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Guidance for the correct use of residual current-operated protective devices (RCDs) for household and similar use

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Indications pour un bon usage des dispositifs différentiels résiduels (DDR) pour usages domestiques et analogues

Guidance for the correct use of residual current-operated protective devices (RCDs) for household and similar use

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CONTENTS

INTRODUCTION

It is the purpose of this document to provide guidance and information to designers, manufacturers, installers, users and persons in charge of installation maintenance on the selection, erection and use of RCDs in fixed installations with a view to optimisation of the long term availability of the protection provided by RCDs.

Over the last forty years the experience accumulated on RCDs by manufacturers, laboratories, installers, users and installation bodies has been collated and used by IEC technical committees (in particular within SC23E) to achieve improvements in the reliability of RCDs through revisions of IEC RCD standards. Requirements and tests have been added or improved within such IEC standards towards this objective. Considerable progress was made when SC23E decided to introduce requirements such as a 28-day environmental test whose purpose is to simulate RCD ageing.

Users, installers and other committees within IEC need to be informed that although the reliability of an RCD compliant with relevant RCD standards has been substantially improved in comparison to earlier RCDs, availability of protection provided by RCDs is linked to many parameters, not all being related to RCDs themselves but including also the installation and the environmental conditions.

This guide has identified and addressed in a comprehensive way the key factors impacting on availability of RCD protection so as to contribute further towards the reliable operation of RCDs in service and further enhance the valuable protective functions provided by these devices. SC23E will continue to monitor this important area with a view to building on the work that has been completed through publication of this guide.

Additional information: during a meeting between TC64 and SC23E officers it was confirmed that this guide does not conflict with TC64 standards and that the purpose of the guide is to provide information leading to a better understanding of the correct use of RCDs.

GUIDANCE FOR THE CORRECT USE OF RESIDUAL CURRENT-OPERATED PROTECTIVE DEVICES (RCDs) FOR HOUSEHOLD AND SIMILAR USE

1 Scope

This technical report provides an overview of protection availability provided by residual current-operated protective devices (RCDs) complying with IEC standards for household and similar uses. It highlights the main parameters influencing protection reliability and provides information on how to install and operate RCDs in relationship to their environmental conditions after installation.

This guide gives general information concerning availability of the protection within the fixed installation and how to keep a high level of availability of protection during use (installation and maintenance). It has been drafted for the benefit of IEC technical committees, installers, inspectors and users.

NOTE 1 The term RCD is a generic term applied to a family of products which open automatically in response to a residual current at or exceeding the RCD's rated residual operating current, $I_{\Delta n}$. This generic term is often applied to the following.

RCCB - **R**esidual **C**urrent **C**ircuit **B**reaker without overcurrent protection

RCBO - **R**esidual **C**urrent **B**reaker with **O**vercurrent protection

SRCD - **S**ocket outlet **R**esidual **C**urrent **D**evice

PRCD - **P**ortable **R**esidual **C**urrent **D**evice

A RCCB differs from a RCBO in that the RCBO will additionally respond to overcurrent conditions whereas the RCCB will not respond to such conditions.

NOTE 2 PRCDs are not considered to be part of the fixed installation, and are not covered by this guide.

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 60364 (all parts), *Electrical installations of buildings*

IEC 60364-4-44:2001, *Electrical installations of buildings – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-5-51, *Electrical installations of buildings – Part 5-51: Selection and erection of electrical equipment – Common rules*

IEC 61008 (all parts), *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs)*

IEC 61008-1:1996, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*
Amendment 1 (2002)
Amendment 2 (2006)

IEC 61009 (all parts), *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)*

IEC 61009-1:1996, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 1: General rules*
Amendment 1 (2002)
Amendment 2 (2006)

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

IEC 61543:1995, *Residual current-operated protective devices (RCDs) for household and similar use - Electromagnetic compatibility*

3 Terms and definitions

(See in Annex B official definitions from IEV)

4 General information concerning availability of RCD protection

4.1 Availability of RCD protection

Availability of RCD protection is the ability of an item to perform a required protective function under given conditions within an appropriate installation over a given period of time. Availability of RCD protection is not limited to the equipment but includes parameters from the installation such as PE continuity, appropriate earth resistance value, insulation resistance and environmental conditions.

NOTE 1 Periodic verification of the installation including verification of electrical loads and equipment incorporating RCDs is advised. After verification, appropriate corrective measures have to be taken, e.g. repairing the installation or replacing faulty equipment, etc.

The value of availability of RCD protection may be expressed in percentage terms when looking at a homogeneous population of RCDs within the same installation, or to express the probability for a single device to perform the protective function after a defined period of time.

NOTE 2 Protection: the required function is to operate when required to do so and not to operate when not required to do so.

NOTE 3 The availability of the protective measure corresponds to the real need of the user.

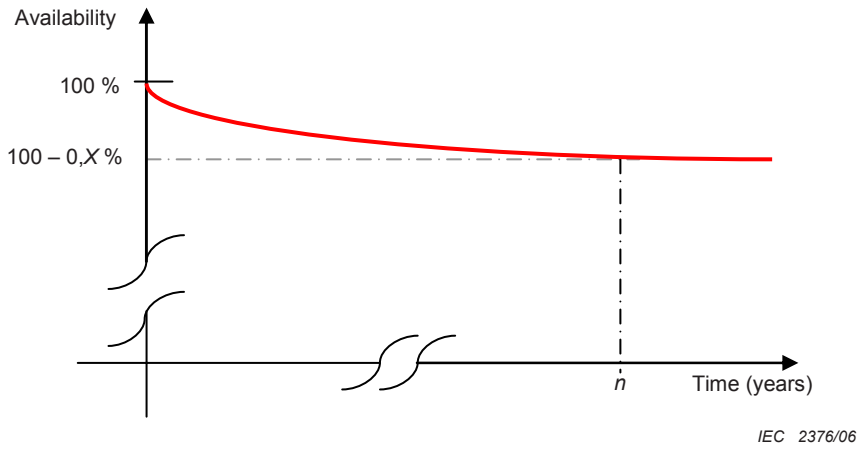
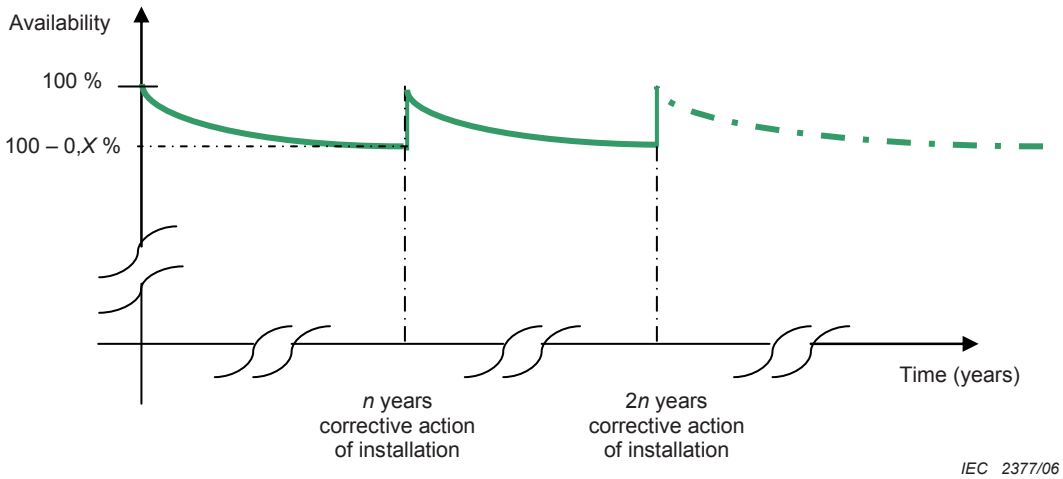


Figure 1 – Theoretical availability of protection without corrective measure within the installation



NOTE This figure is based on hypothesis of Figure 3, which supposes that the failure rate is stable within the useful life.

Figure 2 – Theoretical availability of protection with corrective measures made within the installation during periodical verification

Figure 1 shows that the RCD protection will decrease if the installation is not verified. For example a 300 mA RCD used for indirect contact protection might not trip if the earth resistance increases after a certain time.

Figure 2 shows that in case of periodic verification within the installation, the availability of protection is restored to 100 % if appropriate corrective measures are taken, e.g. replacement of faulty equipment.

4.2 Failure of the RCD to operate

The lack of operation of an RCD which should have operated but which did not operate as intended.

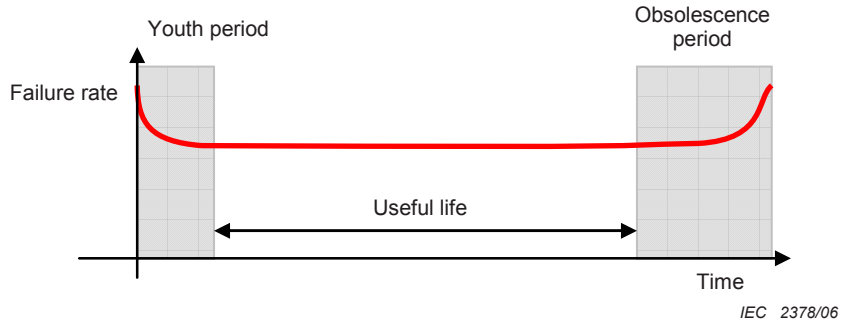
4.3 Failure rate

The probability of occurrence of a “failure to operate” over a given period of time.

4.4 **Useful life** (see Figure 3)

Under given conditions, the time interval from commencement of use to when the failure level becomes unacceptable.

NOTE The useful life of an RCD cannot be expressed in hours or years due to the influence of the particular conditions of service. Endurance, short-circuit and accelerated life tests, etc. are conventional means to assess an expected useful life.



NOTE At the end of the useful life period the failure rate will increase and availability of the protection can only be assured by replacement of the protective device.

Figure 3 – Failure rate and useful life

4.5 Available surveys

Several surveys have been published in relation to RCDs installed in various countries over many years and in different types of installation.

The analysis of these surveys highlights the following key information.

– Up to 50 % of the “faulty” RCDs were found to be fully functional when subsequently tested in the laboratory. These “failures” were attributed to installation conditions, such as faulty installations, miswiring, etc.

– Many RCDs had been fitted in installations in agricultural premises without due regard for the environmental conditions in such installations which were far more severe than those encountered in households and similar installations.

– Climatic and electromagnetic environmental conditions were major influencing factors. It was noted that the failure rate increased significantly in cases of use of RCDs in conditions that are beyond those defined in the relevant RCD standards.

Most of the studies related

– to RCDs fitted in installations more than twenty years old,

– and to RCDs not covered by current editions of IEC RCD standards. Most of the RCDs tested had been installed prior to publication of IEC 61543 (1995), which sets out EMC requirements for RCDs. Prior to 1996, RCDs were not subjected to a broad range of EMC tests.

5 Information related to contribution of products to the availability of protection

5.1 Contribution of compliance with RCD standards

5.1.1 General

The relevant IEC standards covering RCDs intended for household and similar use are as follows:

– IEC 61008 RCCBs for household and similar use,

– IEC 61009 RCBOs for household and similar use,

– IEC 61543 EMC requirements for RCDs.

Compliance with relevant product standards has to be ensured by the manufacturer for all devices produced. This compliance can be ensured through

– type test conformity assessment (manufacturer's declaration or certification), and

– routine tests as required by the standard.

Installers and users should only use RCDs fully complying with IEC standards.

RCD ratings are given in the relevant RCD product standards. Except for the tolerances specified in these standards, the RCD ratings must not be exceeded. Operation of the RCD outside its specified ratings is likely to result in damage to the RCD and undermine availability of the protective function.

5.1.2 Contribution of standardised environmental conditions to the availability of protection

RCDs complying with IEC 61008, IEC 61009 and IEC 61543 are intended to be used in normal indoor conditions expected in household and similar uses where

– the extreme temperature range does not exceed –5 °C to 40 °C, with a reference value of 20 °C;

– the relative humidity level does not exceed 50% at 40°C;

– the air pressure remains in the range of 70 kPa to 106 kPa (altitude < 2 000 m);

– the quality of the atmosphere is that to be normally expected in a household, being neither corrosive nor lacking of adequate ventilation;

– the external magnetic field does not exceed 5 times the earth's magnetic field in any direction.

5.1.3 Contribution of the standardised tests to the availability of protection

The availability of the RCD protection during its useful life and under the conditions of use as foreseen is considered to be verified by specific tests (see list below referring to IEC 61008) performed in the different type test sequences.

These specific requirements and tests either simulate ageing of the RCD or verify the withstand capability to stresses that may occur at any time during use.

– Marking
– Mechanism
– Trip-free mechanism
– Resistance to heat
– Resistance of insulation against impulse voltages
– Reliability at 40 °C
– Ageing of electronic components
– Mechanical and electrical endurance
– Unwanted tripping
– Performance at $I_{\Delta m}$
– Test device
– Non-operating current under overcurrent conditions
– Coordination at I_{nc}
– Performance at I_m
– Coordination at I_m
– Coordination at $I_{\Delta c}$
– Reliability (climatic tests)

EMC phenomena, IEC 61543

– Conducted unidirectional transients of the ms and µs time scale
– Conducted and radiated high frequency voltages
– Conducted unidirectional transients of the ns time scale (burst)
– Electrostatic discharges

5.2 Contribution of design and manufacturing

5.2.1 General

Reliability of equipment is basically a design parameter such as technical performances that are addressed by the manufacturer and that can also be affected by installation considerations.

The manufacturer must apply design considerations that address mechanical, electrical, software and other factors that contribute to reliability.

Additionally, the following actions may be applied by the manufacturer:

– follow up tests (as defined in annex in IEC 61008 and IEC 61009) (manufacturer's declaration or certification);
– quality assurance (compliance with ISO 9000 series);
– continuous improvement.

5.2.2 Mechanical and electrical design

All RCDs contain circuitry and mechanism parts and may also include electrical or electronic components all of which contribute to the protective function.

Such circuitry, mechanism and components may be sensitive to temperature, humidity and voltage stresses. With appropriate design and manufacturing, these parts will be tolerant to humidity, temperature, corrosion and voltage stresses that are to be expected in normal use in household and similar applications as given in relevant IEC standards.

6 Availability of protection in installations fitted with RCDs

6.1 General considerations

Although availability of protection provided by RCDs or other electrical equipment depend on good design and high quality manufacturing, it must also be acknowledged that RCDs are not used alone, but form part of an electrical installation.

Factors relating to the installation and use of the electrical installation may influence the availability of protection or correct operation of electrical equipment such as RCDs after installation. This type of availability cannot be checked by tests in product standards and therefore requires periodic verification of installations.

RCDs tested in accordance with IEC 61008 or IEC 61009 standards concern devices intended to be used by unskilled and uninstructed persons in installations or equipment not subject to maintenance. Nevertheless, a regular verification of installations including the verification of RCD equipment is advised in order to keep a high level of availability of the protection (see Figure 2).

– Equipment provided for checking the correct tripping of RCDs after installation should be used with care since measurement may be influenced by parameters linked to the installation. Analysis of some RCDs apparently not functioning indicated that they were actually incorrectly wired or installed.
– Environmental conditions can have a considerable influence on ageing and availability of the RCD protection. The use or operation of an RCD outside its intended range may impair its correct operation or reliability. Such environmental conditions may include; high humidity level; extreme temperatures, the presence of corrosive gas; high keraunic level; recurring overvoltages; vibrations, etc.
– Quality of the mains supply can also influence ageing of RCDs. Tolerances to voltage levels, dips, frequencies, sinusoidal wave distortion, etc. should be considered.

Excessive operations or abnormal use of electrical equipment such as RCDs will reduce the availability of the protection. RCDs should therefore be replaced in the event of abnormal use. Examples for excessive operations or abnormal use are as follows:

– reclosing several times in quick succession (e.g. in an attempt to locate a fault within an installation);
– use of RCDs without appropriate enclosure in humid environment;
– temperature outside the specified limits;
– excessive shock or vibration.

From the above consideration and due to the large number of parameters influencing the correct operation of RCDs, it is understandable that it is not possible to predict a number of years or months for an expected lifetime of the RCD.

Nevertheless, users of RCDs should also understand that, although RCDs tested in accordance with IEC 61008 or IEC 61009 standards are recognised reliable and not subject to maintenance, they cannot provide protection for ever. Considering all aspects of availability of protection, it is therefore important

– to check installations, including the functioning of the RCD, during commissioning;
– to regularly verify installations, electrical loads and electrical equipment including RCD equipment during the installation life and to replace failing loads and electrical equipment including RCDs;
– to consider replacing loads or equipment, including RCDs, after a certain number of years depending on the conditions of use or installation.

It is recommended that consideration be given to replacing RCDs complying with IEC standards published before 1996 or not tested in accordance with climatic tests (e.g. 28-day test) because such RCDs are unlikely to have been designed to meet the more demanding requirements of the later standards and tests.

6.2 Recommendations concerning the correct use of the test button

The test button provided on the RCD offers a quick and easy way to simulate a fault current within the RCD for checking the ability of the RCD to operate. Tripping in response to operation of the test button indicates that the RCD is able to operate correctly. Any external means of testing the RCD should be used with care due to the possible influence of the installation.

NOTE Several reports mentioned that testing an RCD within an installation is sometimes difficult since the installation may influence the results. Field studies indicated that RCDs were considered faulty at the first glance during installation testing but worked perfectly when removed and tested again. The earth leakage within an installation (e.g. through filters in electronic loads or capacitors in cables) can have a strong effect on the test results. The characteristics of the installation may also need to be considered when testing an RCD by external means.

It is recommended to use the test button during regular verification of installation. A marking on the device and/or in the vicinity of the device should highlight this recommendation. Examples of use of the test button are given in Annex D.

6.3 Recommendations for testing the availability of RCD protection within the installation

Circuits downstream of the RCD may have permanent leakage, load leakage, stored energy or abnormal neutral to earth fault. This can affect the result of testing and increase the measured trip time.

NOTE 1 For a reliable measurement of the RCD's performance it is highly recommended to disconnect all loads connected to the circuit downstream of the RCD. In certain cases where the length of cable downstream of an RCD is substantial, permanent leakage current due to the capacitance of cables should be considered.

NOTE 2 The use of RCD testers according to IEC 61557-6 is preferred.

The testing current should be applied between the upstream and downstream terminal of the RCD.

RCDs may contain components, such as SPDs, that may not pass an insulation test and may have a withstand voltage below 500 V d.c.. Some RCDs may have electronic circuits between Neutral and earth.

A test made between one phase terminal and earth is not suitable for two reasons:

– it may be hazardous in case of disconnected PE;

– it may lead to erroneous measurement due to installation characteristics.

The measurement should therefore be made according to the relevant product standard procedure.

Testing using an RCD tester or instruments should be done by a skilled person.

NOTE 3 Skilled person: a person with relevant education and experience to enable him or her to avoid dangers and to prevent risks which electricity may create. (IEV 826-18-01).

In the frame of this document, it is also a person having the necessary practical and theoretical skills, acquired through training, qualification, experience or a combination of these, to correctly undertake the testing of an RCD in the field.

It is expected that this person should

(i) be able to use test equipment safely and effectively in accordance with the information provided in this guide;

(ii) have an understanding of the dangers of electricity, leading to an appreciation of the need for inspection and testing;

(iii) have an understanding of the construction of class I and class II equipment, and of the terms: basic, reinforced and double insulation, protective earth and earth continuity, insulation resistance and earth leakage current;

(iv) have an understanding of the application and requirements of IEC product standards for RCDs;

(v) follow technological advances in both the testing instrumentation available and the equipment being examined.

Insulation resistance tests should not be carried out unless specifically agreed by the manufacturer. If agreed, the values typically from line and neutral joined together and earth should be less than 0,5 MΩ.

NOTE 4 The insulation resistance of RCDs with functional earth (FE) connections should not be less than 0,1 MΩ. Alternatively, portable RCDs which require the supply to be closed, and units with a FE connection may be tested for leakage current with a maximum value allowed being 2,5 mA. (A functional earth is a connection to earth to ensure the correct normal operation of the RCD in case of a broken supply Neutral connection).

6.4 Recommendations concerning the choice and installation of RCDs

6.4.1 Selection of RCDs according to the type of earth fault current

It is recommended to select the RCD according to the type of application and earth fault current that can occur.

RCDs are classified into different categories, as follows, in according with their ability to ensure protection against various types of earth fault currents. (Additional information is provided in Annex C).

– **Type AC residual current device**

  Residual current device for which tripping is assured

  – for residual sinusoidal alternating currents, whether suddenly applied or slowly rising.

– **Type A residual current device**

  Residual current device for which tripping is assured:

  – as for type AC; and

  – for residual pulsating direct currents, and

  – for residual pulsating direct currents superimposed on a smooth direct current of 0,006 A

with or without phase-angle control, independent of polarity, whether suddenly applied or slowly rising.

– **Type B residual current device**

Under consideration.

Residual current device for which tripping is assured as for type A according to IEC 61008-1 or IEC 61009-1 as applicable and in addition

- for residual sinusoidal alternating currents up to 1000 Hz,
- for residual smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA, whichever is the highest value superimposed on an alternating current,
- for residual smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA, whichever is the highest value superimposed on a pulsating direct current,
- for residual pulsating rectified d.c. currents which results from two or more phases,
- for residual smooth direct currents originating from multiphase circuits.

The above specified residual currents may be suddenly applied or slowly increased.

6.4.2 Selection of RCDs according to residual operating current (sensitivity)

RCDs can be provided with any value of rated residual operating current, $I_{\Delta n}$. However, the following are standard values used in IEC standards.

– 6 mA, 10 mA, 30 mA, 100 mA, 300 mA and 500 mA.

NOTE 30 mA is the maximum value permissible for personal shock protection, and 300 mA is the maximum value permissible for fire protection. If RCDs with non-standard values are used, the limits for shock protection and fire protection must not be exceeded. See 7.4.2.

6.4.3 Minimizing unwanted tripping

In accordance with relevant product standards, RCDs have to meet EMC requirements given in IEC 61543. They therefore provide adequate immunity against disturbances usually encountered in public supply networks. However RCDs may be prone to unwanted tripping due to a number of factors. The most common are as follows:

i) impact of standing leakage currents on the installation;

ii) impact of harmonics and high frequency leakage currents;

iii) impact of transient residual currents on an installation (e.g. caused by switching loads);

iv) surge currents caused by lightning strikes.

The user or installer who suspects the likelihood of any of the major factors above should consider the following possibilities. (See also Subclause 7.3.)

– Consideration should be given either to dividing the installation into several individual circuits, each of which is protected by an RCD, or to reducing the length and number of loads connected to one RCD.

– Consideration should be given to the effect on RCD operation if SPDs are installed in a circuit protected by an RCD (see 7.2.2).

– Use of RCDs type S or installation of specially designed filters or the use of special RCDs being careful to closely follow the manufacturer's specifications provided with the product.

NOTE In the case of socket-outlet circuits protected by a single RCD, in particular in the case of RCDs having $I_{\Delta n}$ lower than or equal to 30 mA, consideration should be given to the number of socket-outlets protected and to the nature of the equipment likely to be connected to them.

7 Information related to the installation and use of RCDs in the field

7.1 General considerations and measures concerning harsh environment

RCDs complying with IEC 61008 and IEC 61009 and IEC 61543 are intended to be used in normal indoor conditions found in "Household and Similar Use" (see 5.1.1). They are not subjected to maintenance.

EMC environmental requirements are given in IEC 61543. Consequently, long term availability of protection provided by RCDs complying with the above standards can be reasonably assured. It is not possible to allocate RCDs to different categories linked to environmental conditions because the number of combinations of particular conditions and levels is too high to allow realistic classification.

If an RCD is used under different conditions than those described in Table 2 of IEC 61008-1 or Table 4 in IEC 61009-1 (for example agricultural premises, outdoor uses, vicinity to radio transmitters close to a seaside, in a corrosive ambience such as bleach or other corrosive substance, etc.), special precautions should be taken in order to avoid accelerated ageing.

In order to keep availability of protection at a high level, it is recommended to check the manufacturer's documentation in order to determine if an RCD is suitable for use in harsh environmental conditions, e.g. special IP rated, high surge rated RCDs. Consideration should be given as to whether additional protective measures should be recommended:

– first, it is advised to regularly check the installation, enclosures and equipment such as RCDs in accordance with the recommendation in this guideline. Replacing RCDs after a shorter period of time than usual under normal environmental conditions should be considered;
– install the RCD in appropriate shelter to reduce influences by external environmental conditions, e.g. using enclosures, ventilation, heating and drying means. The result of sheltering should be to represent the normal environmental conditions.

NOTE 1 For special installations, the minimum degree of protection IP provided by the equipment or its enclosure is defined in the relevant part 7 of IEC 60364 (IEC 60364-7, *Electrical installations of buildings - Part 7: Requirements for special installations or locations*).

NOTE 2 Heating an enclosure in order to reduce the relative humidity level may be inappropriate. Efficiency of the heating system depends on ventilation and humidity control. Heating humid air may be worse than doing nothing. It may be better to dry air than to heat.

7.2 Most significant parameters to take into account

7.2.1 General

The following table derived from IEC 60364-5-51 sets out in detail the most significant external influences regarding the functioning and availability of protection of RCDs. It also sets out the standard levels according to the external influences found in household and similar use.

For more severe conditions, attention is drawn to the importance of the relevant criteria, which may impair the functioning of RCDs. The advice of the manufacturer should be sought before selecting and installing RCDs in such conditions.

Classification from IEC 60364-5-51				Existing RCD standards
Code	External influences [d]	Importance [b]	Standard level	Corresponding standard characteristics
AA	*Temperature (°C)*	++	AA4	–5 °C +40 °C [c]
AB	*Temperature and humidity*	+++ [a]	AB4	5 % 95 %
AC	*Altitude (m)*	+	AC1	≤ 2 000 m
AD	*Water*	++ [a]	AD1	IPX0
AE	*Foreign bodies*	++	AE1	IP2X
AF	*Corrosion*	+++ [a d]	AF1	Negligible
AG	*Impact*	+	AG1	Low severity
AH	*Vibration*	+	AH1	Low
AK	*Flora and moulds growth*	+	AK1	No hazard
AL	*Fauna*	+	AL1	No hazard
AM	*Radiation (EMC)*	+++	See IEC 61543	
AQ	*Lightning*	++	AQ2	Indirect exposure according to IEC 60364-4-44 Clause 443.

[a] The influence of humidity on the surface of electrical, electronic and mechanical parts of the equipment may impair reliability due to corrosion and influence on insulation.

[b] The number of + signs indicates an approximate evaluation of importance of the external influence. The minus sign indicates that there is no influence on the availability of the protection.

[c] In some countries, the current standards include a classification according to the ambient temperature:
–5/+40 °C
–25/+40 °C

[d] An example of an environmental test is the Kesternich test specified in ISO 6988:1985.

7.2.2 Discrimination

Installation of an RCD upstream of another RCD is often referred to as discrimination although the word “selectivity” is sometimes used. The normal purpose of such discrimination is to ensure that a residual current on a subcircuit causes only the RCD protecting the sub-circuit to trip and does not cause the upstream RCD to trip unless the fault is sustained beyond a certain time.

The general rule to ensure appropriate discrimination is based on two conditions that have to be fulfilled:

– minimum non-actuating time of the upstream RCD shall be higher than the maximum break time of the RCDs installed downstream;
– the rated residual operating current of the upstream RCD shall be at least 3 times the rated residual operating current of the RCDs installed down stream.

For example, it is possible to ensure discrimination between a 100 mA S Type RCD installed upstream of a 30 mA General Type RCD. In case of a fault current of 500 mA, the maximum tripping time of the downstream 30 mA RCD will be 40 ms whereas the minimum non-actuating time of the upstream RCD will be 50 ms, so discrimination is ensured.

NOTE See also IEC 60364-5-53, section 535.3.

7.2.3 Use of surge protective devices (SPDs)

During the operation of surge protective devices, large surge currents may flow to earth as a result of limiting transient overvoltages in the installation.

In the particular case when an SPD is connected downstream of an RCD, the resultant surge current to earth will be seen by the RCD as a residual current. In this situation, the RCD can trip. In order to avoid unwanted tripping, the selection and the installation need to take into account the RCD classification.

RCD standards include two levels of immunity to surge currents:

– general type RCD with a minimum surge current immunity of 200 A with a 0,5 μs/100 kHz shape;

– S type RCD with a minimum surge current immunity of 3000 A with an 8/20μs shape.

Therefore, the following is recommended:

- in general, to install SPDs upstream of RCDs (RCDs installed upstream of SPDs may operate on the expected surge currents);
- if SPDs are installed downstream of RCDs, the expected surge currents to earth should not exceed the immunity value of the RCD.

NOTE See also IEC 60364-5-53 section 534.2.6.

7.3 Recommendation for selection and installation to avoid unwanted tripping of RCDs

7.3.1 Impact of standing leakage current at power frequency (50/60 Hz)

Standing leakage currents in a circuit are usually either due to low insulation levels or to the presence of filters or capacitance between line and earth. Such standing leakage current can either be of rated frequency (50/60 Hz) or harmonics.

IEC 61140 recommends maximum standing leakage currents values as follow for loads connected to either plug in socket-outlets or powered from the fixed installation:

– Values for plug-in current-using equipment fitted with a single phase or multiphase plug and socket-outlet system rated up to and including 32 A.

Equipment rated current	Maximum protective conductor current
≤ 4 A	2 mA
>4 A but ≤ 10 A	0,5 mA/A
>10 A	5 mA

– Values for current-using equipment for permanent connection and current using stationary equipment, both without special measures for the protective conductor, or plug-in, current-using equipment fitted with a single phase or multiphase plug and socket-outlet system, rated more than 32 A:

Equipment rated current	Maximum protective conductor current
≤ 7 A	3,5 mA
>7 A but ≤ 20 A	0,5 mA/A
>20 A	10 mA

The following are typical examples of leakage current levels likely to be produced by common appliances:

1 mA to 2 mA for computers

0,5 mA to 1 mA printers

0,5 mA to 0,75 mA for small portable appliances

0,5 mA to 1 mA for telecopiers

0,5 mA to 1,5 mA for photocopiers

about 1 mA for filters

Calculation of the total leakage current from different appliances does not follow an arithmetic sum and needs to be corrected by a factor of 0,7/0,8.

As the operating range of RCDs is normally from 0,5 $I_{\Delta n}$ to 1 $I_{\Delta n}$, it is recommended that the standing leakage current in a circuit does not exceed 0,3 $I_{\Delta n}$ of the protective RCD at the rated frequency. In cases of leakage currents >0,3 $I_{\Delta n}$, it is recommended to divide the protected circuit into subcircuits and install an RCD on each subcircuit.

After a first fault in an IT system with distributed neutral, the standing leakage current can be increased by a factor of 2,6.

7.3.2 Impact of harmonics and high frequency leakage current

High frequency leakage currents can be produced by particular equipment, such as electronic ballasts, motor speed control, etc.

NOTE In some cases where the installed equipment generates a large amount of harmonic current, it may be necessary or prudent to install filters or make special circuit arrangements so that the effect of the harmonic current is reduced to a tolerable level.

RCD immunity against high frequency leakage currents is ensured by compliance with IEC 61543, whose requirements have been based on IEC 61000-4-3, IEC 61000-4-6 and IEC 61000-4-16.

7.3.3 Impact of transient residual currents

Transient residual currents generally have paths to earth through

a) surge protective devices (SPDs)

b) capacitances

– **Surge protective devices**

See 7.2.2.

– **Capacitances**

When surge voltages occur between phase(s) and earth or neutral and earth, surge current flows to earth through the common mode capacitances. Lightning can induce common mode surge voltages in the range of several kilovolts. Switching operations can also produce large transient overvoltages.

In some cases, common mode capacitances may have values in the nF range. Filter capacitors can have values of around 30 nF. Cable can have a capacitance of 150-400 pF per metre length throughout the installation.

7.4 Relationship between availability of the protection and the selection of RCDs

7.4.1 Selection of RCDs with or without overcurrent protection

Product standards recognise two main types of RCDs:

– RCDs without integral overcurrent protection according to IEC 61008 (RCCB);

– RCDs with integral overcurrent protection according to IEC 61009 (RCBO).

Selection of an RCD has to take into account the protection of the circuits downstream of the RCD and protection of the RCD itself against the effects of overcurrent and overheating.

Where an RCD with integral overcurrent protection (RCBO) is selected for the protection of a circuit, it is not necessary to consider external protection of the RCD because the integral overcurrent protection will protect the RCD.

The RCD's integral overcurrent protection will also provide adequate overcurrent protection for the downstream circuit provided that the overcurrent rating of the RCD is appropriate for the protected circuit.

Where an RCD without integral overcurrent protection (RCCB) is used, overcurrent protection must be provided to protect the RCD and the downstream circuit. In this case, co-ordination between the RCD and the overcurrent protective device is required. See manufacturer's instructions for information on overcurrent co-ordination.

For protection of a single circuit only (1, 2 or 3 phase), it is often more convenient to select an RCD with integral overcurrent protection (RCBO) to provide the residual current and overcurrent protection. This solution avoids any problem of co-ordination as stated above.

If several circuits are protected by a single device against a residual current fault, it is possible to choose an RCD with integral overcurrent protection (RCBO) or an RCD without integral overcurrent protection (RCCB). This may give a more economical installation for residential applications but some precautions to ensure overcurrent protection and minimise unwanted tripping are necessary as follows:

– overcurrent protection

- if an RCBO is used, then it will give overcurrent protection to itself and to the conductors;
- if an RCCB is used, then it has no overcurrent protection and it must be ensured that the current carried does not exceed the rated current. The rating of the RCCB must not be less than the rating of the upstream overcurrent device, or the sum of the downstream circuit breaker ratings multiplied by a diversity factor (e.g. 3 x 20 A MCBs (Miniature Circuit breakers). 60 A x 0,9 = 54 A), or the calculated design current (e.g. a 25 A RCCB may be suitable for 3 x 20 A circuits of socket outlets).

– unwanted tripping
  - the rated residual operating current of the RCD should be at least 3 times higher than the standing leakage current (see also 7.3.1);
  - the downstream circuits should be subdivided into several circuits to avoid that in case of tripping of the RCD the whole installation is switched off. For example it should be ensured that not all the area lighting is turned off.

7.4.2 Selection of RCDs according to the type of protection

RCDs can be used where it is necessary to protect a circuit or an installation against dangerous residual currents. The three main areas for such protection are as follows:

– protection against fire
– protection against fault protection (protection against indirect contact)
– protection against basic protection (protection against direct contact)

– Protection against fire

An RCD is an effective protective device to eliminate dangerous leakage currents to earth that could cause a fire within an installation. These currents are called tracking currents. Tracking currents are linked to ageing of installations where a reduction in humidity and drying out of pollution at the surface of isolating materials may lead to a degradation of the isolating material and the deposit of carbon.

It is recommended to use and select RCDs having a rated residual operating current not higher than 300 mA at the beginning of installations or circuits where fire protection is required. In domestic applications, where installations are not maintained, the use of such RCDs is highly recommended. For fire protection, the RCD must break all phase(s) and neutral. It may be an S Type RCD in order to allow discrimination with other RCDs.

– Fault protection (protection against indirect contact)

In the event of an insulation fault between a live part and earth a residual current flows back to the transformer through the earthing circuits and can cause exposed metal parts to reach a dangerous touch voltage. A person touching such live parts may be exposed to a potentially fatal shock risk, so the fault must be eliminated. This is referred to as fault protection (protection against indirect contact).

The choice of the RCD must follow the recommendations made in IEC 60364 taking into account different cases in relation to the earthing system. In general, a medium sensitivity RCD can be selected for this type of fault protection, e.g. an RCD with a rated residual operating current of up to 300 mA. If this value is appropriate it is possible to use a single RCD for fire protection and fault protection (protection against indirect contact)

– Basic protection (protection against direct contact)

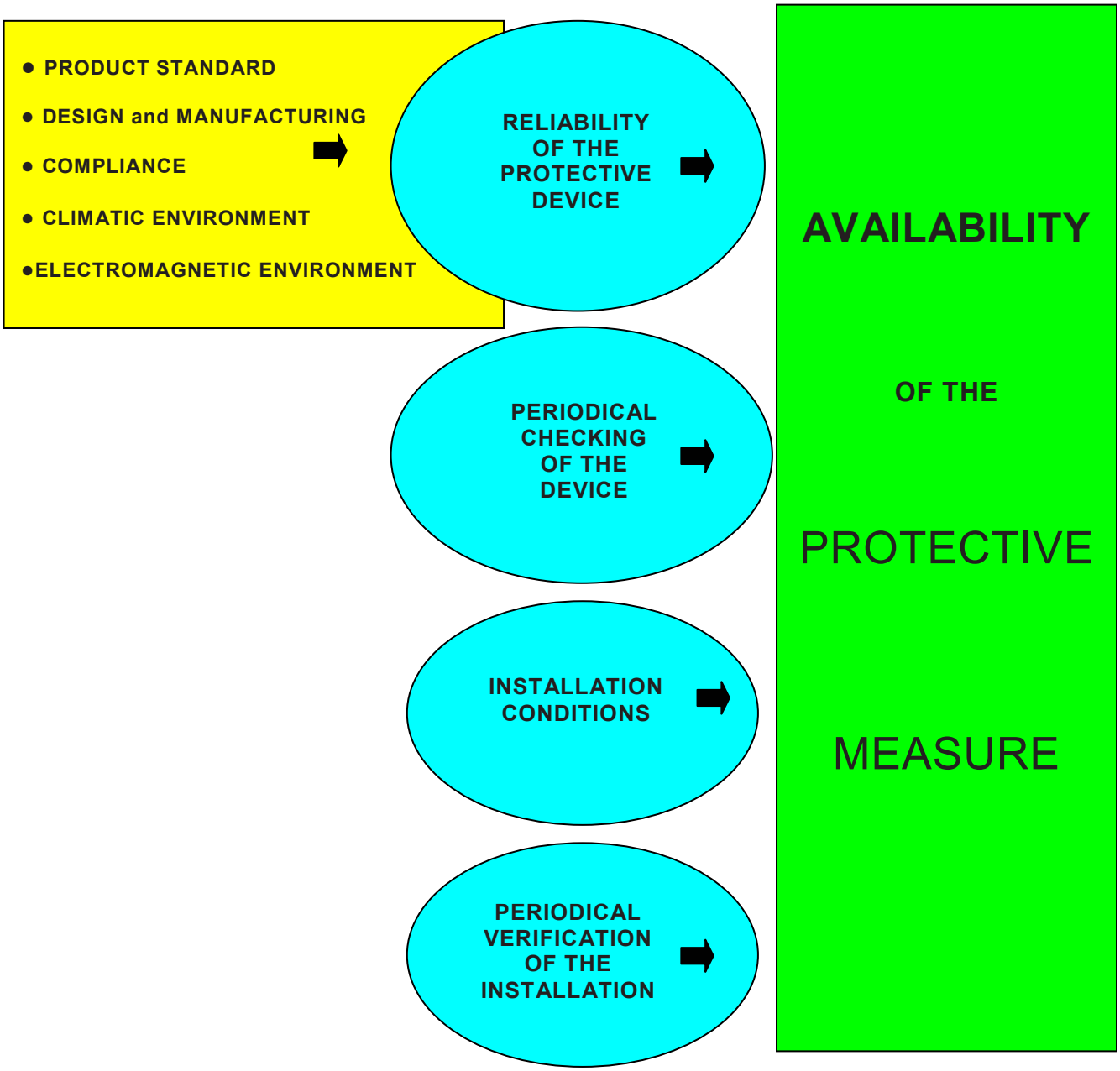
In the event of direct contact between a person and a live conductor, a residual current will flow through the body of the person. This current may cause a fatality if not eliminated quickly. An RCD having a rated residual operating current not higher than 30 mA will provide adequate protection in this situation.

NOTE An RCD having a rated residual operating current not higher than 30 mA will provide adequate protection in this situation (additional protection against electric shock).

In a domestic application, a 30 mA RCD used at the origin of the installation can provide efficient protection covering fire protection, fault protection (protection against indirect contact) and basic protection (protection against direct contact). For basic protection (protection against direct contact) the RCD should not be a delayed type (selective type).

Annex A
(informative)

General diagram showing contribution to availability of the protective measure



Annex B
(informative)

Definitions from the IEV

191-02-03
dependability
collective term used to describe the availability performance and its influencing factors: reliability performance, maintainability performance and maintenance support performance.

NOTE Dependability is used only for general descriptions in non-quantitative terms.

191-02-05
availability (performance)
ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval assuming that the required external resources are provided.

NOTE 1 This ability depends on the combined aspects of the reliability performance, the maintainability performance and the maintenance support performance.

NOTE 2 Required external resources, other than maintenance resources do not affect the availability performance of the item.

NOTE 3 In French, the term “disponibilité” is also used in the sense of “instantaneous availability”

191-02-06
reliability (performance)
ability of an item to perform a required function under given conditions for a given time interval.

NOTE 1 It is generally assumed that the item is in a state to perform this required function at the beginning of the time interval.

NOTE 2 Generally, reliability performance is quantified using appropriate measures. In some applications, these measures include an expression of reliability performance as a probability, which is also called reliability.

191-04-01
failure
termination of the ability of an item to perform a required function.

NOTE 1 After failure the item has a fault.

NOTE 2 “Failure” is an event, as distinguished from “fault”, which is a state.

NOTE 3 This concept as defined does not apply to items consisting of software only.

191-10-06
useful life
under given conditions, time interval beginning at a given instant of time, and ending when the failure intensity becomes unacceptable or when the item is considered unrepairable as a result of a fault.

NOTE In French, the term “durée de vie utile” is the duration of this time interval.

191-12-02
(instantaneous) failure rate
limit, if it exists, of the quotient of the conditional probability that the instant of a failure of a non-repaired item falls within a given time interval (t, $t + \Delta t$) and the duration of this time interval, Δt, when Δt tends to zero, given that the item has not failed up to the beginning of the time interval.

NOTE 1 The instantaneous failure rate is expressed by the formula:

$$\lambda(t) = \lim_{\Delta t \Rightarrow 0} \frac{1}{\Delta t} \frac{F(t+\Delta t) - F(t)}{R(t)} = \frac{f(t)}{R(t)}$$

where $F(t)$ and $f(t)$ are respectively the distribution function and the probability density of the failure instant, and where $R(t)$ is the reliability function, related to the reliability $R(t_1,t_2)$ by $R(t) = R(0,t)$.

NOTE 2 An estimated value of the instantaneous failure rate can be obtained by dividing the ratio of the number of items which have failed during a given time interval to the number of non-failed items at the beginning of the time interval, by the duration of the time interval.

NOTE 3 In English, the instantaneous failure rate is sometimes called "hazard function".

448-12-01
correct operation of protection
correct operation of relay system (USA)
initiation of tripping signals and other commands from a protection in the intended manner in response to a power system fault or other power system abnormality.

448-12-02
incorrect operation of protection
incorrect operation of relay system (USA)
failure to operate or an unwanted operation.

448-12-03
unwanted operation of protection
operation of a protection either without any power system fault or other power system abnormality, or for a system fault or other power system abnormality for which that protection should not have operated.

448-12-04
failure to operate of protection
failure to trip (USA)
lack of operation of a protection which should have operated but which did not operate.

448-12-05
reliability of protection
reliability of relay system (USA)
probability that a protection can perform a required function under given conditions for a given time interval.

NOTE The required function for protection is to operate when required to do so and not to operate when not required to do so.

448-12-06
security of protection
security of relay system (USA)
probability for a protection of not having an unwanted operation under given conditions for a given time interval.

448-12-07
dependability of protection
dependability of relay system (USA)
probability for a protection of not having a failure to operate under given conditions for a given time interval.

Annex C
(informative)

Operation of RCDs with possible fault currents

Possible fault currents are shown for circuits containing semiconductors.

	Connection	Normal mains current	Fault earth current
1	Single-phase L, I_L, I_F, N, PE	I_L, t	I_F, t
2	Single-phase with smoothing L, I_L, I_F, N, PE	I_L, t	I_F, t
3	Three-phase star L_1, L_2, L_3, I_L, I_F, N, PE	I_L, t	I_F, t
4	Two-pulse bridge I_L, L, N, I_F, PE	I_L, t	I_F, t
5	Two-pulse bridge, half-controlled I_L, L, N, I_F, PE	I_L, t	I_F, t
6	Two-pulse bridge between phases I_L, L_1, L_2, N, I_F, PE	I_L, t	I_F, t
7	Six-pulse bridge I_L, L_1, L_2, L_3, I_F, PE	I_L, t	I_F, t
8	Phase control I_L, L, I_F, N, PE	I_L, t	I_F, t
9	Burst control I_L, L, I_F, N, PE	I_L, t	I_F, t

Fault current in connections with semiconductor devices

Type AC RCDs will provide protection against earth fault currents shown in diagrams 8 and 9.

Type A RCDs will provide protection against earth fault currents shown in diagrams 1, 4, 5, 8 and 9.

Type B RCDs will provide protection against earth fault currents shown in diagrams 1 – 9.

Annex D
(informative)

Example of use of the test button

The information given in the following two tables is only given as examples. It is partly extracted from standards from different countries and shows how the use of the test button has been introduced in local standards.

Location of installation	Interval between inspection and tests	
	Push-button test by user	
	Portable appliances	Fixed appliances
Factories, workshops, places of work repair manufacturing, assembly, maintenance or fabrication	Daily, or before every use, whichever is the longer	6 months
Laboratories, health care and educational establishment, tea room and office kitchen	3 months	6 months
Office environment	3 months	6 months
Hire equipment	Prior to each hire. Test monthly	NA
Equipment used for commercial cleaning	3 months	NA
Residential type areas: residential institution, hotels, boarding houses, hospitals, accommodations houses, motels, hostels and the like	6 months	6 months

Location of Installation	Type of verification	Frequency
Medical locations	Verification of the operating with a residual test current equal to I_{dn}	1 year
Construction and demolition site installations	For the constructional site it is preferable that periodical verifications are carried out six-monthly and that they include - verification of the correct operating of the RCDs.	6 months (ADVISED)
Historical and artistic places	Operating test of the RCDs by means of the test button Such devices shall be compulsorily verified monthly by operating the test button and yearly by means of an external test equipment.	**6 months**
Schools	Operating test of the RCDs by means of the test button. Operating test of the RCDs by means of an external test equipment.	6 months 3 years

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