>first revision</i> )	do

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

<i>International Standard</i>	<i>Title</i>
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
IEC 60934 (1988)	Circuit-breakers for equipment (CBE)
IEC 61000-4-5 (1995)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 5: Surge immunity test
IEC 61000-4-6 (1996)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 6: Immunity to conducted disturbances, induced by radio frequency fields
IEC 61000-4-11 (1994)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 11: Voltage dips, short interruptions and voltage variations immunity tests
IEC 61000-5-2 (1997)	Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines — Section 2: Earthing and cabling

Only the English text of the International Standard has been retained while adopting it as an Indian Standard, and as such the page numbers given here are not same as in the IEC Publication.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

*Indian Standard***LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR****PART 2 CIRCUIT BREAKERS****1 General**

The provisions of the general rules dealt with in IEC 60947-1 (hereinafter referred to as Part 1) are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and appendices of the general rules thus applicable are identified by reference to Part 1, for example, 1.2.3 of Part 1, table 4 of Part 1, or annex A of Part 1.

**1.1 Scope and object**

This standard 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.

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 overcurrent 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.

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 un instructed persons, are contained in IEC 60898.

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

## IS/IEC 60947-2 : 2003

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 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 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests. Test N: Change of temperature*

IEC 60068-2-30:1980, *Environmental testing – Part 2: Tests – Test Db and guidance: Damp heat, cyclic (12+12-hour cycle)*

IEC 60364 ( all parts), *Electric installations of buildings*

IEC 60364-4-41:1982, *Electric installations of buildings – Part 4: Protection for safety – Chapter 41: Protection against shock*

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*

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

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

IEC 60947-1:1999, *Low-voltage switchgear and controlgear – Part 1: General rules*

Amendment 1 (2000)

Amendment 2 (2001)

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

IEC 61000-3-2:2000, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current  $\leq 16$  A per phase)*

IEC 61000-3-3:1994, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current  $\leq 16$  A*

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

Amendment 1 (1998)

Amendment 2 (2000)

IEC 61000-4-3:2002, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated radio-frequency electromagnetic field immunity test*

Amendment 1 (2002)

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test*

Amendment 1 (2000)

Amendment 2 (2001)

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

Amendment 1 (2000)

IEC 61000-4-6:1996, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 6: Immunity to conducted disturbances, induced by radiofrequency fields*

Amendment 1 (2000)

IEC 61000-4-11:1994, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 11: Voltage dips, short interruptions and voltage variation immunity tests*

Amendment 1 (2000)

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

IEC 61008-1:1990, *Residual current operated circuit-breakers without integral over-current protection for household and similar uses (RCCB's) – Part 1: General rules*

IEC 61009-1:1991, *Residual current operated circuit-breakers with integral over-current protection for household and similar uses (RCBO's) – Part 1: General rules*

CISPR 11:1997, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*  
Amendment 1 (1999)

CISPR 22:1997, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*

## **2 Definitions**

For the majority of the definitions required in connection with this standard, see Clause 2 of Part 1.

For the purpose of this standard, the following additional definitions shall apply:

NOTE Where these definitions are taken unchanged from the *International Electrotechnical Vocabulary (IEV)*, IEC 60050(441), the IEV reference 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

[IEV 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. Frame size is expressed in amperes corresponding to the highest current rating of the group. Within a frame size, the width may vary according to the number of poles

NOTE 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

[IEV 441-14-22]

### **2.3**

#### **current-limiting circuit-breaker**

a circuit-breaker with a break-time short enough to prevent the short-circuit current reaching its otherwise attainable peak value

[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 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**

a circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be disconnected from the main circuit, in the withdrawn 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

[IEV 441-14-24]

**2.7**

**air circuit-breaker**

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

[IEV 441-14-27]

**2.8**

**vacuum circuit-breaker**

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

[IEV 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 Part 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 Part 1 applies, with the following additions:

- 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 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.

**2.17**

**over-current protective co-ordination**

subclause 2.5.22 of Part 1 applies

**2.17.1**

**over-current discrimination**

subclause 2.5.23 of Part 1 applies

[IEV 441-17-15]

**2.17.2**

**total discrimination (total selectivity)**

over-current discrimination 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 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

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 Part 1 applies

**2.17.6****take-over current ( $I_B$ )**

subclause 2.5.25 of Part 1 is amplified as follows:

For the purpose of this standard, 2.5.25 of Part 1 applies to two over-current protective devices in series for operating times  $\geq 0,05$  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.

**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

**3 Classification**

Circuit-breakers may be classified:

**3.1** According to their utilization category, A or B (see 4.4).

**3.2** According to the interrupting medium, for example:

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

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**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 7.1.11 of Part 1).

## **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 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

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

The rated values established for a circuit-breaker shall be stated in accordance with 4.3.1 to 4.4, but it is not necessary to establish all the rated values listed.

### 4.3.1 Rated voltages

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

#### 4.3.1.1 Rated operational voltage ( $U_e$ )

Subclause 4.3.1.1 of Part 1 applies with the following amplification:

– Circuit-breakers covered by item a) of note 2:

$U_e$  is generally stated as the voltage between phases.

NOTE A 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 277/480 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 B According to present practice in Canada and the USA, circuit-breakers covered by item b) of note 2 are identified by the voltage between phases only.

#### 4.3.1.2 Rated insulation voltage ( $U_i$ )

Subclause 4.3.1.2 of Part 1 applies.

#### 4.3.1.3 Rated impulse withstand voltage ( $U_{imp}$ )

Subclause 4.3.1.3 of Part 1 applies.

### 4.3.2 Currents

A circuit-breaker is defined by the following currents:

#### 4.3.2.1 Conventional free-air thermal current ( $I_{th}$ )

Subclause 4.3.2.1 of Part 1 applies.

**4.3.2.2 Conventional enclosed thermal current ( $I_{the}$ )**

Subclause 4.3.2.2 of Part 1 applies.

**4.3.2.3 Rated current ( $I_n$ )**

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

**4.3.2.4 Current rating for four-pole circuit-breakers**

Subclause 7.1.8 of Part 1 applies.

**4.3.3 Rated frequency**

Subclause 4.3.3 of Part 1 applies.

**4.3.4 Rated duty**

The rated duties considered as normal are as follows:

**4.3.4.1 Eight-hour duty**

Subclause 4.3.4.1 of Part 1 applies.

**4.3.4.2 Uninterrupted duty**

Subclause 4.3.4.2 of Part 1 applies.

**4.3.5 Short-circuit characteristics**

**4.3.5.1 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 4.3.5.3).

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.

**4.3.5.2 Rated short-circuit breaking capacities**

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.

#### 4.3.5.2.1 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.).

#### 4.3.5.2.2 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 as a % of  $I_{cu}$  (for example  $I_{cs} = 25\% I_{cu}$ ).

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 1000 kA for utilization category B, the manufacturer may declare a value  $I_{cs}$  of 50 kA.

Table 1 – Standard ratios between  $I_{cs}$  and  $I_{cu}$

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

**4.3.5.3 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 <i>I</i> kA r.m.s.	Power factor	Minimum value required for <i>n</i> $n = \frac{\text{short - circuit making capacity}}{\text{short - circuit breaking capacity}}$
4,5 ≤ <i>I</i> ≤ 6	0,7	1,5
6 < <i>I</i> ≤ 10	0,5	1,7
10 < <i>I</i> ≤ 20	0,3	2,0
20 < <i>I</i> ≤ 50	0,25	2,1
50 < <i>I</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.

**4.3.5.4 Rated short-time withstand current (*I<sub>cw</sub>*)**

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 8.3.6.2.

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:

$$0,05 - 0,1 - 0,25 - 0,5 - 1 \text{ s}$$

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>I<sub>n</sub></i> A	Rated short-time withstand current <i>I<sub>cw</sub></i> – Minimum values kA
<i>I<sub>n</sub></i> ≤ 2 500 <i>I<sub>n</sub></i> > 2 500	12 <i>I<sub>n</sub></i> or 5 kA, whichever is the greater 30 kA



**4.4 Utilization 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).

Attention is drawn to the differences of the tests applying to the two utilization 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**

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	<p>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.</p> <p>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.</p>
<p>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).</p> <p>NOTE 2 Attention is drawn to the different requirements for the minimum required percentage of <math>I_{cs}</math> for utilization categories A and B, in accordance with table 1.</p> <p>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.</p>	

**4.5 Control circuits**

**4.5.1 Electrical control circuits**

Subclause 4.5.1 of Part 1 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**

d.c. V	Single-phase a.c. V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230
<p>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.</p>	

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

Subclause 4.5.2 of Part 1 applies.

#### 4.6 Auxiliary circuits

Subclause 4.6 of Part 1 applies.

#### 4.7 Releases

##### 4.7.1 Types

- 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 Part 1). 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

- 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).

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 on the release or on its scale. The marking may be either directly in amperes, or as a multiple of the current value marked on the release.

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  $-5\text{ }^{\circ}\text{C}$  to  $+40\text{ }^{\circ}\text{C}$ ;
- for releases of the thermal type, the values stated are for a reference temperature of  $+30\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ . 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**

##### **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 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 Part 1 applies.

The manufacturer shall provide the necessary information.

### **5 Product information**





#### **5.1 Nature of the information**

Subclause 5.1 of Part 1 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  and  respectively, if symbols are used (see 7.1.5.1 of Part 1).
- 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 category;
  - rated operational voltage(s)  $U_e$  (see 4.3.1.1 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  $\text{-----}$ );
  - 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 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 7.1.9.3 of Part 1);
  - reference temperature for non-compensated thermal releases, if different from 30 °C.
- 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 4.3.5.1;
  - 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 Appendix C of Part 1);
  - 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.

- 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 Part 1) and rated frequency for a.c.;
  - rated control circuit voltage of the shunt release (see 7.2.1.4 of Part 1) and/or of the under-voltage release (or of the no-voltage release) (see 7.2.1.3 of Part 1), 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 7.1.7.4 of Part 1 applies (see also item b) above).

### **5.3 Instructions for installation, operation and maintenance**

Subclause 5.3 of Part 1 applies.

## **6 Normal service, mounting and transport conditions**

Clause 6 of Part 1 applies with the following addition:

*Pollution degree* (see 6.1.3.2 of Part 1)

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**

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.

### **7.1.1 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 re-closed 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.

### **7.1.2 Additional requirements for circuit-breakers suitable for isolation**

For additional requirements concerning performance, see 7.2.7.

Subclause 7.1.6 of Part 1 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.

### **7.1.3 Clearances and creepage distances**

Minimum values are given in tables 13 and 15 of IEC 60947-1.

### **7.1.4 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).

### **7.1.5 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) and c) 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).

#### **7.1.6 Additional requirements for circuit-breakers provided with a neutral pole**

Subclause 7.1.8 of IEC 60947-1 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.

### **7.2 Performance requirements**

#### **7.2.1 Operating conditions**

##### **7.2.1.1 Closing**

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.

##### **7.2.1.1.1 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.

##### **7.2.1.1.2 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.

**7.2.1.1.3 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.

**7.2.1.1.4 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.

**7.2.1.1.5 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 and, unless otherwise agreed between manufacturer and user, shall have their energy for the tripping operation stored prior to the completion of the closing operation.



**7.2.1.2.2 Opening by undervoltage releases**

Subclause 7.2.1.3 of Part 1 applies.

**7.2.1.2.3 Opening by shunt releases**

Subclause 7.2.1.4 of Part 1 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  $\pm 20\%$  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 Part 1) as a function of prospective current (r.m.s. symmetrical);
- $I^2t$  characteristics (see 2.18) for circuit-breakers of utilization category A and, if applicable, B for circuit-breakers with instantaneous override (see note to 8.3.5).

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 It may be 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  $\pm 10\%$  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 Part 1), i.e. with the conventional non-tripping current (see 2.5.30 of Part 1), the opening release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 2.5.30 of Part 1) 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 Part 1), tripping shall then occur in less than the conventional time later.

NOTE 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*
* 1 hour when $I_n \leq 63$ A		

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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 8.3.3.6. The temperature-rises of the terminals shall not exceed the limiting values stated in table 7 during the tests made in accordance with 8.3.4.4 and 8.3.6.3.

#### **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 Part 1.

#### **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) 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 4.3.4, 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 8.3.3.6.

#### **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 *	Temperature-rise limits ** K
– Terminals for external connections	80
– Manual operating means: metallic non-metallic	25 35
– Parts intended to be touched but not hand-held: metallic non-metallic	40 50
– Parts which need not be touched for normal operation: metallic non-metallic	50 60
* No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.	
** 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

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

Type tests shall be made in accordance with 8.3.3.2.

The verification of dielectric withstand during all test sequences shall be made in accordance with 8.3.3.5.

Routine tests shall be made in accordance with 8.4.5.

#### 7.2.3.1 Impulse withstand voltage

Subclause 7.2.3.1 of IEC 60947-1 applies.

#### 7.2.3.2 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.

#### 7.2.3.3 Clearances

Subclause 7.2.3.3 of IEC 60947-1 applies.

#### 7.2.3.4 Creepage distances

Subclause 7.2.3.4 of IEC 60947-1 applies.

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### 7.2.3.5 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, 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.

### 7.2.3.6 Spacing between separate circuits

Subclause 7.2.3.6 of IEC 60947-1 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 8.3.3.4.

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 Part 1 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 8.3.3.3.3;
- for the test of operational performance with current in the main circuit under the test conditions specified in 8.3.3.3.4.

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 Rated current * A	2 Number of operating cycles per hour **	3 Number of operating cycles			5 Total
		Without current	With current ***		
$I_n \leq 100$	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	

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

\*\* 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.

\*\*\* 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 Part 1 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 4.3.5.1 and 4.3.5.3.

The rated short-circuit breaking capacity shall be in accordance with 4.3.5.2.

The rated short-time withstand current shall be in accordance with 4.3.5.4.

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 applies and tests shall be made in accordance with 8.3.3.2, 8.3.3.5, 8.3.3.9, 8.3.4.3, 8.3.5.3 and 8.3.7.7, 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 Coordination between a circuit-breaker and another short-circuit protective device

For the coordination 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

Subclause 8.1 of Part 1 applies, with the following additions:

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

- type tests (see 8.3);
- routine tests (see 8.4).

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8.1.2 Type tests include the following tests:

Test	Subclause
Temperature-rise	8.3.2.5
Tripping limits and characteristics	8.3.3.1
Dielectric properties	8.3.3.2
Operational performance capability	8.3.3.3
Overload performance (where applicable)	8.3.3.4
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

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 comprise the tests listed in 8.4.

### 8.2 Compliance with constructional requirements

Subclause 8.2 of Part 1 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 (8.3.2.1 to 8.3.2.4);
- 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 Part 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, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

#### 8.3.1 Test sequences

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.

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

- test of dielectric properties (8.3.3.2);
- test of undervoltage releases of 8.3.3.3.2 (item c) and 8.3.3.3.3, to verify the requirements of 7.2.1.3 of Part 1;
- test of shunt trip releases of 8.3.3.3.2 (item d) and 8.3.3.3.3, to verify the requirements of 7.2.1.4 of Part 1;
- additional tests for operational capability without current for withdrawable circuit-breakers (8.3.3.3.5).

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
Dielectric properties	8.3.3.2
Dielectric withstand (verification)	8.3.3.5 – 8.3.4.3 – 8.3.5.3 – 8.3.6.5 – 8.3.7.3 – 8.3.7.7 – 8.3.8.5
Individual pole short-circuit test (for phase-earthed systems)	Annex C
Individual pole short-circuit test (for IT systems)	Annex H
Indication of main contact position	8.3.3.9
Integrally fused circuit-breakers (short-circuit tests)	8.3.7.1 – 8.3.7.5 – 8.3.7.6
Operational performance capability	8.3.3.3 – 8.3.4.2 – 8.3.4.4
Overload performance	8.3.3.4
Overload releases (verification)	8.3.3.7 – 8.3.4.4 – 8.3.5.1 – 8.3.5.4 – 8.3.6.1 – 8.3.6.6 – 8.3.7.4 – 8.3.7.8 – 8.3.8.1 – 8.3.8.6
Service short-circuit breaking capacity	8.3.4.1 – 8.3.8.3
Short-circuit breaking capacity test at maximum short-time withstand current	8.3.6.4
Short-time withstand current	8.3.6.2 – 8.3.8.2
Temperature-rise (verification)	8.3.3.6 – 8.3.4.3 – 8.3.6.3 – 8.3.7.2 – 8.3.8.5
Tripping limits and characteristics	8.3.3.1
Ultimate short-circuit breaking capacity	8.3.5.2
Withdrawable circuit-breakers (additional tests)	8.3.3.3.5

Table 9 – Overall schema of test sequences <sup>1)</sup>

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 main contact position (where applicable)
II Rated service short-circuit breaking capacity (8.3.4)	All circuit-breakers <sup>2)</sup>	Rated service short-circuit breaking capacity Verification of dielectric withstand Verification of temperature-rise Verification of overload releases Operational performance capability
III Rated ultimate short-circuit breaking capacity (8.3.5)	All circuit-breakers <sup>3)</sup> of utilization category A and circuit-breakers of utilization category B with instantaneous override*	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 category B <sup>2)</sup>	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)	Integrally fused circuit-breakers Stage 1 Stage 2	Short-circuit at the selectivity limit current Verification of temperature-rise Verification of dielectric withstand Verification of overload releases Short-circuit at take-over current Short-circuit at rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
Combined test sequence (8.3.8)	Circuit-breakers of utilization 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 Verification of dielectric withstand Verification of temperature-rise Verification of overload releases Operational performance capability
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 (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
<p>* See note to 8.3.5</p> <p>1) For the selection of circuit-breakers for tests and the applicability of the various test sequences according to the relationship between <math>I_{CS}</math>, <math>I_{CU}</math> and <math>I_{CW}</math>, see table 9a.</p> <p>2) Except where the combined test sequence is applied.</p> <p>3) Except – where <math>I_{CS} = I_{CU}</math> (but see 8.3.5) – where the combined test sequence is applied – for integrally fused circuit-breakers.</p>		



**Table 9a – Applicability of test sequences according to the relationship between  $I_{CS}$ ,  $I_{CU}$  and  $I_{CW}$  <sup>1)</sup>**

$I_{CS}$ , $I_{CU}$ and $I_{CW}$ relationship	Test sequence	Utilization category			
		A	A Integrally fused	B	B Integrally fused
CASE 1  $I_{CS} \neq I_{CU}$ for utilization category A $I_{CS} \neq I_{CU} \neq I_{CW}$ for utilization category B	I	X	X	X	X
	II	X	X	X	X
	III	X		X <sup>2)</sup>	
	IV	X <sup>4)</sup>		X	X
	V		X		X
CASE 2  $I_{CS} = I_{CW} \neq I_{CU}$ for utilization category B	I			X	X
	II			X	X
	III			X <sup>2)</sup>	
	IV			X	X
	V				X
	Combined			X <sup>3)</sup>	X <sup>3)</sup>
CASE 3  $I_{CS} = I_{CU}$ for utilization category A $I_{CS} = I_{CU} \neq I_{CW}$ for utilization category B	I	X	X	X	X
	II	X	X	X	X
	III				
	IV	X <sup>4)</sup>		X	X
	V		X		X
CASE 4  $I_{CS} = I_{CU} = I_{CW}$ for utilization category B	I			X	
	II			X	
	III				
	IV			X	
	V				
	Combined			X <sup>3)</sup>	
<sup>1)</sup> 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. <sup>2)</sup> Test applicable only if $I_{CU} > I_{CW}$ . <sup>3)</sup> At the discretion of, or in agreement with the manufacturer, this sequence may be applied to circuit-breakers of utilization category B, in which case it replaces test sequences II and IV. <sup>4)</sup> Test sequence IV applies only in the case of circuit-breakers covered by note 3 of table 4.					

**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.

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### 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.

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 7.1.5) within the frame size, further samples shall be tested in accordance with note 8 of table 10.

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.

If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as specified in 7.2.1.1.3. 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.

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).

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 (8.3.3.4), short-circuit (8.3.4.1, 8.3.5.2, 8.3.6.4, 8.3.7.1, 8.3.7.5, 8.3.7.6 and 8.3.8.3), and short-time withstand current (8.3.6.2 and 8.3.8.2) 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: 0,45-0,65;
- size of hole: not exceeding 30 mm<sup>2</sup>;
- 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 Part 1) 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 Part 1.

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

Test sequence	Number of marked $U_e$ ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting <sup>1)</sup>		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	8)
II ( $I_{CS}$ ) and combined	X			X		2	1		X	$U_e$	X		X	8)9)
							2	X		$U_e$	X			2)
	X				X	3	1		X	$U_e$	X		X	8)9)
							2	X		$U_e$	X			2)
							3		X	$U_e$	X		X	3)
		X		X	X	3	1		X	$U_e$ max corr		X	X	8)9)
							2	X		$U_e$ max corr		X		2)
							3		X	$U_e$ max	X		X	4)
				X	X	4	1		X	$U_e$ max corr		X	X	8)9)
							2	X		$U_e$ max corr		X		2)
			X	X	4	3		X	$U_e$ intermed	X		X	6)	
						4		X	$U_e$ max	X		X	4)	
III ( $I_{CU}$ )	X			X		2	1		X	$U_e$	X			8)
							2	X		$U_e$	X			2)
	X				X	3	1		X	$U_e$	X			8)
							2	X		$U_e$	X			2)
							3		X	$U_e$	X			3)
		X		X	X	3	1		X	$U_e$ max corr		X		8)
							2	X		$U_e$ max corr		X		2)
							3		X	$U_e$ max	X			4)
IV ( $I_{CW}$ )				X	X	4	1		X	$U_e$ max corr		X		8)
							2	X		$U_e$ max corr		X		2)
							3		X	$U_e$ intermed	X			6)
							4		X	$U_e$ max	X			4)
V ( $I_{CU}$ )	X	X	X	X	X	2	1		X	$U_e$ max	X			7)8)
							2	X		$U_e$ max	X			2)
Individual pole (annex C) ( $I_{SU}$ )	X	X	X	X	X	2	1		X	$U_e$ max	$I_{SU}$			8)
							2	X		$U_e$ max	$I_{SU}$			-
Individual pole (annex H) ( $I_{IT}$ )	X	X	X	X	X	1			X	$U_e$ max	$I_{IT}$			8)

Notes for table 10

<p>Mul = multiple; Corr = corresponding; Intermed = intermediate</p> <p>1) Min means the minimum <math>I_n</math> of a given frame size; in the case of adjustable overload releases, it means the minimum setting of the minimum <math>I_n</math>. Max means the maximum <math>I_n</math> of a given frame size.</p> <p>2) This sample is omitted in the following cases:</p> <ul style="list-style-type: none"> <li>- a circuit-breaker having a single non-adjustable current setting for a given frame size;</li> <li>- a circuit-breaker provided only with a shunt release (i.e. without an integral overcurrent release);</li> <li>- 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).</li> </ul> <p>3) Connections reversed.</p> <p>4) Connections reversed, if terminals unmarked.</p> <p>5) Applies to category B circuit-breakers and also to category A circuit-breakers covered by note 3 of table 4.</p> <p>6) To be agreed between test station and manufacturer.</p> <p>7) If terminals unmarked an additional sample shall be tested with connections reversed.</p> <p>8) 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.</p> <p>9) The requirement of note 8) applies only to the combined sequence.</p>
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**8.3.2.2 Test quantities**

**8.3.2.2.1 Values of test quantities**

Subclause 8.3.2.2.1 of Part 1 applies.

**8.3.2.2.2 Tolerances on test quantities**

Subclause 8.3.2.2.2 of Part 1 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  $\pm 5\%$ .

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

**8.3.2.2.4 Power factor of the test circuit**

Subclause 8.3.4.1.3 of Part 1 applies with the following modification:

Table 16 of Part 1 is replaced by table 11 of this standard.

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

Test current / kA	Power factor			Time constant ms		
	Short-circuit	Operational performance capability	Overload	Short-circuit	Operational performance capability	Overload
$I \leq 3$	0,9			5		
$3 < I \leq 4,5$	0,8			5		
$4,5 < I \leq 6$	0,7			5		
$6 < I \leq 10$	0,5	0,8	0,5	5	2	2,5
$10 < I \leq 20$	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 Part 1 applies with the following modification:

Table 16 of Part 1 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 Part 1 applies.

**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 Part 1 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 Part 1 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.

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 Part 1 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<sup>3</sup> ± 0,05 g/cm<sup>3</sup>;
- 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.

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- 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 Part 1 applies.

### 8.3.2.6.3 Calibration of the test circuit

Subclause 8.3.4.1.5 of Part 1 applies.

### 8.3.2.6.4 Test procedure

Subclause 8.3.4.1.6 of Part 1 applies with the following amplification:

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.

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 75 cm in length, having a cross-section corresponding to the conventional thermal current (see 8.3.3.3.4, tables 9 and 10 of Part 1) shall be included as follows:

- 50 cm on the supply side,
- 25 cm on the load side.

The sequence of operations shall be that which is applicable to each test sequence, as specified in 8.3.4.1, 8.3.5.2, 8.3.6.4 and 8.3.7.6.

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 Part 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.



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 re-close 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 Part 1) 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 Part 1 applies.

**8.3.2.6.6 Interpretation of records**

Subclause 8.3.4.1.8 of Part 1 applies.

**8.3.2.6.7 Verification after short-circuit tests**

- a) After the opening operations of the short-circuit making and breaking capacity tests of 8.3.4.1, 8.3.5.2, 8.3.6.4, 8.3.7.1, 8.3.7.6, 8.3.8.3, as applicable, the polyethylene sheet shall show no holes visible with normal or corrected vision without additional magnification.

**NOTE** Minute visible holes of less than 0,26 mm diameter can be ignored.

- b) 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**

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

Test	Subclause
Tripping limits and characteristics	8.3.3.1
Dielectric properties	8.3.3.2
Mechanical operation and operational performance capability	8.3.3.3
Overload performance (where applicable)	8.3.3.4
Verification of dielectric withstand	8.3.3.5
Verification of temperature-rise	8.3.3.6
Verification of overload releases	8.3.3.7
Verification of undervoltage and shunt releases (if applicable)	8.3.3.8
Verification of main contact position (for circuit-breakers suitable for isolation)	8.3.3.9

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One sample shall be tested; the setting of adjustable releases shall be in accordance with table 10.

### 8.3.3.1 Test of tripping limits and characteristics

Subclause 8.3.3.2 of Part 1 is amplified as follows:

#### 8.3.3.1.1 General

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 Part 1) and of length according to 8.3.3.3.4 of Part 1.

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. The connections should be compatible with the test current and induced thermal stresses.

For circuit-breakers with adjustable over-current releases, the tests shall be made at the minimum and maximum current settings, with conductors corresponding to the rated current  $I_n$  (see 4.7.2).

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.

#### 8.3.3.1.2 Opening under short-circuit conditions

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. The test current shall have no asymmetry.

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

The operation of multipole short-circuit releases shall be verified by loading two poles in series with the test current, using all possible combinations of poles having a short-circuit release.

In addition, the operation of short-circuit releases shall be verified on each phase pole individually, at the value of the tripping current declared by the manufacturer for a single pole, at which value they shall operate:

- within 0,2 s in the case of instantaneous releases;
- 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 8.3.3.1.4.

#### 8.3.3.1.3 Opening under overload conditions

##### 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. The test current shall have no asymmetry. 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 8.3.3.1.4.

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,
- 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,
- 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 8.3.3.1.1), 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 8.3.3.1.1), 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 releases declared by the manufacturer to be independent of ambient air temperature, the operating characteristic shall be verified by two measurements, one at  $30\text{ °C} \pm 2\text{ °C}$ , the other at  $20\text{ °C} \pm 2\text{ °C}$  or at  $40\text{ °C} \pm 2\text{ °C}$ , the release being energized on all phase poles.

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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 and V (see 8.3.5.1, 8.3.5.4, 8.3.6.1, 8.3.6.6, 8.3.7.4, 8.3.7.8, 8.3.8.1 and 8.3.8.6).

### 8.3.3.1.4 Additional test for definite time-delay releases

#### 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 8.3.3.1.1), the test current for this release shall be 1,5 times the current setting;
- in the case of short-circuit releases, with two poles in series carrying the test current, using successively all possible combinations of poles having a short-circuit release.

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

#### 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 current and maintained at this value for twice the time-delay stated by the manufacturer. The circuit-breaker shall not trip.

### 8.3.3.2 Test of dielectric properties

Subclause 8.3.3.4.1 of IEC 60947-1 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: 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: 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;
- (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.

### 8.3.3.3 Tests of mechanical operation and of operational performance capability

#### 8.3.3.3.1 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 8.3.3.3.2, 8.3.3.3.3 and 8.3.3.3.4 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 8.3.3.3.2 and 8.3.3.3.3 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.

#### 8.3.3.3.2 Construction and mechanical operation

##### a) Construction

A withdrawable circuit-breaker shall be checked for the requirements stated in 7.1.1.

A circuit-breaker with stored energy operation shall be checked for compliance with 7.2.1.1.5, regarding the charge indicator and the direction of operation of manual energy storing.

##### b) Mechanical operation

Tests shall be made as specified in 8.3.3.3.1 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 7.2.1.1.3.

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 7.2.1.1.5 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.

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

### c) Undervoltage releases

Undervoltage releases shall comply with the requirements of 7.2.1.3 of Part 1. 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 8.3.3.6.

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.

### d) Shunt releases

Shunt releases shall comply with the requirements of 7.2.1.4 of Part 1. 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  $+55\text{ °C} \pm 2\text{ °C}$  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.

#### 8.3.3.3.3 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.

#### **8.3.3.3.4 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 Part 1.

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.

#### **8.3.3.3.5 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.

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

**8.3.3.4 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 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 Part 1.

The test shall be made at the maximum operational 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 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 With the agreement of the manufacturer the test may be made under more severe conditions than specified.

**Table 12 – Test circuit characteristics for overload performance**

	a.c.	d.c.
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.

#### **8.3.3.5 Verification of dielectric withstand**

The test shall be made in accordance with 8.3.3.4.1, item 4), of IEC 60947-1. The use of the metal foil specified in 8.3.3.4.1 of IEC 60947-1 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 8.3.3.2, except that the leakage current shall not exceed 2 mA.

#### **8.3.3.6 Verification of temperature-rise**

Following the test according to 8.3.3.5, 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.

#### **8.3.3.7 Verification of overload releases**

Immediately following the test according to 8.3.3.6, 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 8.3.3.6 and 8.3.3.7 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.

#### **8.3.3.8 Verification of undervoltage and shunt releases**

Circuit-breakers fitted with undervoltage releases shall be subjected to the test of 8.3.3.3.2, item c), 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 8.3.3.3.2, item d), 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.

#### **8.3.3.9 Verification of the main contact position**

For circuit-breakers suitable for isolation (see 3.5), following the verification of 8.3.3.7, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 8.2.5 of part 1.

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

Except when the combined test sequence 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	8.3.4.1
Verification of operational capability	8.3.4.2
Dielectric withstand	8.3.4.3
Verification of temperature-rise	8.3.4.4
Verification of overload releases	8.3.4.5

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.

#### 8.3.4.1 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 4.3.5.2.2.

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.

#### 8.3.4.2 Verification of operational capability

Following the test according to 8.3.4.1, the operational capability shall be verified in accordance with 8.3.3.3.4 except that this verification shall be made at the same rated operational voltage as used for the test of 8.3.4.1, 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 8.3.4.1 has been made on a circuit-breaker of minimum  $I_n$  or at the minimum overload release setting as specified in table 10.

#### 8.3.4.3 Verification of dielectric withstand

Following the test according to 8.3.4.2, the dielectric withstand shall be verified according to 8.3.3.5.

For circuit-breakers suitable for isolation, the leakage current shall be measured in accordance with 8.3.3.5.

#### 8.3.4.4 Verification of temperature-rise

Following the test according to 8.3.4.3, 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 8.3.4.1 has been made on a circuit-breaker of minimum  $I_n$  or at the minimum overload release setting.

#### 8.3.4.5 Verification of overload releases

Immediately following the test according to 8.3.4.4, the operation of overload releases shall be verified in accordance with 8.3.3.7.

NOTE With the manufacturer's consent, a time interval between the tests of 8.3.4.4 and 8.3.4.5 may occur.

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

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

NOTE For this type of utilization category B circuit-breaker, the instantaneous release operates at values of current in excess of those stated in column 2 of table 3 (4.3.5.4); this type of release may be referred to as "instantaneous override".

For circuit-breakers of utilization 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 the following verifications shall be additionally made in test sequence II:

- the verification of 8.3.5.1, at the beginning of the test sequence
- the verification of 8.3.5.4, at the end of the test sequence.

This test sequence comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.5.1
Rated ultimate short-circuit breaking capacity	8.3.5.2
Verification of dielectric withstand	8.3.5.3
Verification of overload releases	8.3.5.4

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

##### 8.3.5.1 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 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. 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.

**8.3.5.2 Test of rated ultimate short-circuit breaking capacity**

Following the test according to 8.3.5.1, 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:

$$O - t - CO$$

**8.3.5.3 Verification of dielectric withstand**

Following the test according to 8.3.5.2, tests shall be made to verify that the circuit-breaker shall be capable, without maintenance, of withstanding a voltage equal to twice the corresponding rated operational voltage  $U_e$ , with a minimum of 1 000 V, according to 8.3.3.2.

For circuit-breakers suitable for isolation, the leakage current shall be measured in accordance with 8.3.3.2, except that the leakage current shall not exceed 6 mA.

**8.3.5.4 Verification of overload releases**

Following the test according to 8.3.5.3, the operation of overload releases shall be verified in accordance with 8.3.5.1, 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**

Except where the combined test sequence 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; it comprises the following tests.

Test	Subclause
Verification of overload releases	8.3.6.1
Rated short-time withstand current	8.3.6.2
Verification of temperature-rise	8.3.6.3
Short-circuit breaking capacity at maximum short-time withstand current	8.3.6.4
Verification of dielectric withstand	8.3.6.5
Verification of overload releases	8.3.6.6

Where integrally fused circuit-breakers are of utilization 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.

#### **8.3.6.1 Verification of overload releases**

The operation of overload releases shall be verified in accordance with 8.3.5.1.

#### **8.3.6.2 Test of rated short-time withstand current**

Subclause 8.3.4.3 of Part 1 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.

#### **8.3.6.3 Verification of temperature-rise**

Following the test according to 8.3.6.2, 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 (8.3.6.5). This verification need not be made where, for a given frame size, the test of 8.3.6.2 has been made on a circuit-breaker of minimum  $I_n$  or at the minimum overload release setting.

#### **8.3.6.4 Test of short-circuit breaking capacity at the maximum short-time withstand current**

Following the test according to 8.3.6.3, 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 8.3.6.2) 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.

#### **8.3.6.5 Verification of dielectric withstand**

Following the test carried out according to 8.3.6.4, the dielectric withstand shall be verified according to 8.3.3.5.

#### **8.3.6.6 Verification of overload releases**

Following the test according to 8.3.6.5, the operation of overload releases shall be verified according to 8.3.5.1.

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

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	8.3.7.1
	Verification of temperature-rise	8.3.7.2
	Verification of dielectric withstand	8.3.7.3
Stage 2	Verification of overload releases	8.3.7.4
	Short-circuit at 1,1 times take-over current	8.3.7.5
	Short-circuit at ultimate short-circuit breaking capacity	8.3.7.6
	Verification of dielectric withstand	8.3.7.7
	Verification of overload releases	8.3.7.8

This test sequence is divided into two stages:

- Stage 1 comprises the tests according to 8.3.7.1 to 8.3.7.3;
- Stage 2 comprises the tests according to 8.3.7.4 to 8.3.7.8.

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 8.3.7.3 may be omitted.

The test according to 8.3.7.2 need only be made if  $I_{cs} > I_s$ .

Tests according to 8.3.7.1, 8.3.7.5 and 8.3.7.6 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.

#### 8.3.7.1 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.

#### 8.3.7.2 Verification of temperature-rise

NOTE This verification of temperature-rise is made since the fuses may have blown during the short-circuit test of test sequence II, 8.3.4.1, in which case the test of 8.3.7.1 is more severe.

Following the test according to 8.3.7.1 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.

**8.3.7.3 Verification of dielectric withstand**

Following the test according to 8.3.7.2 the dielectric withstand shall be verified according to 8.3.5.5.

**8.3.7.4 Verification of overload releases**

The operation of overload releases shall be verified in accordance with 8.3.5.1.

**8.3.7.5 Short-circuit at 1,1 times the take-over current**

Following the test according to 8.3.7.4 a short-circuit test is made under the same general conditions as in 8.3.7.1, with a value of prospective current equal to 1,1 times the take-over current declared by the manufacturer (see 2.17.6).

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.

**8.3.7.6 Short-circuit at ultimate short-circuit breaking capacity**

Following the test according to 8.3.7.5, a short-circuit test is made under the same general conditions as in 8.3.7.1, 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.

**8.3.7.7 Verification of dielectric withstand**

Following the test according to 8.3.7.6 and with a new set of fuses fitted, the dielectric withstand shall be verified according to 8.3.5.3.

**8.3.7.8 Verification of overload releases**

Following the test according to 8.3.7.7, the operation of overload releases shall be verified in accordance with 8.3.5.1 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 Combined test sequence**

At the discretion of, or in agreement with the manufacturer, this test sequence may be applied to circuit-breakers of utilization 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;

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- 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	8.3.8.1
Rated short-time withstand current	8.3.8.2
Rated service short-circuit breaking capacity*	8.3.8.3
Verification of operational capability	8.3.8.4
Verification of dielectric withstand	8.3.8.5
Verification of temperature-rise	8.3.8.6
Verification of overload releases	8.3.8.7
* For circuit-breakers falling into the case of item b) 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.

**8.3.8.1 Verification of overload releases**

The operation of overload releases shall be verified in accordance with 8.3.5.1.

**8.3.8.2 Test of rated short-time withstand current**

Following the test according to 8.3.8.1, a test shall be made at the rated short-time withstand current according to 8.3.6.2.

**8.3.8.3 Test of rated service short-circuit breaking capacity**

Following the test according to 8.3.8.2, a test shall be made at the rated service short-circuit breaking capacity according to 8.3.4.1, 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.

**8.3.8.4 Verification of operational capability**

Following the test according to 8.3.8.3, the operational capability shall be verified in accordance with 8.3.4.2.

**8.3.8.5 Verification of dielectric withstand**

Following the test according to 8.3.8.4, the dielectric withstand shall be verified according to 8.3.3.5.

For circuit-breakers suitable for isolation, the leakage current shall be measured according to 8.3.3.5.

**8.3.8.6 Verification of temperature-rise**

Following the test according to 8.3.8.5, 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.



This verification need not be made where, for a given frame size, the test of 8.3.8.3 has been made on a circuit-breaker of minimum  $I_n$  or at the minimum overload release setting.

#### 8.3.8.7 Verification of overload releases

After cooling down following the test according to 8.3.8.6, the operation of overload releases shall be verified in accordance with 8.3.3.7.

Thereafter, the operation of the overload releases shall be verified on each pole individually in accordance with 8.3.5.1, 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.

### 8.4 Routine tests

For the definition of routine tests, see 2.6.2 and 8.1.3 of part 1.

The following tests apply:

- mechanical operation (8.4.1);
- verification of the calibration of overcurrent releases (8.4.2);
- verification of the operation of undervoltage and shunt releases (8.4.3);
- additional tests for CBRs to annex B (8.4.4);
- dielectric tests (see note) (8.4.5);
- verification of clearances (8.4.6).

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

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 8.4.2, 8.4.3 and 8.4.4 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 8.4.1, 8.4.2, 8.4.3, 8.4.5 and 8.4.6, the term "circuit-breakers" covers CBRs, where applicable.

#### 8.4.1 Mechanical operation tests

The tests of 8.4.1.1 and 8.4.1.2 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 part 1.

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**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.

### **8.4.2 Verification of the calibration of overcurrent releases**

#### **8.4.2.1 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).

#### **8.4.2.2 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 8.3.3.1.2 or 8.3.3.1.3, 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.

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.

### **8.4.3 Verification of the operation of undervoltage and shunt releases**

#### **8.4.3.1 Undervoltage releases**

Tests shall be made to verify that the release will operate in accordance with 7.2.1.3 of part 1 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 8.3.3.3.2, item c) 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.

#### 8.4.3.2 Shunt releases (for opening)

A test shall be made to verify that the release will operate in accordance with 7.2.1.4 of part 1. 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 8.3.3.3.2, item d). 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.

#### 8.4.4 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.

#### 8.4.5 Dielectric tests

The test conditions shall be in accordance with 8.3.3.4.1, item 1), of IEC 60947-1, 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), 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

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### 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, 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  $5 \text{ mA} \pm 1 \text{ mA}$ .

The value of the test voltage shall be  $2 U_e \text{ max}$ , with a minimum of 1 000 V r.m.s., applied for not less than 1 s. The overcurrent relay shall not trip.

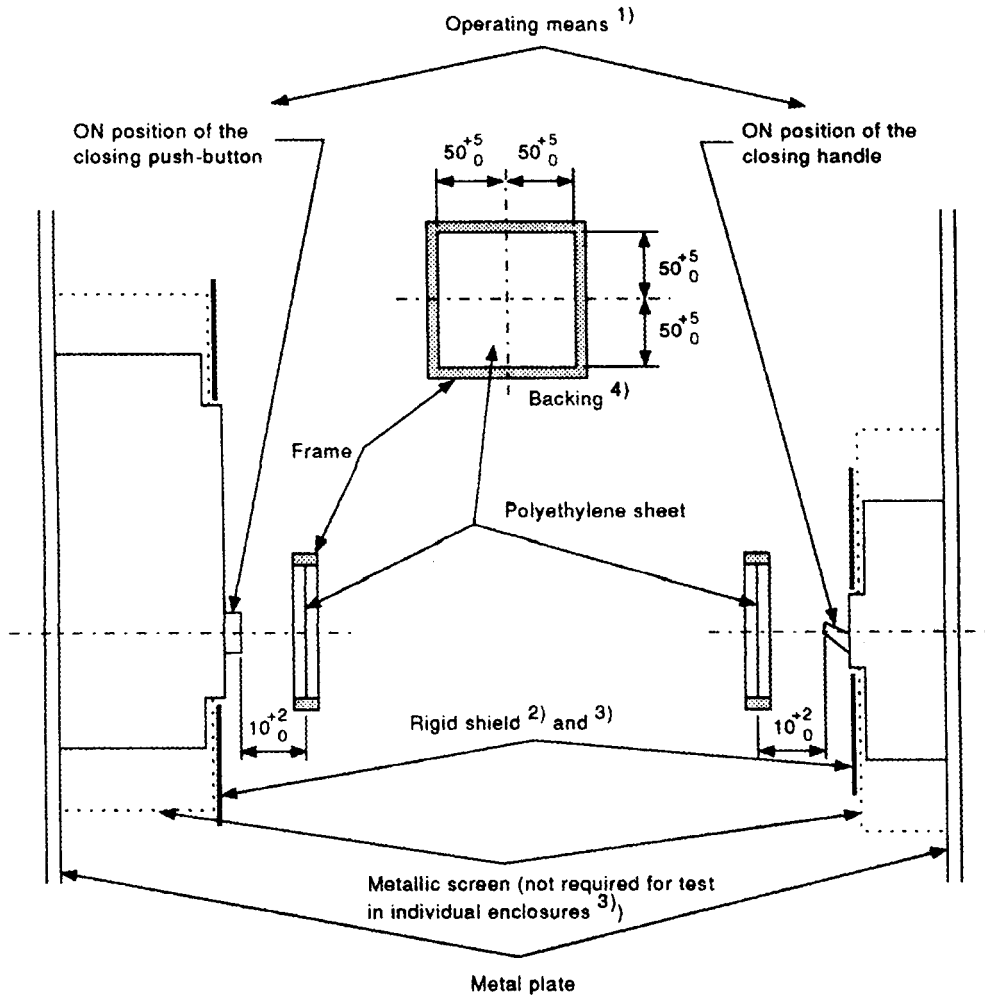
- b) A single power frequency test in accordance with item a) 2) above at a test voltage such that the peak value of the sinusoidal wave corresponds to the highest of the peak values of the following: 30 % of  $U_{\text{imp}}$ ,  $2 U_i$ ,  $2 U_e \text{ max}$  or 1 000 V r.m.s.
- c) An insulation resistance test at 500 V d.c.. The insulation resistance shall be not less than 1 M $\Omega$  at any point.

If dielectric properties are tested according to a sampling plan in accordance with the note to 8.4, a power frequency withstand test shall be made according to 8.4.5, item a) 2) of this subclause, but with a test voltage in accordance with table 12A of IEC 60947-1.

### 8.4.6 Test for the verification of clearances less than those corresponding to case A of table 13 of IEC 60947-1

Subclause 8.3.3.4.3 of IEC 60947-1 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 is covered by the tests of 8.4.5.



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)

**Coordination under short-circuit conditions between  
a circuit-breaker and another short-circuit protective device  
associated in the same circuit**

**A.1 Introduction**

To ensure coordination 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 behaviour as an association.

**NOTE** An SCPD may 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 figures A.2 to A.5.)

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.

$C_1$  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 may have to decide, on the basis of a desk study alone, how the optimum level of coordination 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 "coordination" includes consideration of discrimination (see 2.5.23 of Part 1 and also 2.17.2 and 2.17.3) as well as consideration of back-up protection (see 2.5.24 of Part 1).

Consideration of discrimination can in general be carried out by desk study (see clause A.5), whereas the verification of back-up protection normally requires the use of tests (see clause 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 coordination of circuit-breakers with other SCPDs associated in the same circuit, as regards discrimination as well as back-up protection.

The object of this annex is to state:

- the general requirements for the coordination of a circuit-breaker with another SCPD;
- the methods and the tests (if deemed necessary) intended to verify that the conditions for coordination have been met.

## A.3 General requirements for the coordination of a circuit-breaker with another SCPD

### A.3.1 General considerations

Ideally, the coordination 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 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 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.
- 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 2.17.6), 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 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.4).

### 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 Part 1, 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 Part 1) 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**

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.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

#### 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 figures A.4 and A.5), it may be possible 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.6).

Each test shall consist of a O–t–CO sequence of operations made in accordance with 8.3.5 of this standard, whether at  $I_{cu}$  or  $I_{cs}$ , 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 Part 1).

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  $C_2$ .

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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.

This requires that the contacts of  $C_2$  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.4). The duration of interruption of supply, 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.

This requires that the contacts of  $C_2$  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 interruption of supply, if any, shall be recorded during these tests.

b) if the associated SCPD is a fuse (or a set of fuses):

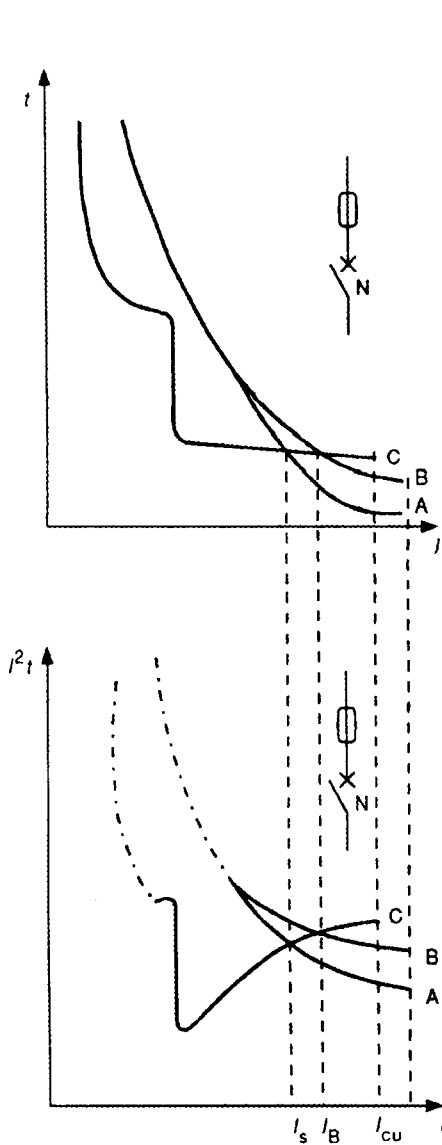
- in the case of a single-phase circuit at least one fuse shall blow;
- in the case of a multi-phase circuit either two or more fuses shall blow, or one fuse shall blow and  $C_1$  shall trip.

### A.6.4 Results to be obtained

Subclause 8.3.4.1.7 of Part 1 applies.

Following the tests,  $C_1$  shall comply with 8.3.5.3 and 8.3.5.4

In addition, if the associated SCPD 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.

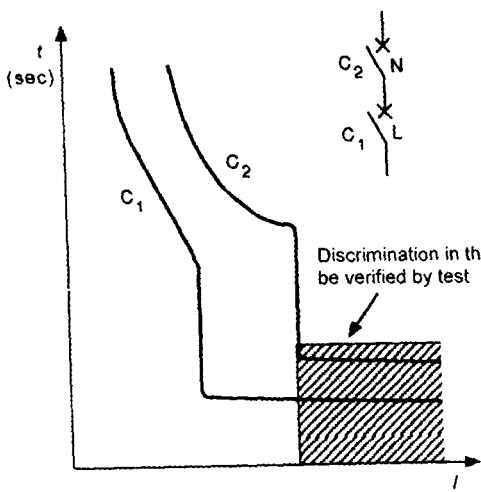


- $I$  = Prospective short-circuit current
- $I_{cu}$  = Rated ultimate short-circuit breaking capacity (4.3.5.2.1)
- $I_s$  = Selectivity limit current (2.17.4)
- $I_B$  = Take-over current (2.17.6)
- A = Pre-arcing characteristic of the fuse
- B = Operating characteristic of the fuse
- C = Operating 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.

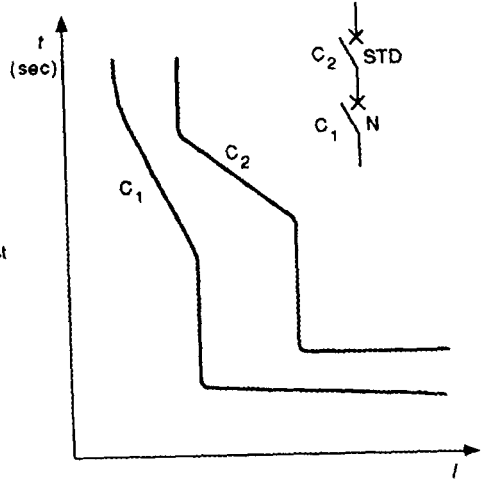
NOTE 2 Non-adiabatic zone for  $I^2t$  shown chain-dotted.

Figure A.1 – Over-current coordination 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 (N)  
(tripping characteristic)



$C_1$  = Non-current-limiting circuit-breaker (N)  
(break-time characteristic)

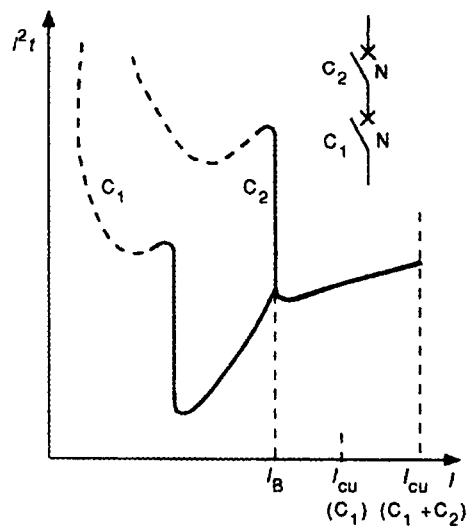
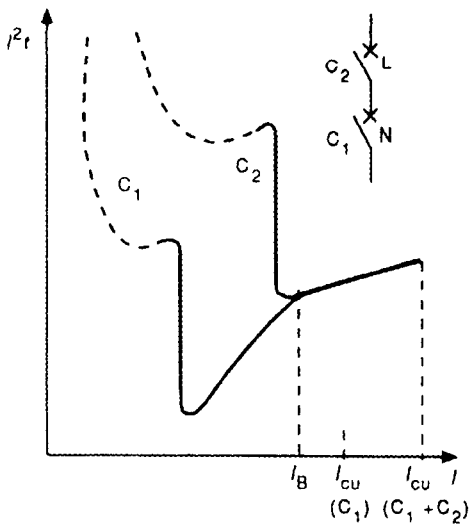
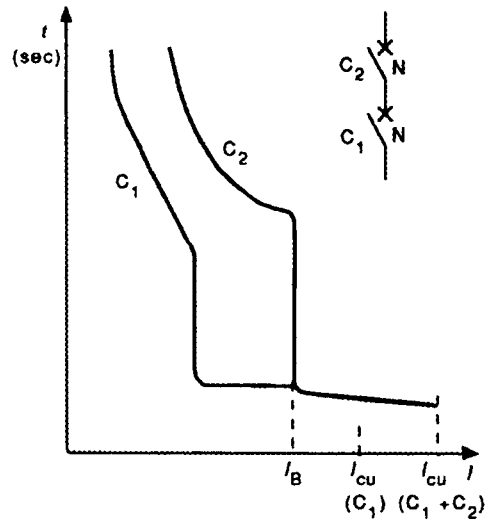
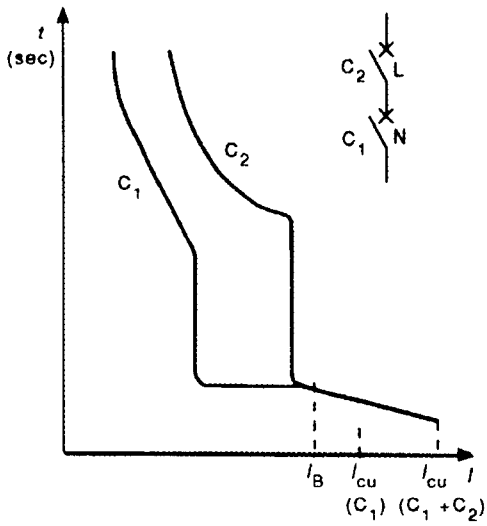
$C_2$  = Circuit-breaker with intentional short-time  
delay (STD) (tripping characteristic)

Values of  $I_{cu}$  (or  $I_{cs}$ ) are not shown.

Figure A.2

Figure A.3

**Total discrimination between two circuit-breakers**



C<sub>1</sub> = Non current-limiting circuit-breaker (N)  
 C<sub>2</sub> = Current-limiting circuit breaker (L)

C<sub>1</sub>, C<sub>2</sub> = Non current-limiting circuit-breaker (N)

$I_B$  = Take-over current

NOTE 1 Where applicable, restoration of supply by C<sub>2</sub> occurs.

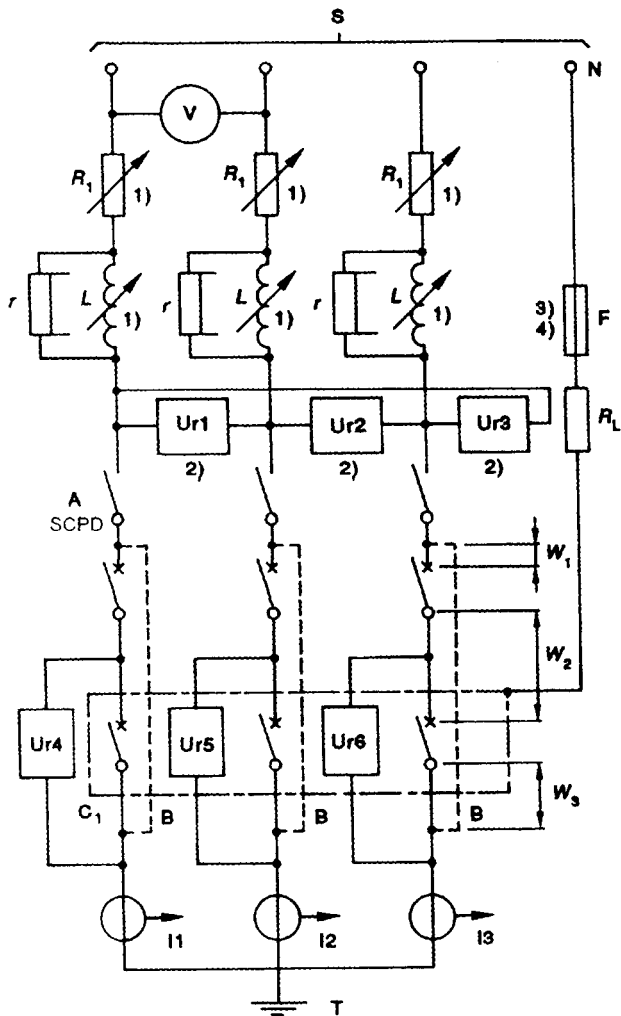
NOTE 2  $I_{cu}(C_1 + C_2) \leq I_{cu}(C_2)$

NOTE 3 For values of  $I > I_B$ , the curve is that of the association (shown in bold) for which data must be obtained by tests.

Figure A.4

Figure A.5

Back-up protection by a circuit-breaker – Operating characteristics



- S = Supply
- Ur1, Ur2, Ur3 = Voltage sensors
- Ur4, Ur5, Ur6
- V = Voltage measuring device
- A = Closing device
- R<sub>1</sub> = Adjustable resistor
- N = Neutral of supply (or artificial neutral)
- F = Fusible element (8.3.4.1.2, item d) of Part 1)
- L = Adjustable reactors
- R<sub>L</sub> = 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 Part 1)
- W<sub>1</sub> = 75 cm of cable rated for SCPD
- W<sub>2</sub> = 50 cm of cable rated for C<sub>1</sub>
- W<sub>3</sub> = 25 cm of cable rated for C<sub>1</sub>
- SCP<sub>D</sub> = Circuit-breaker C<sub>2</sub> or set of 3 fuses
- C<sub>1</sub> = Circuit-breaker under test

NOTE 1 Adjustable loads L and R<sub>1</sub> 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 note to 4.3.1.1) F shall be connected:

- to one phase of the supply for equipment marked with a single value of U<sub>e</sub>;
- to the neutral for equipment marked with a twin voltage.

**Figure A.6 – Example of test circuit for conditional short-circuit breaking capacity tests showing cable connections for a 3-pole circuit-breaker (C<sub>1</sub>)**

## Annex B (normative)

### Circuit-breakers incorporating residual current protection

#### INTRODUCTION

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.

This annex is essentially based upon the relevant requirements of IEC 60755, IEC 61008-1 and IEC 61009-1.

#### B.1 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 be external to the circuit-breaker or the combination, as the case may be.

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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 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 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

##### 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

#### B.2.2 Definitions relating to the energization of a CBR

##### B.2.2.1

##### **energizing quantity**

an 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 specific conditions

These conditions may involve, for example, the energizing of certain auxiliary elements.



**B.2.2.3**

**residual current ( $I_{\Delta}$ )**

vectorial sum of the currents flowing in the main circuit of the CBR, expressed as an r.m.s. value

**B.2.2.4**

**residual operating current**

value of the residual current which causes the CBR to operate under specified conditions

**B.2.2.5**

**residual non-operating current**

value of the residual current at which (and below which) the CBR does not operate under specified conditions

**B.2.3 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 It is understood that the line voltage for detection, evaluation or interruption is applied to the CBR.

**B.2.3.4**

**detection**

function consisting of sensing the presence of a residual current

NOTE This function may for example, be performed, by a transformer effecting the vectorial sum of the currents.

**B.2.3.5**

**evaluation**

function consisting of giving to the CBR the possibility to operate when the detected residual current exceeds a specified reference value

**B.2.3.6**

**interruption**

function consisting of bringing automatically the main contacts of the CBR from the closed position to the open position, thereby interrupting the current flowing through them

**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

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### **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

The residual current time-delay characteristic may or may not be of an inverse time/current nature.

### **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

### **B.2.3.10**

#### **test device**

device simulating a residual current for checking that the CBR operates

## **B.2.4 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 (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)

- by fixed steps;
- 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**

- by fixed steps;
- by continuous variation.

**B.3.4 Classification according to behaviour in presence of a d.c. component**

- CBRs of type AC (see B.4.4.1);
- 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.2.4.2) assigned to the CBR by the manufacturer, which the CBR can make, carry and break under specified conditions.

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### 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	$I_{\Delta n}$	$2I_{\Delta n}$	$5I_{\Delta n}$ <sup>1)</sup>	$10I_{\Delta n}$ <sup>2)</sup>
Maximum break time s	0,3	0,15	0,04	0,04

<sup>1)</sup> For CBRs having  $I_{\Delta n} \leq 30$  mA, 0,25 A may be used as an alternative to  $5I_{\Delta n}$   
<sup>2)</sup> 0,5 A if 0,25 A is used according to note <sup>1)</sup>.

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  $2I_{\Delta n}$  and shall be declared by the manufacturer.

The minimum limiting non-actuating time at  $2I_{\Delta n}$  is 0,06 s.

Preferred values of limiting non-actuating time at  $2I_{\Delta n}$  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  $I_{\Delta n}$  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.2 – Operating characteristic for time-delay-type having a limiting non-actuating time of 0,06 s**

Residual current	$I_{\Delta n}$	$2I_{\Delta n}$	$5I_{\Delta n}$	$10I_{\Delta n}$
Maximum break time s	0,5	0,2	0,15	0,15

In the 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**

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  $\Delta t$  followed by the limiting non-actuating time in ms; alternatively, where the limiting non-actuating time is 0,06 s, the symbol may be  $\boxed{S}$  (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 

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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  $I_n \leq \dots A$  ( $I_n$  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  $I_{\Delta n0}$  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.8.2.

#### **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.

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### 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 category B since the requirements of this subclause are verified during test sequence IV (or the combined test sequence).

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.8.6.1.

#### B.7.2.8.2 Resistance to unwanted tripping in case of flashover without follow-on current

CBRs shall withstand the test of B.8.6.2.



**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 tables B.1 and B.2, as applicable, shall also be valid, the test current values specified being, however, increased

- by the factor 1,4 for CBRs having  $I_{\Delta n} > 0,015 \text{ A}$
- by the factor 2 for CBRs having  $I_{\Delta n} \leq 0,015 \text{ A}$  (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 8.3.3.3.4 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.8.8.2
	With delay	Opening with delay according to item b) of B.8.8.2
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.

Tests shall be made in accordance with B.8.12 to B.8.14.

Immunity to voltage variations is covered by the requirements of B.7.2.11.

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### B.8 Tests

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.

#### B.8.1 General

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 8.3.3.5) 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.

##### b) Routine tests

Subclause 8.4.4 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 8.3.3.3.4) 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 (8.3.3.3.4).

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.8.2.4.1.

**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 8.3.5.1 and 8.3.5.4 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.5.1 and 8.3.5.4 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.8.2.4.3.

**B.8.1.1.2.3 Rated short-time withstand current (test sequence IV or combined test sequence)**

a) Behaviour during rated short-time withstand current test

No tripping shall occur during the test of 8.3.6.2 or 8.3.8.2, 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 8.3.6.1 and 8.3.6.6, the single pole tests specified in 8.3.5.1 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 8.3.8.1, the single pole test specified in 8.3.5.1 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 8.3.8.6, the test specified in 8.3.3.7 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.8.2.4.3.

**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 8.3.7.4 and 8.3.7.8 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.7.4 and 8.3.7.8 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.8.2.4.3.

**B.8.1.1.2.5 Combined test sequence**

Following the tests of 8.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.3.

**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

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.8.2.5.1;
- 1,1 times the maximum rated voltage for the tests specified in B.8.2.5.2.

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**

The connections being as in figure B.1 the CBR shall perform the tests of B.8.2.4.1, B.8.2.4.2 and B.8.2.4.3, and also, where applicable, B.8.2.4.4, all made on one pole only. 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.8.2.4.1 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 S1 and S2 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  $I_{\Delta n0}$  and less than or equal to  $I_{\Delta n}$ .

##### **B.8.2.4.2 Verification of the correct operation 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 S1 and S2 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, as applicable.

##### **B.8.2.4.3 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  $I_{\Delta}$  specified in B.4.2.4.1 or B.4.2.4.2, as applicable, and the switch S1 and the CBR being in the closed position, the residual current is suddenly established by closing switch S2.

The CBR shall trip during each test.

Three measurements of the break time are made at each value of  $I_{\Delta}$ . No value shall exceed the relevant limiting value.

**B.8.2.4.4 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 S1 and the CBR being in the closed position, the residual current is established by closing the switch S2 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**

NOTE The upper temperature limit may 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.8.2.5.1 Off-load test at  $-5\text{ }^{\circ}\text{C}$**

The CBR is placed in a chamber having a stabilized ambient temperature within the limits of  $-7\text{ }^{\circ}\text{C}$  and  $-5\text{ }^{\circ}\text{C}$ . After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.3 and, if applicable, B.8.2.4.4.

**B.8.2.5.2 On-load test at the reference temperature or at  $+40\text{ }^{\circ}\text{C}$**

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  $40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ . 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.8.2.4.3 and, where applicable, B.8.2.4.4.

**B.8.3 Verification of dielectric properties**

CBRs shall comply with 8.3.3.2.

**B.8.4 Verification of the operation of the test device at the limits of rated voltage**

- 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 For the purpose of this current adjustment, the CBR D (see figure B.2) may 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 S1, 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 The time of 2 s may 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**

For CBRs with adjustable time delay (see B.3.3.2.2) the time delay shall be set at minimum.

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### B.8.6.1 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:  $200 \text{ A } \begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \%$ ;
- virtual front time:  $0,5 \mu\text{s} \pm 30 \%$ ;
- period of the following oscillatory wave:  $10 \mu\text{s} \pm 20 \%$ ;
- each successive peak: about 60 % of the preceding peak.

During the tests the CBR shall not trip.

### B.8.6.2 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  $\mu\text{s}$  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:  $250 \text{ A } \begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \%$ ;
- virtual front time ( $T_1$ ):  $8 \mu\text{s} \pm 10 \%$ ;
- virtual time to half value ( $T_2$ ):  $20 \mu\text{s} \pm 10 \%$ .

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 figures B.8 and 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.8.3.2.2), 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  $\alpha$  of  $0^\circ$ ,  $90^\circ$  and  $135^\circ$  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

$$\frac{1,4 I_{\Delta n}}{30} \text{ A/s for CBRs of } I_{\Delta n} > 0,015 \text{ A;}$$

$$\frac{2 I_{\Delta n}}{30} \text{ A/s for CBRs of } I_{\Delta n} \leq 0,015 \text{ A.}$$

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 $\alpha$	Tripping current A	
	Lower limit	Upper limit
$0^\circ$	$0,35 I_{\Delta n}$	$\left\{ \begin{array}{l} 0,03 \text{ A for } I_{\Delta n} \leq 0,015 \text{ A} \\ \text{or} \\ 1,4 I_{\Delta n} \text{ for } I_{\Delta n} > 0,015 \text{ A} \end{array} \right.$
$90^\circ$	$0,25 I_{\Delta n}$	
$135^\circ$	$0,11 I_{\Delta n}$	

**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  $\alpha = 0^\circ$ , two with the auxiliary switch in position I and two in position II.

For CBRs with  $I_{\Delta n} > 0,015 \text{ A}$ , the test shall be made at each value of  $I_{\Delta n}$  specified in table B.1, multiplied by the factor 1,4.

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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 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  $\alpha = 0^\circ$ ) 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  $1,4I_{\Delta n}/30$  amperes per second, tripping shall occur before the current reaches a value not exceeding  $1,4I_{\Delta n} + 0,006$  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  $2I_{\Delta n}/30$  amperes per second, tripping shall occur before the current reaches a value not exceeding  $0,03A + 0,006$  A.

### B.8.8 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1

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.8.8.1 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.8.8.2 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**

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.8.9.1 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 S4; the CBR is then submitted to the test of B.8.2.4.3. The switch S4 being closed again, a further test is made by opening switch S5; the CBR is then submitted to the test of B.8.2.4.3.

This test procedure is repeated by connecting the adjustable resistor *R* to each of the other two phases in turn.

**B.8.9.2 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 S1. The CBR shall not trip.

S1 is then re-closed and the voltage is reduced as follows:

- a) for CBRs for use with a three-phase supply: to 70 % of the lowest rated voltage;

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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**

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.8.10.1 Test conditions**

The CBR shall be tested according to the general test conditions specified in 8.3.2.6, using figure 9 of Part 1, 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.8.10.2 Test procedure**

The sequence of operations to be performed is

O – t – CO

##### **B.8.10.3 Conditions of the CBR after test**

**B.8.10.3.1** Following the test of B.8.10.2 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. 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.8.10.3.2** The CBR shall be capable of performing satisfactorily the tests specified in B.8.2.4.3, 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.8.10.3.3** Where applicable the CBR shall also be submitted to the test of B.8.2.4.4.

**B.8.10.3.4** 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  $55\text{ °C} \pm 2\text{ °C}$  (variant 1) and the number of cycles shall be

- 6 for  $I_{\Delta n} > 1\text{ A}$
- 28 for  $I_{\Delta n} \leq 1\text{ A}$

NOTE The 28 cycle test should be applied to CBRs having multiple settings of residual operating current when one of the possible settings is  $\leq 1\text{ A}$ .

At the end of the cycles the CBR shall be capable of complying with the tests of B.8.2.4.3, but with a residual operating current of  $1,25 I_{\Delta n}$  and without measurement of break time. Only one verification need be made.

Where applicable the CBR shall also comply with the test of B.8.2.4.4. Only one verification need 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.

###### **B.8.12.1.2 Electrostatic discharges**

Annex J applies, in particular J.2.2.

The tests are made without load.

During the test the CBR may trip. If this is the case, a further test shall be made at the immediately lower level, and the CBR shall not trip.

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Following the tests, the correct operation of the CBR shall be verified in the case of a sudden appearance of a residual current according to B.8.2.4.3, but at  $I_{\Delta n}$  only.

The break time shall not exceed the limiting time specified for  $I_{\Delta n}$  in B.4.2.4.1 or B.4.2.4.2, as applicable.

### **B.8.12.1.3 Radiated radio-frequency 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, 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), one pole of the CBR, chosen at random, is loaded with a residual current equal to  $0,3 I_{\Delta n}$ . The CBR shall not trip.

For step 2 (see J.2.3), one pole of the CBR, chosen at random, is loaded with a residual current equal to  $1,25 I_{\Delta n}$ . The dwell time at each frequency shall be no 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. The CBR shall trip at each frequency tested.

Following the two tests (step 1 and step 2), the correct operation of the CBR shall be verified in the case of sudden appearance of a residual current according to B.8.2.4.3, but at  $I_{\Delta n}$  only.

The break time shall not exceed the limiting time specified for  $I_{\Delta n}$  in B.4.2.4.1 or B.4.2.4.2, as applicable.

### **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, taking into consideration the manufacturer's instructions for installation.

During the tests the CBR shall not trip.

Following the tests, the correct operation of the CBR shall be verified in the case of sudden appearance of a residual current according to B.8.2.4.3, but at  $I_{\Delta n}$  only.

The break time shall not exceed the limiting time specified for  $I_{\Delta n}$  in B.4.2.4.1 or B.4.2.4.2, as applicable.

### **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 shall 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, taking into consideration the manufacturer's instructions for installation.

During the tests the CBR shall not trip.

Following the tests, the correct operation of the CBR shall be verified in the case of sudden appearance of a residual current according to B.8.2.4.3, but at  $I_{\Delta n}$  only.

The break time shall not exceed the limiting time specified for  $I_{\Delta n}$  in B.4.2.4.1 or B.4.2.4.2, as applicable.

#### **B.8.12.1.6 Conducted disturbances induced by radio-frequency fields (common mode)**

Annex J applies, in particular J.2.6.

For step 1 (see J.2.6), one pole of the CBR, chosen at random, is loaded with a residual current equal to  $0,3 I_{\Delta n}$ . The CBR shall not trip.

For step 2 (see J.2.6), one pole of the CBR, chosen at random, is loaded with a residual current equal to  $1,25 I_{\Delta n}$ . The dwell time at each frequency shall be no 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. The CBR shall trip at each frequency tested.

Following the two tests (step 1 and step 2), the correct operation of the CBR shall be verified in the case of a sudden appearance of a residual current according to B.8.2.4.3, but at  $I_{\Delta n}$  only.

The break time shall not exceed the limiting time specified for  $I_{\Delta n}$  in B.4.2.4.1 or B.4.2.4.2, as applicable.

#### **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 –30 MHz)**

Annex J applies, in particular J.3.2.

##### **B.8.12.2.3 Radiated RF disturbances (30 MHz – 1 000 MHz)**

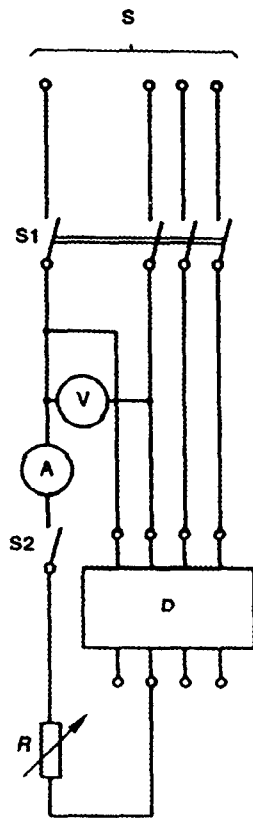
Annex J applies, in particular J.3.3.

#### **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
- S1 = All-pole switch
- S2 = 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)



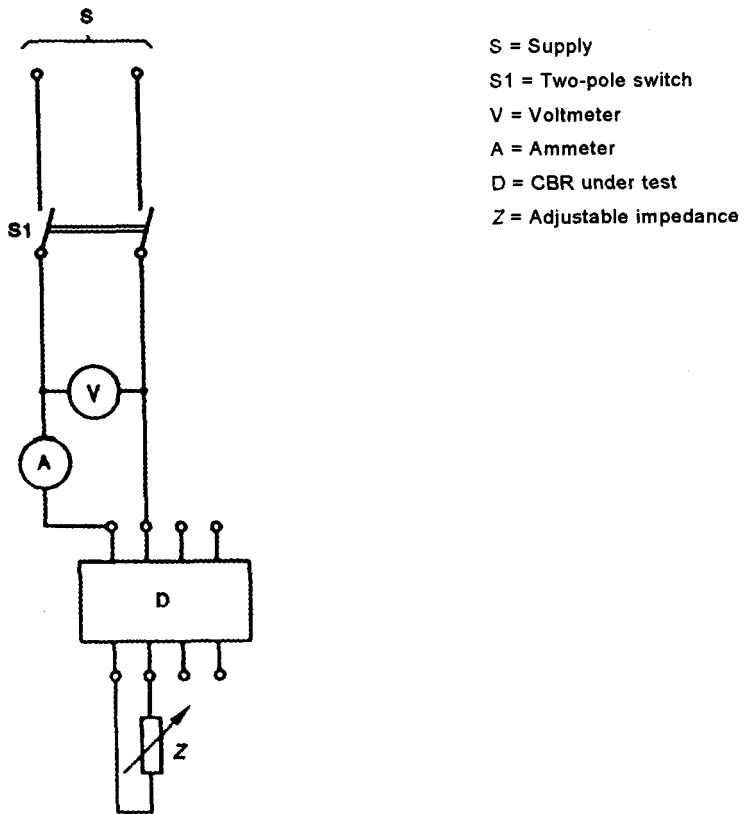
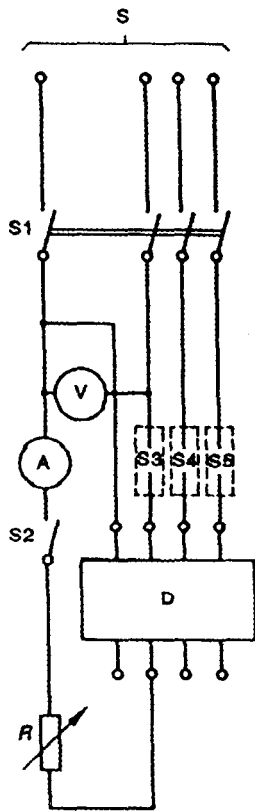


Figure B.2 – Test circuit for the verification of the limiting value of the non-operating current under over-current conditions (see B.8.5)



- S = Supply
- V = Voltmeter
- A = Ammeter
- S1 = All-pole switch
- S2 = Single-pole switch
- S3, S4, S5 = 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)

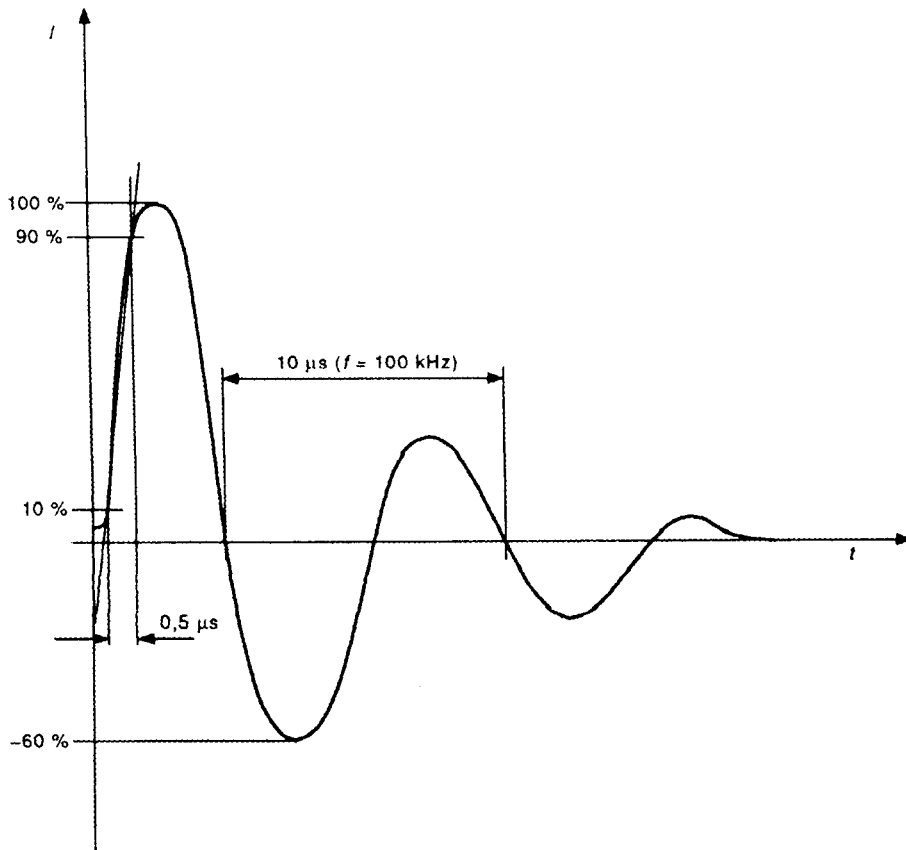
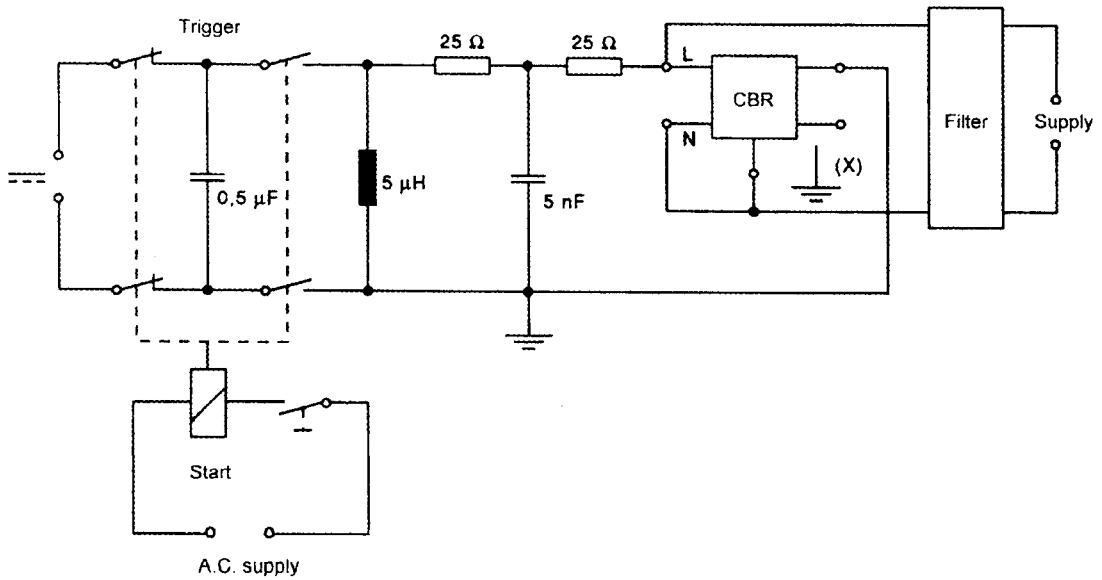


Figure B.4 – Current ring wave  $0,5 \mu\text{s}/100 \text{ kHz}$



(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

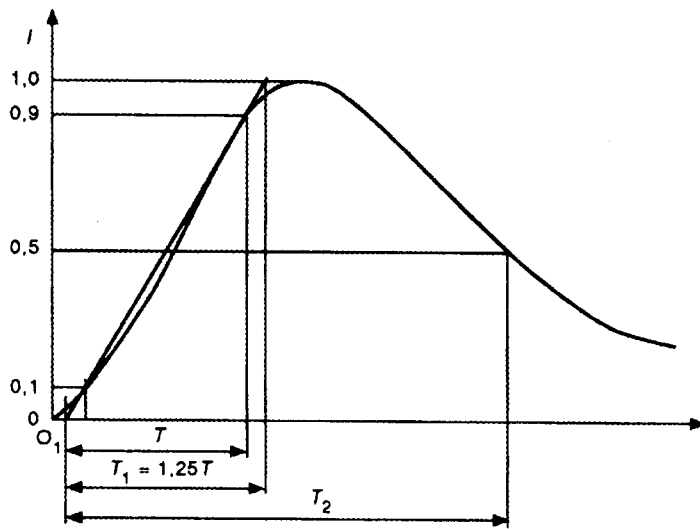
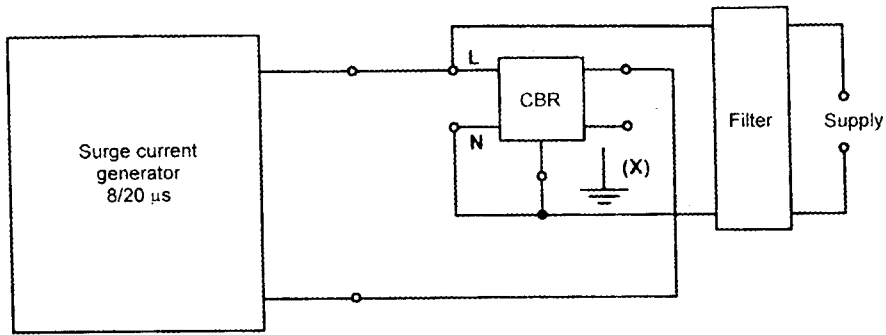
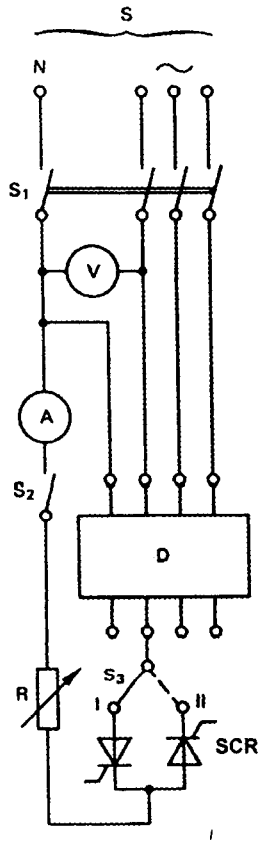


Figure B.6 – Surge current wave 8/20 μs



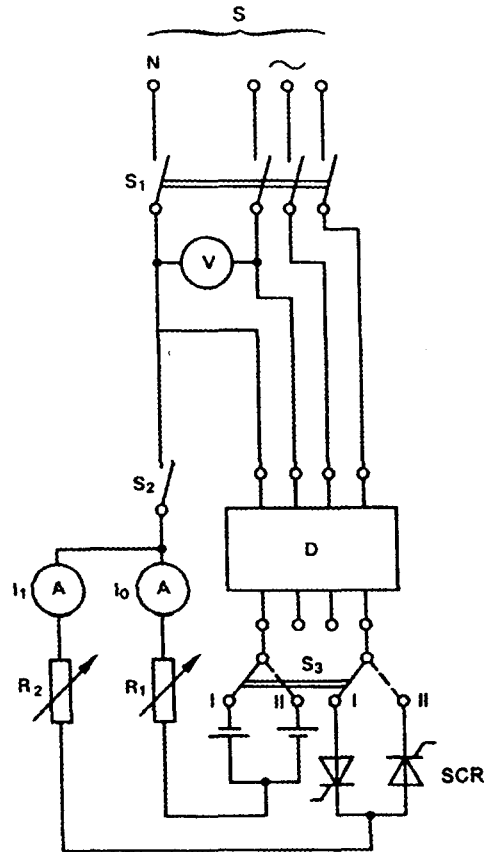
- (X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

**Figure B.7 – Test circuit for the verification of resistance to unwanted tripping in case of flashover without follow-on current (B.8.6.2)**



- |                                      |                                     |
|--------------------------------------|-------------------------------------|
| S = Supply                           | R = Variable resistor               |
| V = Voltmeter                        | S <sub>1</sub> = All-pole switch    |
| A = Ammeter (measuring r.m.s values) | S <sub>2</sub> = Single pole switch |
| D = CBR under test                   | S <sub>3</sub> = Two-way switch     |
| SCR = Thyristors                     |                                     |

**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                           | $R_1, R_2$ = Variable resistor |
| V = Voltmeter                        | $S_1$ = All-pole switch        |
| A = Ammeter (measuring r.m.s values) | $S_2$ = Single pole switch     |
| D = CBR under test                   | $S_3$ = Two-way switch         |
| SCR = Thyristors                     |                                |

**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 4.3.1.1; 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 be tested and declared by the manufacturer.

The applied voltage shall be 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. 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 subclause 8.3.4.1.2 and figure 9 of Part 1, 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 8.3.5.3.

**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 8.3.5.4.



**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 Part 1 applies with regard to clauses and subclauses of this standard, with the following additions:

Clause or subclause number of this standard	Item
4.3.5.3	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
8.3.2.5	Method of temperature-rise tests for four-pole circuit-breakers having a conventional thermal current higher than 63 A
8.3.2.6.4	Value of test current for short-circuit tests on the fourth pole of four-pole circuit-breakers
8.3.3.1.3, item b)	Test current value for the verification of inverse time/current characteristics
8.3.3.4	To increase the severity of the conditions for testing overload performance
8.3.3.7	Permissible delay between the verification of temperature-rise and that of overload relays in test sequences I and II
8.3.4.4	Calibration of releases other than over-current releases, shunt releases and undervoltage releases
8.4.2	Calibration of releases other than over-current releases, shunt releases and undervoltage releases
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**

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**

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.2.1 Electromagnetic compatibility (EMC) tests**

###### **F.2.1.1 General**

Circuit-breakers with electronic overcurrent protection shall be tested according to tables J.1 and J.3.

###### **F.2.1.2 Performance criteria**

The results of immunity tests shall be classified on the basis of the following performance criteria:

Criterion A:

During the test, the circuit-breaker when loaded at 0,9 times the current setting shall not trip, and when loaded at 2,0 times the current setting, it 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.

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.

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### **F.2.2 Suitability for multiple frequencies**

The test shall be performed in accordance with clause F.6.

### **F.2.3 Dry heat test**

The test shall be performed in accordance with clause F.7.

### **F.2.4 Damp heat test**

The test shall be performed in accordance with clause F.8.

### **F.2.5 Temperature variation cycles at a specified rate of change**

The test shall be performed in accordance with clause 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 of F.4 and F.5, annex J applies.

### **F.3.2 Electromagnetic compatibility tests**

Annex J applies.

For the high-frequency tests (F.4.3 to F.4.7) one circuit-breaker per frame size and per type of current sensor design shall be tested; a change of winding turns is not considered a different design in this context.

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.4.5, F.4.6 and F.4.7, 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.4.2, 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 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  $\leq$  third harmonic  $\leq$  88 % of fundamental component;
    - peak factor:  $2,0 \pm 0,2$ ;
  - test of the fifth harmonic and peak factor
    - 45 % of fundamental component  $\leq$  fifth harmonic  $\leq$  55 % of fundamental component;
    - peak factor:  $1,9 \pm 0,2$ ;

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– 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  $\leq 21$  % of the period;
- peak factor:  $\geq 2,1$ .

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  $> 7$  %.

Higher harmonics may also be present.

NOTE 3 The test current waveform for option b) may 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) 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 figures F.3 or 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.2.1.2 shall apply.

## F.4.2 Current dips

### F.4.2.1 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 figures F.3 or 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 where  $I_R$  is the setting current,  $I_D$  is the dip test current and  $T$  is the period of the sinusoidal current.

NOTE An alternative method to perform the tests on the electronic controls alone is under consideration.

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.	$I_D$	$\Delta t$
1		0,5 T
2	0	1 T
3		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.4.2.2 Test results

Performance criterion B of F.2.1.2 shall apply, except that the after-test verification is not required.

#### F.4.3 Electrostatic discharges

Annex J, in particular J.2.2, 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.

The busbar routing shown in figures J.1, J.2 and J.3 may be varied providing the 0,1 m distances, with a tolerance of  $^{+10}_0\%$ , to the metallic enclosure are maintained. The actual configuration used shall be shown in the test report.

Performance criterion B of F.2.1.2 applies.

#### F.4.4 Radiated radio-frequency electromagnetic fields

Annex J, in particular J.2.3, 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.

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Tests shall be performed as follows:

- a) For step 1 (see J.2.3), the circuit-breaker shall be loaded with a current of 0,9 times the current setting. The circuit-breaker shall not trip.
- b) For step 2 (see J.2.3), the circuit-breaker shall be loaded with a current of 2,0 times the current setting. The tripping time shall then be measured.

Performance criterion A of F.2.1.2 applies.

### F.4.5 Electrical fast transients/bursts (EFT/B)

Annex J, in particular J.2.4, applies with the following additions.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the EUT 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.

Tests shall be performed as follows:

- a) To verify the resistance against unwanted tripping, the EUT shall be supplied with a current of 0,9 times the current setting during the application of the disturbance.  
The disturbance shall be applied for a duration of 1 min.
- b) To verify the time-current characteristics, the circuit-breaker shall be supplied with a current of 2,0 times the current setting during the application of the disturbance.

Performance criterion A of F.2.1.2 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.

### F.4.6 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.

The circuit is supplied with a current of 0,9 times the current setting during the application of the pulses.

Performance criterion B of F.2.1.2 applies.



**F.4.7 Conducted disturbances induced by radio-frequency fields (common mode)**

Annex J, in particular J.2.6, applies with the following additions.

Tests shall be performed as follows:

- a) For step 1 (see J.2.6), the circuit-breaker shall be loaded with a current of 0,9 times the current setting. The circuit-breaker shall not trip.
- b) For step 2 (see J.2.6), the circuit-breaker shall be loaded with a current of 2,0 times the current setting. The tripping time shall then be measured.

Performance criterion A of F.2.1.2 applies.

**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 – 30 MHz)**

Circuit-breakers covered by this annex are independent of line voltage or of any auxiliary supply and have no direct coupling to the supply; the electronic circuits 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 – 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 figures F.3 or 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**

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 – 60 Hz only (see clause F.3).

## **IS/IEC 60947-2 : 2003**

### **F.6.1 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.6.2 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 figures F.3 or 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.6.3 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.

Tightening torques applied to the terminals shall be in accordance with the manufacturer's instructions. 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  $55\text{ °C} \pm 2\text{ °C}$  (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  $1\text{ K/min} \pm 0,2\text{ K/min}$ . The temperature, once reached, shall be maintained for at least 2 h.

The number of cycles shall be 28.

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### **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.

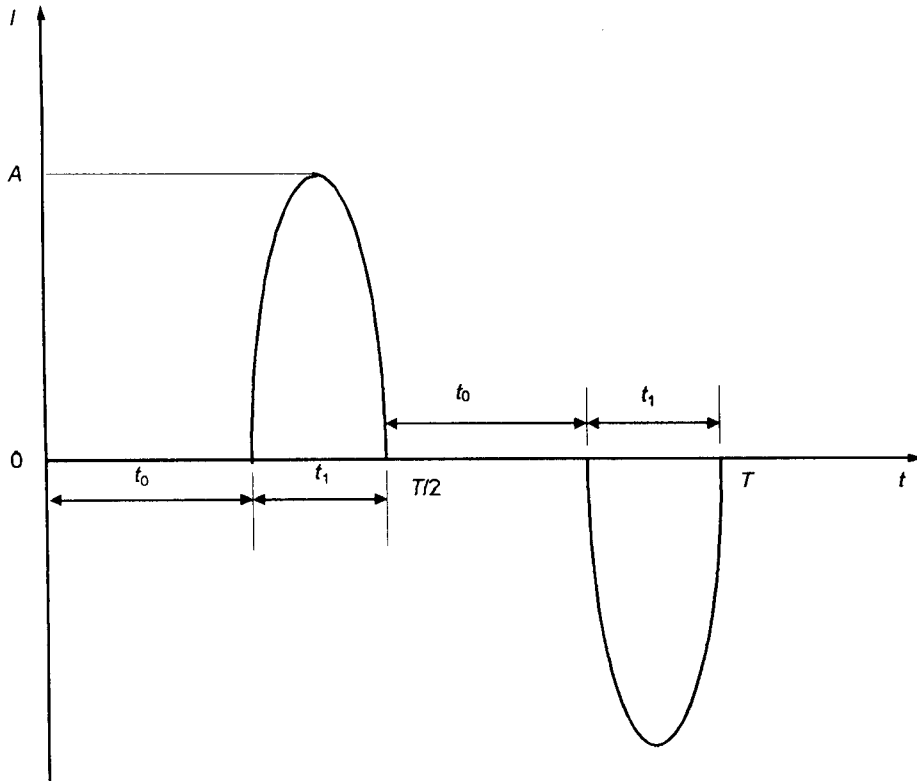
### **F.9.3 Test results**

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

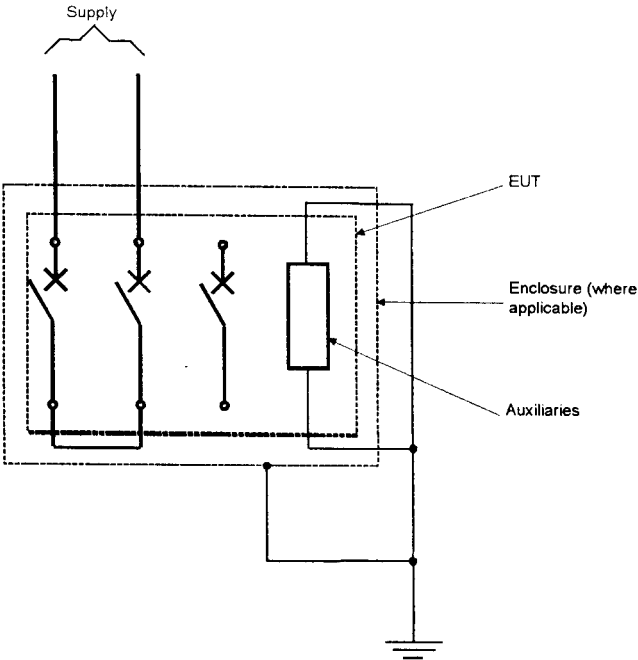
T period

$t_1$  conducting time during each half-cycle

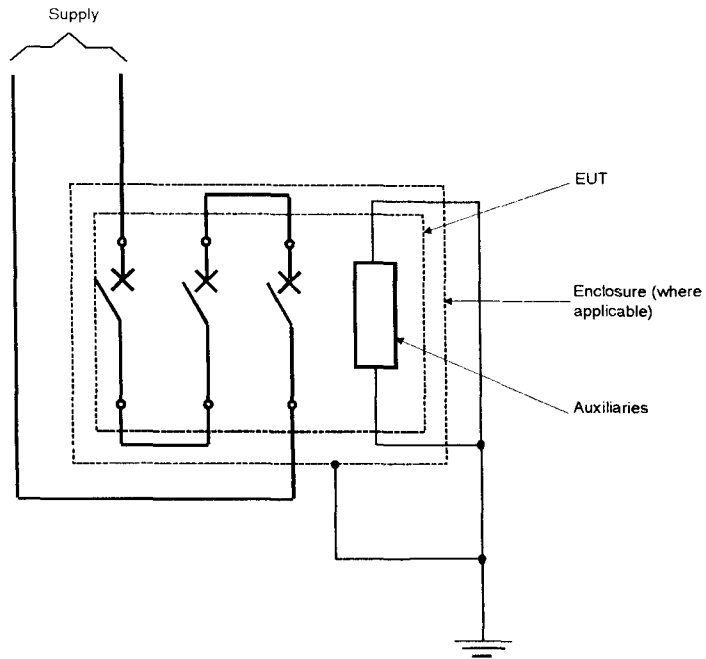
$t_0$  delay time

$$\text{Peak factor} = \frac{A}{\sqrt{\frac{2}{T} \int_0^{T/2} i^2(t) dt}}$$

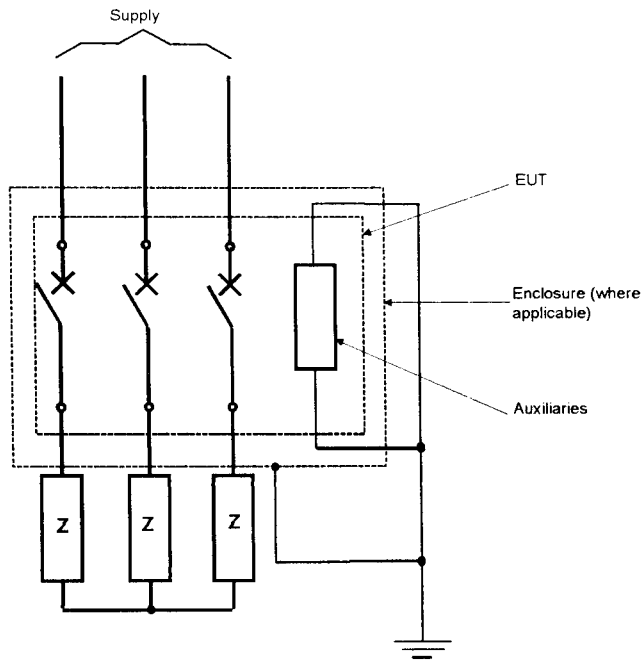
**Figure F.1 – Representation of test current produced by back-to-back thyristors in accordance with F.4.1**



**Figure F.2 – Test circuit for emission tests, immunity to harmonics, current dips, electrostatic discharges and radiated electromagnetic fields in accordance with F.4.1.3, F.4.2.1, F.4.3, F.4.4, F.5.4 and F.6.2 – Two phase poles in series**



**Figure F.3 – Test circuit for emission tests, immunity to harmonics, current dips, electrostatic discharges and radiated electromagnetic fields in accordance with F.4.1.3, F.4.2.1, F.4.3, F.4.4, F.5.4 and F.6.2. – Three phase poles in series**

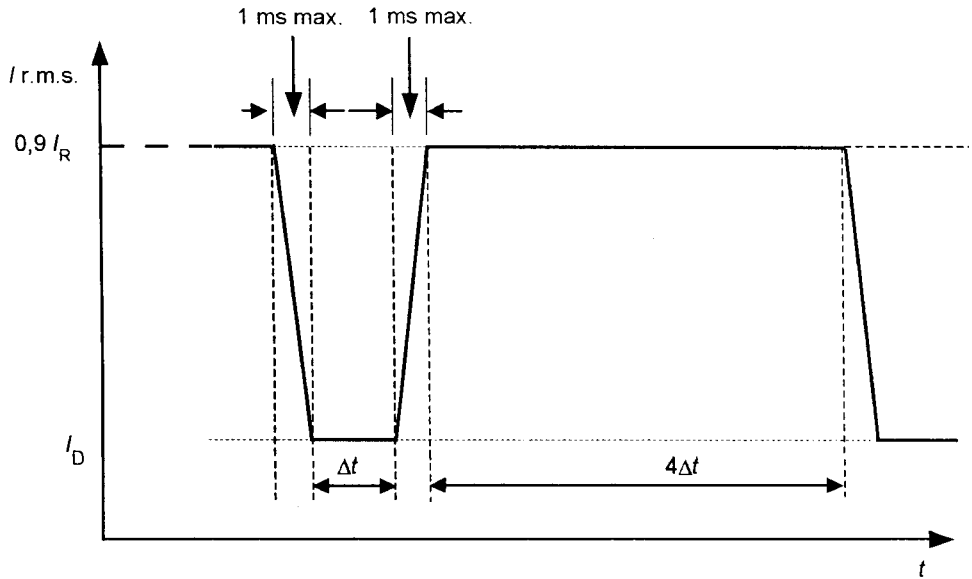


**Components**

Z impedance for adjusting the current (where required)

**Figure F.4 – Test circuit for emission tests, immunity to harmonics, current dips, electrostatic discharges and radiated electromagnetic fields in accordance with F.4.1.3, F.4.2.1, F.4.3, F.4.4, F.5.4 and F.6.2. – Three-phase connection**



**Key**

- $I_R$  setting current
- $I_D$  dip test current
- $\Delta t$  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.4.2.1**

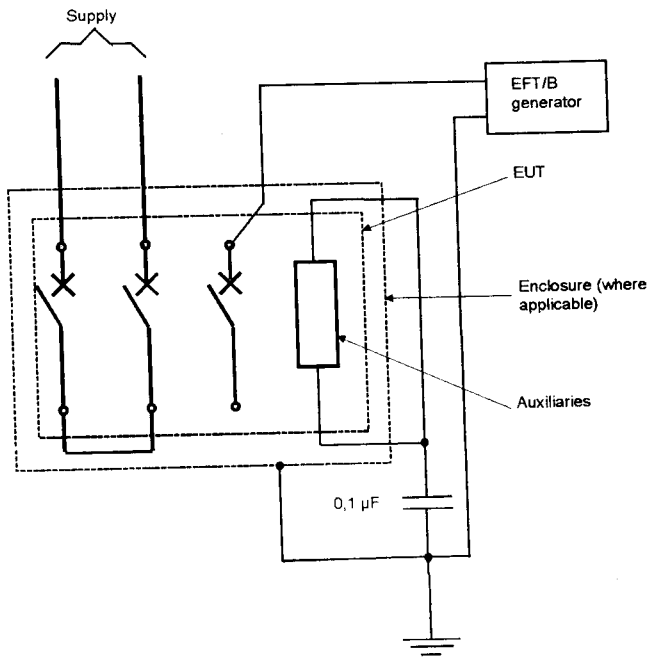
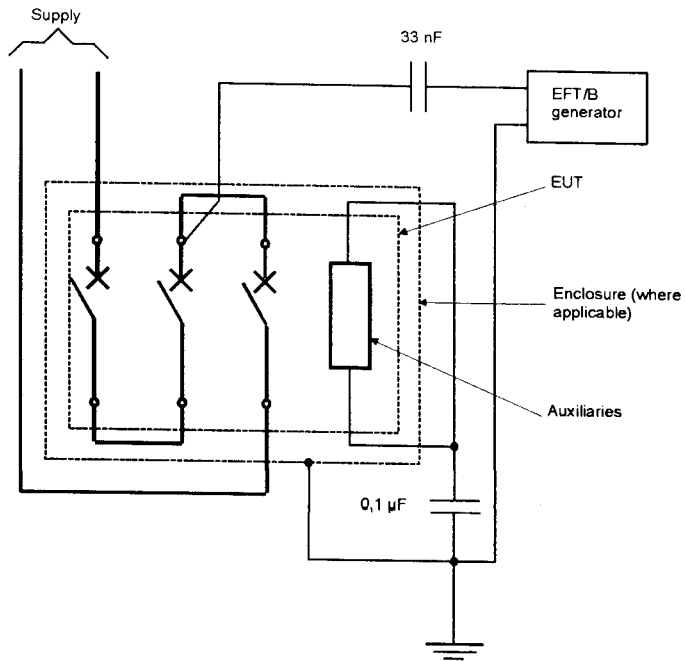
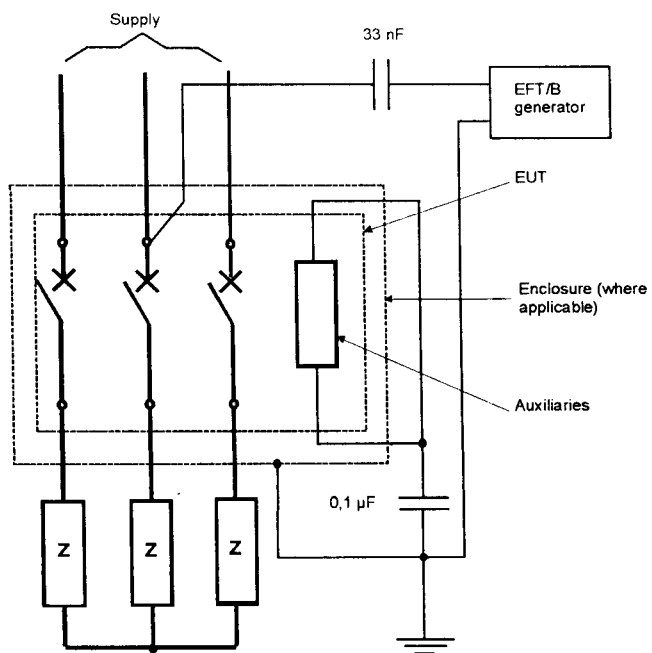


Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.5 – Two phase poles in series



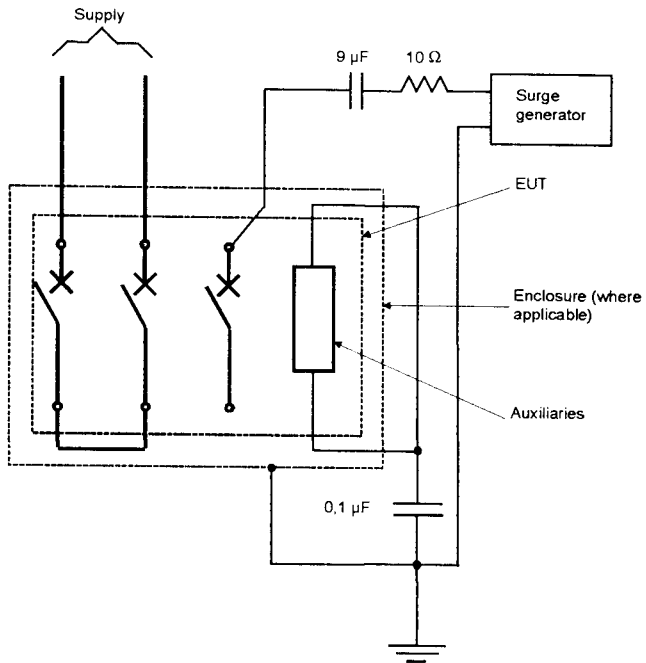
**Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.5 – Three phase poles in series**



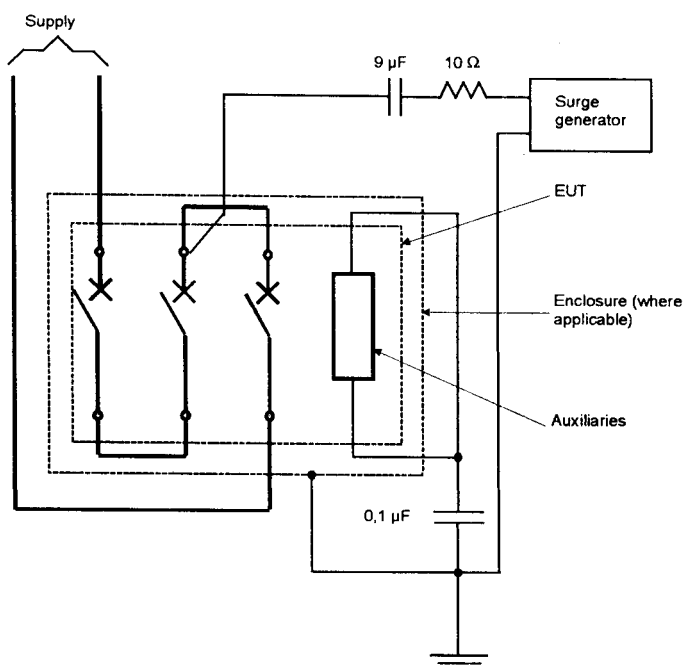
**Components**

Z impedance for adjusting the current (where required)

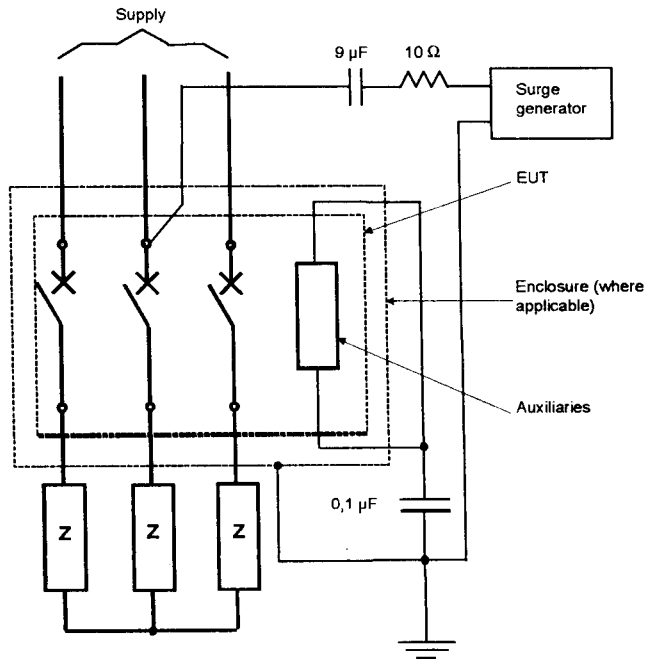
**Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.5 – Three-phase connection**



**Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.6 – 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.4.6 – Three phase poles in series**



**Components**

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.4.6 – Three-phase connection**

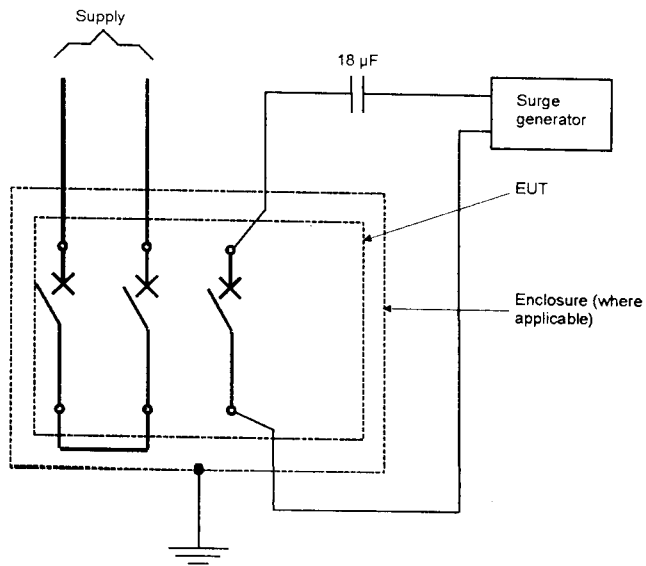


Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.6 – Two phase poles in series

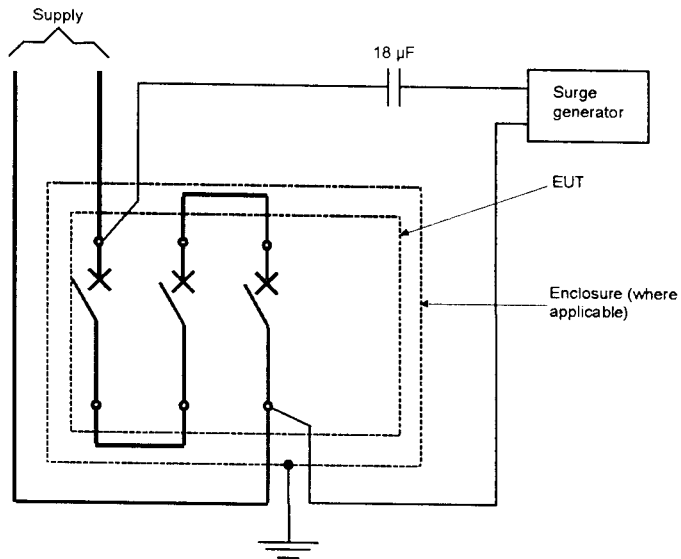
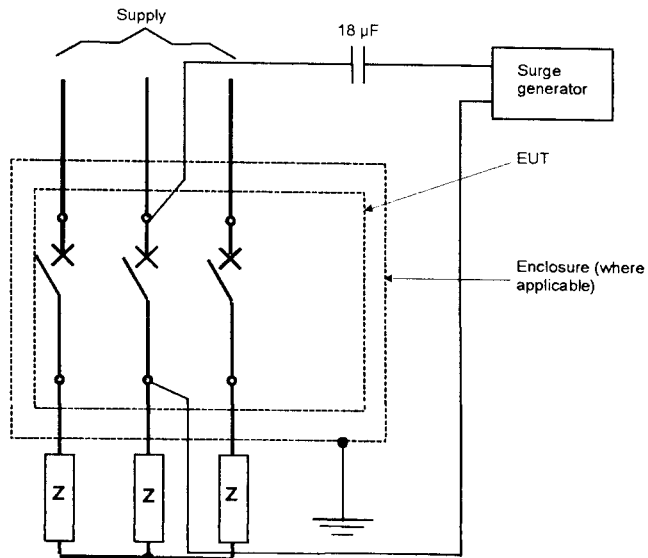


Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.6 – Three phase poles in series

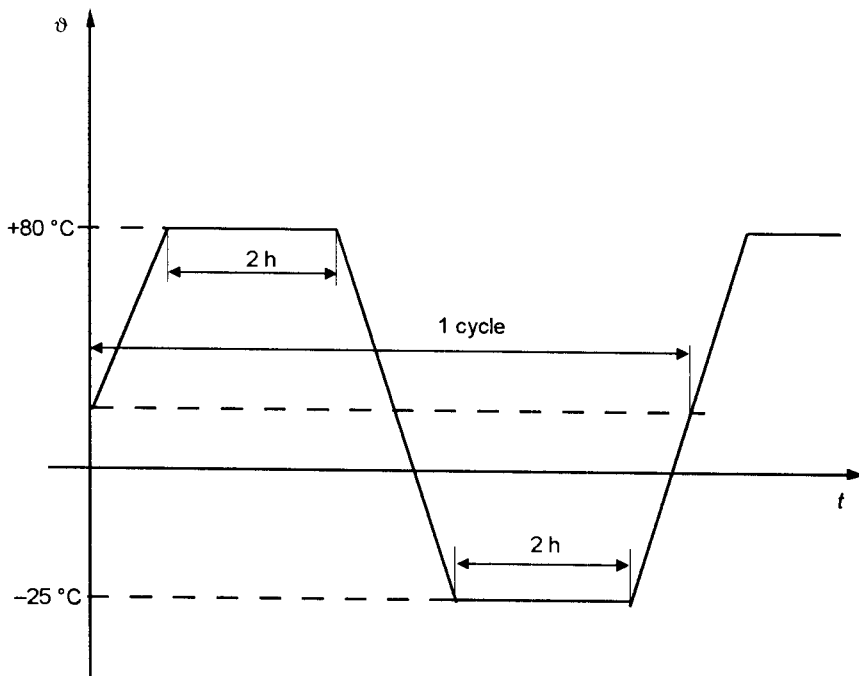




#### Components

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.4.6 – Three-phase connection**



**Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.9.1**

**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**

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;

$\Delta U$  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**

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;

$\Delta U$  is the voltage drop;

$I_n$  is the rated current.

### G.2.3

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.

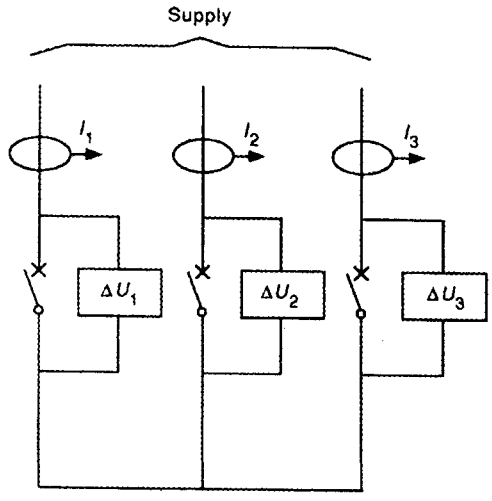


Figure G.1 – Example of power loss measurement according to G.2.1

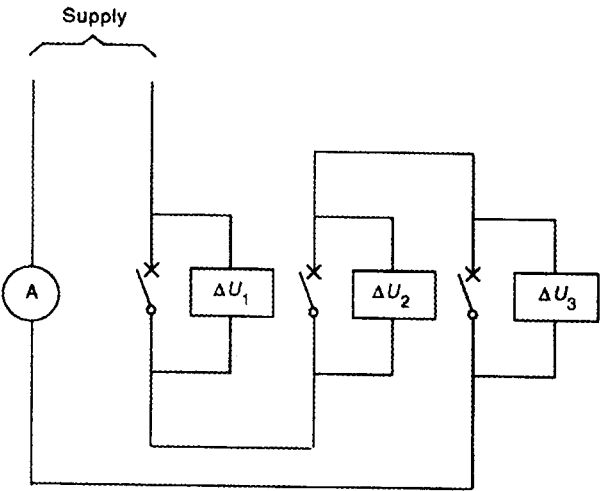


Figure G.2 – Example of power loss measurement according to G.2.2 and G.2.3

## 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 4.3.1.1).

#### H.1 General

This test sequence applies to multipole circuit-breakers for application on IT systems, in accordance with 4.3.1.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit ( $I_{1T}$ )	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  $I_{1T}$  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 exceeding 50 kA.

NOTE Values higher than  $I_{1T}$  may be required, tested instead and declared by the manufacturer.

The applied 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. 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.

For 4-pole circuit-breakers with a protected neutral pole, the test voltage for that pole shall be phase-to-phase voltage divided by  $\sqrt{3}$ . 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 and figure 9 of Part 1, 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 clause H.2, the dielectric withstand shall be verified according to 8.3.5.3.

### H.4 Verification of overload releases

Following the test according to clause H.3, the operation of the overload releases shall be verified according to 8.3.5.4.

### 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  $\otimes$  which shall be marked on the circuit-breaker immediately following these values of rated voltage, e.g., 690 V  $\otimes$  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  $\otimes$  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:

- a) environment A;
- b) 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 "circuit-breaker" or "EUT" (equipment under test) means a circuit-breaker, a CBR or an MRCD, as applicable.

NOTE 5 The EMC requirements for a CBI (annex L) are deemed to be covered by the relevant tests on the equivalent circuit-breaker (see L.2.1).

The tests of clauses J.2 and J.3 are applicable to circuit-breakers incorporating electronic circuits except where specified otherwise in this standard.

The test methods in clauses 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, test details and performance criteria are given in the relevant parts of this standard, e.g. annex B for CBRs, annex F for circuit-breakers with electronic overcurrent protection, annex M for MRCDs and annex N for circuit-breaker auxiliaries.

A new circuit-breaker may be used for each test or one circuit-breaker may be used for several tests, at the manufacturer's discretion.

Circuit-breakers rated 50 Hz/60 Hz shall be tested at either one of the rated frequencies.

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In the case of a range of circuit-breakers with identical electronic controls (including dimensions, components, printed circuit board assemblies and enclosure, if any) and the same design of sensors, it is sufficient to test only one circuit-breaker in the range.

Tests shall be performed in free air or in the specified enclosure according to table J.1 or table J.3, as applicable.

Where specified, the ground connection of the enclosure shall be made as in normal installation conditions but taking into account the high-frequency requirements in accordance with the general "earthing and bonding" requirements indicated in IEC 61000-5-2. In particular, the use of a "bonding strap" consisting of a flat conductor having a length/width ratio less than or equal to five is recommended. The specification of the bonding strap shall be given in the test report.

### **J.2 Immunity**

#### **J.2.1 General**

Subclause 7.3.2.2 of IEC 60947-1 applies with the following additions.

Immunity tests are carried out according to table J.1.

The reference data for the application of the figures for immunity tests are given in table J.2.

For the purposes of this clause (J.2), "power port" covers any auxiliary connected to the main circuit.



Table J.1 – EMC – Immunity tests

Description	Reference standard	Test level	Mounting
Electrostatic discharges	IEC 61000-4-2	8 kV contact <sup>a)</sup> 8 kV air	Enclosure figure J.1, J.2 or J.3
Radiated radio-frequency electromagnetic fields	IEC 61000-4-3	10 V/m	Free air <sup>c)</sup>
Electrical fast transients/bursts	IEC 61000-4-4	Power port: $U_e \geq 100$ V, a.c. or d.c.: 4 kV <sup>a)</sup> $U_e < 100$ V, a.c. or d.c.: 2 kV Signal port: 2 kV <sup>a)</sup>	Enclosure figure J.1, J.2 or J.3
Surges	IEC 61000-4-5	Power port, $U_e \geq 100$ V a.c.: 4 kV line-to-earth <sup>a)</sup> 2 kV line-to-line (annexes F and N) <sup>a)</sup> 4 kV line-to-line (annexes B and M) <sup>e)</sup>  Power port, $U_e < 100$ V a.c.: 2 kV line-to-earth 1 kV line-to-line  Power port, d.c.: 0,5 kV line-to-earth 0,5 kV line-to-line  Signal port: 2 kV line-to-earth 1 kV line-to-line	Enclosure figure J.1, J.2 or J.3
Conducted disturbances induced by radio-frequency fields	IEC 61000-4-6	Power port: 10 V Signal port: 10 V	Free air <sup>c)</sup>
Power frequency magnetic fields	Not required (see 7.3.2)	Not applicable	Not applicable
Voltage dips and interruptions	IEC 61000-4-11	<sup>d)</sup>	Free air
Harmonic currents	<sup>b)</sup>	<sup>b)</sup>	Free air
Current dips	<sup>b)</sup>	<sup>b)</sup>	Free air
<sup>a)</sup> The immunity levels specified are in excess of the requirements of IEC 60947-1 in order to provide greater security for the circuit protection functions of the circuit-breaker. <sup>b)</sup> A specific test procedure is defined in the case of electronic overcurrent devices in annex F, in the absence of an appropriate basic standard. <sup>c)</sup> 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. <sup>d)</sup> A specific test procedure is defined in the case of CBRs to annex B functionally dependent on line voltage and MRCDs to annex M 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 to annex F (see F.1), but are replaced by tests for current dips and interruptions (see F.4.2). <sup>e)</sup> Immunity level is higher for residual current devices because they perform safety functions.			

Table J.2 – Reference data for the application of the figures for immunity tests

Test and subclause	Test set-up	Enclosure/ conductors arrangement	Circuit diagram for test (during EMC test)	Circuit diagram for verification (after EMC test)	
Electrostatic discharges	B.8.12.1.2	Figure J.4	Figure J.1	a)	Figure B.1
	F.4.3	Figure J.4	Figure J.1, J.2 or J.3	Figure F.2, F.3 or F.4	Figure F.2, F.3 or F.4
	M.8.16.1.2	Figure J.4	Figure J.1	a)	Figure M.3
Radiated radio- frequency electromagnetic fields	B.8.12.1.3	Figure J.5	a)	a)	Figure B.1
	F.4.4	Figure J.5	a)	Figure F.2, F.3 or F.4	a)
	M.8.16.1.3	Figure J.5	a)	a)	Figure M.3
Electrical fast transients/bursts	B.8.12.1.4	Figure J.6	Figure J.1	a)	Figure B.1
	F.4.5	Figure J.6	Figure J.1, J.2 or J.3	Figure F.6, F.7 or F.8	a)
	M.8.16.1.4	Figure J.6	Figure J.1	a)	Figure M.3
Surges	B.8.12.1.5	a)	Figure J.1	a)	Figure B.1
	F.4.6	a)	Figure J.1, J.2 or J.3	Line-to-earth: figure F.9, F.10 or F.11  Line-to-line: figure F.12, F.13 or F.14	Line-to-earth: figure F.9, F.10 or F.11  Line-to-line: figure F.12, F.13 or F.14
	M.8.16.1.5	a)	Figure J.1	a)	Figure M.3
Conducted disturbances induced by radio-frequency fields	B.8.12.1.6	Figure J.7	a)	a)	a)
	F.4.7	Figure J.7, J.8 or J.9	a)	a)	a)
	M.8.16.1.6	Figure J.7	a)	a)	a)
a) No additional figure necessary.					

### J.2.2 Electrostatic discharges

The circuit-breaker shall be tested as a floor-standing equipment (see 7.1.2 of IEC 61000-4-2), the test set-up being as shown in figure J.4.

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 circuit-breaker normally accessible to the user, such as setting means, keyboards, displays, pushbuttons etc. The application points shall be stated in the test report.

If a direct discharge on to the circuit-breaker (air or contact) occurs at any test point, the test at such a point is repeated 10 times, for both polarities, at intervals of  $\geq 1$  s.

Indirect discharges shall be applied at selected points on the surface of the enclosure; the test at such points is repeated 10 times, for both polarities, at intervals of  $\geq 1$  s.

### J.2.3 Radiated radio-frequency electromagnetic fields

The test conditions of clause 7 of IEC 61000-4-3 shall apply.

The circuit-breaker shall be tested on the front face only, the test set-up being as shown in figure J.5.

To enable repeatability, the actual test set-up including supply bars, transformer, etc. 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 where the circuit-breaker is tested for unwanted operation (e.g. unwanted tripping) on the whole range of frequencies, and a second step where the circuit-breaker is tested for correct operation (i.e. correct tripping) at discrete frequencies.

For step 1, the frequency shall be swept over the ranges of 80 MHz to 1 000 MHz and 1 400 MHz to 2 000 MHz, in accordance with clause 8 of IEC 61000-4-3. The dwell time 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, a test shall be performed at each of the following frequencies: 80; 100; 120; 180; 240; 320; 480; 640; 960; 1 400 and 2 000 MHz, the operation being verified after the field at each frequency has stabilized.

Specific test parameters for step 1 and step 2 are given in the relevant annex, as applicable.

### J.2.4 Electrical fast transients/bursts (EFT/B)

The metallic enclosure shall be connected to the ground plane (see J.1).

The circuit-breaker shall be tested as a floor-standing equipment (see 7.2.1 of IEC 61000-4-4), the test set-up being as shown in figure J.6.

NOTE 1 It is advisable to supply the transformer via a coupling-decoupling network to avoid disturbances on the mains network.

NOTE 2 The disturbance injection distance is defined in order to ensure test repeatability.

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 J.6).

For signal ports the coupling-decoupling network or the clamp injection method shall be used, as applicable.

### J.2.5 Surges

The metallic enclosure shall be connected to the ground plane (see J.1).

NOTE It is advisable to supply the transformer via a coupling-decoupling network to avoid disturbances on the mains network.

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Signal port disturbances shall be injected by means of coupling-decoupling networks as specified in figures 6 and 7 of IEC 61000-4-5.

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 fields (common mode)**

The disturbances shall be injected by means of a coupling-decoupling network M1 or M2 according to IEC 61000-4-6, as applicable.

The test circuit for the a.c. main circuit port shall be in accordance with figure J.7.

For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with figure J.8 or J.9 as applicable.

To enable repeatability, the actual test set-up including supply bars, transformer, etc. shall be detailed in the test report.

The test is performed in two steps: a first step where the circuit-breaker is tested for unwanted operation (e.g. unwanted tripping) on the whole range of frequencies, and a second step where the circuit-breaker is tested for correct operation (i.e. correct tripping) 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. The dwell time 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, a test shall be performed at each of the following frequencies: 0,150; 0,300; 0,450; 0,600; 0,900; 1,20; 1,80; 2,40; 3,60; 4,80; 7,20; 9,60; 12,0; 19,2; 27,0; 49,4; 72,0 and 80,0 MHz, the operation being verified after the level of the disturbing voltage at each frequency has stabilized.

Specific test parameters for step 1 and step 2 are given in the relevant annex, as applicable.

## **J.3 Emission**

### **J.3.1 General**

Subclause 7.3.3.2 of IEC 60947-1 applies with the following additions.

Emission tests are carried out 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	Not applicable <sup>c)</sup>	
Voltage fluctuations	IEC 61000-3-3	Not applicable <sup>c)</sup>	
Conducted RF disturbances 150 kHz to 30 MHz	CISPR 11 / CISPR 22	Class A or class B, group 1 <sup>b)e)</sup>	Free air <sup>d)</sup>
Radiated RF disturbances 30 MHz to 1 000 MHz <sup>a)</sup>	CISPR 11 / CISPR 22	Class A or class B, group 1 <sup>b)</sup>	Free air <sup>d)</sup>

<sup>a)</sup> Applicable only for circuit-breakers containing processing devices (e.g. microprocessors) or switched-mode power supplies operating at frequencies greater than 9 kHz.

<sup>b)</sup> 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.  
Equipment class B in CISPR 11 and CISPR 22 corresponds to environment B in IEC 60947-1. Environment B equipment will not cause electromagnetic interferences when installed in environment A.

<sup>c)</sup> No test required since the electronic control circuits operate at very low power and hence create negligible disturbances.

<sup>d)</sup> 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.

<sup>e)</sup> 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 the application of the figures for emission tests

Test and subclause		Test set-up	Enclosure/ conductors arrangement	Circuit diagram for test (during EMC test)	Circuit diagram for verification (after EMC test)
Conducted RF disturbances	B.8.12.2.2	a)	a)	a)	a)
	F.5.3	No test	No test	No test	No test
	M.8.16.2	a)	a)	a)	a)
Radiated RF disturbances	B.8.12.2.3	Figure J.10	a)	a)	a)
	F.5.4	Figure J.10	a)	Figure F.2, F.3 or F.4	a)
	M.8.16.2	Figure J.10	a)	a)	a)

<sup>a)</sup> No additional figure necessary.

**J.3.2 Conducted RF disturbances (150 kHz –30 MHz)**

Descriptions of the test method and test arrangement are given in CISPR 11 or in CISPR 22, as relevant.

**J.3.3 Radiated RF disturbances (30 MHz – 1 000 MHz)**

The test set-up is shown in figure J.10.

The height from the floor of the EUT shall be  $1\text{ m} \pm 0,1\text{ m}$ .

To enable repeatability, the actual test set-up including supply bars, transformer, etc. shall be detailed in the test report.

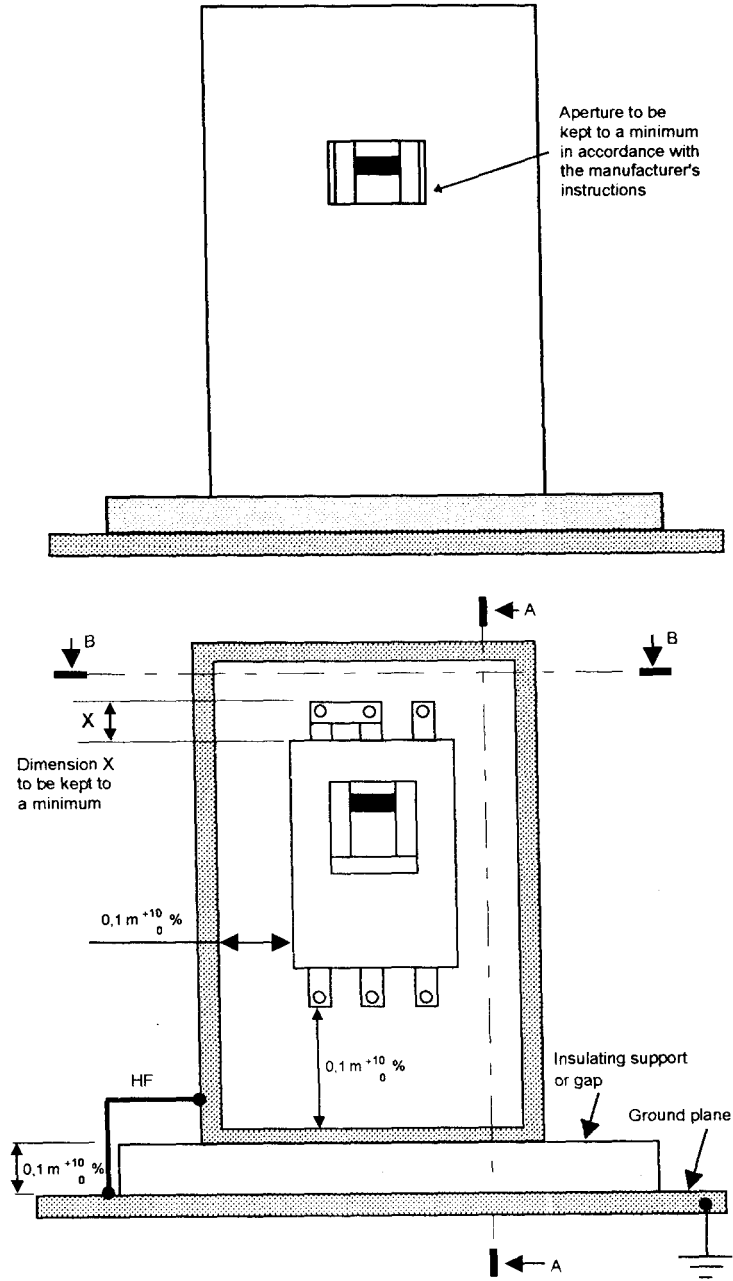
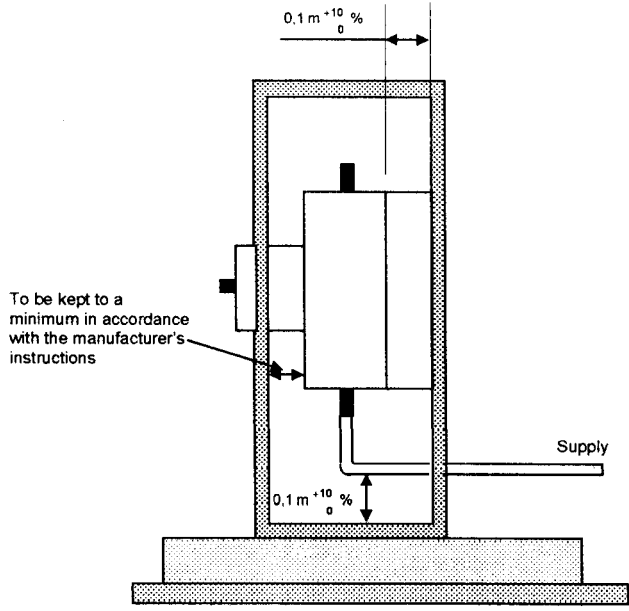
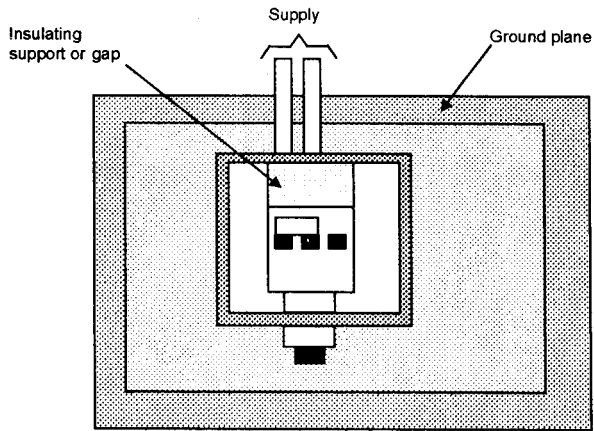


Figure J.1a – Elevation



Section A-A



Section B-B

Figure J.1b – Sections A-A and B-B

NOTE Connector details only applicable in the case of tests to annex F.

Figure J.1 – EUT mounted in metallic enclosure – Two phase poles in series



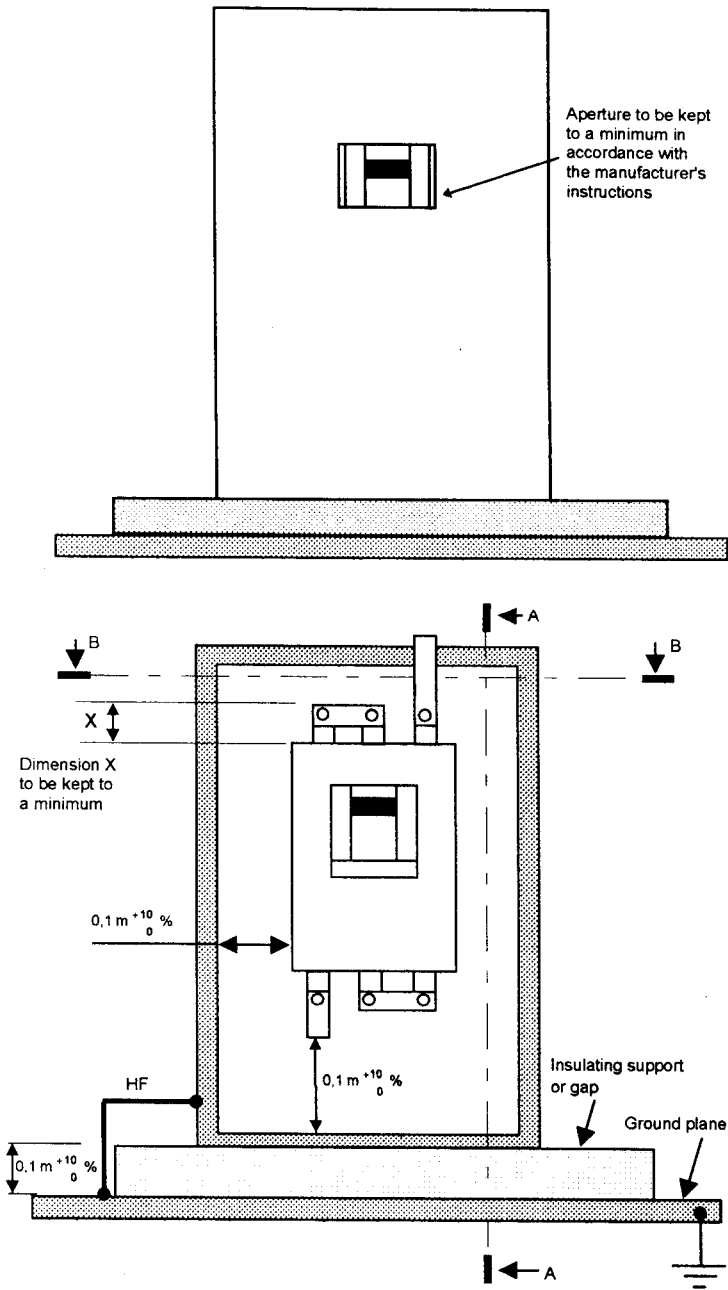
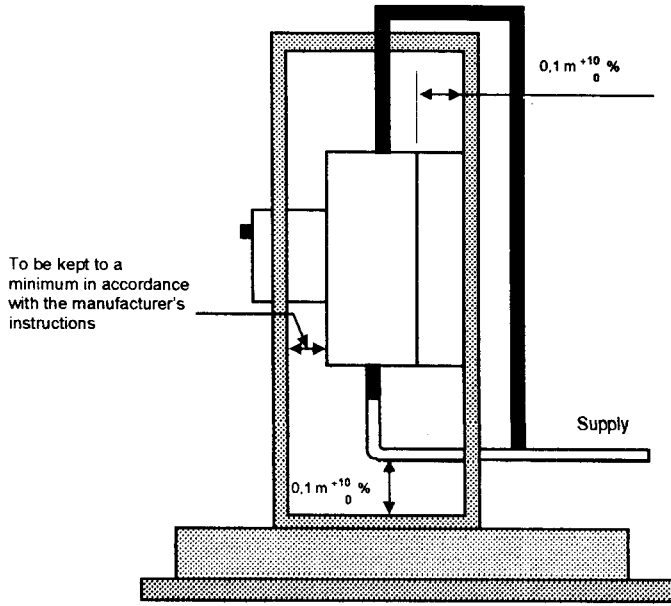
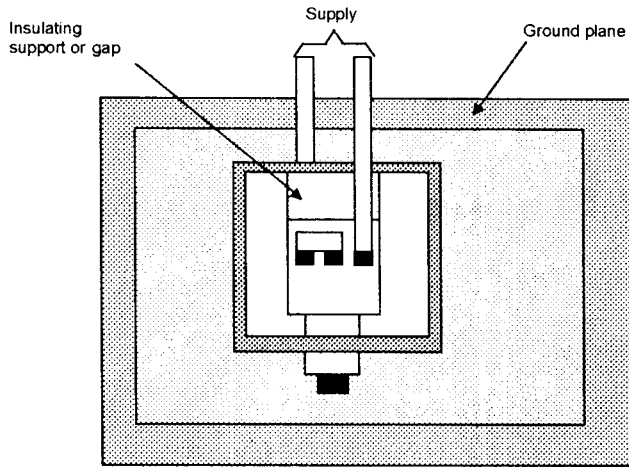


Figure J.2a – Elevation



Section A-A



Section B-B

Figure J.2b – Sections A-A and B-B

Figure J.2 – EUT mounted in metallic enclosure – Three phase poles in series

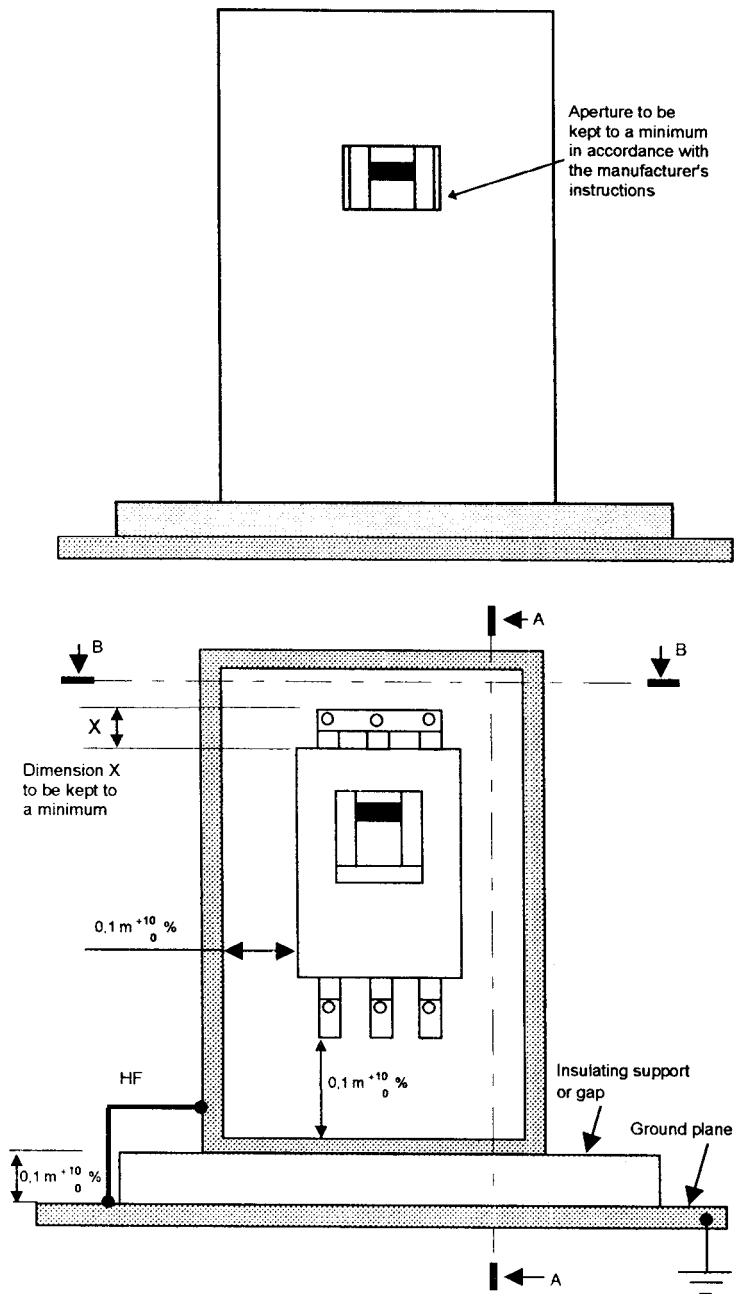
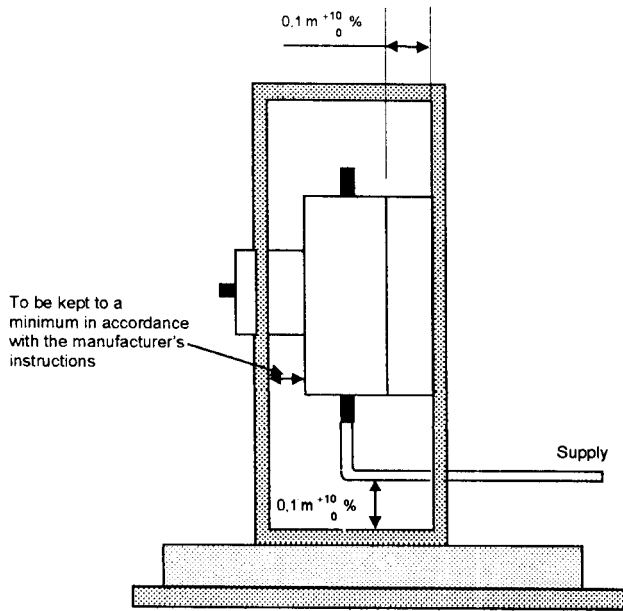
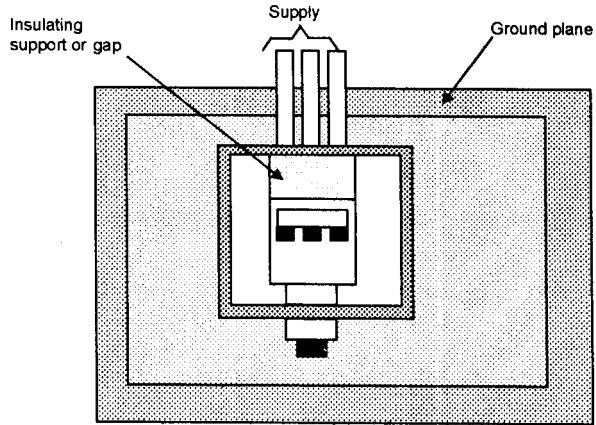


Figure J.3a – Elevation



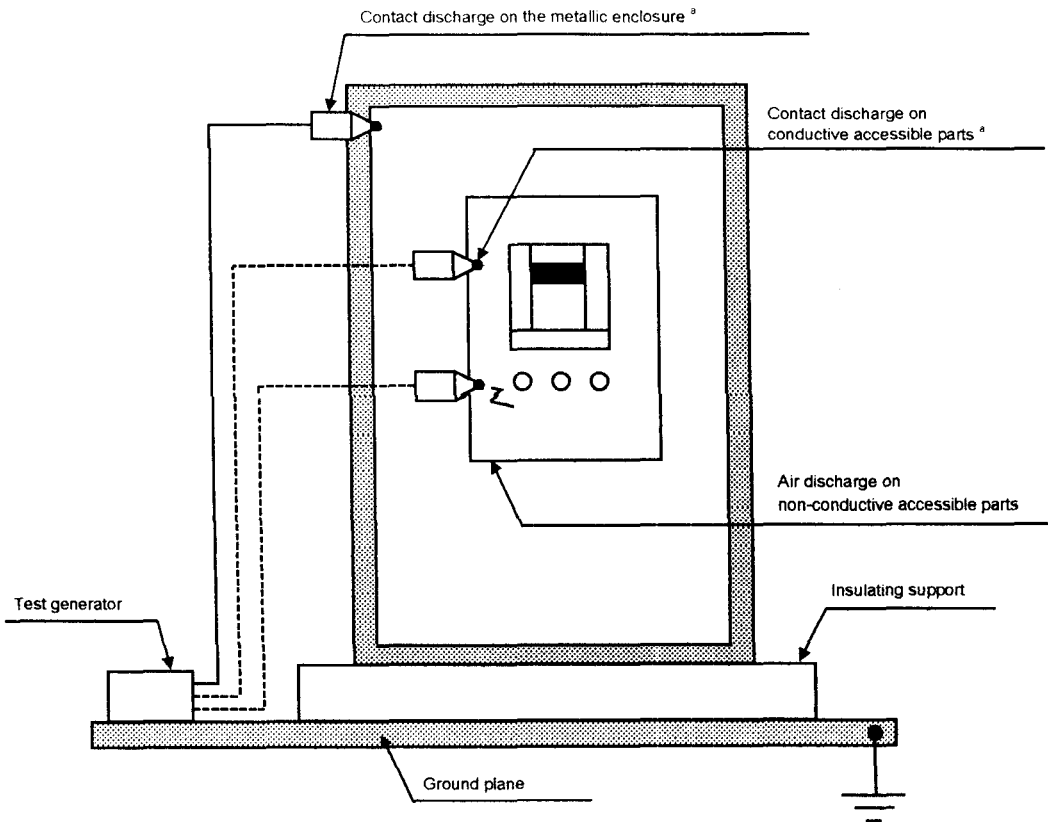
Section A-A



Section B-B

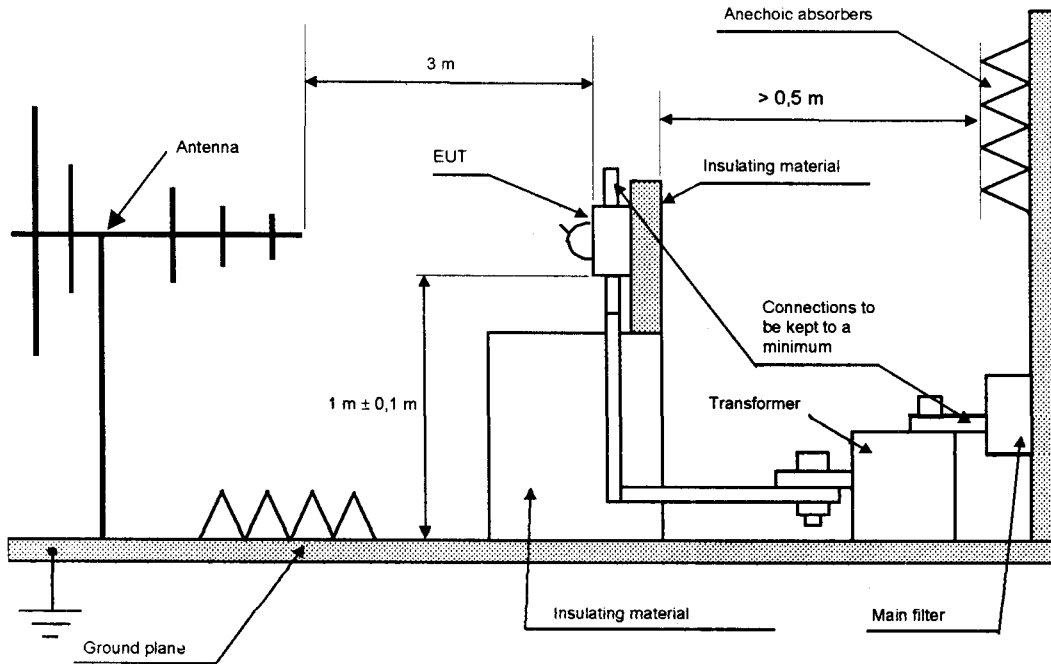
Figure J.3b – Sections A-A and B-B

Figure J.3 – EUT mounted in metallic enclosure – Three-phase connection

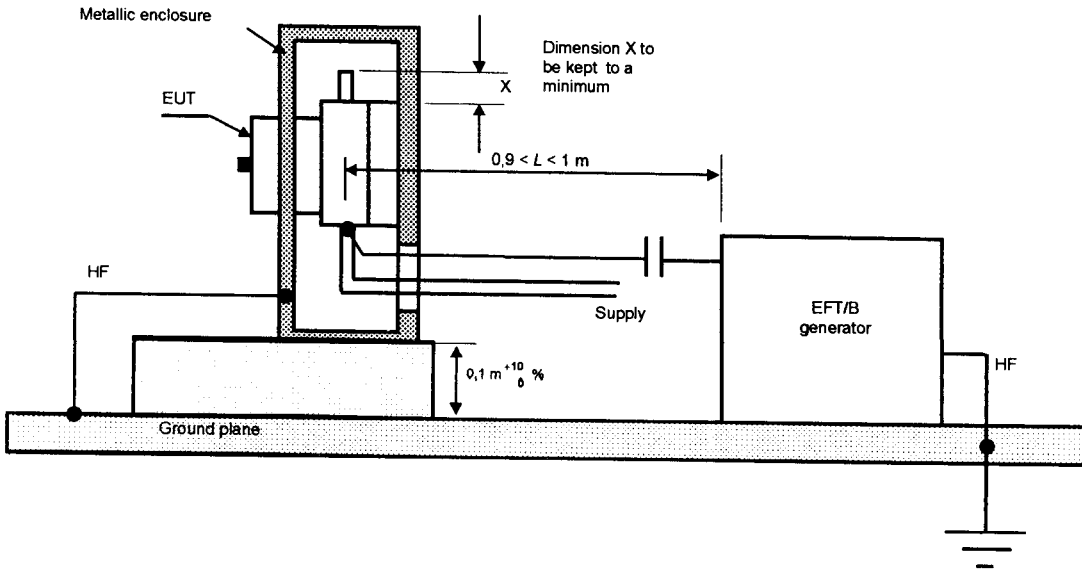


<sup>a</sup> Contact discharge probe shall be applied perpendicular to the surface under test.

**Figure J.4 – Test set-up for the verification of immunity to electrostatic discharges**

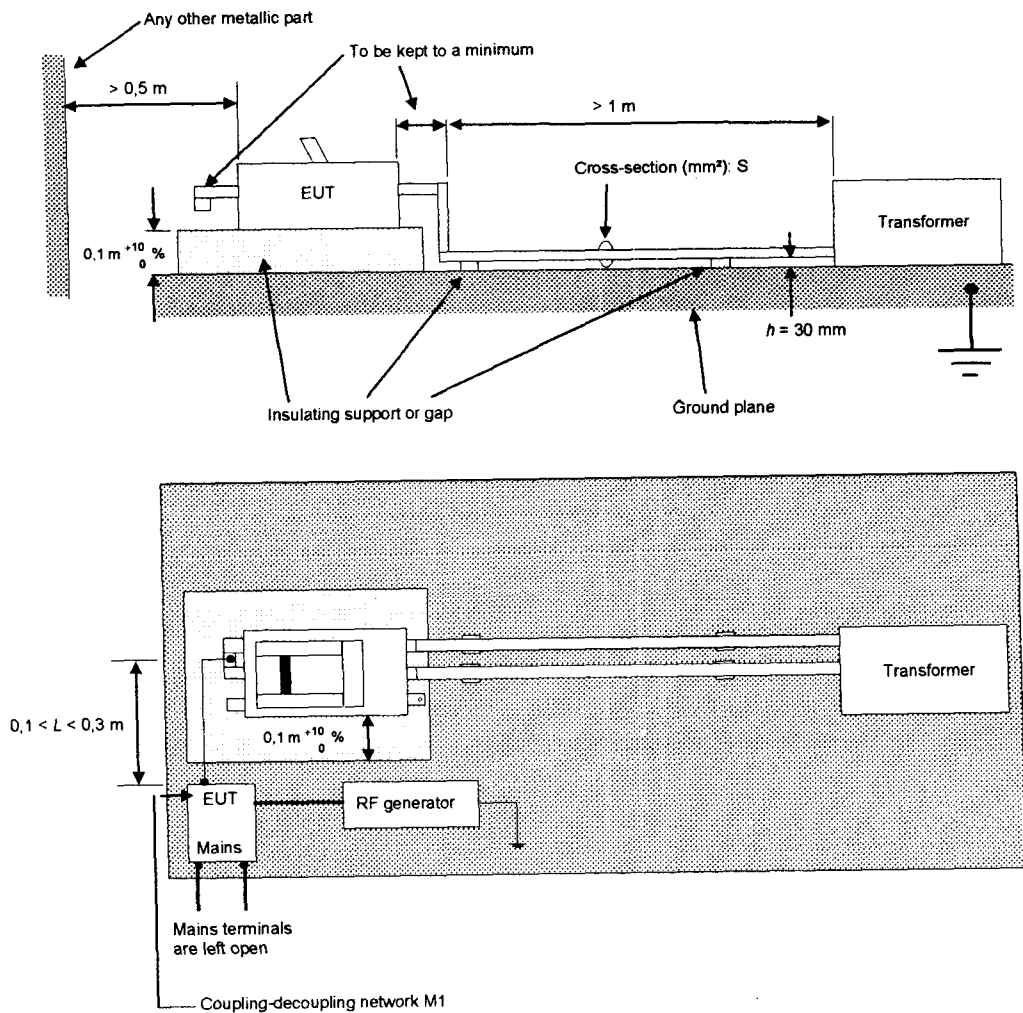


**Figure J.5 – Test set-up for the verification of immunity to radiated electromagnetic fields**



NOTE This is a representative example; other test set-ups may be used providing the requirements for the tests are complied with.

**Figure J.6 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B)**



**Key**

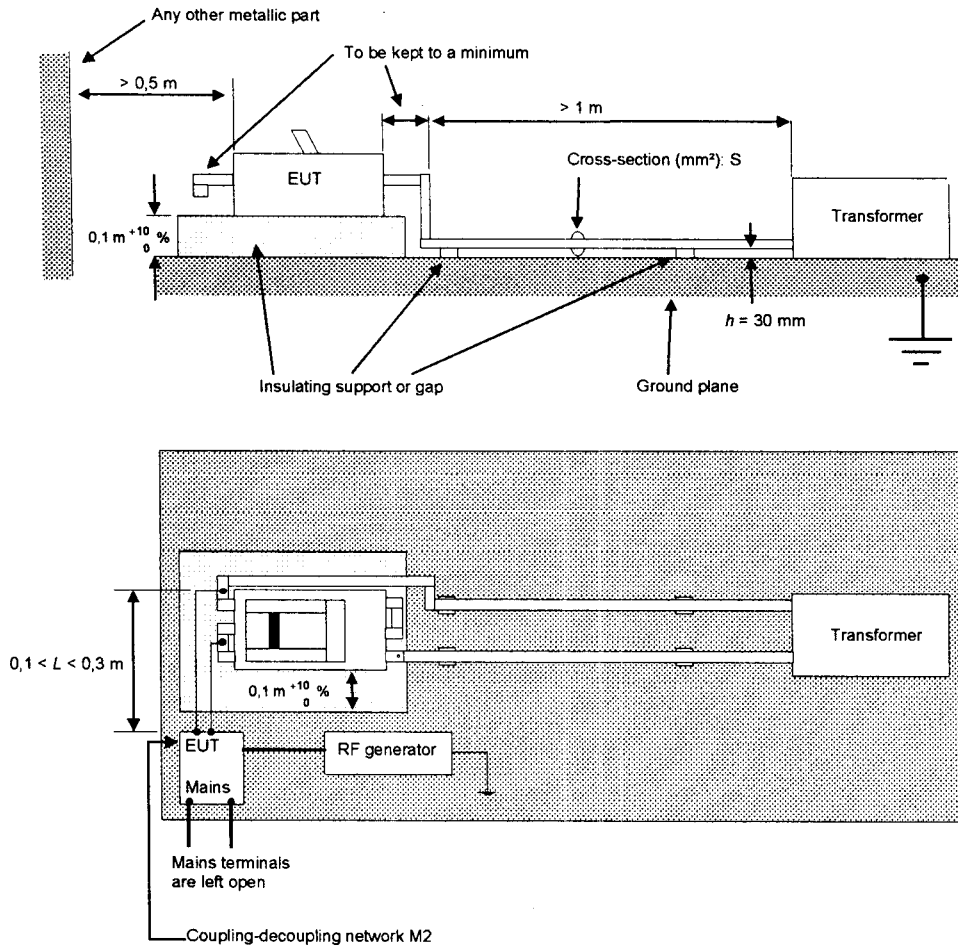
$L$  total cable length

NOTE 1 As an alternative to the coupling-decoupling network M1, coupling-decoupling network M2 or M3 may be used in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

NOTE 2 Connector details only applicable in the case of tests to annex F, in all other cases figures 2 and 6 of IEC 61000-4-6 apply.

**Figure J.7 – Test set-up for the verification of immunity to conducted disturbances induced by radio-frequency fields (common mode) – Two phase poles in series**

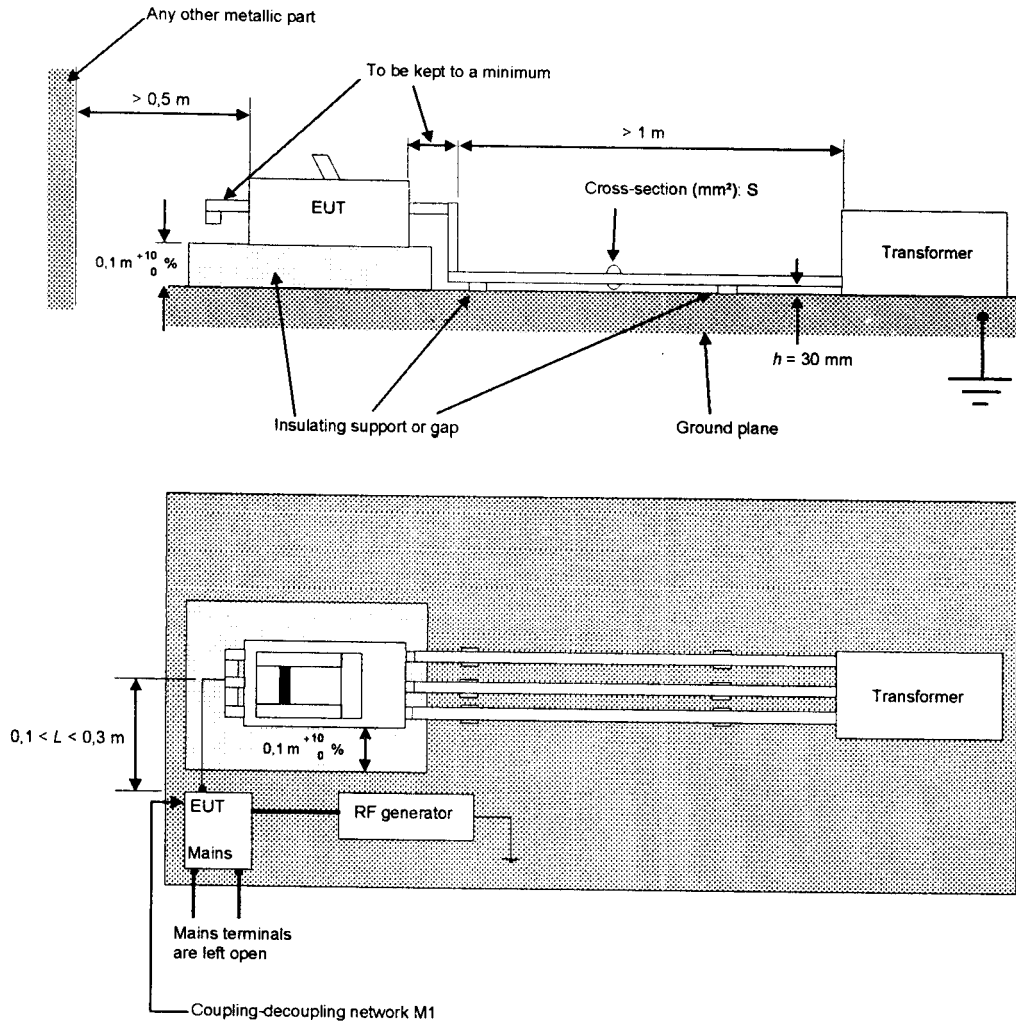




**Key**

$L$  total cable length

**Figure J.8 – Test set-up for the verification of immunity to conducted disturbances induced by radio-frequency fields (common mode) – Three phase poles in series**

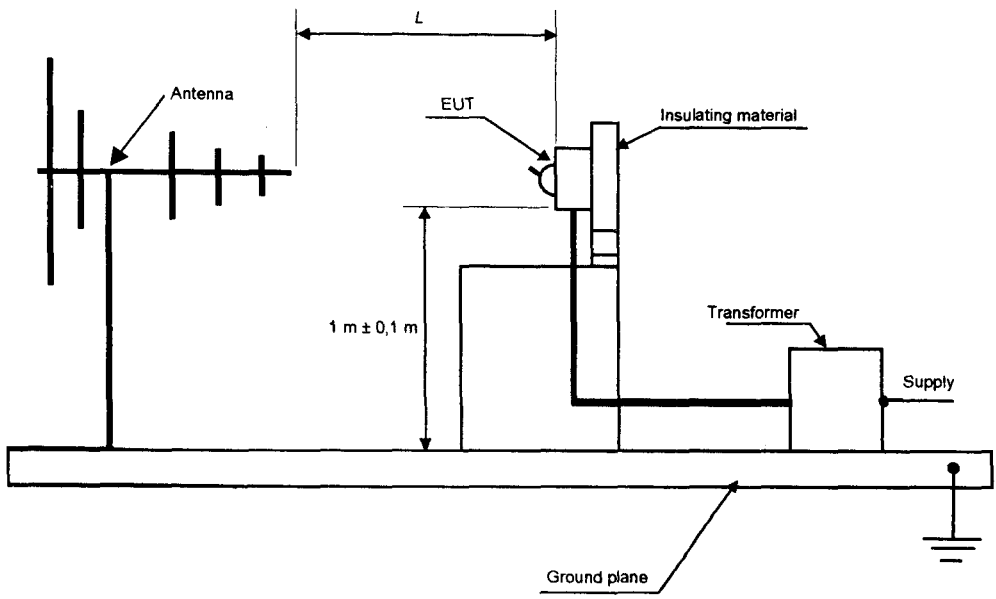


**Key**

$L$  total cable length

NOTE As an alternative to the coupling-decoupling network M1, coupling-decoupling network M2 or M3 may be used in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

**Figure J.9 – Test set-up for the verification of immunity to conducted disturbances induced by radio-frequency fields (common mode) – Three-phase connection**



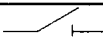






**Key**

L 10 m or 3 m according to reference standard (CISPR 11/CISPR 22)

**Figure J.10 – Test set-up for radiated emissions**

**Annex K**  
(informative)

**Glossary of symbols related to products covered by this standard**

Characteristics list	Symbol	Reference
Circuit-breaker, closed position	I	5.2
Circuit-breaker, open position	O	5.2
Isolation suitability		5.2
Neutral pole terminal	N	5.2
Protective earth terminal		5.2
Rated control circuit voltage	$U_c$	4.7.2
Rated current	$I_n$	4.3.2.3
Rated impulse withstand voltage	$U_{imp}$	4.3.1.3
Rated insulation voltage	$U_i$	4.3.1.2
Rated operational voltage	$U_e$	4.3.1.1
Rated service short-circuit breaking capacity	$I_{cs}$	4.3.5.2.2
Rated short-circuit making capacity	$I_{cm}$	4.3.5.1
Rated short time withstand current	$I_{cw}$	4.3.5.4
Rated ultimate short-circuit breaking capacity	$I_{cu}$	4.3.5.2.1
Selectivity limit current	$I_s$	2.17.4
Take-over current	$I_B$	2.17.6
Conventional enclosed thermal current	$I_{the}$	4.3.2.2
Conventional free air thermal current	$I_{th}$	4.3.2.1
CBRs of type AC		B.4.4.1
CBRs of type A		B.4.4.2
Current setting of adjustable overload release	$I_R$	*
Corresponding tripping time	$t_R$	*
Ground fault current setting	$I_g$	*
Corresponding tripping time	$t_g$	*
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
Instantaneous pick-up current	$I_i$	Figure K.1 and annex L
Maximum corresponding tripping time	$t_i$	*
Not suitable for use in IT systems		Annex H
Rated residual short-circuit making and breaking capacity	$I_{\Delta m}$	Annex B
Rated residual non-operating current	$I_{\Delta no}$	Annex B
Rated residual operating current	$I_{\Delta n}$	Annex B
Residual operating current	$I_{\Delta R}$	*
Short time pick-up current	$I_{sd}$	*
Corresponding tripping time	$t_{sd}$	*
Suitability for phase earthed systems	C	4.3.1.1
Limiting non actuating time at $2 I_{\Delta n}$	$\Delta t$	B.4.2
Time delay CBR with limiting non actuating time of 0,06 s		B.5.1
CBRs for use with 3-phase supply only		B.8.9.2

\* These terms are not used in this standard. For their identification, see figure K.1.

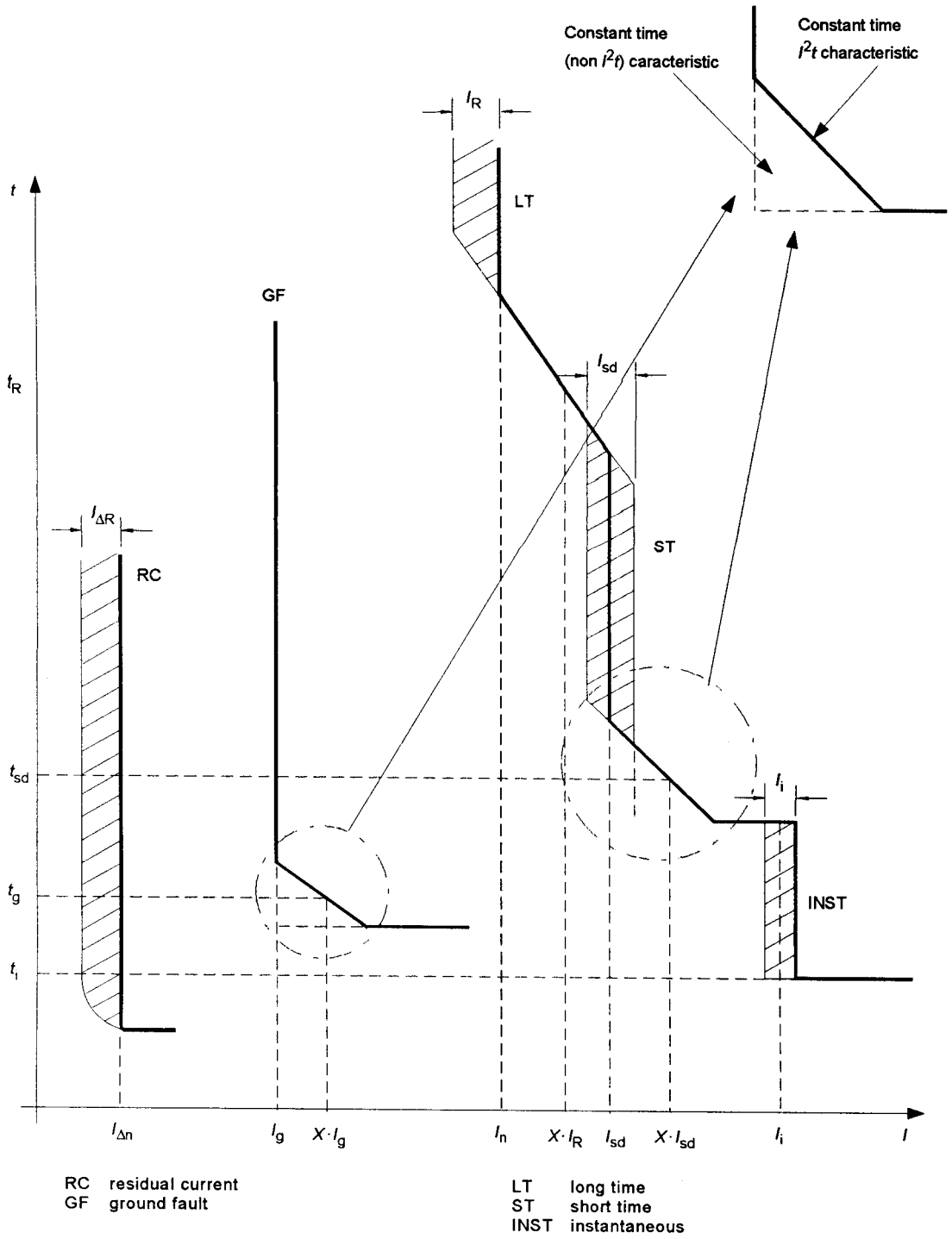


Figure K.1 – Relationship between symbols and tripping characteristics

**Annex L**  
(normative)

**Circuit-breakers not fulfilling the requirements  
for overcurrent protection**

**L.1 Scope**

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<sup>1)</sup> 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 Definitions**

In addition to the definitions given in clause 2, the following 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 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.

NOTE CBIs with integral adjustable or non-adjustable instantaneous short-circuit releases for equipment and circuit protection are under consideration.

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<sup>1)</sup> This applies in particular to overload protection.

**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 may be correlated to the rated current corresponding to utilization category AC-22 (see annex A of IEC 60947-1).

**L.4.2 Rated conditional short-circuit current ( $I_{cc}$ )**

Subclause 4.3.6.4 of IEC 60947-1 applies.

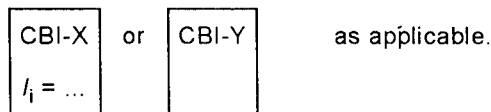
A CBI may have a value of  $I_{cc}$  equal to or higher than that of the  $I_{cu}$  of the equivalent circuit-breaker.

**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:



where  $I_i$  is the instantaneous tripping current.

- 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 additionally comply with IEC 60947-3 and be marked accordingly.

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### 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 be

- the equivalent circuit-breaker (see L.2.1);
- another circuit-breaker (see L.2.2);
- a fuse of conventional fusing current  $\leq$  the conventional tripping current of the equivalent circuit-breaker and of a breaking capacity  $\geq I_{cc}$  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  $\leq$  the conventional tripping current of the equivalent circuit-breaker and a breaking capacity  $\geq I_{cc}$  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 instantaneous tripping current 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**

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.

**L.7.2.1.1 Test conditions**

Subclause 8.3.2.6 applies.

The test circuit shall be according to figure A.6, 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.6).

**L.7.2.1.2 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 8.3.5.2, the CO operation being made by closing the CBI.

After each operation, the CBI shall be manually closed and opened three times.

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### 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 8.3.5.3.

### 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 8.3.5.2, 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 8.3.5.3.

**Annex M**  
(normative)

**Modular residual current devices**  
**(without integral current breaking device)**

INTRODUCTION

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 Scope and object**

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 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.

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### M.2 Definitions

The definitions of annex B apply.

The following additional definitions apply to this annex.

#### M.2.1 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 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.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**

- MRCD of type AC (see M.4.2.2.1);
- MRCD of type A (see M.4.2.2.2);
- 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 4.3.2.3 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 applies.

**M.4.1.2.4 Rated impulse withstand voltage ( $U_{imp}$ )**

Subclause 4.3.1.3 of IEC 60947-1 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 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 applies.

**M.4.3.2 Rated conditional residual short-circuit current ( $I_{\Delta c}$ )**

Subclause 4.3.6.4 of IEC 60947-1 applies.

**M.4.3.3 Rated short-time withstand current ( $I_{cw}$ )**

Subclause 4.3.6.1 of IEC 60947-1 applies.

**M.4.3.4 Peak withstand current**

Subclause 2.5.28 of IEC 60947-1 applies to the primary circuit of the MRCD.

**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.

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### M.4.4.2 Minimum value of the rated residual non-operating current ( $I_{\Delta no}$ )

Subclause B.4.2.2 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.4.2.3 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)	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		Visible	a)		a)
s) limiting non-operating time (value or range) at $2 I_{\Delta n}$ for time-delay type, as applicable	$\Delta t$ or 	Visible	a)		a)
t) test device	T	Visible	a)		a)
u) wiring diagram		Literature			
a) Information/markings 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 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 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 Rated conditional short-circuit current ( $I_{CC}$ ), rated short-time withstand current ( $I_{CW}$ ) and rated conditional residual short-circuit current ( $I_{\Delta C}$ )

MRCDs shall have a rated conditional short circuit current or a rated short-time withstand current, but may have both. They shall also have a rated conditional residual short circuit current.

MRCDs shall comply with the 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.

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 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.

**M.7.2.11.2 Ambient air temperature**

The temperature-rise limits given in tables 2 and 3 of IEC 60947-1 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 tables 2 and 3 of IEC 60947-1.

**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

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.

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### **M.8.1.2 Routine tests**

Subclause 8.4.4 applies.

### **M.8.2 Compliance with constructional requirements**

Subclause 8.2 of IEC 60947-1 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, M.2 or 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 S1 and S2, and Sa 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), and the test switches S1 and S2, and Sa if applicable, being closed, the breaking device is closed onto the monitored circuit. 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 (figures M.2 and 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  $I_{\Delta}$  specified in M.4.2, the test switches S1, and Sa 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 S2.

Three measurements of operating time and of combination time (if applicable) are made at each value of  $I_{\Delta}$ :

- 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 S1, and Sa if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is established by closing the switch S2 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.

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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 $-5\text{ }^{\circ}\text{C}$**

Subclause B.8.2.5.1 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 $+40\text{ }^{\circ}\text{C}$**

Subclause B.8.2.5.2. 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 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.

###### **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 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 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 rated voltage by 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), figure M.4 b) or figure M.4 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 S1 being open. The switch Sa, 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.8.6.1 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.8.6.2 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 of 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 S1 and S2, and Sa 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 figures M.8 or 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 S1, and Sa if applicable, are in the closed position and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S2.

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), figure M.10 b) or figure M.10 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 of 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 S1 and S2, and Sa if applicable, being closed. Each current path is tested twice in position I and twice in position II of switch S3.

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 figures M.12 and 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 S1 or Sa, as applicable, being closed and the MRCD being ready to operate, the residual current is suddenly established by closing switch S2.

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 S3 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 S1 and S2, and Sa 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 S1 and S2, and Sa 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  $\alpha = 0^\circ$ .

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, 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 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, at the rated current  $I_n$ .

During this test, temperature rise shall not exceed the values listed in tables 2 and 3 of IEC 60947-1.

## **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.

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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.

NOTE 2 For MRCDs having more than one output rating, any additional tests required are under consideration.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.3.2.

NOTE 3 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.8.8.1, 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.8.8.2, 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 Sa or S1, as applicable; the MRCD shall not operate.

The switch Sa or S1, 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 S2; 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 applies, replacing figures 9, 10, 11 and 12 by figures M.17, M.18 and 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 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 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 impedances Z1 and Z2 are 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 8.3.3.5.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.3.2 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 Test conditions**

The negligible impedance connections are replaced by the SCPD and, if applicable, by the terminal type MRCD. The switch S1 remains open (no residual current).

**M.8.14.3.2 Test procedure**

The rated voltage of the voltage source, if applicable, is applied.

The following sequence of operations is performed:

O – t – O

**M.8.14.3.3 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 applies to the primary circuit.

The test may be carried out at any convenient voltage. The SCPD of figures M.17, M.18 and 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 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.

The test is carried out on one current path.

The negligible impedance connections are replaced by the SCPD and, where applicable, by the MRCD.

The switch S1 remains closed.

**M.8.14.5.2 Test procedure**

The following sequence is performed without synchronisation with respect to the voltage wave:

$$O - t - O$$
**M.8.14.5.3 Behaviour of the MRCD during the tests**

During the tests the MRCD may operate.

***Test sequence M III*****M.8.15 Verification of effects of environmental conditions**

The test 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.8.10.3.2.

***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.

**M.8.16.1.2 Electrostatic discharges**

Subclause B.8.12.1.2 applies, except that the verification after the test 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.

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### **M.8.16.1.3 Radiated radio-frequency electromagnetic fields**

Subclause B.8.12.1.3 applies, except that the verification after the tests of step 1 and step 2 (see J.2.3) 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.8.16.1.4 Electrical fast transients/bursts (EFT/B)**

Subclause B.8.12.1.4 applies, except that the verification after the test 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.8.16.1.5 Surges**

Subclause B.8.12.1.5 applies, except that the verification after the test 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.8.16.1.6 Conducted disturbances induced by radio-frequency fields (common mode)**

Subclause B.8.12.1.6 applies, except that the verification after the tests of step 1 and step 2 (see J.2.6) 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.

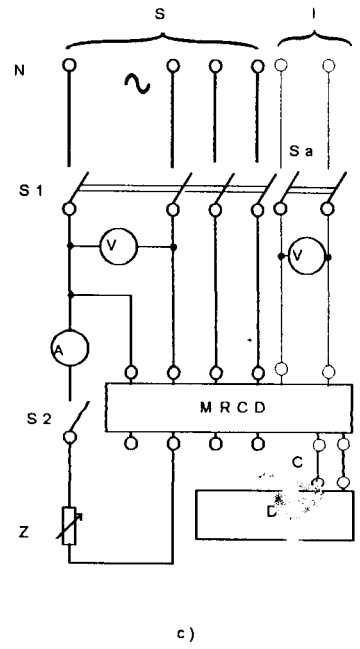
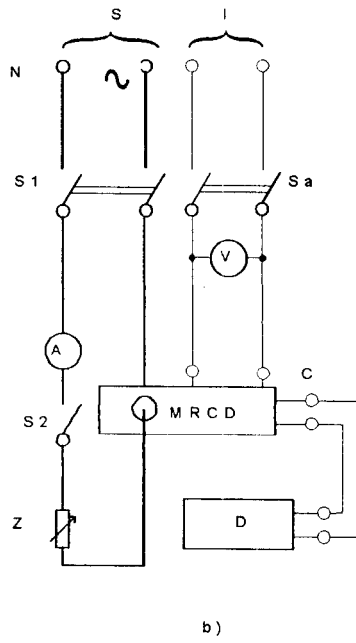
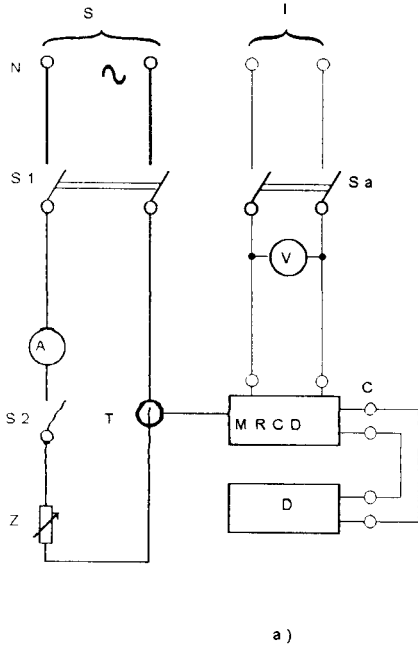
### **M.8.16.2 Emission tests**

Subclause B.8.12.2 applies.

**MRCD with separate sensing means**

**MRCD with integral sensing means**

**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                             |
| S1 | multipole switch                       | D  | instrument indicating the change of status |
| S2 | single-pole switch                     |    |  |

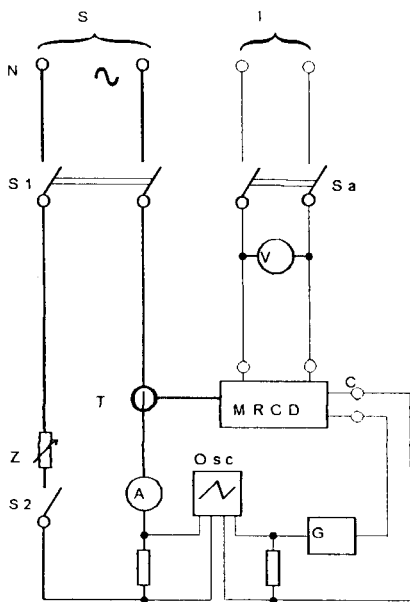
**Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current**



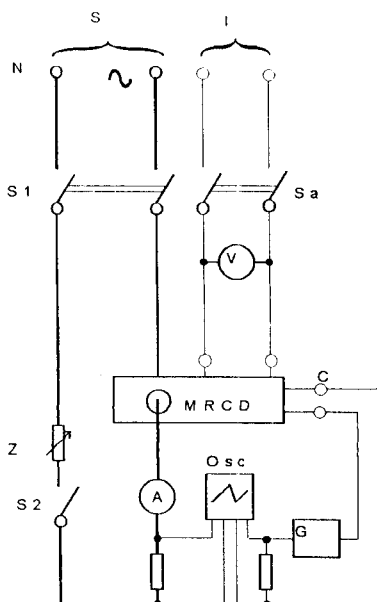
**MRCD with separate sensing means**

**MRCD with integral sensing means**

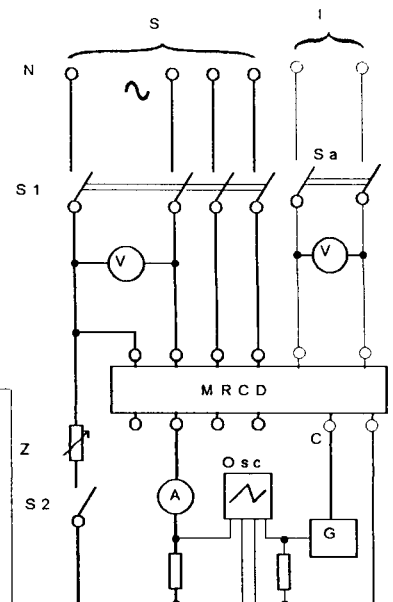
**Terminal type MRCD**



a)



b)



c)

**Key**

- S power supply
- I separate voltage source, if applicable
- V voltmeter
- A ammeter
- S1 multipole switch
- S2 single-pole switch

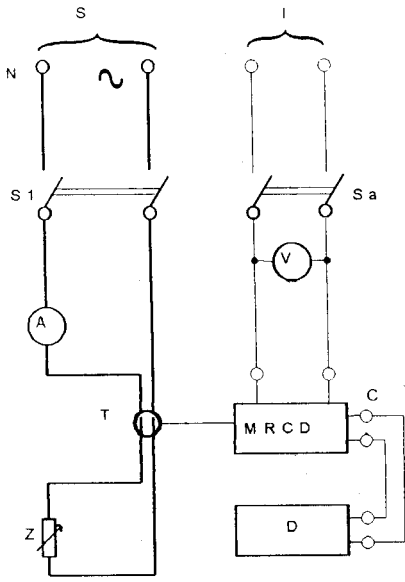
- Sa auxiliary switch
- Z variable impedance
- T sensing means
- C output circuit
- G generator
- Osc oscilloscope

**Figure M.3 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (without breaking device)**

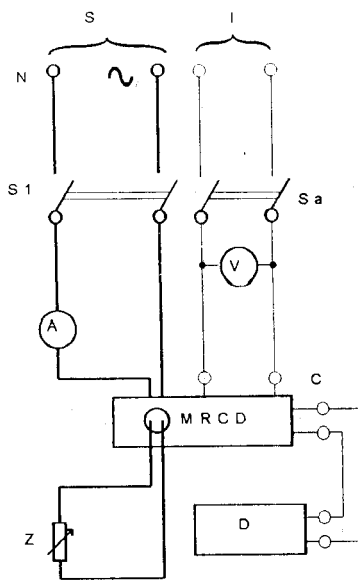
**MRCD with separate sensing means**

**MRCD with integral sensing means**

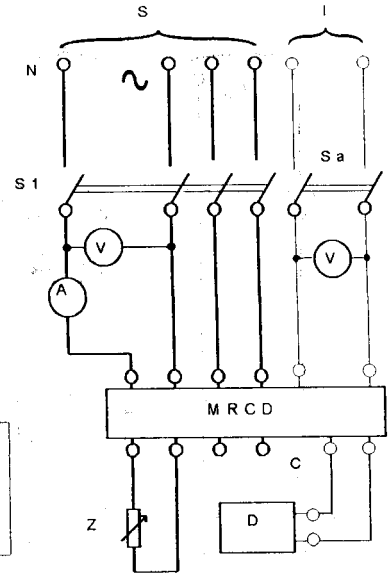
**Terminal type MRCD**



a)



b)



c)

**Key**

- S power supply
- I separate voltage source, if applicable
- V voltmeter
- A ammeter
- S1 multipole switch

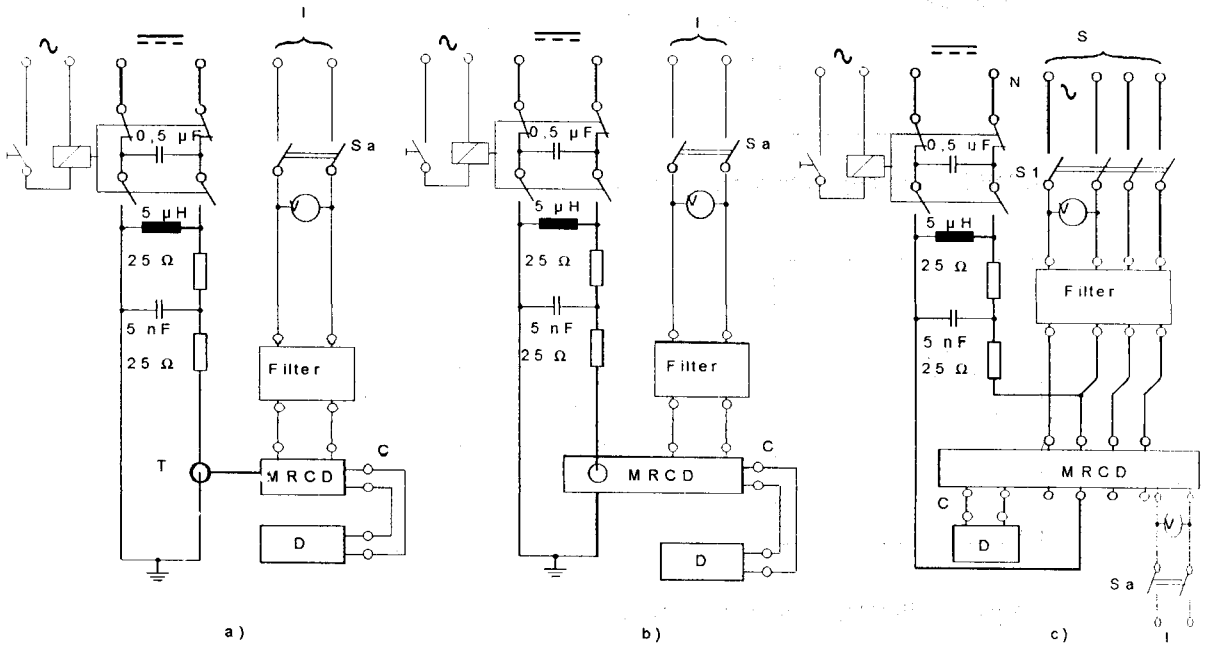
- Sa auxiliary switch
- Z variable impedance
- T sensing means
- C output circuit
- D instrument indicating the change of status

**Figure M.4 – Test circuits for the verification of the limiting value of non-operating current under overcurrent conditions**

MRCD with separate sensing means

MRCD with integral sensing means

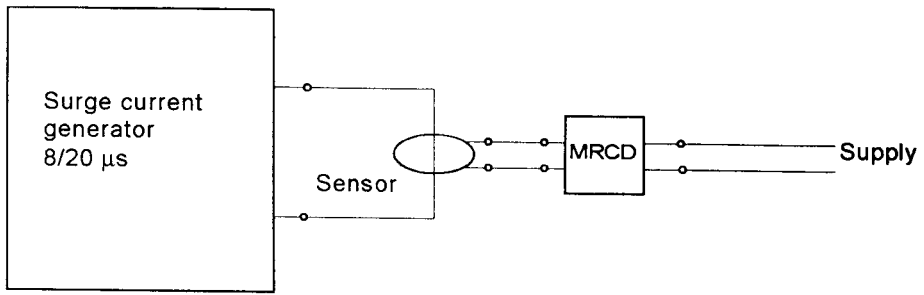
Terminal type MRCD



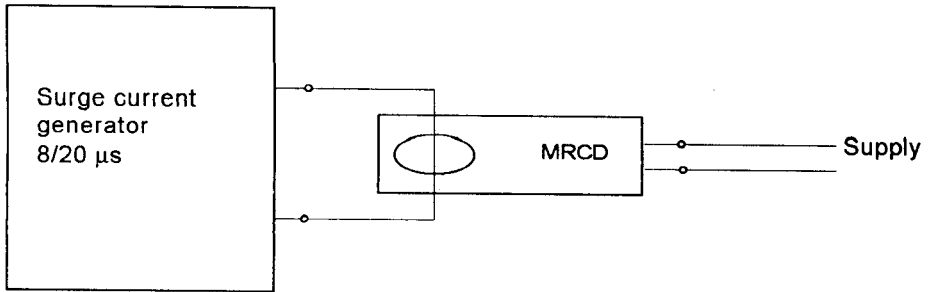
Key

- |    |  |   |  |
|----|--|---|--|
| S  | power supply                           | T | sensing means                              |
| V  | voltmeter                              | C | output circuit                             |
| I  | separate voltage source, if applicable | D | instrument indicating the change of status |
| Sa | auxiliary switch                       |   |  |

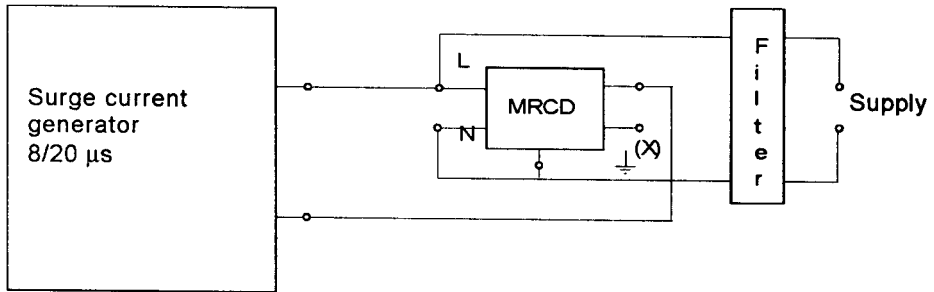
Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance



a) MRCD with separate sensing means



b) MRCD with integral sensing means

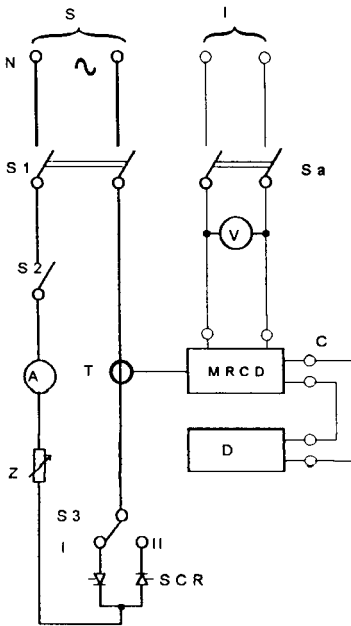


c) Terminals type MRCD

Figure M.6 – Test circuit for the verification of the resistance to unwanted tripping in the case of flashover without follow-on current

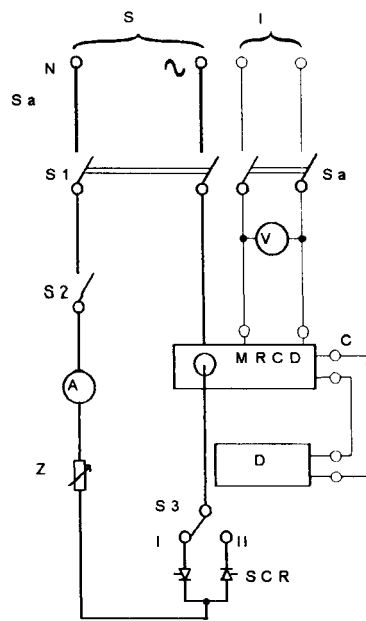


**MRCD with separate sensing means**



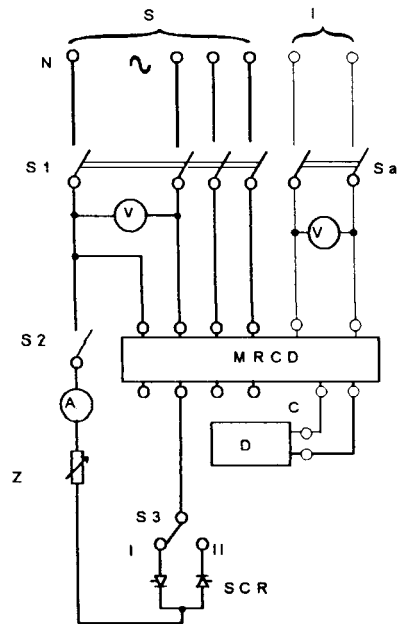
a)

**MRCD with integral sensing means**



b)

**Terminal type MRCD**



c)

**Key**

- S power supply
- I separate voltage source, if applicable
- V voltmeter
- A ammeter
- S1 multipole switch
- S2 single-pole switch
- S3 inverter switch

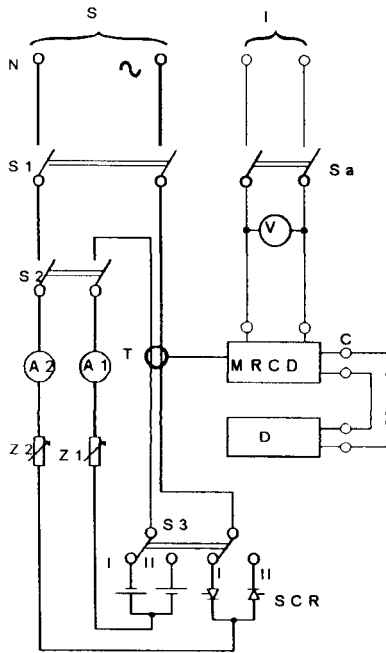
- Sa auxiliary switch
- Z variable impedance
- T sensing means
- C output circuit
- D instrument indicating the change of status
- SCR thyristor

**Figure M.7 – Test circuits for the verification of operation in the case of a continuous rise of a residual pulsating direct current**



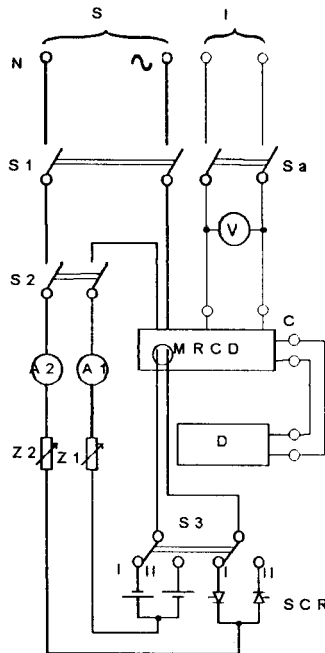


**MRC D with separate sensing means**



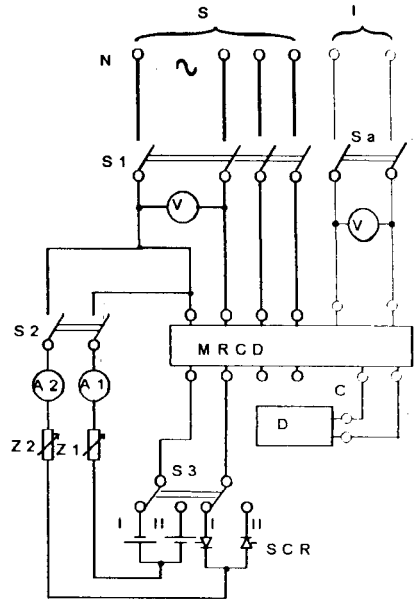
a)

**MRC D with integral sensing means**



b)

**Terminal type MRCD**



c)

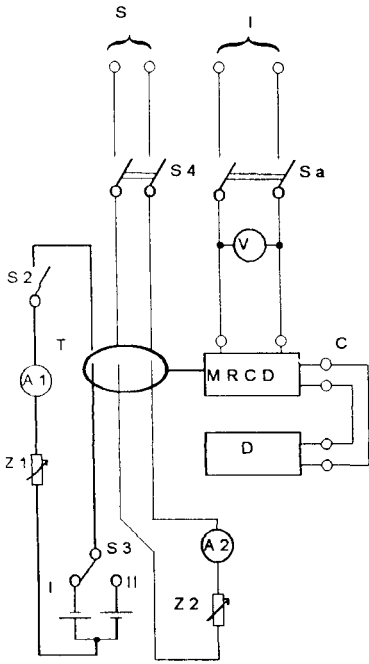
**Key**

- S power supply
- I separate voltage source if applicable
- V voltmeter
- A1 ammeter measuring d.c. current
- A2 ammeter measuring a.c. r.m.s. current
- S1 multipole switch
- S2 two-pole switch

- S3 double inverter switch
- Sa auxiliary switch
- Z variable impedance
- T sensing means
- C output circuit
- D instrument indicating the change of status
- SCR thyristor

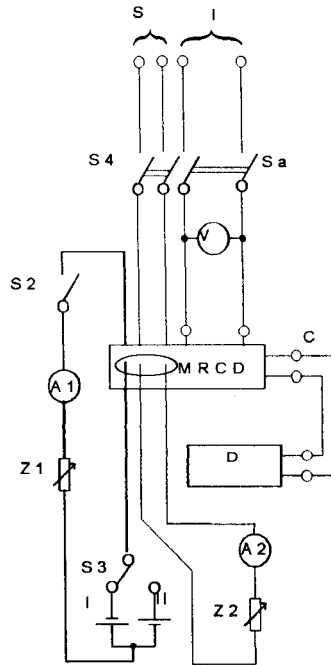
**Figure M.10 – Test circuits for the verification of operation in the case of a residual pulsating direct current superimposed by smooth direct current of 6 mA**

**MRCD with separate sensing means**



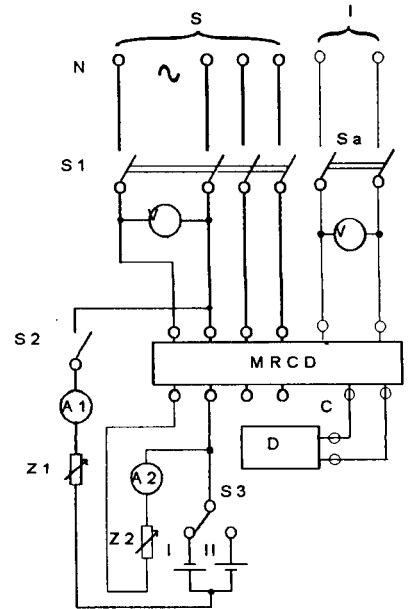
a)

**MRCD with integral sensing means**



b)

**Terminal type MRCD**



c)

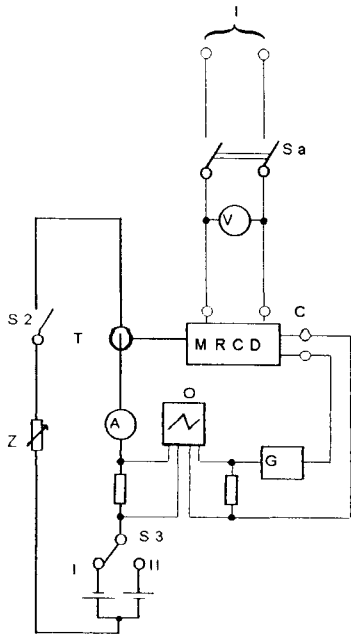
**Key**

- S power supply
- I separate voltage source, if applicable
- V voltmeter
- A1 ammeter measuring d.c. current
- A2 ammeter measuring a.c. r.m.s. current
- S1 multipole switch
- S2 two-pole switch

- S3 double inverter switch
- S4 two-pole switch
- Sa auxiliary switch
- Z1, Z2 variable impedances
- T sensing means
- C output circuit
- D instrument indicating the change of status

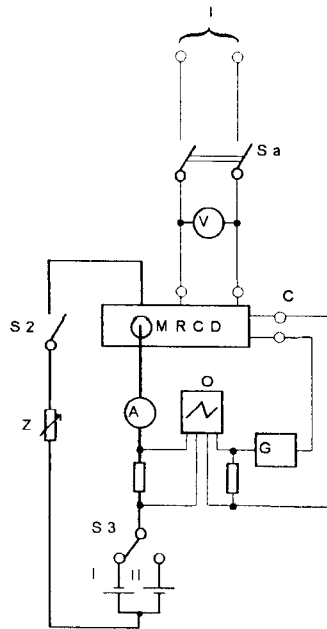
**Figure M.11 – Test circuits for the verification of operation in the case of a slowly rising residual smooth direct current**

**MRC D with separate sensing means**



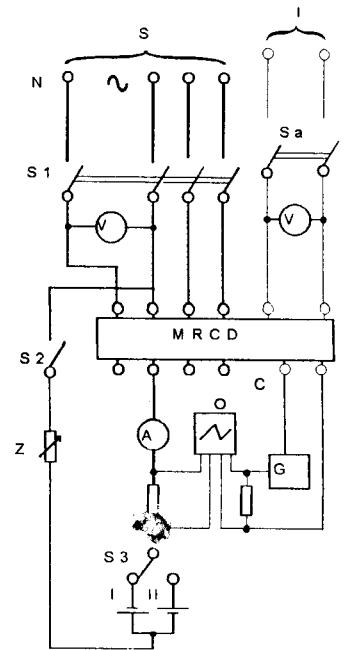
a)

**MRC D with integral sensing means**



b)

**Terminal type MRC D**



c)

**Key**

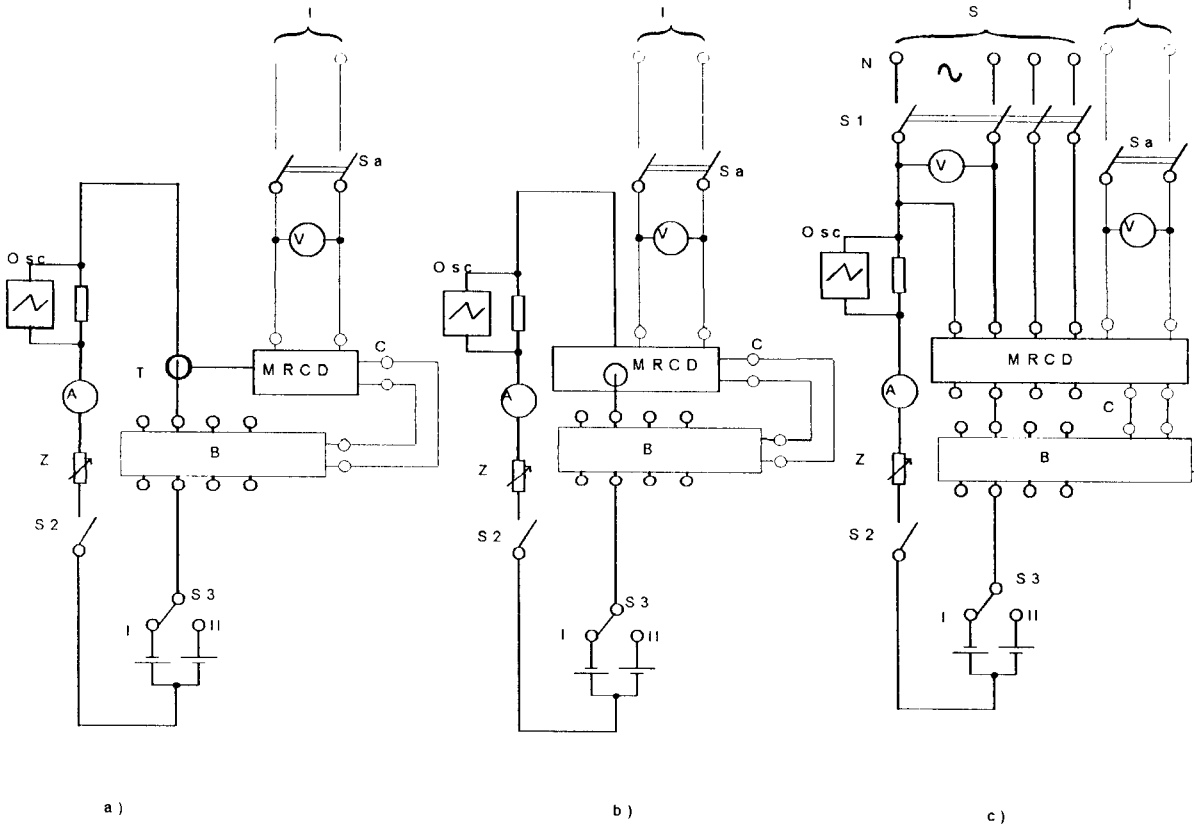
- |    |  |     |                    |
|----|--|-----|--------------------|
| S  | power supply                           | Sa  | auxiliary switch   |
| I  | separate voltage source, if applicable | Z   | variable impedance |
| V  | voltmeter                              | T   | sensing means      |
| A  | ammeter measuring d.c. current         | C   | output circuit     |
| S1 | multipole switch                       | G   | generator          |
| S2 | two-pole switch                        | Osc | oscilloscope       |
| S3 | 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)**

**MRC D with separate sensing means**

**MRC D with integral sensing means**

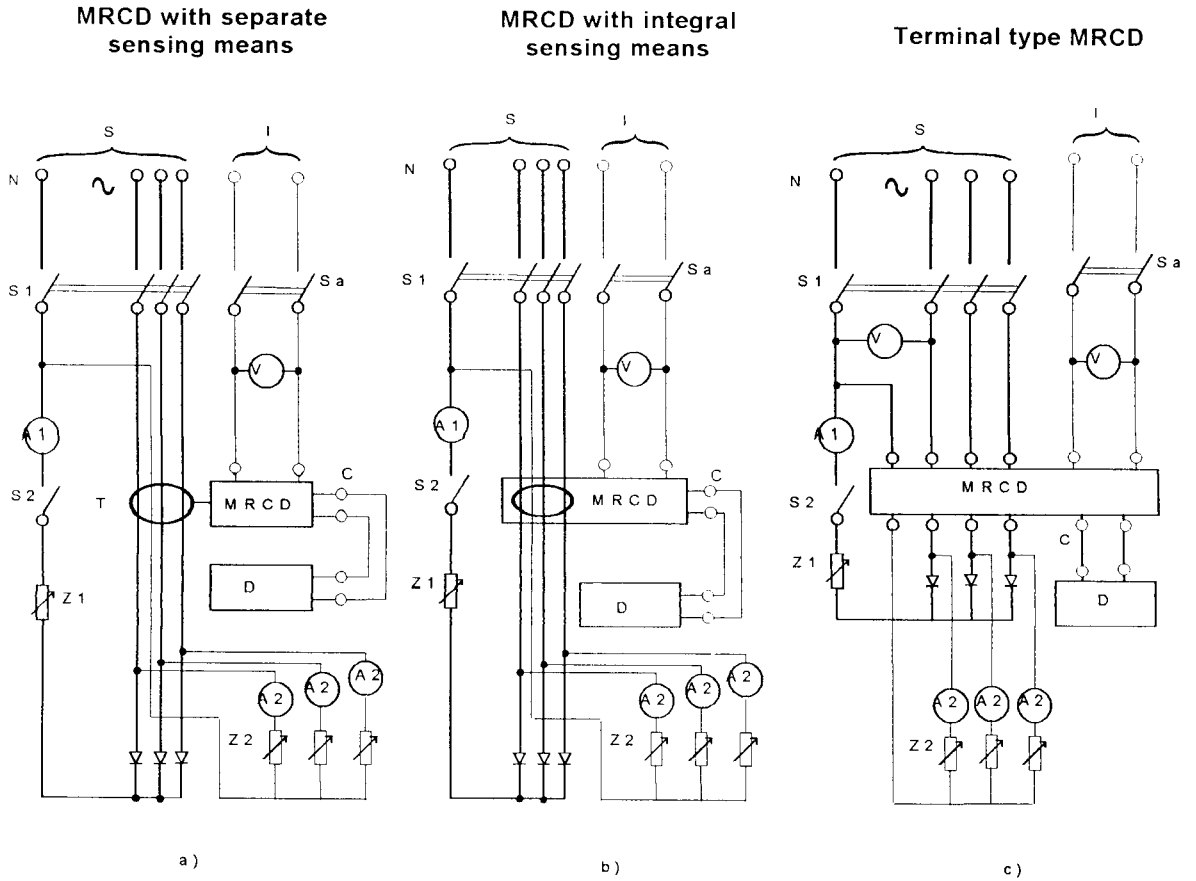
**Terminal type MRC D**



**Key**

- |    |                                       |     |                    |
|----|---------------------------------------|-----|--------------------|
| S  | power supply                          | Sa  | 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     |
| S1 | multipole switch                      | B   | breaking device    |
| S2 | single-pole switch                    | Osc | oscilloscope       |
| S3 | inverter switch                       |     |                    |

**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)**



**Key**

- S power supply
- I separate voltage source, if applicable
- V voltmeter
- A1 ammeter measuring r.m.s. current
- A2 ammeter measuring a.c. current
- S1 multipole switch

- S2 single-pole switch
- Sa auxiliary switch
- Z1, Z2 variable impedances
- T sensing means
- C output circuit
- D instrument indicating the change of status

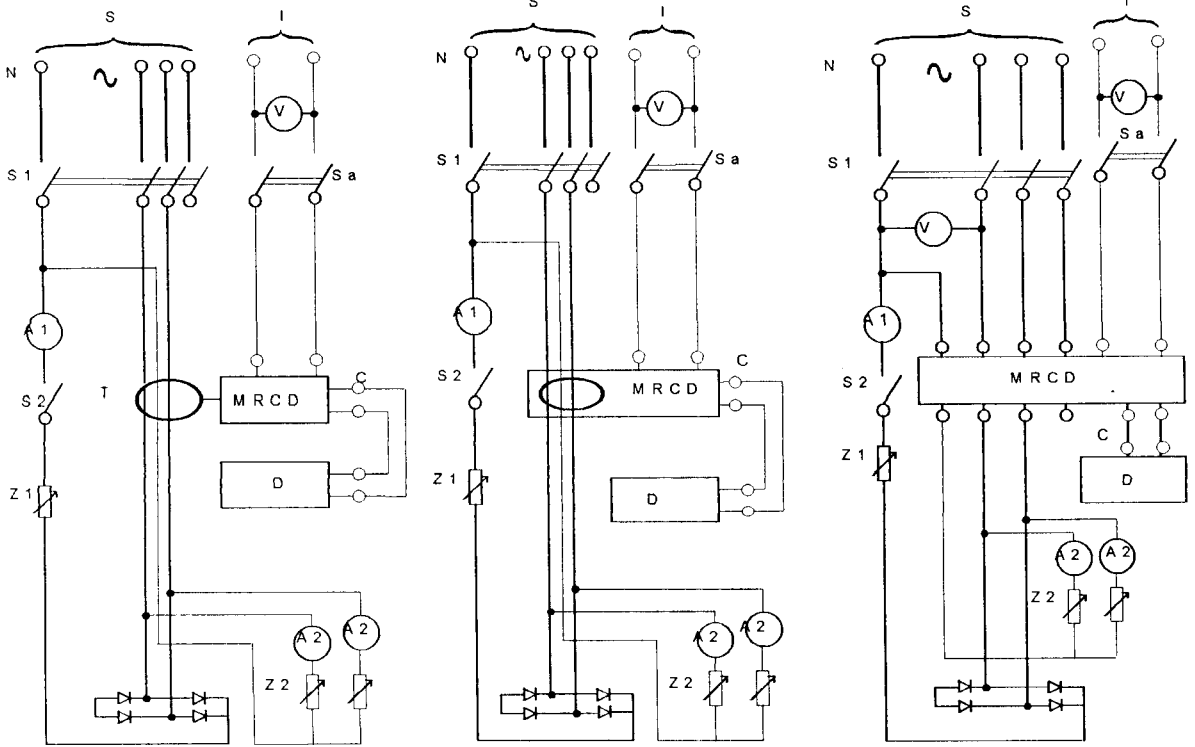
**Figure M.14 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection**



**MRCD with separate sensing means**

**MRCD with integral sensing means**

**Terminal type MRCD**



a)

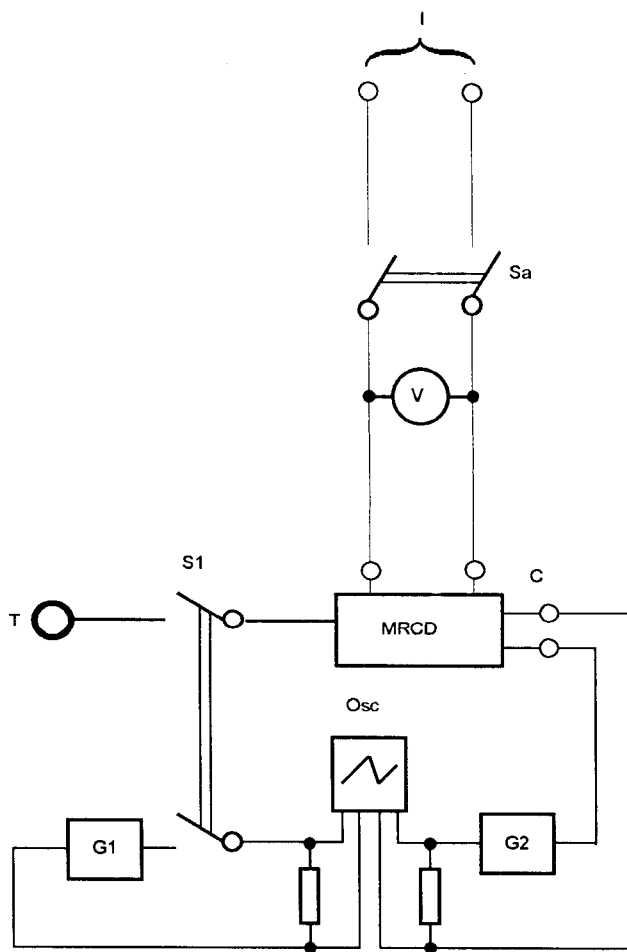
b)

c)

**Key**

- |    |  |        |  |
|----|--|--------|--|
| S  | power supply                           | S2     | single-pole switch                         |
| I  | separate voltage source, if applicable | Sa     | auxiliary switch                           |
| V  | voltmeter                              | Z1, Z2 | variable impedances                        |
| A1 | ammeter measuring r.m.s. current       | T      | sensing means                              |
| A2 | ammeter measuring a.c. current         | C      | output circuit                             |
| S1 | multipole switch                       | D      | instrument indicating the change of status |

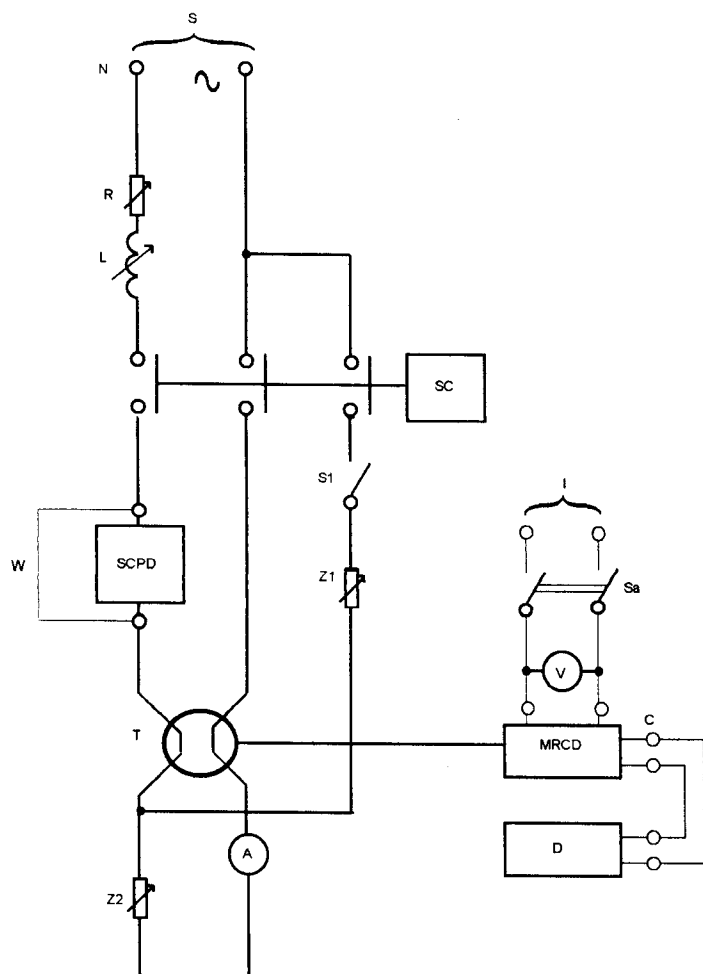
**Figure M.15 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line**



**Key**

- |    |  |     |                |
|----|--|-----|----------------|
| I  | separate voltage source, if applicable | T   | sensing means  |
| V  | voltmeter                              | C   | output circuit |
| S1 | multipole switch                       | G   | generator      |
| Sa | auxiliary switch                       | Osc | oscilloscope   |

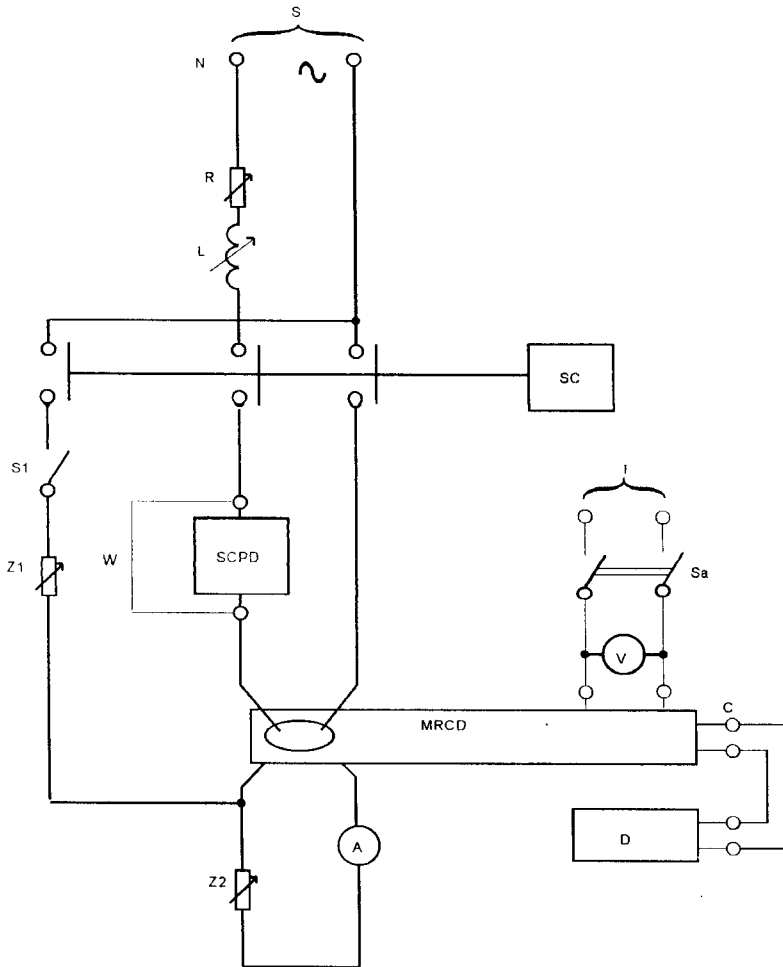
**Figure M.16 – Test circuit for the verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensor means connection**



## Key

S	power supply	L	variable reactor
I	separate voltage source, if applicable	R	variable resistance
V	voltmeter	Z1, Z2	variable impedance
A	ammeter	T	sensing means
S1	single-pole switch	C	output circuit
Sa	auxiliary switch	D	instrument indicating the change of status
SC	short-circuit switch	SCPD	short-circuit protective device
W	temporary connection		

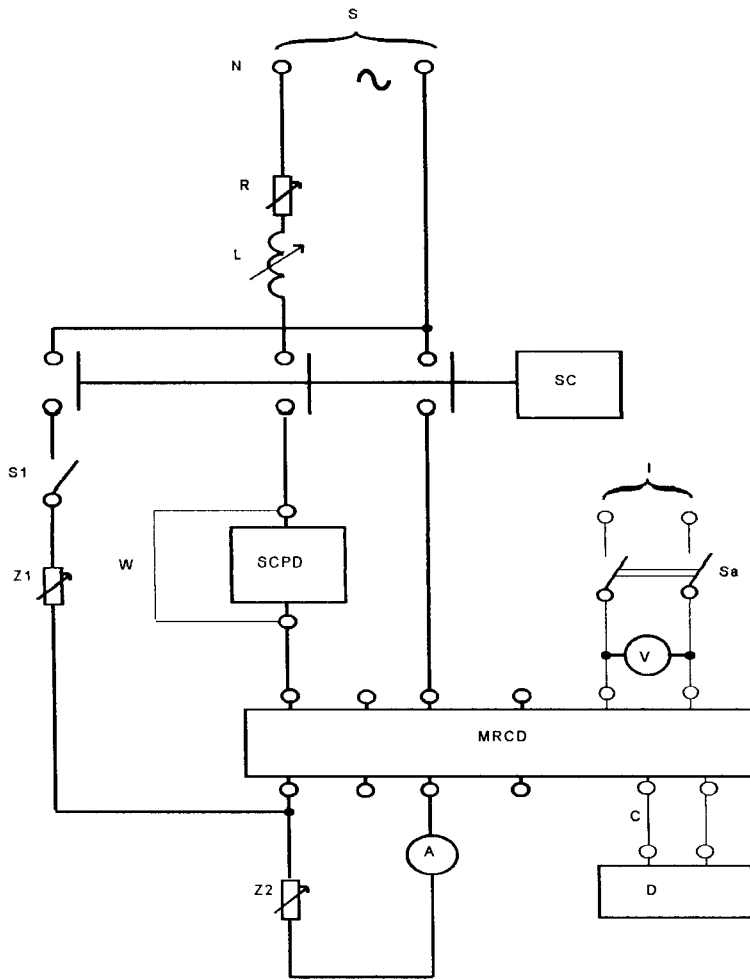
**Figure M.17 – Test circuit for the verification of the behaviour of MRCD with separate sensing means under short-circuit conditions**



**Key**

- |    |  |        |  |
|----|--|--------|--|
| S  | power supply                           | W      | temporary connection                       |
| I  | separate voltage source, if applicable | L      | variable reactor                           |
| V  | voltmeter                              | R      | variable resistance                        |
| A  | ammeter                                | Z1, Z2 | variable impedances                        |
| S1 | single-pole switch                     | C      | output circuit                             |
| Sa | auxiliary switch                       | D      | instrument indicating the change of status |
| SC | short-circuit switch                   | 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         | R      | variable resistor                          |
| A  | ammeter              | Z1, Z2 | variable impedances                        |
| S1 | single-pole switch   | C      | output circuit                             |
| SC | short-circuit switch | D      | instrument indicating the change of status |
| W  | temporary connection | SCPD   | short-circuit protective device            |
| L  | variable reactor     |        |  |

**Figure M.19 – Test circuit for the verification of the behaviour of terminal type MRCD under short-circuit conditions**

**Annex N**  
(normative)

**Electromagnetic compatibility (EMC) –  
Additional requirements and test methods for devices  
not covered by annexes B, F and M**

**N.1 General**

**N.1.1 Scope**

This annex applies to devices, mounted in or on the circuit-breaker, incorporating electronic circuits (see 7.3 of IEC 60947-1), and not covered by annexes B (circuit-breakers incorporating residual current protection), F (circuit-breakers with electronic overcurrent protection) and 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 50 Hz – 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 annexes B and F, where applicable (e.g. electrostatic discharges, radiated radio-frequency 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.

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### **N.2.3 Radiated radio-frequency 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, 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 figure 4 of IEC 61000-4-4, 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 6, 7, 8 or 9 of IEC 61000-4-5, taking into consideration the manufacturer's instructions for installation.

*Performance criterion B applies.*

### **N.2.6 Conducted disturbances induced by radio-frequency 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.

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), 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 annexes B and 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 – 30 MHz)**

Annex J applies, in particular J.3.2.

#### **N.3.3 Radiated RF disturbances (30 MHz – 1 000 MHz)**

Annex J applies, in particular J.3.3.

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## BUREAU OF INDIAN STANDARDS

### Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002

Telephones: 2323 0131, 2323 3375, 2323 9402

Website: [www.bis.org.in](http://www.bis.org.in)

### Regional Offices:

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg  
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Telephones

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2323 3841

Eastern : 1/14, C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi  
KOLKATA 700 054

{ 2337 8499, 2337 8561  
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Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160 022

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