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INSPECTION AND TESTING OF ELECTRICAL INSTALLATIONS

RESIDUAL CURRENT DEVICES

By Mark Coles

The IEE receives many enquiries relating to the inspection and testing of electrical installations and the applicable requirements of BS 7671: 2001 (2004). The queries vary greatly and cover all aspects of inspection and testing, from the initial verification process of domestic installations to the periodic inspection of major industrial installations. In this, the first of a series of articles, we will look at Residual Current Devices (RCDs).

1. What is an RCD and what does it do?

An RCD is defined, in BS 7671, as: *'A mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions'*.

An RCD is a protective device used to automatically disconnect the electrical supply when an imbalance is detected between live conductors. In the case of a single-phase circuit, the device monitors the difference in currents between the phase and neutral conductors. In a healthy

circuit, where there is no earth fault current or protective conductor current, the sum of the currents in the phase and neutral conductors is zero. If a phase to earth fault develops, a portion of the phase conductor current will not return through the neutral conductor. The device monitors this difference, operates and disconnects the circuit when the residual current reaches a preset limit, the residual operating current ($I_{\Delta n}$).

RCDs are used to provide protection against the specific dangers that may arise in electrical installations including:

- > protection against indirect contact
- > supplementary protection against direct contact
- > protection against fire and thermal effects

An RCD on its own does not provide protection against overcurrents. Overcurrent protection is provided by a fuse or a miniature circuit-breaker (MCB). However, combined RCD and MCBs are available and are designated RCBOs.

	Type of RCD	Description	Usage
RCCB	Residual current operated circuit-breaker without integral overcurrent protection	Device that operates when the residual current attains a given value under specific conditions	Consumer units Distribution boards
RCBO	Residual current operated circuit-breaker (RCCB) with integral overcurrent protection	Device that operates when the residual current attains a given value under specific conditions and incorporates overcurrent protection	Consumer units Distribution boards
CBR	Circuit-breaker incorporating residual current protection	Overcurrent protective device incorporating residual current protection.	Distribution boards in larger installations
SRCD	Socket-outlet incorporating an RCD	A socket-outlet or fused connection unit incorporating a built-in RCD.	Often installed to provide supplementary protection against direct contact for portable equipment used out of doors
PRCD	Portable residual current device	A PRCD is a device that provides RCD protection for any item of equipment connected by a plug and socket. Often incorporates overcurrent protection	Plugged into an existing socket-outlet. PRCDs are not part of the fixed installation
SRCBO	Socket-outlet incorporating an RCBO	Socket-outlet or fused connection unit incorporating an RCBO	Often installed to provide supplementary protection against direct contact for portable equipment used out of doors

2. Types of RCDs

RCD is the generic term for a device that operates when the residual current in the circuit reaches a predetermined value.

The list above indicates the different types of RCD available, a description of each device and examples of how the device is used.

2.1 Older installations with ELCBs

Historically, two basic types of earth-leakage circuit-breaker (ELCB) were

recognised by the Regulations; the familiar current-operated type and the earlier voltage-operated type. The voltage-operated type ceased to be recognised by the Regulations in 1981 and today, only the current-operated type is recognised. The voltage-operated device can be distinguished by its two separate earthing terminals – one for the connection of the earthing conductor of the installation and the other for a connection to a means of earthing. Such devices were

often used on installations forming part of a TT system where the means of earthing was an earth electrode. The major drawback with the voltage-operated earth leakage circuit-breaker is that a parallel earth path can disable the device.

2.2 Recognised devices

RCDs are manufactured to harmonised standards and can be identified by their BS EN numbers. An RCD found in an older installation may not provide

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protection in accordance with current standards. The following list identifies the applicable current standards:

> **BS 4293 : 1983 (1993)**

Specification for residual current operated circuit-breakers. (Replaced by BS EN 61008-1: 1995, BS EN 61008-2-1: 1995 and BS IEC 61008-2-2: 1990). This Standard remains current

> **BS 7071 : 1992 (1998)**

Specification for portable residual current devices

> **BS 7288 : 1990 (1998)**

Specification for socket-outlets incorporating residual current devices. (SRCDs)

> **BS EN 61008-1 : 1995 (2001)**

Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs)

> **BS EN 61009-1 : 2004**

Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)

2.3 Characteristics of RCDs

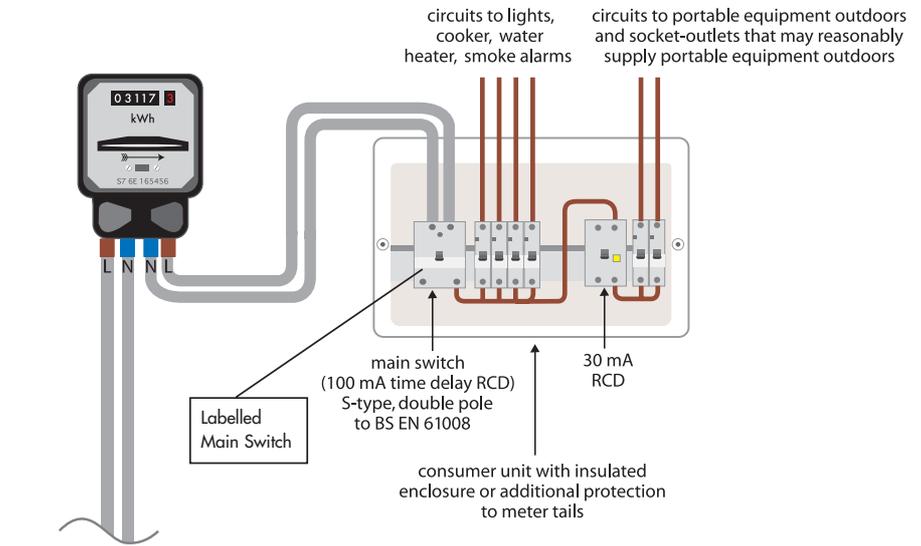
RCDs are defined by a series of electrical characteristics, three main characteristics are:

1. The rating of the device in amperes, I.
2. The rated residual operating current of the protective device in amperes, I_{Δn}.
3. Whether the device operates instantaneously or incorporates an intentional time delay to permit discrimination. Such devices are called 'S' or Selective.

Devices are manufactured with different values of rated current and rated residual operating current but we will just consider the rated residual operating current of the protective device in amperes, I_{Δn}.

3. Applications

The correct device must be selected for



Above: Discrimination achieved

the particular application. Choosing the wrong device could have serious consequences and could result in electric shock or fire.

The list overleaf gives examples of particular applications of RCDs and includes references to the relevant Regulations in BS 7671.

3.1 Unwanted tripping

Unwanted tripping of RCDs can occur when a protective conductor current or leakage current causes unnecessary operation of the RCD. An RCD must be so selected and the electrical circuits so subdivided that any protective conductor current that may be expected to occur during normal operation of the connected load(s) will be unlikely to cause unnecessary tripping of the device (Regulation 531-02-04 refers). Such tripping can occur on heating elements, cooking appliances etc., which may have elements that absorb a small amount of moisture through imperfect element-end seals when cold. When energised, this moisture provides a conductive path for increased leakage and could operate the RCD. The moisture dries out as the element heats up. Although not precluded in BS 7671, it is not a

requirement to use an RCD on such circuits if other satisfactory means of protection are available. Providing an RCD with a higher rated residual operating current may solve the problem but the requirements of the Regulations would still have to be met.

3.2 Discrimination

Where two, or more, RCDs are connected in series, discrimination must be provided, if necessary, to prevent danger (Regulation 531-02-09 refers). During a fault, discrimination will be achieved when the device electrically nearest to the fault operates and does not affect other upstream devices.

Discrimination will be achieved when 'S' (Selective) types are used in conjunction with downstream general type RCDs. The 'S' type has a built-in time delay and provides discrimination by simply ignoring the fault for a set period of time allowing more sensitive downstream devices to operate and remove the fault.

For example, when two RCDs are connected in series, to provide discrimination, the first RCD should be an 'S' type. RCDs with built in time delays should not be used to provide personal protection.

RCD, I _{Δn}	Application	Regulation
10mA	A very sensitive device that is sometimes used to protect laboratory benches in schools	412-06-02
30mA	Portable equipment used outdoors must be protected by an RCD with a rated residual operating current not exceeding 30mA	471-16-01 412-06-02
30mA	Certain equipment in bathrooms and shower rooms must be protected by a 30mA RCD. For example, a 230V fan in zone 1 of a bathroom, that cannot be located elsewhere, must be protected by a 30mA device and must have an IP rating of at least IPX4 (IPX5 if hosed down)	601-09-02 601-06-01
30mA	Mains-supplied socket-outlets in bedrooms with showers must be protected by an RCD. Note that such socket-outlets must be located outside of the zones	601-08-02
30mA	Socket-outlets in workshops, school laboratories, used by performers and entertainers. Street market stalls are often protected by 30mA RCDs.	412-06-02
30mA	In zone C of swimming pool installations, luminaires must be protected either by electrical separation, SELV or a 30mA RCD.	602-08-03
30mA	Any socket-outlet used on a building site must be to BS EN 60309-2 and must be protected by a 30mA RCD.	604-08-03 604-12-02
30mA	Caravans, motor caravans and caravan parks. 30mA RCDs must be provided both in the vehicle and the park installation.	608-03-02 608-07-04 608-04-01
30mA	Caravan pitch socket-outlets – Each socket-outlet must be protected individually by an overcurrent device, which may be a fuse but is more usually a circuit-breaker and either individually or in groups of not more than three socket-outlets by an RCD having the characteristics specified in Regulation 412-06-02. Note: the CENELEC harmonisation document HD 384.7.708 allows only three sockets to one RCD while the international standard IEC 364-7-708 permits six.	608-13-04 608-13-05
30mA	Underfloor heating systems are installed in bathrooms and swimming pools supplied at voltages other than SELV, the heating element should be provided either with a metallic sheath or screen overall or a metallic grid installed above the heating elements. The screen or grid shall be incorporated within the supplementary bonding for the facility. In addition, the supply to the heating elements should be protected by an RCD with a residual operating current not exceeding 30mA.	601-09-04
100mA	For an installation forming part of a TT system, a 100mA RCD is generally installed at the origin. A time-delayed or 100mA 'S-type' (or selective) device is often used to permit discrimination with a downstream 100mA device	413-02-19 531-02-09 314-01-02
100mA	Where an RCD is fitted only because the earth loop impedance is too high for shock protection to be provided by an overcurrent device, for example in a TT system	413-02-16
100mA	Under certain supply-system fault conditions (external to the installation), a potential can develop between the conductive parts connected to the PME earth terminal and the general mass of earth. However, there are areas of special risk within or outside buildings and there are special situations and installations where it is appropriate to take additional measures for part or all of the installation. Alternatively, it may be appropriate not to use the PME earthing terminal and provide earth fault protection with a separate earth electrode and RCD. Seek advice from the local supply authority when exporting PME supplies.	413-02-17
300mA	In TN and TT systems, in locations with risks of fire due to the nature of processed or stored materials, wiring systems, except for MICC and busbar trunking systems must be protected against insulation faults to earth by a 300mA device	482-02-06
500mA	In agricultural and horticultural premises, a 500mA device must be installed to protect equipment against fire and harmful thermal effects, other than that essential to the welfare of livestock.	605-10-01
500mA	At exhibitions, shows & stands, where there is increased risk of damage to cables, distribution circuits should be protected by an RCD with a residual operating current not exceeding 500mA.	GN7, p95
Adjustable ≤2000 mA	Devices with a residual operating current of 2A or more are sometimes used in specific industrial and distribution applications. Advice must be sought from the designer	531-02-10

Device	Instrument test current setting	Satisfactory result
General purpose RCDs to BS 4293 and RCD protected socket-outlets to BS 7288	50% of operating current	Device should not operate
	100% of operating current	Device should operate in less than 200ms. Where the RCD incorporates an intentional time delay it should trip within a time range from 50% of the rated time delay plus 200ms' to 100 % of the rated time delay plus 200ms
General purpose RCCBs to BS EN 61008 or RCBOs to BS EN 61009	50% of operating current	Device should not operate
	100% of operating current	Device should operate in less than 300ms unless it is of 'Type S' (or selective) which incorporates an intentional time delay. In this case, it should trip within a time range from 130ms to 500ms
Supplementary protection against direct contact $I_{\Delta n} \leq 30\text{mA}$	Test current at $5 I_{\Delta n}$ The maximum test time must not be longer than 40ms, unless the protective conductor potential does not exceed 50V. (The instrument supplier will advise on compliance).	Device should operate in less than 40ms.

4. Labelling

Regulation 514-12-02, states that:

“Where an installation incorporates a residual current device a notice shall be fixed in a prominent position at or near the origin of the installation. The notice shall be in indelible characters not smaller than those here illustrated and shall read as follows:”

This installation, or part of it, is protected by a device which automatically switches off the supply if an earth fault develops. Test quarterly by pressing the button marked 'T' or 'Test'. The device should switch off the supply and should then be switched on to restore the supply. If the device does not switch off the supply when the button is pressed, seek expert advice.

5. Testing

RCDs must be tested. The requirements are stated in the following Regulations:

- a. The effectiveness of the RCD must be verified by a test simulating an appropriate fault condition and independent of any test facility, or

test button, incorporated in the device (Regulation 713-13-01)

- b. Where an RCD of 30mA provides supplementary protection the operating time must not exceed 40 ms at a residual current of $5 I_{\Delta n}$. (Regulation 412-06-02 refers)

Tests are made on the load side of the RCD between the phase conductor of the protected circuit and the associated cpc. Any load or appliances should be disconnected prior to testing. RCD test instruments require a few milliamperes to operate; this is normally obtained from the phase and neutral of the circuit under test. When testing a three-phase RCD protecting a three-wire circuit, the instrument's neutral is required to be connected to earth. This means that the test current will be increased by the instrument supply current and will cause some devices to operate during the 50% test, possibly indicating an incorrect operating time. Under this circumstance it is necessary to check the operating parameters of the RCD with the

manufacturer before failing the RCD.

5.1 Range of tests

While the following tests are not a specific requirement of BS 7671, it is recommended that they are carried out.

5.2 Integral test device

An integral test device is incorporated in each RCD. This device enables the mechanical parts of the RCD to be verified by pressing the button marked 'T' or 'Test'.

6. Test Instrument

The test instrument used to test RCDs should be capable of applying the full range of test current to an in-service accuracy, as given in BS EN 61557-6. This in-service reading accuracy will include the effects of voltage variations around the nominal voltage of the tester. To check RCD operation and to minimise danger during the test, the test current should be applied for no longer than 2s. Instruments conforming to BS EN 61557-6 will fulfil the above requirements. ■