Guide to the Selection & Use of Residual Current Devices

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Contents

Foreword

This Guide has been prepared by the ETCI Residual Current Devices Task Force (RCD TF)

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Section 1 Introduction, Objective & Scope

1.1 Introduction

This Guide is intended to provide guidelines for the selection, installation and use of Residual Current Devices (RCDs). The Guide is likely to be of benefit to electrical contractors, specifiers, and persons wishing to gain a wider understanding of the use of RCDs.

1.2 Objective

This Guide is intended to provide specifiers, installers and users of RCDs with a better understanding of the application, selection and use of such products. However, it is important to note that this Guide is intended for use as a guide only, and has no regulatory or statutory status. This Guide should therefore be used in conjunction with the current issue of the National Rules for Electrical Installations (ET101), relevant product standards, and I.S. EN60439 – Low Voltage Switchgear and Control Gear Assemblies, where applicable.

1.3 Scope

This Guide is limited to RCDs intended for domestic and similar use, having a rated voltage not exceeding 400V AC and a rated current not exceeding 125A.

1.4 Definition & Principle of Operation

By definition, an RCD is a device or association of devices designed to cause the opening of one or more contacts when the residual current flowing in the circuit protected by the RCD reaches the rated residual operating current ($I_{\Delta N}$) of the device.

In an electrical installation, current will flow from the supply to a load and back to the supply. The load can be connected between phases or between phases and neutral on multiphase installations, or between phase and Neutral on a single phase installation. Under perfect conditions, the magnitude of the current flowing to the load will equal the magnitude of the current returning from the load back to the supply. Any difference in the current flowing to the load and returning from the load is known as a residual current. Under earth fault conditions, a current will flow to earth, giving rise to a residual current.

An RCD comprises means to detect a residual current, means to compare the residual current with the rated residual operating current of the device, (usually a relay for electromechanical RCDs or an electronic circuit for electronic RCDs), and means for removing the supply to the protected circuit (a circuit breaker element) when the residual current exceeds the rated residual operating current of the device.

Section 2 Regulatory Requirements

2.1 Regulatory Requirements.

The Low Voltage Directive (LVD) is a European Union Directive which, in its simplest form, requires that products placed on the EU market shall be safe. European Harmonised Standards may be used to demonstrate compliance with the essential requirements of the Directive and are the recommended route to establish compliance with the law. The LVD first came into force in 1973, and was revised in 1995 to include a requirement that the CE Mark be placed on relevant equipment marketed within the EU.

The EMC (Electromagnetic Compatibility) Directive places limits on emissions from electrical products, and requires that electrical products have the required level of immunity in order to function correctly in their operational environment. EMC requirements are generally specified in the relevant product standard.

The CE mark is a statement by the manufacturer that equipment complies with the requirements of all applicable EU Directives, which in the case of RCDs specifically include the LVD and EMC Directive. CE marking of products covered by the LVD became mandatory in January 1997.

On the basis of the above, all RCDs supplied to the Irish market are required to have a CE marking. RCD products which fail to bear the CE marking should not be used.

2.2 RCD Product Standards

IEC (the International Electrotechnical Commission) is the world body responsible for international standardisation within the electrical industry.

CENELEC is the body responsible for standardisation in the electrical industry in Europe. It is CENELEC policy to achieve harmonised standards for products and procedures within the member countries where possible, and it achieves this mainly by adopting IEC standards. CENELEC product standards are referred to as European Standards (ENs), and where an EN cannot be agreed (e.g. for reasons of incompatibility between member states), a Harmonisation Document (HD) may be prepared.

For the purpose of implementing the CENELEC harmonisation policy, member states should adopt ENs or HDs, and in the absence of a relevant EN or HD, preference should be given to an IEC standard, and in the absence of an IEC standard a National Standard may be used.

Each member country adds a prefix to the relevant standard for national use. In the case of Ireland, the prefix is I.S. (Irish Standard).

The relevant standards covering RCD products for use in Ireland are as follows.

I.S. EN61008-1:	Electrical Accessories – Residual Current Operated Circuit-Breakers Without Integral Overcurrent Protection for Household and Similar Uses (RCCBs) – Part 1: General Rules.
I.S. EN61008-2-1:	Residual Current Operated Circuit-Breakers Without Integral Overcurrent Protection for Household and Similar Uses (RCCBs) - Applicability of the General Rules to RCCBs Functionally Independent of Line Voltage.
I.S. IEC61008-2-2:	Residual Current Operated Circuit-Breakers Without Integral Overcurrent Protection for Household and Similar Uses (RCCBs) - Part 2-2: Applicability of the General Rules to RCCBs Functionally Dependent of Line Voltage.
I.S. EN61009-1:	Electrical Accessories – Residual Current Operated Circuit-Breakers With Integral Overcurrent Protection for Household and Similar Uses (RCBOs) – General Rules.
I.S. EN61009-2-1:	Residual Current Operated Circuit-Breakers With Integral Overcurrent Protection for Household and Similar Uses (RCBOs) - Applicability of the General Rules to RCBOs Functionally Independent of Line Voltage.
I.S. IEC61009-2-2:	Residual Current Operated Circuit-Breakers With Integral Overcurrent Protection for Household and Similar Uses (RCBOs) - Part 2-2: Applicability of the General Rules to RCBOs Functionally Dependent of Line Voltage.
I.S. EN60947-2:	Low Voltage Switchgear and Controlgear – Circuit Breakers (Annex B, Circuit Breakers Incorporating Residual Current Devices)

Note: RCDs constructed to I.S. EN60947-2 are mainly intended for industrial applications.

2.3 Installation Rules

RCDs fitted in electrical installations in Ireland should be installed in accordance with requirements of ET 101, National Rules for Electrical Installations, current edition and its amendments.

2.4 Assembly Requirements

When fitted into assemblies, RCDs should comply with the requirements of I.S. EN60439, Low Voltage Switchgear and Control Gear Assemblies

Section 3 RCD Product Types

3.1 Product Names/Types

The term, RCD, is a generic term applied to a family of products which open automatically in response to a residual current equal to or greater than the RCD's rated residual operating current, $I_{\Delta N}$. This generic term is often applied to the following:

RCCB - Residual **C**urrent **C**ircuit **B**reaker
RCBO - Residual **C**urrent **B**reaker with **O**vercurrent protection
SRCD - Socket outlet **RCD**
PRCD - Portable **R**esidual **C**urrent **D**evice

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

The term SRCD is applicable to an RCD which is an integral part of a socket outlet or which is fitted in a box immediately adjacent to a socket outlet. (See IEC 61541), The term SRCD should not be confused with S Type RCDs (See 3.5 below).

3.2 RCD Technology

RCDs may be distinguished by their technology, as follows.

i. **Voltage Independent RCDs (VI).**
These RCDs rely on the energy of the residual current to activate the RCD. These devices are sometimes referred to as **Electromechanical RCDs**, and are voltage-independent in operation.

ii. **Voltage Dependent RCDs (VD).**
These RCDs use the mains supply voltage to power an electronic circuit and the tripping mechanism to activate the RCD. These devices are sometimes referred to as **Electronic RCDs** and are voltage-dependent in operation.

3.3 Supply Voltage Response.

The standard or general purpose VI or VD RCD will not respond to mains voltage fluctuations or loss of supply, and will remain closed under such conditions unless a residual current flows.

Some VD RCDs, in addition to providing shock protection, are designed to open automatically if the supply voltage falls below a certain level. This is referred to as undervoltage release. (See ET101 National Rule for Electrical Installations, current edition, for undervoltage protection.) Such RCDs fall into two categories as follows.

i) RCDs tripping automatically on loss of supply and reclosing automatically on restoration of the supply.

ii) RCDs tripping automatically on loss of supply and not reclosing automatically on restoration of the supply. This type of RCD should not be used where continuity of supply is required.

3.4 Values of Rated Residual Operating Current ($I_{\Delta N}$)

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

10mA, 30mA, 100mA and 300mA.

30mA is the maximum value permissible for personal shock protection and 300mA is the maximum value permissible for fire protection. Non standard values may be used, but the shock and fire limits must not be exceeded.

3.5 Types of Residual Current

RCDs fall into three categories in terms of their response to different types of residual currents, as follows:

i) Type AC RCDs which can detect full wave AC residual currents only.

ii) Type A RCDs which can detect full wave AC and pulsating DC residual currents. Pulsating DC fault currents can be produced by any load incorporating power control devices such as rectifiers, thyristors, etc.

iii) Type B RCDs which can detect full wave AC, pulsating DC and pure DC residual currents.
(Type B RCDs are not normally used for domestic applications)

3.6 Operating Times

RCDs fall into two categories in terms of the time taken to respond to and clear residual currents, as follows:

i) **General Type** These RCDs have no specified minimum response time but have specified maximum response times as follows.

$I_{\Delta N}$ $\leq$ 300mS
5 $I_{\Delta N}$ $\leq$40mS

ii) **S Type** These RCDs, commonly known as delayed types, have specified minimum and maximum response times, as follows.

$I_{\Delta N}$ 130 - 500mS
5 $I_{\Delta N}$ 50 - 150mS

Delayed response (S Type) RCDs are commonly fitted upstream of General Type RCDs, but General Type RCDs should never be fitted upstream of Delayed types. (See 5.1.4 Discrimination).

The term "**upstream**" refers to proximity to the origin of the installation and "**downstream**" refers to proximity to the load.

3.7 Poles and Number of Poles

The poles of an RCD may be one of three types:

i) A solid neutral pole – a solid neutral conductor that has no contacts.
ii) A switched neutral pole – a pole with contacts that are not rated for making and breaking capacity. This pole makes early and breaks late, and therefore will not be required to be fully rated.
iii) A rated pole – a pole which is fully rated with making and breaking capacity.

RCDs according to i) and ii) above will normally have the Neutral pole clearly marked so as to avoid misconnecting of the supply to the RCD.

RCDs may comprise one or two poles for use on single phase supplies (two current paths) three poles for use on three phase supplies (three current paths) or four poles for use on three phase & Neutral supplies (four current paths).

Section 4 Application of RCDs

4.1 Shock & Fire Protection

RCDs are intended to provide protection against electric shock, which can result from a person touching an exposed live conductor (Direct Contact) or touching exposed metalwork which has a dangerous touch voltage (Indirect Contact).

According to IEC 60479, two key levels of electric current need to be considered with regard to shock protection.

The first is the “let-go” level, which is generally accepted to be around 7mA. At or above this level, muscles may seize, and a person touching or holding a live part may not be able to let go of the live part. RCDs rated up to 10mA are intended for protection against “let-go” currents, and are recommended for use in hospitals and old peoples’ homes, moist or damp environments, or similar locations.

The second is the “fibrillation” level, which is generally accepted to be around 50mA. At or above this level, heart fibrillation is likely to occur. RCDs rated up to 30mA are the upper limit for RCDs intended to provide protection against fibrillation. It follows that RCDs rated >30mA are not suitable for personal protection.

RCDs may also provide protection against fires likely to arise from earth fault currents. However, RCDs cannot be guaranteed to prevent such fires in all cases. For example, AC Type RCDs will not provide protection against pulsating DC currents flowing to earth even though such currents could result in an electrical fire.

Where an RCD is fitted to reduce the risk of fire arising from an electrical fault, the following factors should be taken into account:

i) IEC has specified an upper limit of 300mA for RCDs intended for fire protection. This is based on a power level of about 60 watts which is considered to be sufficient to cause an electric fire. This level would be exceeded at 230V for a 300mA residual current. Any RCD with a rated residual operating current not exceeding 300mA will meet this requirement.

ii) ET101 requires that RCDs used in areas of fire hazard shall be limited to a maximum rated residual operating current of 300mA, and that they shall disconnect all live poles of the protected circuits. (See National Rules for Electrical Installations, Third Edition, ET101, sub-clause 532.1).

iii) Type AC RCDs will only provide protection against full wave AC fault currents, but fires can be caused by pulsating DC fault currents, and such fault currents can only be detected by Type A or Type B RCDs.

4.2 Protected Circuits

Statutory Instrument 44 of 1993, which applies to all places of work, requires that all circuits supplying portable equipment and socket outlets intended to supply portable or transportable equipment with an operating voltage in the range 125 – 1000V AC must be protected by an RCD having a tripping current not exceeding 30mA.

In addition to the above, the National Rules for Electrical Installations (ET101, current edition) requires RCD protection to be provided in circuits as follows:

RCD $I_{\Delta N}$ Rating

Areas of Increased Fire /Hazard	≤ 30mA/300mA
Socket outlets - rated current ≤32A	≤ 30mA
Immersion heaters	≤ 30mA
Shower units	≤ 30mA
Soil heating equipment	≤ 30mA
Water heaters	≤ 30mA
Swimming pools	≤ 30mA
Fire hazard, farms	≤ 30mA /300mA
TT Systems	$I_{\Delta N} \leq 50V/Ra$

The use of RCDs in locations containing a bath or a shower basin are set out in the National Rules for Electrical Installations, Third Edition, ET101, Section 701.

Special exemptions and controls may apply, e.g. in hospitals and to life supporting equipment, test & research facilities, etc. For example see Part VIII of S.I 44/1993

Section 5 Selection & Installation of RCDs

5.1 Factors influencing the behaviour of RCDs

Various factors can influence the behaviour of RCDs, and may need to be considered when selecting and installing RCDs. Examples of such factors are set out below.

5.1.2 Installation Type

The following are the main types of installation used in Ireland:

i) **TN-C-S system.** The standard installation system in Ireland. (See National Rules for Electrical Installations, Third Edition, ET101, Figure 2A). RCDs are mainly used on this system for protection against Direct Contact, and they also provide protection against Indirect Contact. The rated residual operating current of RCDs intended for protection against Direct Contact must not exceed 30mA.

ii) **TT system.** The use of TT systems in Ireland is relatively rare. The TT system differs from the TN-C-S system in that there is no connection between the protective conductor (PE) and the neutral, and instead protection relies on local earth electrodes. Resultant impedances in the earth return path between the load and the origin of the supply may prevent the operation of overcurrent protection devices in the event of an earth fault. This can result in bonded metalwork reaching dangerous touch voltages and also give rise to fire hazards due to the sustained flow of earth fault currents if the overcurrent protection device fails to operate. The use of RCDs on TT systems for earth fault protection is therefore essential in all cases. RCDs are used to provide protection against Direct Contact and Indirect Contact in TT systems.

iii) **IT system.** Generally used where continuity of supply is required. The use of IT systems in Ireland is confined to special applications such as hospital operating theatres, mines, etc., where continuity of supply under a first earth fault condition is of paramount importance. IT systems are characterised by the absence of a direct connection of the supply to earth or connection to earth via a relatively high impedance which negates the use of RCDs on such systems.

5.1.3 Standing Leakage Currents

In any electrical installation a certain amount of current will flow to earth. This is known as the standing earth leakage current. In modern installations, the greatest source of this current is through RFI filters and surge suppressors fitted on equipment such as fridges, freezers and washing machines. Computers can be adversely affected by such noise or voltage disturbances.

This leakage current will be a minimum on new installations but tends to increase over time due to ageing of the installation and equipment connected to the installation. A general rule of thumb is to assume that the leakage current will be of the order of 2mA for every 10A load current. Thus, for a 100A load current, the leakage current could be as high as 20mA. This would be at or very close to the residual operating current of a 30mA RCD, leaving the RCD highly prone to nuisance tripping. The National Rules for Electrical Installations, ET101, recommends that the standing leakage current should not exceed 0.35 $I_{\Delta N}$, which equates to 10.5mA for a 30mA RCD. There are two solutions available to overcome the problem of high levels of leakage current:

i) Divide the main circuit into sub-circuits and fit an RCD at the beginning of each sub-circuit with the appropriate level of protection for each sub-circuit. In such cases, it is common practice to also fit an RCD at the beginning of the main circuit. When an RCD is fitted upstream of one or more RCDs, the National Rules for Electrical Installations, ET101, requires that the response time and residual operating current of the upstream RCD be above those of the downstream RCDs.

ii) Use an RCD of a higher rated residual current. The maximum permissible rating for shock protection is 30mA and the maximum permissible rating for fire protection is 300mA, therefore these values will set a limit on the RCD that can be used.

On installations where a large number of computers are supplied, no more than four computers should be protected by a single 30mA RCD.

5.1.4 Discrimination.

Connection of an RCD upstream of other RCDs is often referred to as Cascading. The normal purpose of cascading RCDs is to ensure that a residual current on a subcircuit causes only its RCD to trip and does not cause the upstream RCD to trip unless the fault is sustained beyond a certain time. This is referred to as Discrimination. General Type RCDs have maximum trip times of 300mS and 40mS for residual currents of $I_{\Delta N}$ and 5 $I_{\Delta N}$ respectively, but no minimum trip time is specified for such devices. Thus, if a 100mA RCD is installed upstream of a 30mA RCD, there will be no certainty as to which RCD will trip first in the event of residual currents above 100mA. Cascading of General Type RCDs is therefore not recommended. Discrimination can only be provided by ensuring that the upstream RCD has a trip time and trip level envelope which is completely outside that of the downstream RCD. This can only be assured by using an S Type RCD upstream and General types downstream.

5.1.5 Surge Protection Devices (SPDs)

Dangerous surge voltages of the order of several thousand volts may arise on electrical installations due to switching of loads and due to atmospheric phenomena such as lightning. Surge protection devices (SPDs) are installed in electrical installations to protect the installation or equipment connected to it from potential damage that could be caused by such surge voltages. SPDs are intended to limit these surge voltage to a safe level. SPDs may also be connected within equipment.

When connected in Common Mode (i.e. between Live and earth or Neutral and earth), SPDs will cause a large current to flow to earth when suppressing voltage surges. (On TN-C-S systems it is not necessary to connect a SPD between neutral and earth.) The resultant surge currents can have values in the amperes or tens of amperes range, and if the SPD is connected downstream of the RCD, the RCD will see such currents as a residual current and may trip. Ideally, the RCD should be installed downstream of SPDs, but this is not always possible. For example, the SPD may be fitted inside equipment rather than on the installation. When RCDs are connected upstream of SPDs, it is important that the RCD will not trip in response to SPD generated surge currents. S Type RCDs will not respond to such currents because the duration of the surge current flow is usually substantially less than the response time of S type RCDs. However, S Type RCDs may not be suitable, for example for personal shock protection, in which case General Type RCDs will need to be used. It will be important therefore to ensure that any RCD installed upstream of SPDs will not trip in response to resultant surge currents. This information can be provided by the RCD manufacturer.

5.1.6 Neutral to Earth Fault

Under no circumstances should a connection be made between neutral and protective earth downstream of the origin of the installation. If such a connection was made, intentionally or accidentally, it would seriously compromise the safety of the installation and undermine the level of protection provided by an RCD installed upstream of this fault condition. If the Neutral becomes inadvertently shorted to earth on the load side of the RCD (neutral to earth fault condition) due possibly to miswiring or insulation breakdown, two problems will arise.

i) An effective loop or short circuit will be created between the neutral conductor and the earth return path. This short will act as a load on the current transformer in the RCD and cause the RCD trip point to rise, effectively desensitising the RCD.
ii) The earth fault current will divide between two paths, part of the fault current returning to the supply via the earth return path and part of the fault current returning via the Neutral due to the neutral to earth fault. Thus the residual current seen by the RCD will be less than the total earth fault current.

5.2 Installation & Load Characteristics

The following characteristics of the installation and load will need to be taken into account when selecting an RCD:

i) Supply system, TN-C-S, TT or IT
ii) Supply voltage & frequency
iii) Maximum load current seen by the RCD
iv) Whether or not undervoltage release is required, and if it is, whether or not reactivation of the load on restoration of the supply is required. Undervoltage release will usually be related to the type of load on the installation.
v) Type of load, e.g. AC load only or load containing rectification or power control devices.

vi) Type of protection required, e.g. Direct and/or Indirect Contact and/or Fire protection,.
Protection against AC residual currents only (use Type AC RCD)
Protection against AC and pulsating DC residual currents (use Type A RCD).

vii) Likely level of standing earth leakage current downstream of the RCD

viii) Whether or not cascading of RCDs is required

ix) Location of surge protection devices (SPDs).

5.3. RCD Characteristics.

The following RCD characteristics need to be taken into account when selecting RCDs for a particular application:

Rated voltage & frequency
Rated load current (In)
Rated residual operating current ($I_{\Delta N}$)
Rated making & breaking capacity (Im)
General or S Type
Residual current protection, Type AC, Type A or Type B
Number of poles to be broken
Type of Poles, solid neutral, switched neutral or fully rated pole
Response to loss of supply and restoration of supply

5.4 Overcurrent protection

Protection against overload currents is a requirement of the installation rules. Such protection can be provided by a separate overcurrent protection device (OCPD) such as a fuse or circuit breaker and used with an RCCB, or be incorporated into the RCD as in an RCBO. It is important to ensure that where an external OCPD is used, the rated load current of the RCD is not less than that of the OCPD, otherwise the RCD may be damaged during overcurrent conditions. The RCD manufacturer’s instructions should be checked in case of doubt.

Section 6 Testing

6.1 All electrical installations must be tested in accordance with ET101, and Annex 61F provides details of specific tests for RCDs. These tests should be carried out by introducing a residual current at the end of every sub-circuit downstream of the RCD.

RCDs are fitted with a test button to verify their operation. Testing of the RCD by operation of the test button should be carried out on a regular basis, e.g. every three months. However, arrangements should also be made for regular testing by application of an external residual current.

Operation of the test button results in the flow of a residual current within the RCD, causing it to trip. However, tripping of the RCD in response to operation of the test button does not verify that the RCD will provide protection as specified. For example, protection will not be assured in the case of a neutral to earth fault. Verification of the ability of the RCD to provide protection can only be assured by external testing as set out above.

By definition, AC current comprises of positive and negative half cycles with respect to a zero reference point, and an AC fault current can start to flow to earth at any point during either half cycle. An AC Type RCD will only trip in response to either the positive or negative half cycles of the AC earth fault current, whereas an A Type RCD will respond to both half cycles. As the AC Type RCD is blind to either the positive or negative half cycles of an AC fault current, the fault current could flow for up to 10mS before the RCD will see the fault current. This 10mS will be added to the response time of the device. RCD testers are usually provided with a switch to enable the user to start the flow of the test current at 0 degrees or 180 degrees, i.e. starting on a positive going or a negative going half cycle respectively. By starting the testing of the RCD at both settings of the test current conduction angle, the user will be able to determine the maximum trip time of the RCD. This can be done at different test current levels.