543.7
High protective conductor currents

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Requirements for Bathrooms

17th Edition Requirements
for the testing of RCDs

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BS 7671:2008 Requirements for Electrical Installations, IEE Wiring Regulations 17th Edition was published in January this year. Installations designed after the 30th June 2008 are to comply with BS 7671:2008.

The 17th Edition includes a new Part 7 (Special Locations), which includes new requirements for bathrooms. All those involved in electrical installation work need to be familiar with these new requirements. Help is at hand, in the form of a new edition of IEE Guidance Note 7 (Special Locations), available soon.

Section 701, Locations containing a bath or shower

Scope

The particular requirements of this section apply to the electrical installations in locations containing a fixed bath (bath tub) or shower and to the surrounding zones as described in the Wiring Regulations. The Regulations do not apply to emergency facilities, e.g. emergency showers used in industrial areas or laboratories. For locations containing a bath or shower for medical treatment, special requirements may be necessary.

What’s new?

Changes to the zonal system, RCD protection on all bathroom circuits, 230v socket outlets permitted 3 m horizontally from the boundary of zone 1; supplementary equipotential bonding may be omitted subject to the Regulations being met.

The zonal system

The Regulations state: Horizontal or inclined ceilings, walls with or without windows, doors, floors and fixed partitions may be taken into account where these effectively limit the extent of locations containing a bath or shower as well as their zones. This is similar to current requirements in the 16th Edition except that the actual location containing the bath or shower is mentioned as well as the zones.

The zones are similar to current requirements in the 16th Edition except for the omission of zone 3, also that zone 2 no longer extends above zone 1.

Zone 1 has been extended from 0.6 m in the 16th Edition for showers without a basin for a fixed water outlet to a distance of 1.20 m from the centre point of the water outlet. Demountable shower heads are no longer mentioned.
Zone 1 is now limited by the horizontal plane corresponding to the highest fixed shower head or water outlet or the horizontal plane lying 2.25 m above the finished floor level, whichever is higher.

**RCD Protection**

Regulation 701.411.3.3 now requires that additional protection shall be provided for all circuits of the location by the use of one or more RCDs having the characteristics specified in Regulation 415.1.1. This is a significant change. Previously (601-09-02), only fixed current using equipment (other than electric showers) located in zone 1 required 30mA RCD protection and current using equipment (other than fixed current using equipment – such as a washing machine, if suitable for use in a bathroom, connected through a fused connection unit) in zone 3 required 30mA RCD protection. Regulation 701.411.3.3 means that all circuits, including lighting, electric showers, heated towel rails, etc., will require RCD protection, not exceeding 30 mA.

**230 volt socket-outlets**

Another significant change is introduced by Regulation 701.512.3. This now permits 230v socket-outlets
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to be installed in a room containing a bath or shower providing they are installed 3 m horizontally from the boundary of zone 1. This change resolves the ambiguity that existed between locations containing a bath or shower and a bedroom containing a shower.

**Supplementary equipotential bonding**

Regulation 701.415.2 introduces a further significant change regarding supplementary equipotential bonding. The Regulation states that where the location containing a bath or shower is in a building with a protective equipotential bonding system in accordance with Regulation 411.3.1.2, supplementary equipotential bonding may be omitted where all of the following conditions are met:

(i) All final circuits of the location comply with the requirements for automatic disconnection according to 411.3.2, and
(ii) All final circuits of the location have additional protection by means of an RCD in accordance 701.411.3, and
(iii) All extraneous-conductive-parts of the location are effectively connected to the protective equipotential bonding according to 411.3.1.2.

This means the designer needs to make an assessment that all extraneous-conductive-parts of the location are effectively connected to the protective equipotential bonding according to 411.3.1.2.

NOTE: The effectiveness of the connection of extraneous-conductive-parts in the location to the main earthing terminal may be assessed, where necessary, by the application of Regulation 415.2.2.

Regulation 415.2.2 states: Where doubt exists regarding the effectiveness of supplementary equipotential bonding, it shall be confirmed that the resistance $R$ between simultaneously accessible exposed-conductive-parts and extraneous conductive-parts fulfils the following condition:

\[ R \leq 50 \text{ V}/I_a \text{ in a.c. systems} \]
\[ R \leq 120 \text{ V}/I_a \text{ in d.c. systems} \]

where $I_a$ is the operating current in amperes of the protective device for RCDs, $I_{\Delta n}$, for overcurrent devices, the current causing automatic operation in 5 s.

**External influences**

The Regulations state:

Electrical equipment exposed to water jets, e.g. for cleaning purposes, shall have a degree of protection of at least IPX5. The Regulations no longer limit the IPX5 requirement to communal baths or communal showers.

There are no particular ingress protection requirements beyond zone 2. This means that BS 1363 accessories, such as switches and fused connection units, can be installed beyond zone 2, subject to the requirements of Regulation 512.2 (external influences).

**Current-using equipment**

The 16th Edition made a clear division between equipment permitted to be installed in zone 1 and equipment permitted to be installed in zone 2. In the 17th Edition no requirements are stated for zone 2. This is because all circuits of the location now require RCD protection.

The term “current-using equipment other than fixed current-using equipment” no longer appears in the 17th Edition.

Current-using equipment, such as washing machines and tumble dryers for example, continue to be allowed to be installed beyond zone 2, subject to manufacturers’ approval similar to the 16th Edition. Such equipment must be supplied by means of a fused connection unit within 3 m horizontally from the boundary of zone 1. Beyond 3 m they may be supplied by means of a plug and socket-outlet.

**Shaver supply units**

The minimum degree of protection for equipment installed in zones 1 and 2 is IPX4 or IPX5 where water jets are likely to be used for cleaning purposes. An exception to this requirement is a shaver supply unit complying with BS EN 60742 Chapter 2, Section 1, which, although it does not meet the requirements of IP4X, is permitted in zone 2 but must be located where direct spray from showers is unlikely. This type of shaver supply unit, which incorporates a safety isolating transformer, is the only type which is permitted in a bathroom or shower room.

**More information.**

For more information please refer to the 17th Edition of the Wiring Regulations. Also, help is at hand, in the form of a new edition of IEE Guidance Note 7 (Special Locations) available soon.
543.7 is a new group of regulations which replaces the now deleted Section 607 Earthing requirements for the installation of equipment having high protective conductor currents. Section 607 was previously a Special Location in Part 6 of BS 7671 but, as this type of installation is commonplace, the requirements are now included within the main body of the Regulations as it is no longer considered to be a special location or installation.

Overview
Some items of electrical equipment are designed to have a current flowing in the protective conductor when in use; these currents are often created by switch-mode power-supplies.

Commonly, IT (Information Technology) or computer-processing equipment use switch-mode power-supplies in applications where a particular voltage is required for operation.

Other items, such as electronic ballasts in high-frequency fluorescent luminaires or variable speed drives are also known to create currents in protective conductors. Faulty and interconnected equipment can also create protective conductor currents.

In reality, considering that many modern “intelligent” electrical items such as washing machines, refrigerators, A/V equipment, etc., have embedded computer-processing, protective conductor currents are very common and not just a problem for industrial or commercial applications.

Essentially, the requirements of 543.7 are related to the levels of protective conductor current:

- **Individual items**
  Individual items of electrical equipment having a protective conductor current exceeding 3.5 mA but not exceeding 10 mA shall be either permanently connected to the fixed wiring of the installation or connected by means of a plug and socket-outlet complying with BS EN 60309-2, and

- **Accumulative current in the circuit**
  Where the accumulative protective conductor current in a final or distribution circuit is likely to exceed 10 mA, a high integrity connection shall be provided.

**Levels of protective conductor current**
The levels of expected protective conductor current will vary depending on the type of electrical equipment. BS EN 60335-1 Household and similar electrical appliances - Safety - Part 1: General requirements states the fundamental conditions to which items of electrical equipment are manufactured and, hence, should perform when used under normal operating conditions.

Clause 13.2 of BS EN 60335 states that after the appliance has been operated for a duration corresponding to the most unfavourable conditions of normal use, the leakage current (protective conductor current) shall...
not exceed the values shown in figure 1.

For terminology purposes, the term "high" protective conductor current is used when values of current exceed 3.5 mA flowing in the protective conductor.

**The dangers**

Where a current flows in a protective conductor, a voltage will present along the length of the conductor and Ohm’s law dictates the size of the potential difference. If the connection to the means of earthing is lost then the metallic chassis of the electrical equipment will rise in potential in respect to Earth. Should a person or livestock make contact with the metallic chassis then current is likely to flow resulting in an electric shock.

**The requirements of 543.7**

Regulation 543.7.1.1 requires that individual items of electrical equipment having a protective conductor current above 3.5 mA but not exceeding 10 mA should be either permanently connected to the fixed wiring, see figure 2, of the installation or connected by means of a plug and socket-outlet, see figure 3, complying with BS EN 60309-2.

**An earth monitoring system to BS 4444**

An earth monitoring system to BS 4444 (see figure 4) installed which, in the event of a continuity fault occurring in the protective conductor, automatically disconnects the supply to the equipment.

**The connection of equipment**

The table shown in figure 5 (overleaf), shows the level of protective conductor current with the requirements of BS 7671:2008 for equipment.

**Final and distribution circuits**

The table overleaf in figure 6 shows the requirements of BS 7671:2008 for every final circuit and distribution.
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circuit intended to supply one or more items of equipment, such that the total protective conductor current is likely to exceed 10 mA:

**Residual Current Devices**

Regulation 411.3.3 requires that socket outlets, not exceeding 20 A, that are for use by ordinary persons intended for general use, are protected by an RCD rated at 30 mA or less, with an operating time not exceeding 40 ms at a residual current of 5 $\Delta n$; an exception is permitted if the socket-outlets are under the supervision of skilled or instructed persons.

When designing such circuits, the designer must be aware of the type of equipment likely to be supplied. Accumulative high protective conductor currents, in addition to starting surges when many items are energised simultaneously, can cause the RCD to operate.

As there is no testing requirement between $0.5 \Delta n$ and $1 \Delta n$, it is fair to assume that a 30 mA RCD could operate at any level of residual current greater than 15 mA. Therefore, it would be pertinent to design high protective conductor currents for any circuit protected by an RCD rated at 30 mA at a level no greater than 15 mA. See Guidance Note 3 for more information on the testing of RCDs.

**Labelling at distribution boards**

Circuits at distribution boards with high protective conductor currents are to be labelled accordingly so that persons working on the distribution boards can maintain the protective precautions taken. The labelling information is to be in accordance with Regulation 543.7.1.5.

Where a circuit has or is likely to have a high protective conductor current, the protective conductor connection arrangements at the distribution board will be affected by.
 Regulation number  
BS 7671:2008  
Current (mA)  
The requirements of BS 7671:2008

<table>
<thead>
<tr>
<th>Regulation number</th>
<th>Current (mA)</th>
<th>The requirements of BS 7671:2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>543.7.1.3</td>
<td>&gt;10</td>
<td>a single CPC 10 mm² minimum or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a single copper conductor, 4 mm² minimum with mechanical protection or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>two individual CPCs or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>monitored by an earth monitoring device to BS 4444 (see figure 4)</td>
</tr>
</tbody>
</table>

The wiring of every final circuit and distribution circuit intended to supply one or more items of equipment, such that the total protective conductor current is likely to exceed 10 mA, shall have a high integrity protective connection complying with one or more of the following:

- a single CPC 10 mm² minimum
- a single copper conductor, 4 mm² minimum with mechanical protection
- two individual CPCs
- monitored by an earth monitoring device to BS 4444

The example is that the electrical installation has a six-way distribution/consumer unit and consists of six circuits:

![Table showing the requirements of BS 7671 in relation to the protective conductor current of circuits](image)

for example, the sequence of connections.

Regulation 543.7.1.4 requires that where two protective conductors are utilised they are to be terminated independently of each other at all connection points, including accessories. This may pose a problem at the earth bar of the distribution board, i.e. there may not be an adequate number of spare ways to terminate conductors separately. Some large distribution boards may be provided with many spare terminals on the earth bar, whilst some manufacturers may supply an accessory kit to add extra ways. Where this is not an option, the following solution is one method of meeting the requirements:

The example is that the electrical installation has a six-way distribution/consumer unit and consists of six circuits:

![Figure 6: Table showing the requirements of BS 7671 in relation to the protective conductor current of circuits](image)
Regulation 543.7.1.4 requires that where two protective conductors are used on circuits with high protective conductor currents, they are to be terminated into separate ways on the earth bar.

By installing circuits 1 and 2 across two-ways of the earth bar, in addition to marking each conductor with the correct circuit-identification ferrule, there is no ambiguity as to the function of each conductor (see figure 7).

Regulation 543.7.1.5 requires that information is provided at the distribution board indicating those circuits having a high protective conductor current (see figure 8).

**Further information**

Guidance Note 1
Guidance Note 3
Guidance Note 5

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The 17th Edition of the Wiring Regulations (BS 7671: 2008) will introduce a number of new requirements for the installation of RCDs, therefore it is timely to look at the requirements within the 17th Edition for verification of RCDs. The continuing effectiveness of these RCDs needs to be confirmed periodically. This article discusses the verification required where RCDs are used to provide automatic disconnection of supply in the event of a fault and additional protection.

It should be stated at this point that the 17th Edition does not introduce any significant changes in the requirements for the testing of RCDs even where they are installed to provide automatic disconnection in the event of a fault.

Use of RCDs to achieve automatic disconnection in case of a fault

411.3.2.1 requires (in most cases) that a protective device shall interrupt the supply to a line conductor of a circuit or equipment in the event of a fault of negligible impedance between said line conductor and an exposed-conductive-part or a protective conductor for the circuit or equipment within the appropriate required disconnection time.

A disconnection time of 5 seconds for distribution equipment and final circuits of rating exceeding 32A is permitted by 411.3.2.3. Similarly, a disconnection time of 1 second for distribution equipment and final circuits of rating exceeding 32 A is permitted by 411.3.2.4.

411.3.2.2 states that the maximum disconnection times of Table 41.1 shall be applied to final circuits not exceeding 32 A. Table 41.1 gives the maximum disconnection times for final circuits not exceeding 32 A of varying nominal voltages forming part of an installation having either TN or TT system earthing. These disconnection times may be met by the use of fuses, circuit breakers (formerly known as MCBs) or RCDs.

411.4.9 states that where an RCD is used to meet the requirements of Table 41.1, that is, to provide the required disconnection time, the maximum values of earth fault loop impedance in Table 41.5 may be applied.

The maximum permissible earth fault loop impedances (Zs) to ensure RCD operation for non-time delayed RCDs protecting final circuits not exceeding 32 A are given in Table 41.5, a new table introduced in the 17th Edition, which is reproduced below.

Where an RCD is employed to achieve the disconnection time required by Table 41.1, it is necessary to satisfy ourselves that the maximum earth fault loop impedance (Zs) stated for a particular sensitivity of RCD in Table 41.5 is not exceeded in the circuit to which they provide protection. This is in effect the same procedure that we applied in earlier editions where fuses or circuit breakers were used to achieve the necessary disconnection time and indeed continue to apply for fuses and circuit breakers in the 17th Edition.

Regardless of which type of protective device is used to achieve the disconnection times required by Table 41.1, whether fuse, circuit breaker or RCD, there is no requirement to confirm that the required disconnection time can be achieved by testing the protective device. Rather, we confirm that the earth fault loop impedance of the protected circuit does not exceed the relevant tabulated maximum earth fault loop impedance for the type / sensitivity of the protective device intended to provide the required disconnection time.

<table>
<thead>
<tr>
<th>Rated residual operating current (mA)</th>
<th>Maximum earth fault loop impedance Zs (ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 V &lt; U₀ ≤ 120 V</td>
</tr>
<tr>
<td>30</td>
<td>1667*</td>
</tr>
<tr>
<td>100</td>
<td>500*</td>
</tr>
<tr>
<td>300</td>
<td>167</td>
</tr>
<tr>
<td>500</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1: Maximum earth fault loop impedance (Zs) to ensure RCD operation in accordance with Regulation 411.5.3 for non-delayed RCDs to BS EN 61008-1 and BS EN 61009-1 for final circuits not exceeding 32 A
17th Edition requirements for testing of RCDs

The 17th Edition has the following requirements in terms of verification of installed RCDs:

- **612.8.1** requires the effectiveness of automatic disconnection of supply by RCD to be verified using test equipment meeting the requirements of BS EN 61557-6 (Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c. – Equipment for testing, measuring or monitoring of protective measures. Residual current devices (RCD) in TT, TN and IT systems). This is to confirm that the relevant requirements of Chapter 41 (Protection against electric shock) are met.

BS EN 61557-6 has requirements for the following tests to be applied to RCDs:
- Non-tripping (50%) test
- Tripping (100%) test
- 5 $I_{\Delta n}$ (500%) test

- **612.13.1** requires the effectiveness of the integral test facility of an RCD to be verified.

- **415.1.1** states that where an RCD having an $I_{\Delta n}$ of 30 mA or less is installed to provide additional protection, its operating time should not exceed 40 ms at a residual current of 5 $I_{\Delta n}$.

**Recommended test procedures**

Although the following tests are not required by BS 7671: 2008 they are a method of establishing that the device meets the requirements of Chapter 41.

Remember, in order for reliable results to be obtained when performing these tests, any loads should be disconnected from the circuits and/or outlets under test.

**Non-tripping test.**

The purpose of this test is to confirm that an RCD of any type or trip rating is not overly sensitive and is a measure intended to enable unsuitable RCDs to be identified and removed from service. The continued presence of overly sensitive RCDs tends to reduce user confidence in such devices and may encourage the adoption of potentially dangerous practices such as the “bridging-out” of RCDs in order to avoid unwanted tripping.

**Test procedure** - With a leakage current equal to 50% of the rated residual operating current ($I_{\Delta n}$) applied, the RCD should not operate.

**Tripping current test**

The purpose of this test is to confirm that the residual
operating current of the protective device is less than or equal to the rated residual operating current. This is a measure of the continued effectiveness of the device to work as required by BS 7671 and in accordance with its product specification when installed for the purpose of providing automatic disconnection in the event of a fault. It does not demonstrate its suitability in terms of providing additional protection. The test should be performed in both the positive and negative half-cycles.

Test procedure -

- **General purpose RCD to BS EN 61008 and RCBO to BS EN 61009**
  With a leakage current flowing equivalent to 100% of the rated residual operating current ($I_{\Delta n}$) of the RCD, operation should occur within 300 ms.

- **“S” type RCD to BS EN 61008 (incorporating an intentional time delay)**
  With a leakage current flowing equivalent to 100% of the rated residual operating current ($I_{\Delta n}$) of the RCD, operation should occur within a time range from 130 ms to 500 ms.

- **General purpose RCD to BS 4293 and RCD protected socket-outlets to BS 7288**
  With a leakage current flowing equivalent to 100% of the rated residual operating current ($I_{\Delta n}$) of the RCD, operation should occur within 200 ms.

- **General purpose RCD to BS 4293 incorporating an intentional time delay**
  With a leakage current flowing equivalent to 100% of the rated residual operating current ($I_{\Delta n}$) of the RCD, operation should occur within a time range from 50% of the rated time delay plus 200 ms to 100% of the rated time delay plus 200 ms.

**Test to confirm suitability for use to provide additional protection**
The purpose of this test is to confirm the continued suitability of an RCD having a rated residual operating current ($I_{\Delta n}$) not exceeding 30 mA to provide additional protection under no-fault conditions (in the 16th Edition, this was known as supplementary protection against direct contact). The test should be performed in both the positive and negative half-cycles.

Test procedure - With a leakage current flowing equivalent to 500% of (i.e. 5 times) the rated residual operating current ($I_{\Delta n}$) of the RCD, operation should occur within 40 ms.

**Confirmation of the effectiveness of the integral test facility**
RCDs have an integral test device to simulate the passing through the detecting device of a residual current. This makes possible periodic testing of the ability of the residual current device to operate.

However, it should be remembered that operation of the integral test button merely confirms the continuing functioning of the electrical and mechanical components of the RCD. It does not confirm that the device is capable of operating in accordance with the specification of the relevant product standard or, indeed the requirements of BS 7671.

Test procedure - With the supply to the RCD switched on and with the RCD in the “on” position, the button marked “T” or “Test” on the RCD is pressed. The RCD should switch off. IEE Guidance Note 3 Inspection and testing. A revised version reflecting the changes brought about by the advent of the 17th Edition will be available in July 2008.

**Summary**
RCDs should be tested at 50%, 100% and, if providing additional protection, 500% of their rated residual operating current ($I_{\Delta n}$). In addition, the integral test device should be operated quarterly.

Where an RCD is employed to achieve the disconnection time required by Table 41.1 it is necessary to confirm that the maximum earth fault loop impedances ($Z_s$) stated for a particular sensitivity of RCD in Table 41.5 are not exceeded in the circuit to which they provide protection.

More in depth descriptions of both RCD and earth fault loop impedance testing procedures are given in IEE Guidance Note 3 Inspection and testing.
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THE FUNDAMENTAL rule of protection against electric shock is:
- live parts, such as energized conductors, must not be accessible, and
- conductive parts which are accessible, such as metal enclosures of equipment or metal pipes, must not be hazardous-live

These two conditions must be achieved both in normal conditions (no faults on the electrical system) and under single fault conditions (such as a fault from a live conductor to a metal casing).

Protection under normal conditions
Protection under normal conditions is achieved by basic protection, formerly known as protection against direct contact. Protection under single fault conditions is achieved by fault protection and was previously referred to as protection against indirect contact.

Basic protection is defined as:

Protection against electric shock under fault-free conditions

Basic protection is provided to protect persons or livestock coming into direct contact with live parts.

A live part is defined as:

A conductor or conductive part intended to be energized in normal use, including a neutral conductor but, by convention, not a PEN conductor

Figure 1 illustrates a person coming into contact with live parts.

Protection under fault conditions or fault protection is defined as:

Protection against electric shock under single fault conditions

Fault protection provides protection against persons or livestock coming into contact with exposed-conductive-parts which have become live under single fault conditions. An exposed-conductive-part is defined as:

Conductive part of equipment which can be touched and which is not normally live but which can become live when basic insulation fails

Figure 2 illustrates how a person could receive an electric shock under single fault conditions. The person in Figure 2 is in contact with the metal enclosure of an item of Class I electrical equipment which has become live under fault conditions. The potential of the metal enclosure is higher than that of the main earthing terminal of the installation (and that of Earth) because of a potential difference created by the passage of fault current through the impedance of the circuit protective conductors and the means of earthing.

Protective measures
A protective measure must consist of provision of basic protection and provision of fault protection, which normally are independent. For example, in the case of automatic disconnection of supply, basic protection is provided by insulation and barriers and enclosures while fault protection is provided by protective earthing, protective bonding and automatic disconnection of supply. Basic and fault protection are independent.

Enhanced protective measure
A permitted exception is where the protective measure is an enhanced protective measure which provides both basic and fault protection. An example of an enhanced protective measure is reinforced insulation. Basic protection and fault protection are both provided by the reinforced insulation (Refer to Regulation 410.3.2).

Recognized protective measures
BS 7671: 2008 recognizes the protective measures listed in Table 1 (see page 22).

The protective measure of Automatic Disconnection of Supply
The protective measure of automatic disconnection of supply consists of basic protection, fault protection and, for some circuits and locations, additional protection. Basic protection is provided by basic insulation of live parts and/or by barriers or enclosures. Fault protection is provided by (i) protective earthing, (ii) main protective equipotential bonding, and

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PROTECTION AGAINST ELECTRIC SHOCK by John Ware

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A conductor or conductive part intended to be energized in normal use, including a neutral conductor but, by convention, not a PEN conductor

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BS 7671: 2008 recognizes the protective measures listed in Table 1 (see page 22).

The protective measure of Automatic Disconnection of Supply
The protective measure of automatic disconnection of supply consists of basic protection, fault protection and, for some circuits and locations, additional protection. Basic protection is provided by basic insulation of live parts and/or by barriers or enclosures. Fault protection is provided by (i) protective earthing, (ii) main protective equipotential bonding, and
(iii) automatic disconnection of supply in the case of a fault.

Protective earthing
Protective earthing requires all exposed-conductive-parts to be connected to a protective conductor which in turn is connected to the main earthing terminal and hence, via the earthing conductor to the means of earthing.

Main protective equipotential bonding
In each installation main protective bonding conductors complying with Chapter 54 are required to connect to the main earthing terminal extraneous-conductive-parts, such as water and gas installation pipes, other installation pipework and ducting, central heating and air conditioning systems and exposed metallic structural parts of the building.

Automatic disconnection in case of a fault
When a fault occurs, the fault current has to be of sufficient magnitude to operate the circuit protective device to automatically disconnect the supply to the faulty circuit within a prescribed time.

A protective device such as a fuse, circuit-breaker or RCD is to be provided and the circuit designed such that the device operates and disconnects the supply.

In the event of a fault of negligible impedance between a line conductor and an exposed-conductive-part or a protective conductor, the protective device must disconnect the supply within the appropriate time stated in Table 41.1 of BS 7671 (See Table 2, page 22).

Requirements of the protective measure of Automatic Disconnection of Supply include protective earthing, main protective equipotential bonding and automatic disconnection.

TN systems
In a TN system each exposed-conductive-part of the installation is required to be connected by a protective conductor to the main earthing terminal of the installation which must be connected to the earthed point of the power supply system, i.e. the supply transformer. The characteristics of the protective device and the circuit impedances are required to fulfill the following requirement (Regulation 411.4.5):

\[ Z_s \times I_a \leq U_o \]

where:
- \( Z_s \) is the impedance in ohms (Ω) the fault loop comprising:
  - the source
  - the line conductor up to the point of the fault, and
  - the protective conductor between the point of the fault and the source.
- \( I_a \) is the current in amperes (A) causing the automatic operation of the disconnecting device within the time specified in Table 41.1 of BS 7671.
- \( U_o \) is the nominal a.c. rms or d.c. line voltage to Earth in volts (V) which is 230 V.

TT system
In a TT system, every exposed-conductive-part is required to be connected, via the main earthing terminal to a common earth electrode (Regulation 411.5.1 refers). The preferred protective device for fault protection is an RCD (Regulation 411.5.2) but where an RCD is used, as it will be in most cases, overcurrent protection must nonetheless be provided by a fuse or a circuit-breaker; or, alternatively a combined RCD and overcurrent protective device.
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Section 412 
Reinforced insulation

Electrical separation for the supply to
one item of current-using equipment
General 
Insulation or barriers and
Simple separation of the circuit
from other circuits and Earth 
Section 413
Reinforced insulation

Extra-low voltage (SELV and PELV).
General
• Voltage must not exceed 50 V a.c.
• Supply from a suitable source
• Separation 
With SELV the circuit is separated, with
PELV it is earthed
Fault protection provided by 
Section 414

Obstacles
Controlled or supervised by skilled persons
Obstacles
With or without Fault protection 
Refer to Regulations 417.1 and 417.2
Placing out of reach 
Refer to Regulation 417.3
Non-conducting location
Installation is controlled or under
the supervision of skilled or instructed persons so that
unauthorized changes cannot be met
Refer to Regulation 418.1
Insulation or barriers and
Refer to Regulation 418.2
Placing out of reach
Electrical separation for the supply to
more than one item of current-using equipment

Table 1: Recognized protective measures
(an RCBO) may be employed. Where an RCD is used for fault protection, the following conditions are to be fulfilled:

- the disconnection time must be that required by Table 41.1, and
- \( R_A \times I_{\Delta n} \leq 50 \) V

Where:
- \( R_A \) is the sum of the resistances of the earth electrode and the protective conductor connecting it to the exposed-conductive-parts (in ohms).
- \( I_{\Delta n} \) is the rated residual operating current of the RCD.

Additional protection

BS 7671 recognizes this measure as reducing the risk of electric shock in the event of failure of one or other of the two basic protective measures mentioned above (insulation and barriers or enclosures) and/or failure of the provision for fault protection or carelessness by users.

The measure must not be used as the sole means of protection and does not obviate the need to apply one of the protective measures specified in Sections 411 Automatic disconnection of supply, 412 Double or reinforced insulation 413 Electrical separation and 414 Extra low voltage provided by SELV or PELV; Regulation 415.1.2 refers.

Additional protection by means of a 30 mA RCD is specified as part of a protective measure for situations such as:
- socket-outlets for use by ordinary persons for general use (411.3.3)
- mobile equipment outdoors (411.3.3)
- concealed cables in walls and partitions where the installation is not intended to be under the supervision of a skilled or instructed person, (522.6.7)
- circuits in circuits in certain special Locations (410.3.2)

The protective measure of Double or Reinforced Insulation

Double or reinforced insulation is a protective measure in which:
- basic protection is provided by basic insulation, and
- fault protection is provided by supplementary insulation, or
- both basic and fault protection are provided by reinforced insulation between live parts and accessible parts (Regulation 412.1.1).

Double or reinforced insulation is intended to prevent the appearance of...
a dangerous voltage on the accessible parts of electrical equipment through a fault in the basic insulation. There is no provision for the connection of exposed metalwork of the equipment to a protective conductor, and no reliance upon the earthing arrangements in the fixed wiring of the installation.

**Wiring systems**
Wiring systems must have a rated voltage of the cable(s) is not less than the nominal voltage of the system and at least 300/500 V and adequate mechanical protection of the basic insulation must be provided by one or more of the following the non-metallic sheath of the cable, or non-metallic trunking or ducting or non-metallic conduit.

**The protective measure of Electrical Separation**
Electrical separation is a protective measure in which basic protection is provided by basic insulation of live parts or by barriers or enclosures and fault protection is provided by simple separation of the separated circuit from other circuits and from Earth (Regulation 413.1.1).

The two main principles underlying protection by electrical separation is that neither the source of the supply nor any live parts of the separated circuit is connected to any other circuit or to Earth. Thus, in the event of a single fault to an exposed-conductive-part of equipment in the separated circuit, fault protection is afforded because there is no path for fault current to return to the source.

For an installation in a dwelling, the only likely application of the use of electrical separation is a shaver supply unit complying with BS EN 61558-2-5

Except under particular circumstances (Refer to Regulation 418.3 of BS 7671) this protective measure is limited to the supply of one item of current-using equipment supplied from one unearthed source with simple separation.

The source of supply is an isolating transformer conforming to BS EN 61558 (which supersedes BS 3535), or one of the other sources specified in Regulation 414.3 having an equivalent degree of separation from any other system.

Protection by electrical separation requires the following conditions to be met:
- The separated circuit must be supplied through a source with at least simple separation
- The voltage of the separated circuit must not exceed 500 V
- Live parts of the separated circuit must not be connected at any point to another circuit or to Earth or to a protective conductor

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No exposed-conductive-part of the separated circuit must be connected either to the protective conductor or exposed-conductive-parts of other circuits, or to Earth. If the exposed-conductive-parts of the separated circuit are liable to come into contact, either intentionally or fortuitously with the exposed-conductive-parts of other circuits, protection against electric shock no longer depends solely on protection by electrical separation but on the protective provisions to which the latter exposed-conductive-parts are subject.

**Separated circuits**
The use of separate wiring systems is recommended. If separated circuits and other circuits are in the same wiring system, multi-conductor cables without metallic covering, or insulated conductors in insulating conduit, non-metallic ducting or non-metallic trunking shall be used, provided that the rated voltage is not less than the highest nominal voltage, and each circuit is protected against overcurrent.

**The protective measure of Extra-Low Voltage provided by SELV or PELV**
Protection by extra-low voltage provided by SELV or PELV requires all of the following:
- Limitation of voltage in the SELV or PELV system to the upper limit of voltage Band I which is 50 V a.c. or 120 V d.c. and
- Protective separation of the SELV or PELV system from all circuits other than SELV and PELV circuits, and
- Basic insulation between the SELV or PELV system and other SELV or PELV systems, and
- For SELV systems only, basic insulation between the SELV system and Earth.

The extra-low voltage is generally considered insufficient to present a hazard of electric shock (as defined) in dry situations where the person protected has a body resistance within normal limits. In certain locations the requirements of Part 7 limit the value of the extra-low voltage to a value lower than 50 V a.c. or 120 V d.c.

If the nominal voltage exceeds 25 V a.c. or 60 V d.c., or if the equipment is immersed, basic protection shall be provided for SELV and PELV circuits by insulation in accordance with Regulation 416.1. Basic protection and fault protection is provided under the following conditions:
- The nominal voltage cannot exceed the upper limit of voltage Band I, and
- The supply is from a permitted source, and
- The requirements applicable to SELV or PELV circuits listed below are met. (Regulation 414.2 refers). If the system is supplied from a higher voltage by equipment which provides at least simple separation between that system and the extra-low voltage system but which does not meet the requirements for a SELV and PELV source, the requirements for PELV may be applicable.

For further information refer to Guidance Note 5: *Protection against electric shock*.

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**Figure 4: The principle of electrical separation**

**Figure 5: Simple PELV system**
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