Contents

1. Introduction

2. Definitions

3. Application of the measures of protection against electric shock
   3.1 General
   3.2 Locations of increased shock risk

4. Measures of protection against both direct and indirect contact
   4.1 Protection by SELV
   4.2 Protection by limitation of discharge of energy

5. Measures of protection against direct contact

6. Supplementary protection against direct contact by a residual current device (RCD)

7. Measures of protection against indirect contact
   7.1 Protection by Earthing Equipotential Bonding and Automatic Disconnection of supply (EEBAD)
   7.2 Protection by Class II equipment or by equivalent insulation
   7.3 Protection by non-conducting location
   7.4 Protection by earth-free local equipotential bonding
   7.5 Protection by electrical separation

8. Further protective measures recognized by BS 7671
   8.1 Extra-low voltage systems other than SELV
   8.2 Automatic disconnection and reduced low voltage systems

1. Introduction

One of the main objectives of BS 7671 is to protect persons and livestock (in locations intended for them) from the hazard of electric shock currents which may arise in the reasonable use of an electrical installation.

Protection against electric shock requires the provision of an appropriate measure of protection against direct contact and one against indirect contact, selected from those recognized by BS 7671. This topic covers the principles underlying the recognized measures of protection.

Other topics in the Technical Manual cover the requirements relating to each measure.

2. Definitions

In order to aid the understanding of the information given in this topic, it may be helpful to review a number of definitions given in Part 2 of BS 7671.
The definition of ‘electric shock’ is:

“A dangerous physiological effect resulting from the passing of an electric current through a human body or livestock.”

The application of the requirements of BS 7671 can be expected to give protection against electric shock as defined (‘a dangerous physiological effect...’) to the average person; or, from another viewpoint, for most persons under most conditions. Requirements such as short, predictable disconnection times and low RCD operating currents cannot be guaranteed to prevent death or serious injury due to electric shock in all circumstances.

Furthermore, the application of the requirements may not protect against the unpleasant sensation which may be caused when a current of insufficient magnitude and duration to cause danger is passed through the body.

More information about electric shock may be found in Topic E65-5 – ELECTRIC SHOCK: The hazard, physiological effect of electric current.

The definition of ‘Direct contact’ is:

‘The contact of persons or livestock with live parts.’

The definition of direct contact refers to ‘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.’

Figures 1 and 2 illustrate direct contact.

Direct contact – by contact with a live conductor whilst in contact with Earth.

Fig 1
Direct contact – by contact with live conductors at different potentials

Fig 2

The definition of ‘Indirect contact’ is:

‘The contact of persons or livestock with exposed-conductive-parts which have become live under fault conditions.’

The definition of indirect contact refers to ‘exposed-conductive-parts’. An exposed-conductive-part is defined as ‘a conductive part of equipment which can be touched and which is not a live part but which may become live under fault conditions.’

Fig 3 illustrates indirect contact.

Indirect contact

Fig 3
The person in Fig 3 is in contact with the metal enclosure of an item of Class I electrical equipment which has become live under earth 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 earth fault current through the impedance of the circuit protective conductor.

3. Application of the measures of protection against electric shock

3.1 General

Regulation 410-01-01 of BS 7671 requires protection against electric shock to be provided by the application, in accordance with Section 471, of:

(i) an appropriate measure of protection specified in Section 411 (Protection against both direct and indirect contact), or
(ii) a combination of appropriate measures of protection specified in Section 412 (Protection against direct contact) and Section 413 (Protection against indirect contact).

The principles of the measures of protection in (i) are covered in item 4 of this topic, and the principles of the measures of protection in (ii) are covered in items 5 and 7.

3.2 Locations of increased shock risk

In locations where the risk of electric shock is increased (eg due to a reduction in body resistance or contact with earth potential), the application of the measures of protection referred to in (i) and (ii) of item 3.1 may be subject to additional or supplementary requirements. Examples of such requirements which apply in certain of the locations of increased shock risk in Part 6 of BS 7671 are given in the following list:

- The use of one or more of the range of protective measures against electric shock is not permitted. For example, in a number of locations, the use of the following is not permitted:
  - protection by obstacles (see item 5)
  - protection by placing out of reach (see item 5)
  - protection by non-conducting location (see item 7.3)
  - protection by earth-free local equipotential bonding (see item 7.4).
- The only measure of protection permitted is SELV (see item 4.1).
- A reduction in nominal voltage (eg to that of a SELV system), or the use of a reduced low voltage (as referred to Regulation Group 471-15) is required.
- Additional measures are required (such as supplementary equipotential bonding (see Topic B37.65), or the provision of insulation, barriers or enclosures to live parts of a SELV system).
- A reduction in the maximum disconnection time in the event of an earth fault is required, such as where the protective measure of EEBAD is used (see item 7.1).
4. Measures of protection against both direct and indirect contact

Whilst most electrical installations employ separate basic measures to protect against direct contact and indirect contact, Section 411 of BS 7671 recognizes two basic measures which can protect against both direct and indirect contact. The two basic measures are:

(i) protection by SELV (which stands for Separated Extra-low Voltage) according to Regulations 411-02 and 471-02, and

(ii) protection by limitation of discharge of energy according to Regulations 411-04 and 471-03.

4.1 Protection by SELV

SELV is given its own definition in Part 2 of BS 7671, as follows:

'SELV (separated extra-low voltage). 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.'

The protection that SELV affords against electric shock is partly associated with the value of voltage. The maximum nominal voltage permitted between the conductors of a SELV circuit is 50 V a.c. rms or 120 V ripple-free d.c. This 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.

So as to prevent a dangerous voltage occurring in a SELV circuit due, for example, to an insulation breakdown in the primary winding of a step-down transformer, the source of supply to SELV circuits is a safety isolating transformer complying with BS EN 60742, or one of the other sources given in Regulation 411-02-02.

For similar reasons, relating to a possible insulation failure in a conductor of a higher voltage circuit, SELV circuit wiring is electrically (and often physically) separated from the wiring of higher voltage systems.

To further reduce the risk of electric shock, conductors and exposed-conductive-parts of a SELV system are connected neither to Earth nor to other systems.

BS 7671 requires additional protection in locations of increased shock risk, including those in Part 6 of that standard. Such protection may include limiting the nominal voltage to a value not exceeding 25 V a.c. rms or 60 V ripple-free d.c. (or in some cases an even lower limit) and the provision of insulation, barriers or enclosures for protection against direct contact.

In some locations of increased shock risk, such as certain zones of swimming pools, SELV is the only protective measure against electric shock permitted by BS 7671.
4.2 Protection by limitation of discharge of energy

This protective measure limits the current which can pass through the body of a person or livestock to a value lower than that likely to cause danger.

The protective measure usually relates only to individual items of current-using equipment complying with an appropriate British Standard, although Regulation 471-03-01 states that it may be extended to the part of the installation derived from such equipment.

The most commonly-quoted practical application of limitation of discharge of energy is the electric fence energizer and its associated electric fence. Such an arrangement limits the current passed through the human body or livestock to regular pulses, of restricted magnitude and duration.

The requirements relating to protective measures mentioned in items 4.1 and 4.2 are discussed in Topics D37-1 and D37-9, respectively.

5. Measures of protection against direct contact

Four basic measures of protection against direct contact are recognized by BS 7671. As given in Regulation 412-01-01, these are:

(i) protection by insulation of live parts (Regulation 412-02 and Regulation 471-04),
(ii) protection by a barrier or an enclosure (Regulation 412-03 and Regulation 471-05),
(iii) protection by obstacles (Regulation 412-04 and Regulation 471-06), and
(iv) protection by placing out of reach (Regulation 412-05 and Regulation 471-07).

The underlying principle of the above measures (i) to (iv) is to prevent or deter contact with live parts by persons or livestock (in locations intended for them). Protection against such contact is provided either by covering, enclosing or shielding of the live parts, as in basic measures (i) and (ii), or by placing live parts (which may be bare) where they cannot normally be reached, as in basic measures (iii) and (iv).

Basic measures (i) and (ii) (insulation, and barriers or enclosures), are the most commonly used measures of protection against direct contact, and are employed in virtually every electrical installation. They are discussed in Topics D41-1 and D41-5, respectively.

The application of the basic protective measure (iii) (obstacles) is limited to areas accessible only to skilled persons, or to instructed persons under the direct supervision of a skilled person. (A ‘skilled person’ is defined in Part 2 of BS 7671 as ‘A person with technical knowledge or sufficient experience to enable him/her to avoid dangers which electricity may create.’) The same limitation also applies to the application of basic measure (iv) (placing out of reach). The only exception is where the measure is applied to an overhead line for distribution between buildings and structures, installed to the standard of the Electricity Supply Regulations 1988, as amended (Regulation 412-05-01 of BS 7671 refers).
Protection by obstacles or placing out of reach are not permitted in most of the installations and locations of increased shock risk addressed in Part 6 of BS 7671.

Further information on obstacles and placing out of reach may be found in Topics D41-9 and D41-11, respectively.

6. Supplementary protection against direct contact by residual current device (RCD)

BS 7671 recognizes this measure as reducing the risk of electric shock where one or more of the basic protective measures specified in items (i) to (iv) of Regulation 412-01-01 (as referred to in item 4 of this topic) is applied.

The measure must not be used as the sole means of protection against direct contact (Regulation 412-06-01 refers).

The principle of the measure is this. Where a person (or livestock) makes contact with a live part of a circuit to which this type of protection is provided, and such contact results in a current to Earth of not less than the rated residual operating current of the RCD ($I_{\Delta n}$), the RCD disconnects the supply to the circuit. Note that the RCD cannot detect the current flowing through the body of a person making contact between phase and neutral, as shown in Fig 2.

The requirements for the rated residual operating current, $I_{\Delta n}$, and operating time of the RCD are given in Regulation 412-06-02(ii). The device is required to have a rated residual operating current not exceeding 30 mA and an operating time not exceeding 40 ms at a residual current of 5 $I_{\Delta n}$, as given by the product standards listed in the regulation.

With certain exceptions, supplementary protection against direct contact by the use of an RCD is required to be provided for every circuit or socket-outlet which may reasonably be expected to supply portable equipment outdoors (Regulation Group 471-16 refers). This is because of the increased risk of electric shock to users of portable equipment outdoors, due, for example, to exposure of a person to wetness and contact with the general mass of Earth.

For further information on the requirements relating to the above measure of protection, and examples of where it is to be used, reference should be made to Topic D41-13.
7. Measures of protection against indirect contact

Five basic measures of protection against indirect contact are recognized by BS 7671. As given in Regulation 413-01-01, these are:

(i) protection by earthed equipotential bonding and automatic disconnection of supply (Regulation 413-02 and Regulation 471-08)
(ii) protection by Class II equipment or by equivalent insulation (Regulation 413-03 and Regulation 471-09)
(iii) protection by non-conducting location (Regulation 413-04 and Regulation 471-10)
(iv) protection by earth-free local equipotential bonding (Regulation 413-05 and Regulation 471-11)
(v) protection by electrical separation (Regulation 413-06 and Regulation 471-12).

7.1 Protection by Earthed Equipotential Bonding and Automatic Disconnection of supply (EEBAD)

This is the most commonly used basic measure of protection against indirect contact, and is employed in virtually every electrical installation.

The underlying principle of the measure is to ensure that voltages occurring between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts occurring anywhere in the installation under earth fault conditions are of such magnitude and duration as not to cause danger.

The protective measure consists of three separately identifiable components:

- Earthing of the metalwork of the electrical installation (exposed-conductive-parts)
- Equipotential Bonding of metalwork which is not part of the electrical installation but which is liable to introduce a potential (extraneous-conductive-parts)
- Automatic Disconnection of supply to the faulty circuit, by means of an overcurrent protective device or a residual current device, in the event of an earth fault.

Further information on the protective measure of EEBAD may be found in Topic I17-7.

7.2 Protection by Class II equipment or by equivalent insulation

In this protective measure, equipment having double or reinforced insulation (Class II equipment) or equivalent insulation is used to prevent the appearance of a dangerous voltage on the exposed metalwork of the 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.
Protection by Class II or equivalent insulation is generally applicable to **individual items of equipment**, such as items of switchgear or luminaires. Only under certain conditions may the measure be used as the sole means of protection against indirect contact for **an installation**. The conditions are given in Regulation 471-09-03, which requires that it be verified that the installation or circuit concerned will be under effective supervision in normal use so that no change is made that would impair the effectiveness of the protective measure.

In addition, Regulation 471-09-03 does not permit Class II or equivalent insulation to be relied upon for protection against indirect contact in a circuit which includes a socket-outlet or where a user may change items of equipment without authorization.

More information on protection by Class II or equivalent insulation is given in **Topic I17-3**.

### 7.3 Protection by non-conducting location

This protective measure, although included in **BS 7671**, is not recognized in the Regulations for common use. The measure is intended to be applied only in special situations which are under effective supervision. Its use is prohibited in some of the installations and locations of increased shock risk covered in Part 6 of **BS 7671**.

The main principles underlying protection by non-conducting location are that:

- Arrangements are made so that a person cannot come into simultaneous contact with two exposed-conductive-parts or with an exposed-conductive-part and any extraneous-conductive-parts.
- There are no protective conductors, and no socket-outlets or luminaire supporting couplers which include a protective conductor contact.
- The walls and floors of the location are of electrically insulating material, such that the resistance of every point to Earth (under specified conditions) is not less than a specified value.
- Any point of a wall or floor where the resistance is lower than the specified value is deemed to be an extraneous-conductive-part for the purposes of protection against electric shock.
- Permanent arrangements are made which afford protection where the use of mobile or portable equipment is envisaged.
- Precautions are taken so that a potential on extraneous-conductive-parts in the location cannot be transmitted outside the location.

The continued effectiveness of protection by non-conducting location is difficult to ensure. This is because of the risk that other conductive parts may be introduced into the location at a later date, such as by the installation of a metallic water pipe or the introduction of portable Class I equipment plugged into a socket-outlet outside the location.

More information on protection by non-conducting location is given in **Topic I17-9**.
7.4 Protection by earth-free local equipotential bonding

The use of this protective measure is permitted by BS 7671 under effective supervision and only in special situations which are earth-free. Use of the measure is prohibited in some of the installations and locations of increased shock risk covered in Part 6 of BS 7671.

Protection by earth-free local equipotential bonding is intended to prevent the appearance of a dangerous voltage between simultaneously accessible parts in the event of a failure in basic insulation.

The main principles underlying the measure are that:

- An unearthed equipotential bonding conductor connects together every simultaneously accessible exposed-conductive-part and extraneous-conductive-parts, to maintain all the parts at substantially the same potential.
- Precautions are taken so that persons entering and leaving the equipotential location cannot be exposed to dangerous potential difference, in particular where a conductive floor insulated from Earth is connected to the earth-free equipotential bonding conductors.

More information protection by earth-free local equipotential bonding is given in Topic E21-1.

7.5 Protection by electrical separation

This protective measure is for use in a single circuit, which may supply a single item of electrical equipment or, subject to certain requirements being complied with, more than one item of equipment.

The source of supply is an isolating transformer conforming to BS EN 60742, or one of the other sources specified in Regulation 413-06-02, having an equivalent degree of separation from any other system.

There are two main principles underlying protection by electrical separation:

- Neither the source of the supply nor any live parts of the separated circuit are 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, protection is afforded against indirect contact because there is no path for fault current to return to the source.
- Where the electrically separated source is used to supply more than one item of equipment, all exposed-conductive-parts of equipment in the separated circuit are connected together by an unearthed equipotential bonding conductor. Arrangements are made so that, if two faults to exposed-conductive-parts occur and these are fed by conductors of different polarity, the supply will be automatically disconnected so as to prevent danger.
A common application of the use of electrical separation is a shaver supply unit complying with BS EN 60742, Chapter 2, Section 1.

More information on protection by electrical separation is given in Topic E89-1.

8. Further protective measures recognized by BS 7671

In addition to the measures of protection against electric shock already referred to in this topic, BS 7671 recognizes (in Section 471) the following further measures which may be used.

8.1 Extra-low voltage systems other than SELV

Two extra-low voltage systems other than SELV are recognized, namely:

- PELV (protective extra-low voltage), and
- FELV (functional extra-low voltage).

PELV and FELV do not meet all the requirements relating to a SELV system, and their use is not permitted for certain applications in some of the locations of increased shock risk in Part 6 of BS 7671.

In a PELV system (unlike a SELV system, which is described in item 4.1), a connection is normally made – usually at the safety isolating transformer or equivalent source – between a live conductor and Earth or the protective conductor of the primary circuit. In addition, exposed-conductive-parts of a PELV system may be connected to Earth, to a protective conductor or exposed-conductive part of another system, or to an extraneous-conductive-part. For reasons of protection against direct contact, live conductors of a PELV system operating at a nominal voltage exceeding 25 V a.c. rms or 60 V ripple-free d.c. are shielded to specified standards by insulation, barriers or enclosures.

A FELV system does not meet the requirements for SELV in some respect other than those specified for PELV. This is normally that the source of extra-low voltage is a device such as an autotransformer, not providing the standard of electrical separation of a safety isolating transformer. For protection against direct contact, irrespective how low the nominal voltage, live conductors of a FELV system are shielded to specified standards by insulation, barriers or enclosures. In addition, for protection against indirect contact, exposed-conductive-parts of a FELV system are connected to the protective conductor of the primary circuit.

Fuller details of PELV and FELV systems are given in Section E161.
8.2 Automatic disconnection and reduced low voltage systems

Automatic disconnection and reduced low voltage (ADRLV) systems may be used where for functional reasons the use of extra-low voltage is impractical and there is no requirement for the use of SELV. ADRLV systems are commonly used in certain of the installations and locations of increased shock risk covered in Part 6 of BS 7671, particularly construction sites.

The nominal phase to phase voltage in an ADRLV system does not exceed 110 V and the nominal phase to earth voltage does not exceed 63.5 V. Protection against direct contact is provided by insulation, barriers or enclosures. Protection against indirect contact is provided by automatic disconnection of supply.

Fuller information on ADRLV systems may be found in Topic I17-1.