203: Electrical installations technology  
**Handout 20: Protective devices**

**Learning outcome**

The learner will:

1. know wiring systems of electrical installations.

**Assessment criteria**

The learner can:

3.4 state **applications** of different types of **protective devices.**

**Range**

**Protective devices**: Fuses (BS88 (gM, gG), BS3036, BS1362), circuit breaker BSEN60898 types b, c and d, RCD BSEN61008, RCBO BSEN 61009 types b, c and d.

**Protective devices**

It is necessary to install protective devices in circuits for when faults occur, in order to provide protection against electric shock and also to ensure that the premises and wiring systems are not damaged as a result of, for example, fire.

Faults will generally cause one or both of the following to occur:

* overcurrent
* earth leakage.

**Overcurrent**

An overcurrent is defined in BS7671 as ‘**a current exceeding the rated value. For conductors the rated value is the current‑carrying capacity**’.

Protection against overcurrent can be provided by a fuse, circuit breaker or a residual current operated circuit breaker with integral overcurrent protection (RCBO).

Overcurrent can be further subdivided into two categories:

* overload current
* fault current.

BS7671 defines an overload current as ‘**an overcurrent occurring in a circuit which is electrically sound**’. This generally occurs when a circuit is abused, eg too many appliances plugged into socket outlets, or it was badly designed or modified, or a machine is trying to drive a mechanical load that is too much for it. An overload normally results in an overcurrent up to two to three times the rated value of the circuit.

BS7671 defines a fault current as ‘**a current resulting from a fault**’. A fault is further defined as ‘**a circuit condition in which current flows through an abnormal or unintended path. This may result from an insulation failure or a bridging of insulation. Conventionally, the impedance between live conductors or between live conductors and exposed‑ or extraneous‑conductive‑parts at the fault position is considered negligible**.’ A fault current can be many hundreds of times the rated current of the circuit.

In either case, the purpose of circuit protection is to interrupt the circuit quickly, before damage is caused to the installation, as well as ensuring that the risk of electric shock is removed. In order to achieve this, protective devices are placed in the line conductor(s).

**Earth leakage**

In BS7671, earth leakage is referred to as ‘protective conductor current’, as it is defined as an ‘**electric current appearing in a protective conductor, such as leakage current or electric current resulting from an insulation fault**’.

Protection against earth leakage can be provided by a fuse, circuit breaker, a residual current operated circuit breaker with integral overcurrent protection (RCBO) or a residual current device (RCD).

Whilst the most common cause of earth leakage is as a result of an insulation fault, it must be remembered that some equipment, eg computer power supplies, are naturally ‘leaky’. If a number of similar pieces of equipment are connected to the same circuit, the earth leakage current could reach dangerously high levels, as their effect will be cumulative.

Some typical current levels (a.c.) and their effect on the average human body are given below:

* 1mA: perception level (you would start to feel a slight ‘tingle’)
* 10–15mA: can cause powerful muscle contractions; the victim is unable to voluntarily control muscles and cannot release an electrified object.
* >30mA: can cause ventricular fibrillation which can lead to cardiac arrest.

**Fuses**

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| **BS3036 semi‑enclosed fuse**  Also referred to as a rewireable fuse, these were commonly used but, due to their inferior protection characteristics resulting in cables having to be de‑rated, they are now very rarely installed. However, there will still be numerous installations that will be protected by these devices.  A fuse wire is connected between the two blades and provides a ‘weak link’ in the circuit. When a certain current flows through this wire, it will become hot, melt and break the circuit. | 01 BS3036 fuse.PNG |

Available sizes are:

* 5A (white)
* 15A (blue)
* 20A (yellow)
* 30A (red)
* 45A (green).

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| **Advantages of BS3036 fuses:**   * simple to check if blown * low cost to replace fuse element * no moving parts. | **Disadvantages of BS3036 fuses:**   * danger of being repaired with wrong size wire * deteriorate with age * circuit cannot be quickly restored * cannot break large fault currents * danger if replaced on faulty circuit (melting wire) * fusing factor of around 1.8–2.0 means that they cannot be guaranteed to operate up to twice the rated current that is flowing. As a result, cables protected by them must have a larger current‑carrying capacity. |

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| **BS88‑3:2010 cartridge fuses (replacing BS1361)**  These cartridge fuses are for use by unskilled persons, mainly for household and similar applications.  The cartridge fuse breaks a faulty circuit in the same way as a semi-enclosed fuse, but its construction eliminates some of the disadvantages experienced with an open fuse element.  The cartridges are manufactured in such a way that higher rated fuses are physically larger in size; this is done to minimise the risk of replacing a blown fuse with an overrated cartridge. | 01 BS1361 fuses.PNG | |
| **Advantages of BS88‑3:2010 fuses:**   * small physical size * no mechanical moving parts * accurate current rating * not liable to deterioration with age * fusing factor 1.6–1.9.   **Disadvantages of BS88‑3:2010 fuses:**   * more expensive than rewireable * can be shorted by silver foil * cannot break large fault currents. | | 03 BS88-3 fuse.PNG |
| **BS88‑2:2010 fuses (replacing BS88‑2 and BS88‑2.1)**  These cartridge fuses are for use by authorised persons, mainly for industrial applications, and include bolted and clip type.  These generally have a high current breaking capacity and are often referred to as HBC fuses (high breaking capacity), formerly HRC (high rupturing capacity).  These fuses can be classified as either gG or gM, depending on their intended usage. | | 04 BS88.png |

The difference between the two is that gG fuses are general purpose and gM are motor rated.

gG fuses have a single rating, eg 20A, which means it can carry 20 amperes indefinitely.

The gM fuses have a double rating, eg 20M32. The first figure indicates the continuous current rating, whilst the second figure is a short-term characteristic that allows the motor starting current to subside before the device operates.

Motor rated fuses are handy because you can use smaller rated cables/switchgear.

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| **Advantages of BS88‑2:2010 fuses:**   * no mechanical moving parts * declared rating is very accurate * operation is very quick * with gM fuses you can distinguish between a persistent fault and a transient fault such as the large starting current taken by motors * reliable – it can break large current safely * fusing factor 1.25–1.70. | **Disadvantages of BS88‑2:2010 fuses:**   * expensive. | | |
| **BS1362 cartridge fuses**  These cartridge fuses are especially for use in the standard UK BS1363 13 ampere plug top.  This cartridge fuse breaks a faulty circuit in the same way as other fuses, ie by the internal fuse wire melting when current becomes excessive.  When the BS1363 plug was first introduced, there were five fuses in the official BS1362 range (with their specified colour): 2 (blue), 5 (grey), 7 (black), 10 (yellow) and 13 (brown) amps.  The current version, BS1362:1973, allows any fuse rating up to 13A, with 3 amp (coloured red) and 13 amp (coloured brown) as the preferred (but not mandated) values when used in a plug. All other ratings are to be coloured black (this is why 5 amp fuses are now black instead of grey).  The purpose of the plug mounted fuse is to protect the flexible cord, **not** the appliance itself. | | 05 BS1362 fuses.png | |
| **Circuit breaker to BS EN 60898**  With their continual reduction in cost, circuit breakers (CB) are for most electricians the most common type of protective device installed.  BS EN 60898 includes ratings up to 100A and maximum fault capacities of 9kA.  CBs provide much closer overcurrent protection compared to traditional fuses and it is much easier to reset the circuit when the fault is cleared.  Formerly referred to as ‘miniature circuit breakers’ (MCB), they are now simply referred to as ‘circuit breakers’ (CB). | | | 06 BS EN 60898 CB.PNG |
| **Advantages of BS EN 60898 CBs:**   * tripping characteristics, and therefore circuit protection, are set by the installer * circuit protection difficult to interfere with * the circuit provides discrimination * a faulty circuit may be easily and quickly restored by an unskilled operator. | **Disadvantages of BS EN 60898 CBs:**   * they contain mechanical moving parts. | | |

Circuit breakers’ two means of tripping:

* thermal trip that operates relatively slowly and is ideal for detecting overload currents
* magnetic tripping device that operates very quickly and is ideal for detecting fault currents.

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| A typical circuit breaker is shown to the right:   1. Box terminal 2. Thermal element 3. Magnetic hammer action solenoid 4. Arc chamber 5. Trip bar 6. Moving contact 7. Fixed contact 8. DIN clip | Wylex MCB with labels.PNG |

Circuit breakers are graded according to their tolerance to overload and this is summarised in the table below, which is Table 7.2.7(ii) from the IET On‑Site Guide (BS7671:2011).

**Table 7.2.7(ii) Application of circuit breakers**

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| **Circuit-breaker type** | **Trip current (0.1 s to 5 s)** | **Application** |
| **1** | **2.7 to 4 In** | **Domestic and commercial installations having little or no**  **switching surge** |
| **B** | **3 to 5 In** |
| **2** | **4 to 7 In** | **General use in commercial/industrial installations where**  **the use of fluorescent lighting, small motors, etc, can**  **produce switching surges that would operate a Type 1 or**  **B circuit breaker. Type C or 3 may be necessary in highly**  **inductive circuits such as banks of fluorescent lighting.** |
| **C** | **5 to 10 In** |
| **3** | **7 to 10 In** |
| **4** | **10 to 50 In** | **Not suitable for general use.** |
| **D** | **10 to 20 In** | **Suitable for transformers, X‑ray machines, industrial**  **welding equipment, etc, where high inrush currents may**  **occur.** |

**Note**: In is the nominal rating of the circuit‑breaker.

Whilst you will encounter types 1, 2, 3 and 4 already installed, these types are now not available. The recognised types readily available are types B, C and D.

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| **Residual current device (RCD) BS EN 61008**  All the devices mentioned so far will provide protection against both overcurrent and earth leakage. However, providing earth leakage protection with these devices requires a large current to flow to earth.  In order to detect much smaller leakage currents that could still be lethal to life, an RCD must be used.  An RCD compares the current flowing out through the line conductor with the current returning through the neutral; if the current exceeds a predetermined value, the device will trip and disconnect the circuit.  The rated value is referred to as the IΔn and is usually rated in mA. | 08 RCD.PNG |

Until the introduction of the 17th Edition of BS 7671, the use of RCDs was generally limited to protecting socket outlets feeding appliances used outside the premises.

However, it is now likely that most circuits will require RCD protection, including the following:

* locations containing a bath or shower (Regulation 701.411.3.3)
* socket‑outlets with a rated current not exceeding 20A (Regulation 411.3.3)
* mobile equipment with a current rating not exceeding 32A for use outdoors (Regulation 411.3.3)
* where cables are concealed in walls at a depth of less than 50mm without mechanical protection (Regulation 522.6.202).

This list shows examples of use and is not exhaustive.

The diagram below shows the internal circuit arrangement which has been drawn to best show the operation of the RCD.

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| 09 RCD circuit.PNG |

**IMPORTANT NOTE**: An RCD does **not** provide overcurrent protection – it will only provide earth leakage protection.

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| **Residual current operated circuit breaker with integral overcurrent protection (RCBO) BS EN 61009**  An RCBO is a combination of a thermal‑magnetic circuit breaker and an RCD that enable both overcurrent protection and earth fault protection to be provided in a single unit for individual circuits, usually but not exclusively in domestic installations.  The major advantage is that this allows earth fault protection to be restricted to a single circuit and therefore only the circuit with the fault is interrupted, thus providing better discrimination.  With most devices, two additional wires must be connected in order for this device to function. One wire connects to the neutral block, whilst the other connects to the earth block. However, there are RCBOs on the market that do not need an earth connection.  RCBOs are available in types B and C but not in type D. | 10 RCBO.PNG |