



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-conductiveparts which have become live under single fault conditions. An exposedconductive-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 (iii) automatic disconnection of supply in the case of a fault.

### **Protective earthing**

Protective earthing requires all exposedconductive-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 exposedconductive-part of the installation is





Figure 3: Automatic Automatic Disconnection of Supply

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 fulfil the following requirement (Regulation 411.4.5): Zs x Ia  $\leq$  Uo

where:

Zs is the impedance in ohms  $(\Omega)$  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.

Ia 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. Uo 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 exposedconductive-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 circuitbreaker, or, alternatively a combined RCD and overcurrent protective device

Protective measure	Use	Basic protection provided by	Fault protection provided by	Fault protection provided by
Automatic disconnection of supply	General	Insulation or barriers and enclosures	Protective earthing Protective bonding Automatic disconnection	Used in 95% of all installations. Section 411 in BS 7671: 2008. Includes FELV (411.7) and RLV (411.8)
Double or reinforced insulation	General	Basic insulation	Supplementary insulation	Section 412
		Reinforced insulation		
Electrical separation for the supply to one item of current-using equipment	General	Insulation or barriers and enclosures	Simple separation of the circuit from other circuits and Earth	Section 413
Extra-low voltage (SELV and PELV).	General	<ul> <li>Voltage must not exceed 50 V a.c.</li> <li>Supply from a suitable source</li> <li>Separation</li> </ul>		With SELV the circuit is separated, with PELV it is earthed 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		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	Insulation or barriers and enclosures	The conditions of supervision under which the fault protective provisions of Section 418 may be applied as part of the protective measure are given in Regulation 410.3.6.	Refer to Regulation 418.1
Earth-free local equipotential bonding				Refer to Regulation 418.2
Electrical separation for the supply to more than one item of current-using equipment				Refer to Regulation 418.3

### 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
- $\blacksquare \ R_A \ge I\Delta n \le 50 \ V$
- 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

	Final circuit not exceeding 32 A	Final circuit exceeding 32 A	Distribution circuit	
TN system	0.4 s	5 s	5 s	
IT system	0.2 s	1 s	1 s	
TT system <sup>(1)</sup>	0.4 s	5 s	5 s	

<sup>(1)</sup> Where, in a TT system, disconnection is achieved by an overcurrent protective device and main bonding is connected to all the extraneous-conductive-parts within the installation in accordance with Regulation 411.3.1.2, the maximum disconnection times applicable to a TN system may be used. A maximum disconnection time of 5 s applies to all circuits in a reduced low voltage system Regulation 411.8.3 refers). A maximum disconnection time of 5 s applies to all circuits supplying fixed equipment used in highway power supplies (Regulation 559.10.3.3 refers).

### Table 2: Extract from Table 41.1 (and others) of BS 7671: 2008 Maximum disconnection times for a nominal a.c. rms. line voltage to Earth of 230 V

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 exposedconductive-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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Figure 4: The principle of electrical separation



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, nonmetallic 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 is a protective measure which consists of either of two different extra-low voltage systems, SELV (Separated Extra-Low Voltage), or PELV (Protective Extra-Low Voltage), Regulation 414.1.1 refers.

### SELV is defined as:

An extra-low voltage system which is electrically separated from Earth and from other systems in such a way that a single fault cannot give rise to the risk of electric shock

### PELV is defined as:

An extra-low voltage system which is not electrically separated from Earth, but which otherwise satisfies all the requirements for SELV

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 FELV may be applicable.

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