NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronics Engineering

ELECTRICAL INSTALLATION DRAWING PROJECT

Student: MOHAMMAD ALKURDI

NUMBER: 20011152

COURSE: EE 400

TEACHER: ASSIST.PROF.DR KADRI BURUNCUK

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ABSTRACT

As whole world is trying to save energy for future or for coming rainy days, so world is going toward finding out the to protect the electrical installation we have and use alternative resources the practical part about layout the faculty of engineering, hold three floors each of them has three distribution boxes expect the ground floor has four of distributions. There are many different technologies used in circuit breakers and they do not always fall into distinct categories. The following types are common used in our plan domestic, commercial and light industrial applications for low voltage (less than 1000V) use. MCB - Miniature Circuit Breaker - rated current not more than 100A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category. MCCB - Moulded Case Circuit Breaker - rated current up to 1000A. Thermal or thermal-magnetic operation. Trip current may be adjustable.

When choosing a cable one of the most important factors is the temperature attained by its insulation; if the temperature is allowed to exceed the upper design value, premature failure is likely. In addition, corrosion of the sheaths or enclosures may result. For example, P.V.C. becomes hard and brittle at low temperatures, and if a cable insulated with it is installed at temperatures below 5°C it may well become damaged.

The earthing conductor is commonly called the earthing lead. It joins the installation earthing terminal to the earth electrode or to the earth terminal provided by the Electricity Supply Company, but great care must be taken when doing so to ensure that there will be no problems with corrosion or with electrolytic action where they come into contact with other metals.

Later on advantages and disadvantages are discussed briefly in this project.

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INTRODUCTION

These regulations (commonly called the I.E.E. Regulations) have been devised by the wiring committee of the Institution of Electrical Engineers to "ensure safety in the utilization of electricity in and about buildings". The I.E.E. Regulations are of considerable assistance to electricians as they largely cover the requirements of the Electricity Supply Regulations. The I.E.E. Regulations consist of two parts: part 1 contains "requirements for safety" and part 2 contains "means of securing compliance with part 1".

It should be noted that the I.E.E. Regulations are not legally binding but are generally accepted as an efficient standard by Electrical Boards, contractors and industrial and domestic consumers. However, Electrical Boards may have their own particular rules which must be obeyed particular industries have their own regulations for example, coal mines and cinemas these special regulations have the force of law.

Generally, if an installation complies with the I.E.E. Regulations it complies both with the Factory Acts and with the Electricity Supply Regulations since the I.E.E. Regulations are based on the requirements of these statutory regulations.

My project contains two parts, the first part is the practical part about layout the faculty of engineering and the second part is the theoretical part which contains four chapters and the main idea of each chapter are as follows:

The first chapter about cables, conduit and trunking - A cable type is determined by the specifications of the system installed, basic electronic principles, and environment and regulatory agencies. These various criteria dictate the type of conductor(s), gauge of wire, type of insulation, twisted or cabled construction, type of jacket and if any shielding is required. A basic understanding of cable construction should be helpful in selecting and installing the proper cable for a particular system.

Conductors for electronic cables can vary greatly from stranded conductors for maximum flexibility to copper covered steel which provides a stronger cable that will withstand a greater physical strain than copper. The American Society For Testing and Materials (ASTM) standards are followed for all of West Penn Wire conductor material. The ASTM standard defines standard requirements such as tensile strength, elongation, resistivity, dimensions, permissible variations, finish, inspection, and testing.

There are several types of material that conduct electricity well (aluminum, nickel, gold, silver). However, copper is the most popular due to its excellent conductivity compared to other material cost. West Penn Wire uses a variety of conductors in our cable. Material used can be bare copper, tinned copper and copper covered steel. The conductor can consist of solid or stranded construction. The type of conductor selected is determined by the application the cable will be used for.

There are basically three types of shielding techniques: foil shielding, braid shielding, and combination shielding. Shielding is utilized to prevent radiation and signal loss of high frequencies used in electronic circuits and to reduce EMI/RFI interference. However, shielding tends to increase the overall capacitance of the cable.

The second chapter about installation control and protection - The circuit breaker is defined as a mechanical device for making and breaking a circuit both under normal conditions and under abnormal conditions, such as those of a short circuit, the circuit being broken automatically.

The circuit-breaker is generally opened and closed by hand (manually) but is automatically opened under fault conditions by an over-current release. The over-current release is operated by the magnetic effect of the line current flowing in the circuit. This current flows through a current coil consisting of a few turns of heavy-gauge copper wire or copper tape. When a continual overload is placed on the protected circuit the electromagnetic field, due to the current flowing in the coil, draws up a plunger which operates a mechanical trip, thus isolating the circuit from the supply.

Circuit breakers are available in a great variety of sizes and types. Army marine circuit breakers are of the molded case, trip-free type. They must be arranged so that they can be removed without disconnecting the copper or cable connections or de-energizing the power supply to the circuit breaker. The circuit breaker rating should be the value of current the breakers will carry continuously without exceeding the specific temperature rise.

Protection the temporary installation must be protected with an adequate switch which isolates all the poles from the supply.

The third chapter about basic requirements of circuits - The domestic ring circuit is defined as a final sub-circuit in which the current-carrying and earth-continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution fuse board or its equivalent. A spur of ring circuit shall be a branch cable having conductors of a cross-sectional area not smaller than that of the conductors forming the ring.

The fourth chapter about the earthing principle - The main purpose in testing an installation is to detect faults before dangerous situations arise. The main factors against which an installation must be protected are as follows: earth leakage and danger of electric shock, excess current, moisture and corrosion.

The point should be made at this stage that the I.E.E. Regulations are not a set of rules drawn up to make the electrician's life difficult or a textbook to be learnt parrot-fashion. The regulations were complied by a body of qualified electrical engineers and "designed to ensure safety in the use of electricity in and about buildings" The Electrical Inspector, like the football referee, is not always a popular personality but he fulfils an essential function; by ensuring the application of the regulations, he safeguards the standard of workmanship in our craft.

The main tests carried out on an electrical installation are as follows: (a) verification of polarity, (b) insulation resistance tests, (c) test of ring circuit continuity.

When to carry out the Tests. Tests should be carried out (a) on new installations, (b) on additions to existing installations, and (c) periodically on existing installations.

The fifth chapter about electrical installation series – we are doing the calculations of how many flourcent lamps are needed in rooms which have differences in cross sectional area, illumination, and on how much watt will contain.

The luminous flux depends on the type of the flourcent lamp and how much watt. On our plan we used the flourcent lamp that has (2x80w)

The efficiency of the lamp is dependent on (a) the rating of the lamp (efficiency increases with lamp size); (b) the age of the lamp; and (c) the operation voltage Efficiency is decreased when run at values less than rated voltage. This process of ionization is started off by (a) a high voltage being applied across the tube; or (b) the use of heated filaments in the lamp. The filaments are heated at the moment of starting and are coated with a special oxide which emits electrons. This type of lamp is termed a *hot cathode* lamp.

CHAPTER ONE

CABLES, CONDUITS AND TRUNKING

1.1 - Cable insulation materials

Rubber

For many years wiring cables were insulated with vulcanised natural rubber (VIR). Much cable of this type is still in service, although it is many years since it was last manufactured. Since the insulation is organic, it is subject to the normal ageing process, becoming hard and brittle. In this condition it will continue to give satisfactory service unless it is disturbed, when the rubber cracks and loses its insulating properties. It is advisable that wiring of this type which is still in service should be replaced by a more modern cable. Synthetic rubber compounds are used widely for insulation and sheathing of cables for flexible and for heavy duty applications. Many variations are possible, with conductor temperature ratings from 60°C to 180°C, as well as resistance to oil, ozone and ultra-violet radiation depending on the formulation.

Paper

Dry paper is an excellent insulator but loses its insulating properties if it becomes wet. Dry paper is hygroscopic, that is, it absorbs moisture from the air. It must be sealed to ensure that there is no contact with the air. Because of this, paper insulated cables are sheathed with impervious materials, lead being the most common. PILC (paper insulated lead covered) is traditionally used for heavy power work. The paper insulation is impregnated with oil or non-draining compound to improve its long-term performance. Cables of this kind need special jointing methods to ensure that the insulation remains sealed. This difficulty, as well as the weight of the cable, has led to the widespread use of p.v.c. and XLPE (thermosetting) insulated cables in place of paper insulated types.

P.V.C.

Polyvinyl chloride (p.v.c.) is now the most usual low voltage cable insulation. It is clean to handle and is reasonably resistant to oils and other chemicals. When p.v.c. burns, it emits dense smoke and corrosive hydrogen chloride gas. The physical characteristics of the material change with temperature: when cold it becomes hard and difficult to strip, and so BS 7671 specifies that it should not be worked at temperatures below 5°C. However a special p.v.c. is available which remains flexible at temperatures down to -20°C.

At high temperatures the material becomes soft so that conductors which are pressing on the insulation (e.g. at bends) will 'migrate' through it, sometimes moving to the edge of the insulation. Because of this property the temperature of general purpose P.V.C. must not be allowed to exceed 70°C, although versions which will operate safely at temperatures up to 85°C are also available. If p.v.c. is exposed to sunlight it may be degraded by ultra-violet radiation. If it is in contact with absorbent materials, the plasticiser may be 'leached out' making the p.v.c. hard and brittle.

LSF (Low smoke and fume)

Materials which have reduced smoke and corrosive gas emissions in fire compared with p.v.c. have been available for some years. They are normally used as sheathing compounds over XLPE or LSF insulation, and can give considerable safety advantages in situations where numbers of people may have to be evacuated in the event of fire.

Thermosetting (XLPE)

Gross-linked polyethylene (XLPE) is a thermosetting compound which has better electrical properties than p.v.c. and is therefore used for medium- and high-voltage applications. It has more resistance to deformation at higher temperatures than p.v.c., which it is gradually replacing. It is also replacing PILC in some applications. Thermosetting insulation may be used safely with conductor temperatures up to 90°C thus increasing the useful current rating, especially when ambient temperature is high. A LSF (low smoke and fume) type of thermosetting cable is available.

Mineral

Provided that it is kept dry, a mineral insulation such as magnesium oxide is an excellent insulator. Since it is hygroscopic (it absorbs moisture from the air) this insulation is kept sealed within a copper sheath. The resulting cable is totally fireproof and will operate at temperatures of up to 250°C. It is also entirely inorganic and thus non-ageing. These cables have small diameters compared with alternatives, great mechanical strength, are waterproof, resistant to radiation and electromagnetic pulses, are pliable and corrosion resistant. In cases where the copper sheath may corrode, the cable is used with an overall LSF covering, which reduces the temperature at which the cable may be allowed to operate. Since it is necessary to prevent the ingress of moisture, special seals are used to terminate cables. Special mineral-insulated cables with twisted cores to reduce the effect of electromagnetic interference are available.

1.2 - Cables

1.2.1 - Cables for overhead lines

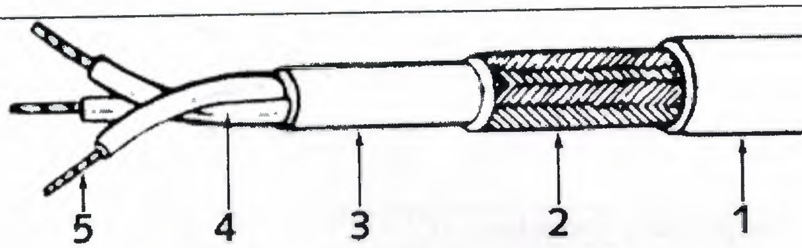
Any of the cables listed in the previous subsection are permitted to be used as overhead conductors provided that they are properly supported. Normally, of course, the cables used will comply with a British Standard referring particularly to special cables for use as overhead lines. Such cables include those with an internal or external catenary wire, which is usually of steel and is intended to support the weight of the cable over the span concerned.

Since overhead cables are to be installed outdoors, they must be chosen and installed so as to offset the problems of corrosion. Since such cables will usually be in tension, their supports must not damage the cable or its insulation.

1.2.2 - Flexible low voltage cables and cords

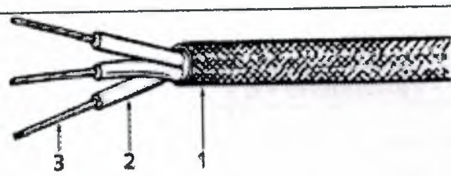
By definition flexible cables have conductors of cross-sectional area 4 mm^2 or greater, whilst flexible cords are sized at 4 mm^2 or smaller. Quite clearly, the electrician is nearly always concerned with flexible cords rather than flexible cables.

(Figure 1.1) - shows some of the many types of flexible cords which are available.



1 - oversheath - PVC	4 - insulation - pvc coloured
2 - braid - plain copper wire	5 - Conductors - plain Copper
3 - inner sheath - pvc	

a) Braided circular - **Figure 1.1a**

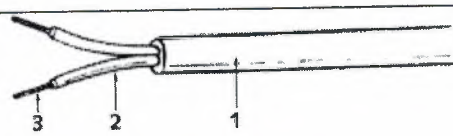


1 - rubber layer collectively textile braided semi-embedded	3 - conductors - tinned copper
2 - insulation (Cores) 60°C rubber	

b) Unkinkable - **Figure 1.1b**

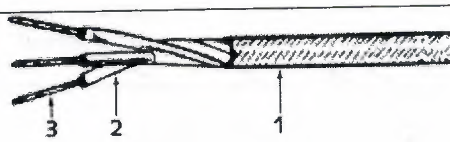
1 - sheath - rubber or pvc	3 - conductors - tinned copper
2 - insulation 60°C rubber or pvc	

c) Circular sheathed - **Figure 1.1c**



1 - sheath - PVC	3 - conductors - plain copper
2 - insulation - PVC	

d) Flat twin sheathed - **Figure 1.1d**



1 - glass braided overall	3 - conductors - stranded Copper
2 - insulation - silicon rubber	

e) Braided circular insulated with glass fibre - **Figure 1.1e**

1 - insulation - pvc	2 - conductors - plain copper

f) Single core p.v.c. - insulated non-sheathed - **Figure 1.1f**

Flexible cables should not normally be used for fixed wiring, but if they are, they must be visible throughout their length. The maximum mass which can be supported by each flexible cord is listed in (Table 4H3A), part of which is shown here as (Table 1.1).

Table 1.1 - Maximum mass supported by twin flexible cord	
Cross-sectional area (mm²)	Maximum mass to be supported (kg)
0.5	2
0.75	3
1.0	5
1.25	5
1.5	5

The temperature at the cord entry to luminaires is often very high, especially where filament lamps are used. It is important that the cable or flexible cord used for final entry is of a suitable heat resisting type, such as 150°C rubber- insulated and braided. (Figure 1.2) shows a short length of such cord used to make the final connection to a luminaire.

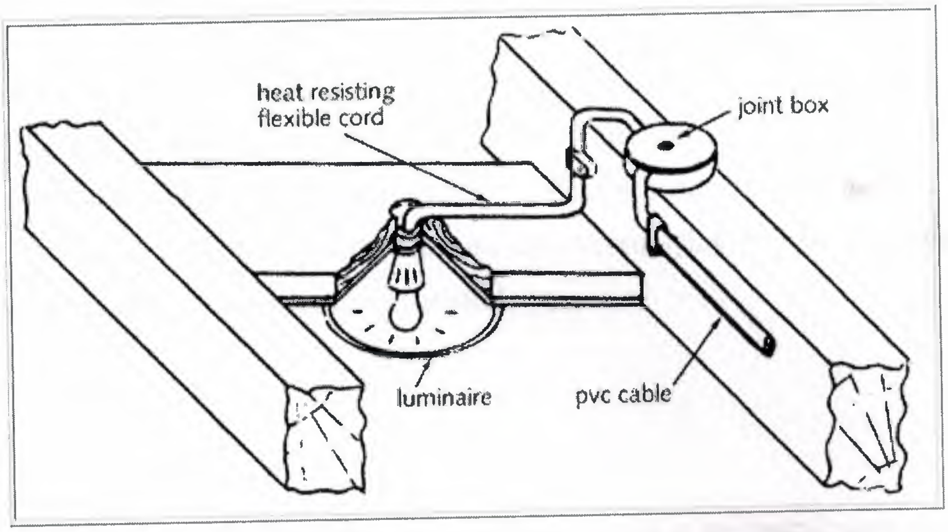


Figure 1.2 - 150°C rubber-insulated and braided flexible cord used for the final connection to a luminaire - [3]

1.2.3 - Corrosion

The metal sheaths and armour of cables, metal conduit and conduit fittings, metal trunking and ducting, as well as the fixings of all these items, are likely to suffer corrosion in damp situations due to chemical or electrolytic attack by certain

materials, unless special precautions are taken. The offending materials include:

1. - unpainted lime, cement and plaster,

2. - floors and dados including magnesium chloride,

3. - acidic woods, such as oak,

4. - plaster undercoats containing corrosive salts,

5. - dissimilar metals which will set up electrolytic action.

In all cases the solution to the problem of corrosion is to separate the materials between which the corrosion occurs. For chemical attack, this means having suitable coatings on the item to be installed, such as galvanising or an enamel or plastic coating. Bare copper sheathed cable, such as mineral insulated types, should not be laid in contact with galvanised material like a cable tray if conditions are likely to be damp. A p.v.c. covering on the cable will prevent a possible corrosion problem.

To prevent electrolytic corrosion, which is particularly common with aluminium-sheathed cables or conduit, a careful choice of the fixings with which the aluminium comes into contact is important, especially in damp situations. Suitable materials are aluminium, alloys of aluminium which are corrosion resistant, zinc alloys complying with BS 1004, porcelain, plastics, or galvanised or sheradised iron or steel.

1.3 - Cable choice

1.3.1 - Cables types

When choosing a cable one of the most important factors is the temperature attained by its insulation; if the temperature is allowed to exceed the upper design value, premature failure is likely. In addition, corrosion of the sheaths or enclosures may result. For example, bare conductors such as busbars may be operated at much higher temperatures than most insulated conductors.

However, when an insulated conductor is connected to such a high temperature system, its own insulation may be affected by heat transmitted from the busbar, usually by conduction and by radiation. To ensure that the insulation is not damaged:

Either the operating temperature of the busbar must not exceed the safe temperature for the insulation, or the conductor insulation must be removed for a suitable distance from the connection with the busbar and replaced with beat resistant insulation.

It is common sense that the cable chosen should be suitable for its purpose and for the surroundings in which it will operate. It should not be handled and installed in unsuitable temperatures. P.V.C. becomes hard and brittle at low temperatures, and if a cable insulated with it is installed at temperatures below 5°C it may well become damaged.

Includes a series of Regulations which are intended to ensure that suitable cables are chosen to prevent damage from temperature levels, moisture, dust and dirt, pollution, vibration, mechanical stress, plant growths, animals, sunlight or the kind of building in which they are installed. Cables must not produce, spread, or sustain fire.

Contains six regulations which are intended to reduce the risk of the spread of fire and are concerned with choosing cables with a low likelihood of flame propagation. A run of bunched cables is a special fire risk and cables in such a situation should comply with the standards stated above.

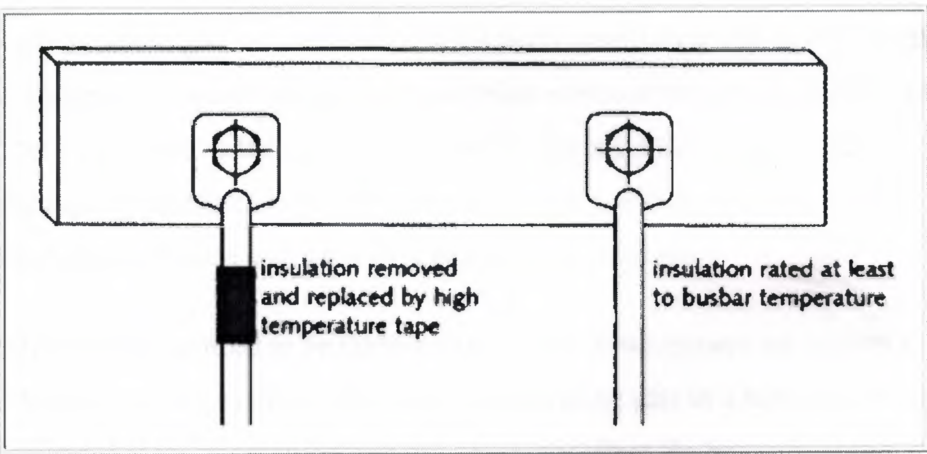


Figure 1.3 - Insulation of a cable connected to hot busbar – [1]

BS 6387 covers cables which must be able to continue to operate in a fire. These special cables are intended to be used when it is required to maintain circuit integrity for longer than is possible with normal cables. Such cables are categorised with three letters. The first indicates the resistance to fire alone (A,B,C and S) and the second letter is a W and indicates that the cable will survive for a time at 650°C when also subject to water (which may be used to tackle the fire). The third letter (X, Y or Z) indicates the resistance to fire with mechanical shock. For full details of these special cables see the BS.

1.3.2 - Methods of cables installation

We have seen that the rating of a cable depends on its ability to lose the heat produced in it by the current it carries and this depends to some extent on the way the cable is installed. A cable clipped to a surface will more easily be able to dissipate heat than a similar cable which is installed with others in a conduit,

Lists twenty standard methods of installation, each of them taken into account in the rating tables of the same Appendix. For example, two 2.5 mm² single core p.v.c. insulated non-armoured cables drawn into a steel conduit (installation method 3) have a current rating of 24 A 2.5 mm² twin p.v.c. insulated and sheathed cable, which contains exactly the same conductors, has a current rating of 27 A when clipped directly to anon-metallic surface. Cables sheathed in p.v.c. must not be subjected to direct sunlight, because the ultra-violet component will leach out the plasticiser, causing the sheath to harden and crack. Cables must not be run in the same enclosure (e.g. trunking, pipe or ducting) as non-electrical services such as water, gas, air, etc. unless it has been established that the electrical system can suffer no harm as a result. If electrical and other services have metal sheaths and are touching, they must be bonded. Cables must not be run in positions where they may suffer or cause damage or interference with other systems. They should not, for example, be run alongside hot pipes or share a space with a hearing induction loop.

Special precautions may need to be taken where cables or equipment are subject to ionising radiation. Where a wiring system penetrates a load bearing part of a building construction it must he ensured that the penetration will not adversely affect the integrity of the construction.

The build-up of dust on cables can act as thermal insulation. In some circumstances the dust may be flammable or even explosive. Design cable runs to minimise dust accumulation: run cables on vertically mounted cable ladders rather than horizontal cable trays. When cables are run together, each sets up a magnetic field with a strength depending on the current carried. This field surrounds other cables, so that there is the situation of current-carrying conductors situated in a magnetic field. This will result in a force on the conductor, which is usually negligible under normal conditions but which can become very high indeed when heavy currents flow under fault conditions. All cables and conductors must be properly fixed or supported to prevent damage to them under these conditions.

1.3.3 - Cable volt drop

All cables have resistance, and when current flows in them this result in a volt drop. Hence, the voltage at the load is lower than the supply voltage by the amount of this volt drop.

The volt drop may be calculated using the basic Ohm's law formula

$$\mathbf{U} = \mathbf{I} \times \mathbf{R}$$

Where **U** is the cable volt drop (V) **I** is the circuit current (A), and **R** is the circuit resistance (ohms).

Unfortunately, this simple formula is seldom of use in this case, because the cable resistance under load conditions is not easy to calculate.

Indicates that the voltage at any load must never fall so low as to impair the safe working of that load, or fall below the level indicated by the relevant British Standard where one applies.

Indicates that these requirements will he met if the voltage drop does not exceed 4% of the declared supply voltage. If the supply is single-phase at the usual level of 240 V, this means a maximum volt drop of 4% of 240 V which is 9.6 V, giving (in simple terms) a load voltage as low as 230.4 V. For a 415 V three-phase system, allowable volt drop will be 16.6 V with a line load voltage as low as 398.4 V.

It should be borne in mind that European Agreement RD 472 S2 allows the declared supply voltage of 230 V to vary by +10% or -6%. Assuming that the supply voltage of 240 V is 6% low, and allowing a 4% volt drop, this gives permissible load voltages of 216.6 V for a single-phase supply, or 374.5 V (line) for a 415 V three-phase supply.

To calculate the volt drop for a particular cable. Each current rating table has an associated volt drop column or table. For example, multicore sheathed non-armoured P.V.C. insulated cables are covered by for current ratings, and volt drops. The exception in the Regulations to this layout is for mineral insulated cables where there are separate volt drop tables for single- and three-phase operation.

Each cable rating in the Tables of [Appendix 4] has a corresponding volt drop figure in millivolts per ampere per metre of run (mV/A/m). Strictly this should be mV/(A m), but here we shall follow the pattern adopted by BS 7671: 1992. To calculate the cable volt drop:

1- take the value from the volt drop table (mV/A/m)
2- multiply by the actual current in the cable (NOT the current rating)
3- multiply by the length of run in metres
4- divide the result by one thousand (to convert millivolts to volts).

The 'length of run' calculations carried out in these examples are often useful to the electrician when installing equipment at greater distances from the mains position.

It is important to appreciate that the allowable volt drop of 4% of the supply voltage applies to the whole of an installation. If an installation has mains, sub-mains and final circuits, for instance.

All of our work in this sub-section so far has assumed that cable resistance is the only factor responsible for volt drop. In fact, larger cables have significant self inductance as well as resistance.There is also an effect called impedance which is made up of resistance and inductive reactance.

Inductive reactance XL = 2(pi) f L

Where XL = inductive reactance in ohms, (pi) = the mathematical constant 3.142, f = the system frequency in hertz (Hz) and L = circuit self inductance in henrys (H)

It is clear that inductive reactance increases with frequency, and for this reason the volt drop tables apply only to systems with a frequency lying between 49 Hz and 61 Hz.

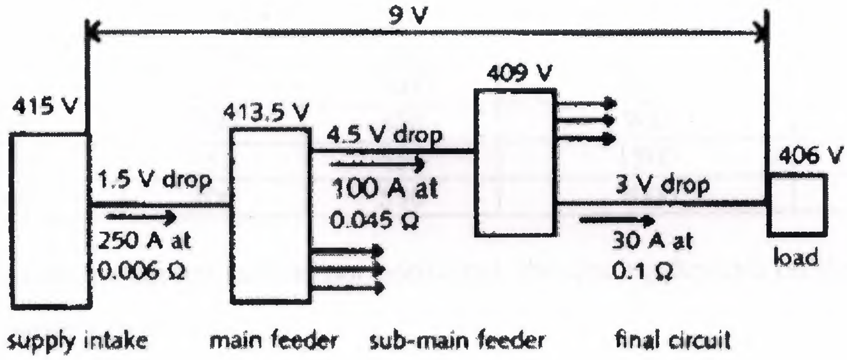


Figure 1.4 - Total volt drop in large installations – [5]

For small cables, the self inductance is such that the inductive reactance is small compared with the resistance. Only with cables of cross-sectional area 25 mm² and greater need reactance be considered. Since cables as large as this are seldom used on work which has not been designed by a qualified engineer, the subject of reactive volt drop component will not be further considered here.

If the actual current carried by the cable (the design current) is less than the rated value, the cable will not become as warm as the calculations used to produce the volt drop tables have assumed, The Regulations include (in [Appendix 4]) a very complicated formula to be applied to cables of cross-sectional area 16 mm² and less which may show that the actual volt drop is less than that obtained from the tables. This possibility is again seldom of interest to the electrician, and is not considered here.

1.4 - Cable supports, joints and terminations

1.4.1 - Cable supports and protection

Cables must be fixed securely at intervals which are close enough to ensure that there will be no excessive strain on the cable or on its joints and terminations, and to prevent cable loops appearing which could lead to mechanical damage. {Table 1.2} indicates minimum acceptable spacings of fixings for some common types of cables.

Table 1.2 - Maximum spacing for cable supports				
Overall cable	p.v.c. sheathed		Mineral insulated	
Diameter	Horizontal	Vertical	Horizontal	Vertical
(mm)	(mm)	(mm)		(mm)
up to 9	250	400	600	800
10 to 15	300	400	900	1200
16 to 20	350	450	1500	2000
21 to 40	400	550	2000	3000

Where cable runs are neither vertical nor horizontal, the spacing depends on the angle as shown in {Figure 1.5}.

Where a cable is flat in cross-section as in the case of a p.v.c. insulated and sheathed type.

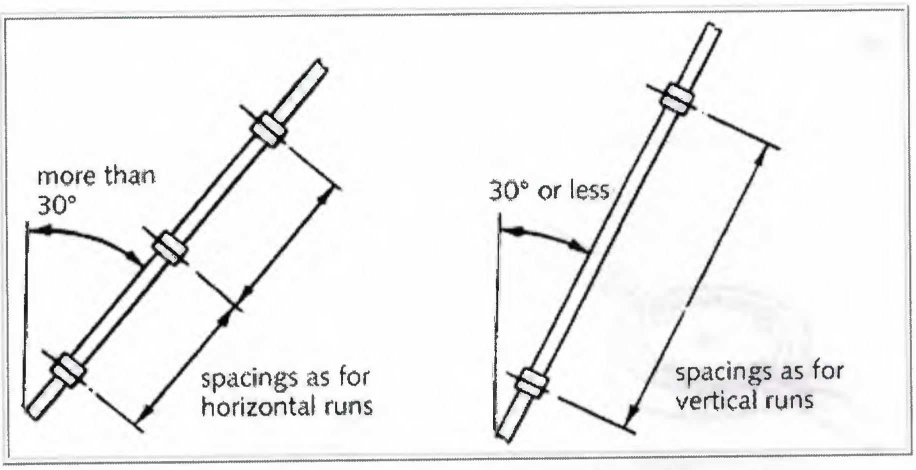


Figure 1.5 - Spacing of support clips on angled runs

1.4.2 - Cables joints and termination

The normal installation has many joints, and it follows that these must all remain safe and effective throughout the life of the system. With this in mind, regulations on joints include the following:

1.-All joints must be durable, adequate for their purpose, and mechanically strong.

2.-They must be constructed to take account of the conductor material and insulation, as well as temperature: e.g., a soldered joint must not be used where the temperature may cause the solder to melt or to weaken. Very large expansion forces are not uncommon in terminal boxes situated at the end of straight runs of large cables when subjected to overload or to fault currents.

3. - All joints and connections must be made in an enclosure complying with the appropriate British Standard.

4. - Where sheathed cables are used, the sheath must be continuous into the joint enclosure.

5.-All joints must be accessible for inspection and testing unless they are buried in compound or encapsulated, are between the cold tail and element of a heater such as a pipe tracer or underfloor heating system, or are made by soldering, welding, brazing or compression.

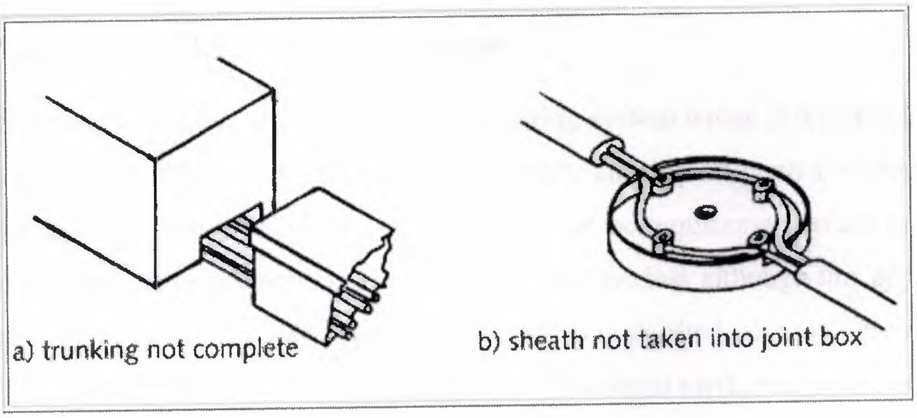


Figure 1.6 - Failure to enclose non-sheathed cables – [1]

1.5 - Conductor and cable identification

1.5.1 - Conduits

The 'electrical' colour to distinguish conduits from pipelines of other services is orange (BS 1710). Oversheaths for mineral insulated cables are often the same colour, which is also used to identify trunking and switchgear enclosures.

1.5.2 - Colours for flexible cables and cords

Unlike the cores of fixed cables, which may be identified by sleeves or tapes where they are connected, flexible must be identified throughout their length. The colour requirements are shown in {Figure 1.7}.

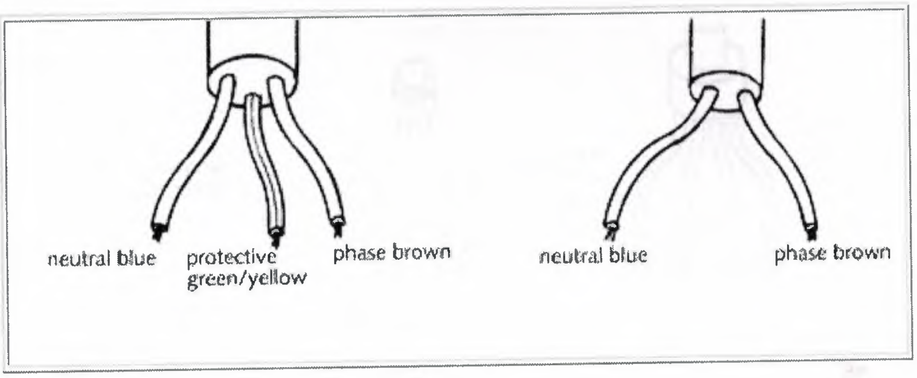


Figure 1.7 - Care colours for flexible cables and cords – [1]

1.5.3 - Identification of fixed wiring conductors

Colour is used to identify the conductors of a wiring system where it is possible to colour the insulation. Where it is not, numbers are used. The requirements for identification of fixed wiring are shown in {Figure 1.8}. There is as yet no requirement to use brown and blue to identify the phase and neutral conductors of fixed wiring, although this applies to flexible cords and cables. The colour green on its own is prohibited, although green and yellow stripes identify the protective conductor. The functional earth conductor for telecommunication circuits is identified by the colour cream.

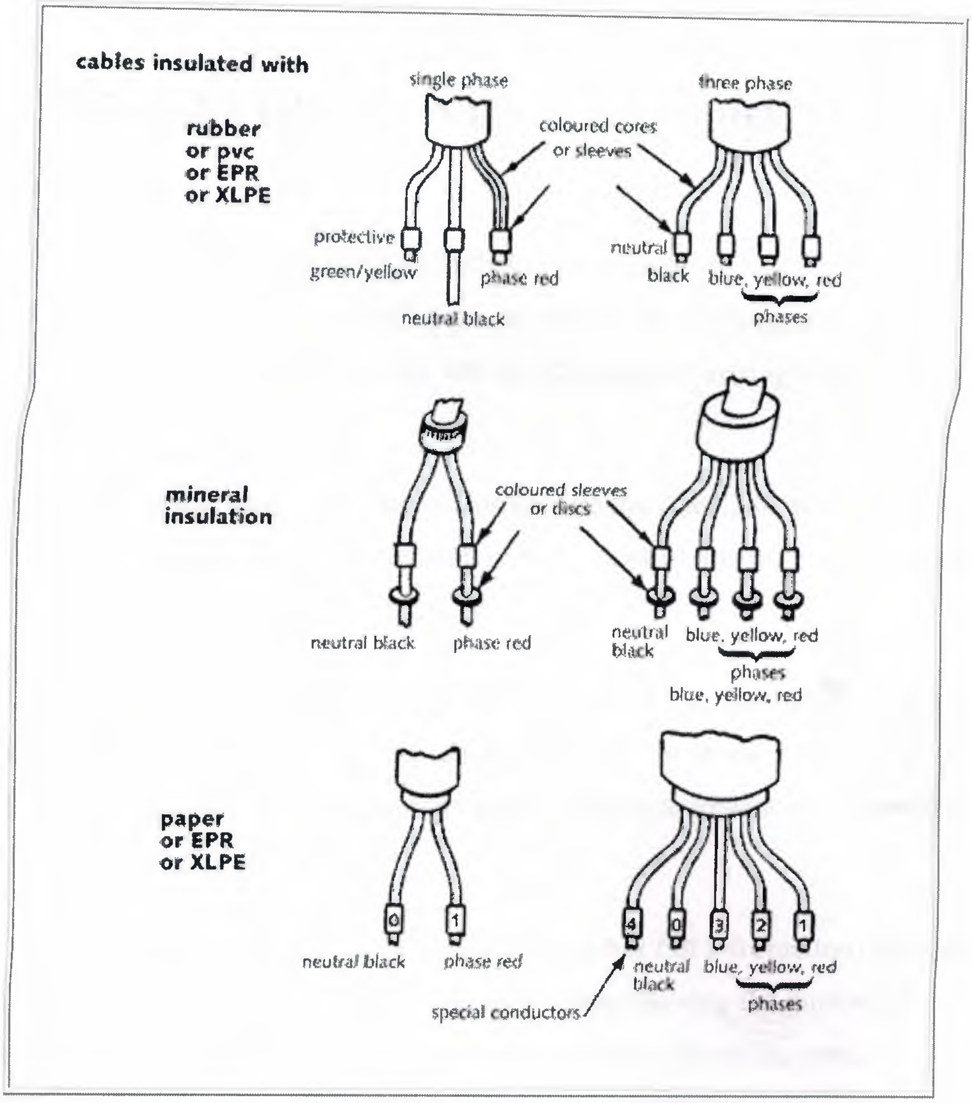


Figure 1.8 - Identification of fixed wiring – [1]

Some cables comply with HD 324:1977 and have blue insulation on the neutral conductor. This colour does not comply with BS 7671 and if such cables are used, they must be correctly identified at their terminations by the use of black cable markers or black tape.

CHAPTER TWO

INSTALLATION CONTROL AND PROTECTION

2.1 - Introduction

Electrical installations must be protected from the effects of short circuit and over-load. In addition, the people using the installations, as well as the buildings containing them, must be protected from the effects of fire and of other hazards arising from faults or from misuse.

Not only must automatic fault protection of this kind be provided, but an installation must also have switching and isolation which can be used to control it in normal operation, in the event of emergency, and when maintenance is necessary.

This Chapter will consider those regulations which deal with the disconnection of circuits, by both manual and automatic means, the latter in the event of shock, short circuit or overload. It does not include the Regulations which concern automatic disconnection in the event of an earth fault.

In order that anyone operating or testing the installation has full information concerning it, a diagram or chart must be provided at the mains position showing the number of points and the size and type of cables for each circuit, the method of providing protection from direct contact and details of any circuit in which there is equipment, such as passive infra-red detectors or electronic fluorescent starters, vulnerable to the high voltage used for insulation testing.

2.2 - Switching

2.2.1 - Switch positions

A switch is defined as a device which is capable of making or breaking a circuit under normal and under overload conditions. It can make, but will not necessarily break, a short circuit, which should be broken by the overload protecting fuse or circuit breaker. A switching device may be marked with ON and OFF positions, or increasingly, the numbers 1 for ON and 0 for OFF are being used.

A semiconductor device is often used for switching some lighting and heating circuits, but will not be suitable for disconnecting overloads; thus, it must be backed up by a mechanical switch. The semiconductor is a functional switch but must NOT be used as an isolator.

{Figure 2.1} shows which poles of the supply need to be broken by the controlling switches. For the TN-S system (earth terminal provided by the Electricity Company), the TNC-S system (protective multiple earthing) and the TT system (no earth provided at the supply), all phase conductors MUST be switched, but NOT the protective (earth) conductor.

The neutral conductor need not be broken except for:

1 - the main switch in a single-phase installation

2 - heating appliances where the element can be touched

3 - autotransformers (not exceeding 1.5 kV) feeding discharge lamps

The neutral will need to he disconnected for periodic testing, and provision must be made for this; it is important that the means of disconnection is accessible and can only be completed with the use of a tool.

The protective conductor should never be switched, except when the supply can he taken from either of two sources with earth Systems which must slot be connected together. In this case the switches needed in the protective conductors must be linked to the phase switches so that it is impossible for the supply to be provided unless the earthing connection is present.

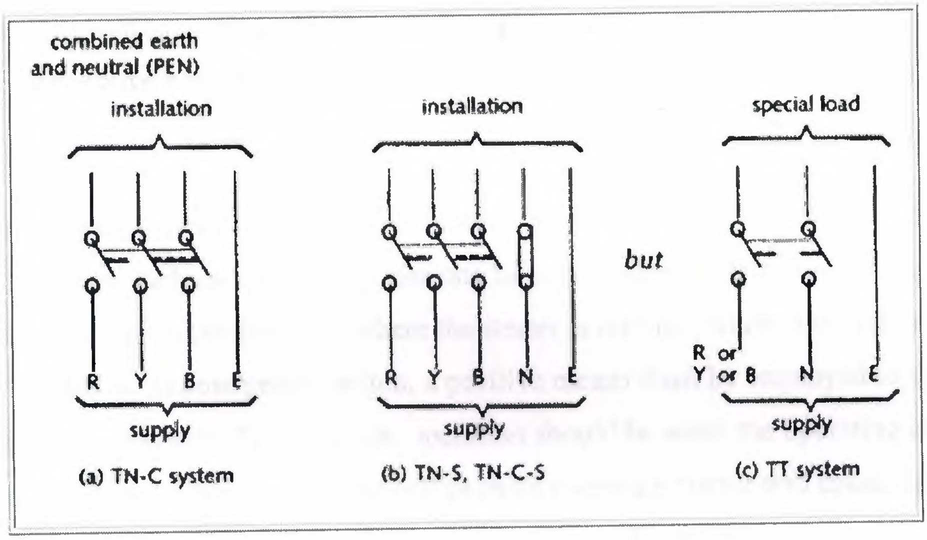


Figure 2.1 - Supply system broken by switches

(a)TN-C Systems (b) TN-S, TN-C-S (c) TT Systems

Every circuit must be provided with a switching system so that it can be interrupted on load. In practice, this does not mean a switch controlling each separate circuit; provided that loads are controlled by switches, a number of circuits may be under the overall control of one main switch. An example is the consumer unit used in the typical house, where there is usually only one main switch to control all the circuits, which are provided with individual switches to operate separate lights, heaters, and so on. If an installation is supplied from more than one source there must he a separate main switch for each source, and each must be clearly marked to warn the person switching off the supplies that more than one switch needs to he operated.

It should he noted that a residual current device (RCD) may be used as a switch provided that its rated breaking capacity is high enough.

2.2.2 - Emergency switching

Emergency switching is defined as rapidly cutting the supply to remove hazards. For example, if someone is in the process of receiving an electric shock, the first action of a rescuer should he to remove the supply by operating the emergency switch, which may well be the main switch. Such switching must be available for all installations. Note that if there is more than one source of supply a number of main switches may need to be opened .The designer must identify all possible dangers, including electric shock, mechanical movement, excessive heat or cold and radiation dangers, such as those from lasers or X-rays.

In the special case of electric motors, the emergency switching must be adjacent to the motor. In practice, such switching may take the form of a starter fitted close to the motor, or an adjacent stop button (within 2 m) where the starter is remote. Where a starter or contactor is used as an emergency switch, a positive means must be employed to make sure that the installation is safe. For example, operation should be when the operating coil is de-energised, so that an open circuit in the coil or in its operating circuit will cause the system to be switched off {Figure 2.2}. This is often called the 'fail-safe' system.

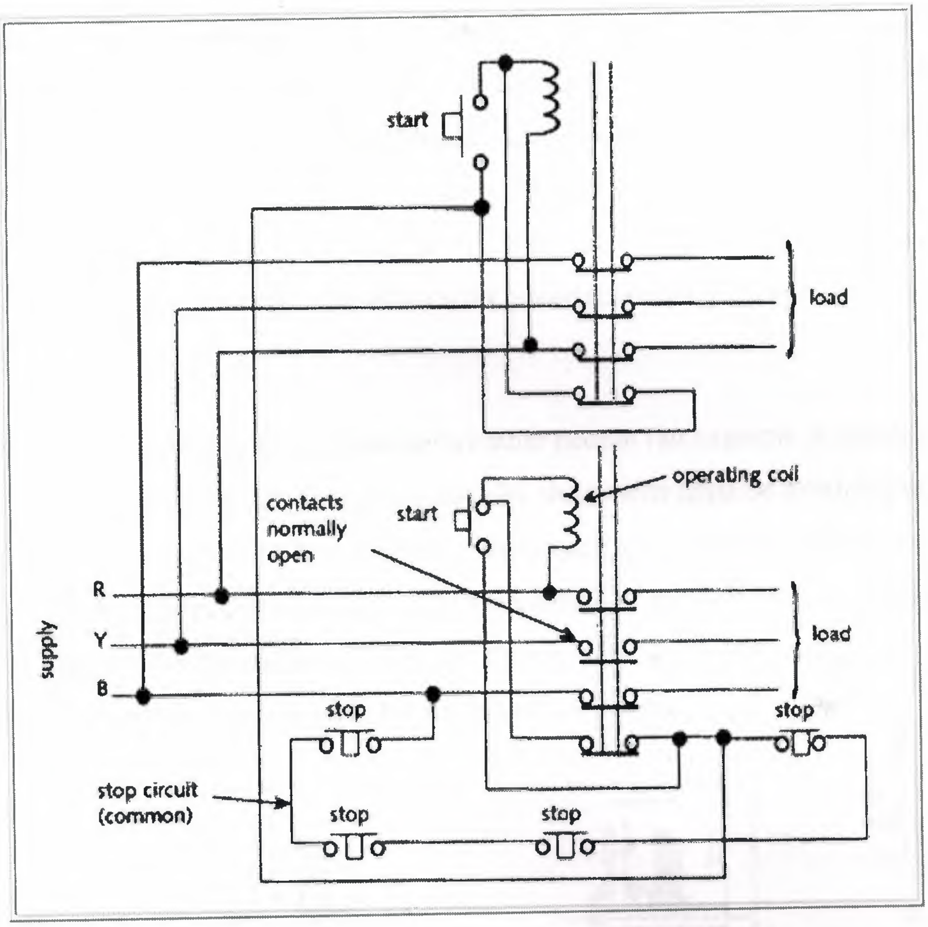


Figure 2.2 - Two circuit breakers linked to a common stop circuit. The system is 'fail-safe' – [4]

To prevent unexpected restarting of rotating machines, the 'latching off' stop button shown in {Fig 2.2} is sometimes used. On operation, the button locks (latches) in the off position until a positive action is taken to release it.

In single-phase systems, it must he remembered that the neutral is earthed. This means that if the stop buttons are connected directly to the neutral, a single earth fault on the stop button circuit would leave the operating coil permanently fed and prevent the safety system from being effective. It is thus essential for the operating coil to be directly connected to the neutral, and the stop buttons to the phase. Such an earth fault would then operate the protective device and make the system safe.

The means of emergency switching must be such that a single direct action is required to operate it. The switch must be readily accessible and clearly marked in a way that will be durable. Consideration must be given to the intended use of the premises in which the switch is installed to make sure as far as possible that the switching system is always easy to reach and to use. For example, the switch should not be situated at the back of a cupboard which, in use, is likely to be filled with materials making it impossible to reach the switch.

In cases where operation could cause danger to other people (an example is where lighting is switched off by operating the emergency switch), the switch must be available only for operation by instructed persons. Every fixed or stationary appliance must be provided with a means of switching which can be used in an emergency. If the device is supplied by an unswitched plug and socket, withdrawal of the plug is NOT acceptable to comply with this requirement,' such action is acceptable for functional switching.

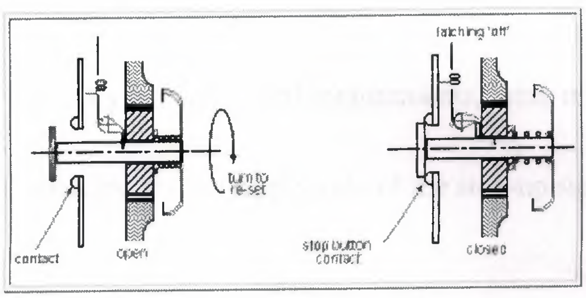


Figure 2.3 - 'latching-off' stop button

Where any circuit operates at a p.d. (potential difference) exceeding low voltage a fireman's emergency switch must be provided. Such installations usually take the form of discharge lighting (neon signs), and this requirement applies for all external systems as well as internal signs which operate unattended. The purpose is to ensure the safety of fire fighters who may, if a higher voltage system is still energised, receive dangerous shocks when they play a water jet onto it. The fireman's switch is not required for portable signs consuming 100 W or less which are supplied via an easily accessible plug and socket.

The fireman's switch must meet the following requirements

1.-The switch must be mounted in a conspicuous position not more than 2.75m from the ground.

2.-It must be coloured red and have a label in lettering at least 13 mm high 'FIREMAN'S SWITCH'. On and off positions should be clearly marked, and the OFF position should be at the top. A lock or catch should be provided to prevent accidental reclosure.

3.-For exterior installations the switch should be close to the load, or to a notice in such a position to indicate clearly the position of the well-identified switch.

4.-For interior installations, the switch should be at the main entrance to the building.

5.-Ideally, no more than one internal and one external switch must be provided. Where more become necessary, each switch must be clearly marked to indicate exactly which parts of the installation it controls.

6.-Where the local fire authority has additional requirements, these must be followed.

7.-The switch should be arranged on the supply side of the step-up sign transformer.

2.3 - Isolation

2.3.1 - Isolator definition

An isolator is not the same as a switch. It should only be opened when not carrying current, and has the purpose of ensuring that a circuit cannot become live whilst it is out of service for maintenance or cleaning. The isolator must break all live supply conductors; thus both phase and neutral conductors must be isolated. It must, however, be remembered that switching off for mechanical maintenance is likely to be carried out by non-electrically skilled persons and that they may therefore unwisely use isolators as on-load switches. To prevent an isolator, which is part of a circuit where a circuit breaker is used for switching, from being used to break load current, it must be interlocked to ensure operation only after the circuit breaker is already open. In many cases an isolator can be used to make safe a particular piece of apparatus whilst those around it are still operating normally.

2.3.2 - Semiconductor isolators

Semiconductors are very widely used in electrical installations, from simple domestic light dimmers (usually using triacs) to complex speed controllers for three phase motors (using thyristors). Whilst the semiconductors themselves are functional switches, operating very rapidly to control the circuit voltage, they must NOT be used as isolators.

This is because when not conducting (in the OFF position) they still allow a very small leakage current to flow, and have not totally isolated the circuit they control. {Figure 2.4} shows semiconductors in a typical speed control circuit.

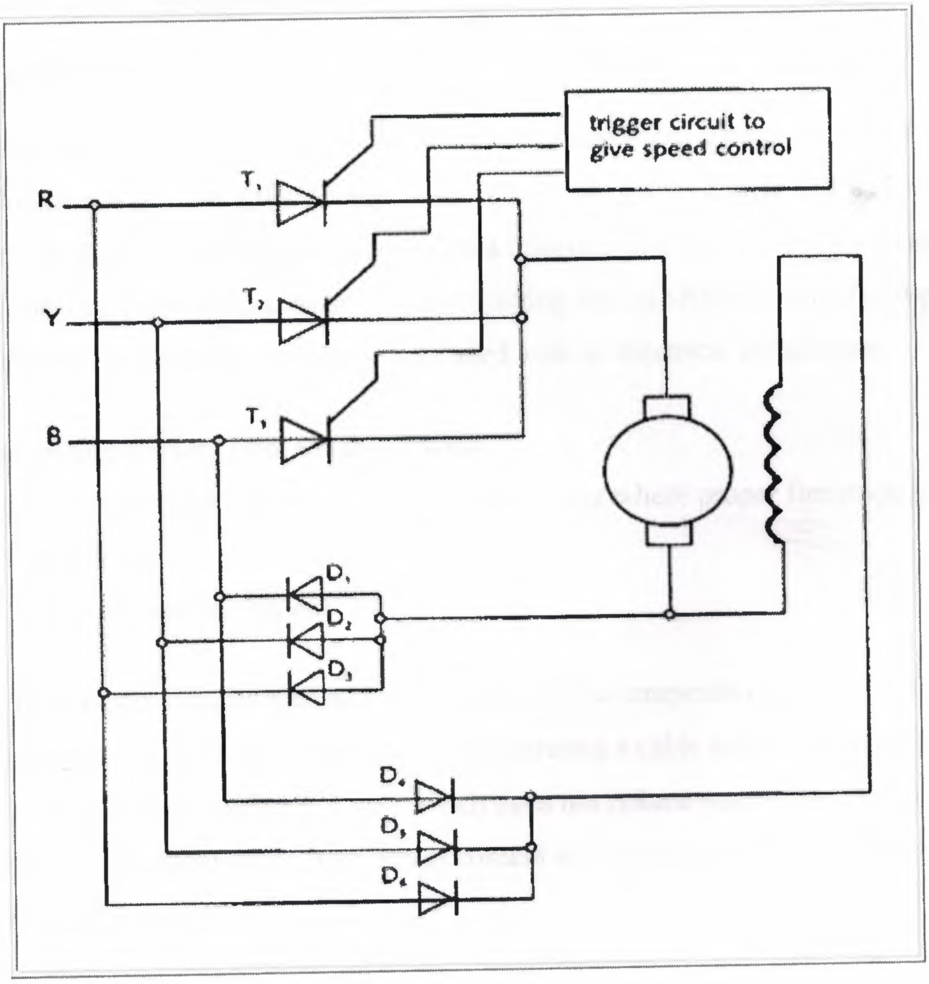


Figure 2.4 - Speed control for a dc motor fed from a three-phase supply – [4]

2.3.3 - Isolator identification

The OFF position on all isolators must be clearly marked and should not be indicated until the contacts have opened to their full extent to give reliable isolation. Every isolator must be clearly and durably marked to indicate the circuit or equipment it protects. If a single isolator will not cut off the supply from internal parts of an enclosure, it must be labelled to draw attention to the possible danger. Where the unit concerned is suitable only for off-load isolation, this should be clearly indicated by marking the isolator "Do NOT open under load".

2.4 - High temperature protection

2.4.1 - Introduction

The Regulations are intended to prevent both fires and burns which arise from electrical causes. Equipment must be selected and installed with the prevention of fire and burns fully considered. Require that persons, equipment and materials adjacent to electrical equipment must be protected from fire, burns and effects limiting the safe functioning of equipment. Three categories of thermal hazard are associated with an electrical installation.

1.-ignition arising directly from the installation,
2.-the spread of fire along cable runs or through trunking where proper fire stops have not been provided, and
3.-burns from electrical equipment.

The heat from direct sunlight will add significantly to the temperature of cables, and 20°C must be added to the ambient temperature when derating a cable subject to direct sunlight, unless it is permanently shaded in a way which does not reduce ventilation. Account must also be taken of the effect of the ultra-violet content of sunlight on the sheath and insulation of some types of cable.

Some types of electrical equipment are intended to become hot in normal service, and special attention is needed in these cases. For example, electric surface heating systems must comply fully with all three parts of BS 6351. Part 1 concerns the manufacture and design of the equipment itself, Part 2 with the design of the system in which it is used, and Part 3 its installation, maintenance and testing.

2.4.2 - Fire protection

Where an electrical installation or a piece of equipment which is part of it is, under normal circumstances, likely to become hot enough to set fire to material close to it, it must be enclosed in heat and fire resistant material which will prevent danger. Because of the complexity of the subject, the Regulations give no specific guidance concerning materials or clearance dimensions. It is left to the designer to take account of the circumstances arising in a particular situation. When fixed equipment is chosen by the installation user or by some other party than the designer or the installer, the latter are still responsible for ensuring that the installation requirements of the manufacturers are met.

The same general principle applies in cases where an equipment may emit arcs or hot particles under fault conditions, including arc welding sets. Whilst it may be impossible in every case to prevent the outbreak of fire, attention must be paid to the means of preventing its spread.

For example, any equipment which contains more than 25 litres of flammable

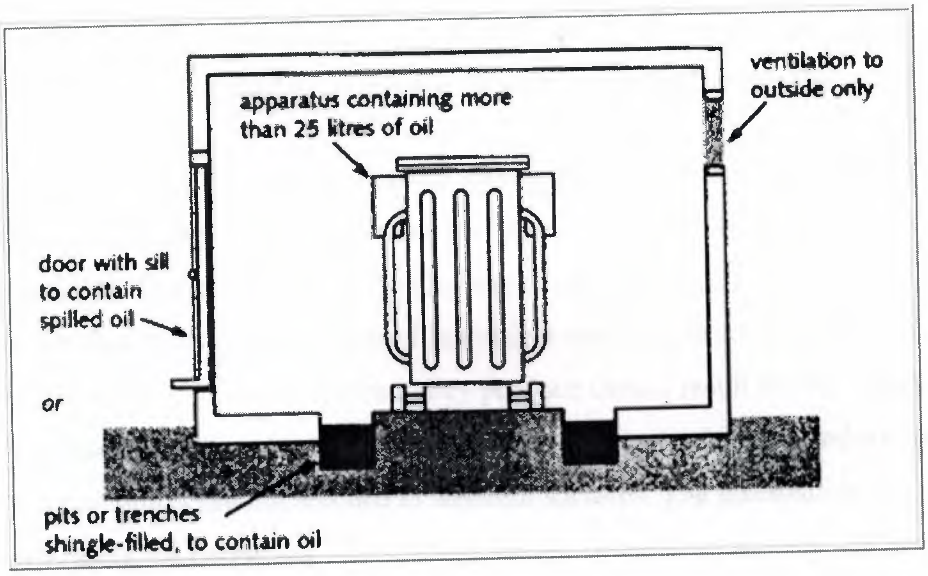


Figure 2.5 - Precautions for equipment which contains flammable liquid

Liquid, must be so positioned and installed that burning liquid cannot escape the vicinity of the equipment and thus spread fire. {Figure 2.5} indicates the enclosure needed for such a piece of equipment, for example an oil-filled transformer. In situations where fire or smoke could cause particular hazards, consideration should be given to the use of low smoke and fire (LSF) cables. Such cables include those with thermosetting insulation and mineral-insulated types.

Perhaps a word is needed here concerning the use of the word 'flammable'. It means something which can catch fire and burn. We still see the word inflammable in everyday use, with the same meaning as flammable. This is very confusing, because the prefix 'in' may be taken as meaning 'not', giving exactly the opposite meaning. 'Inflammable' should never be used, 'non-flammable' being the correct term for something which cannot catch fire.

Under some conditions, especially where a heavy current is broken, the current may continue to flow through the air in the form of an arc. This is more likely if the air concerned is polluted with dust, smoke, etc. The arc will be extremely hot and is likely to cause burns to both equipment and to people; metal melted by the arc may be emitted from it in the form of extremely hot particles which will themselves cause fires and burns unless precautions are taken. Special materials which are capable of withstanding such arc damage are available and must be used to screen and protect surroundings from the arc.

Some types of electrical equipment, notably spotlights and halogen heaters, project considerable radiant heat. The installer must consider the materials which are subject to this heat to ensure that fire will not occur. Enclosures of electrical equipment must be suitably heat-resisting. Recessed or semi-recessed luminaires mounted in ceiling voids must be given special attention to ensure the heat they produce cannot result in fire. Equipment that focuses heat, such as radiant heaters and some luminaires, must be mounted so that excessive temperatures are not reached in adjacent surfaces, The installation of a protecting RCD with a rating not exceeding 300 mA will sometimes prevent a fire in the event of an earth fault.

Additions to an installation or changes in the use of the area it serves may give rise to fire risks. Examples are the addition of thermal insulation, the installation of additional cables in conduit or trunking, dust or dirt which restricts ventilation openings or forms an explosive mixture with air, changing lamps for others of higher rating, missing covers on joint boxes and other enclosures so that vermin may attack cables, and so on.

2.4.3 - Protection from burns

The Regulations provide a Table showing the maximum allowable temperatures of surfaces which could be touched and thus cause burns. The allowable temperature depends on whether the surface is metallic or non-metallic, and on the likely contact between the hand and the surface. Details follow in {Table 2.1}.

Table 2.1 - Allowable surface temperatures for accessible parts
(taken from [Table 42A] of BS 7671: 1992)

Part	*Surface material*	*Max. Temp (°C)*
Hand held	Metallic	55
	Non-metallic	65
May be touched but not held	Metallic	70
	Non-metallic	80
Need not be touched in normal use	Metallic	80
	Non-metallic	90

Other measures intended to prevent water and hot air systems causing burns are contained in Section 424, which was added in the 1994 amendments. They include the requirement that the elements of forced air heaters cannot be switched on until the rate of air flow across them is sufficient to ensure that the air emitted is not too hot, and that water heaters and steam raisers are provided with non self-resetting controls where appropriate. The suitability for connection of high temperature cables must be established with the manufacturer before cables running at more than 700C are connected.

Special attention must be paid to the likely temperature of hot surfaces where they may be touched by the very young, very old or the infirm.

2.5 - Overload currents

2.5.1 - Introduction

'Overcurrent' means what it says - a greater level of current than the materials in use will tolerate for a long period of time. The term can be divided into two types of excess current.

1 Overload currents

These are currents higher than those intended to be present in the system. If such currents persist they will result in an increase in conductor temperature, and hence a rise in insulation temperature. High conductor temperatures are of little consequence except that the resistance of the conductor will be increased leading to greater levels of voltage drop.

Insulation cannot tolerate high temperatures since they will lead to deterioration and eventually failure. The most common insulation material is p.v.c. If it becomes too hot it softens, allowing conductors which press against it (and this will happen in all cases where a conductor is bent) to migrate through it so that they come close to, or even move beyond, the insulation surface. For this reason, p.v.c. insulation should not normally run at temperatures higher than 70°C, whereas under overload conditions it may have allowable temperatures up to 115°C for a short period during transient conditions.

2 Short circuit currents

These currents will only occur under fault conditions, and may be very high indeed. As we shall shortly show such currents will open the protective devices very quickly. These currents will not flow for long periods, so that under such short-term circumstances the temperature of p.v.c. insulation may be allowed to rise to 160°C.

The clearance time of the protective device is governed by the adiabatic equation which is considered more fully in.

2.5.2Overload

Overload currents occur in circuits which have no faults but are carrying a higher current than the design value due to overloaded machines, an error in the assessment of diversity, and so on. When a conductor system carries more current than its design value, there is a danger of the conductors, and hence the insulation, reaching temperatures which will reduce the useful life of the system.

The devices used to detect such overloads, and to break the circuit for protection against them, fall into three main categories:

1. -Semi-enclosed (rewirable) fuses to BS 3036 and cartridge fuses for use in plugs to BS 1362.

2. -High breaking capacity (HBC) fuses to BS 88 and BS 1361. These fuses are still often known as high rupturing capacity (HRC) types.

3. -Circuit breakers, miniature and moulded case types to BS EN 60898.

Examination of the characteristics of these devices indicates that they are not the 'instant protectors' they are widely assumed to be. For example, an overloaded 30 A semi-enclosed fuse takes about 100 s to 'blow' when carrying twice its rated current. If it carries 450 A in the event of a fault (fifteen times rated current), it takes about 0.1 s to operate, or five complete cycles of a 50 Hz supply.

HBC fuses are faster in operation, but BS 88 Part 2 specifies that a fuse rated at 63 A or less must NOT operate within one hour when carrying a current 20% greater than its rating. For higher rated fuses, operation must not be within four hours at the same percentage overload. The latter are only required to operate within four hours when carrying 60% more current than their rated value.

Circuit breakers are slower in operation than is generally believed. For example, BS EN 60898 only requires a 30 A miniature circuit breaker to operate within one hour when carrying a current of 40 A. At very high currents operation is described by the BS as 'instantaneous' which is actually within 0.01 seconds.

All protective devices, then, will carry overload currents for significant times without opening. The designer must take this fact into account in his calculations. The circuit must be designed to prevent, as far as possible, the presence of comparatively small overloads of long duration.

The overload provisions of the Regulations are met if the setting of the device:

1. -exceeds the circuit design current

2. -does NOT exceed the rating of the smallest cable protected

In addition, the current for operation must not be greater than 1.45 times the rating of the smallest cable protected.

The overload protection can be placed anywhere along the run of a cable provided there are no branches, or must be at the point of cable size reduction where

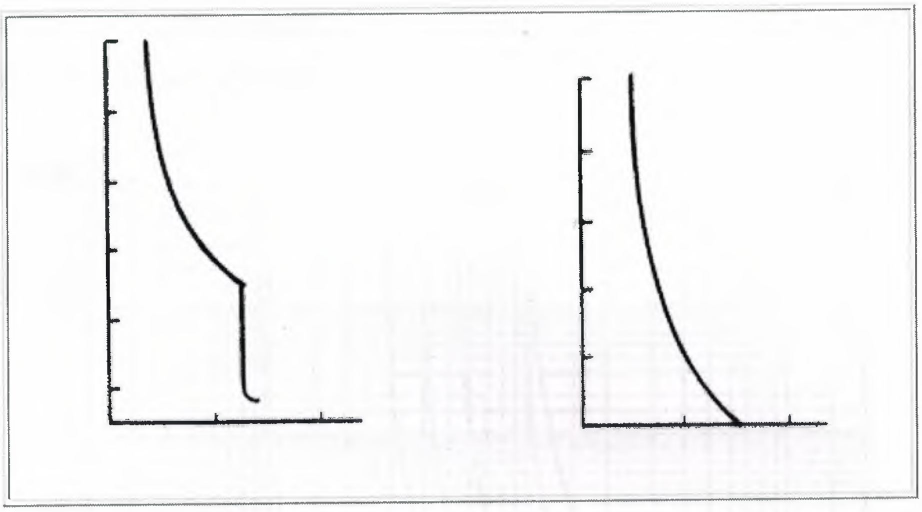


Figure 2.6 - Time/current characteristics – [1]
a) 30 A semi-enclosed fuse   b) 30 A miniature circuit breaker type 3

this occurs. There must be NO protection in the secondary circuit of a current transformer, or other situation where operation of the protective device would result in greater danger than that caused by the overload.

2.5.3 - Fuses

Fuses and circuit breakers controlling a small installation are commonly grouped in a consumer's unit at the mains position. Backless types are still available, and they must be filled with a non-combustible back on installation.

There are some circuits which have widely varying loads, and it would be unfortunate if the protection operated due to a severe but short-lived overload. In such cases, the heating effect of the currents must be taken into account so that the overload setting is based on the thermal loading. Fuses operate because the fuse element is the 'weak link' in the circuit, so that overcurrent will melt it and break the circuit. The time taken for the fuse link to break the circuit (to 'blow') varies depending on the type of fuse and on the characteristic of the device. The figures are adapted from Appendix 3 of the BS 7671: 1992.

Where the current carried is very much greater than the rated value (which is usually associated with a fault rather than with an overload) operation is usually very fast. For small overloads, where the current is not much larger than the rated value, operation may take a very long time, as indicated.

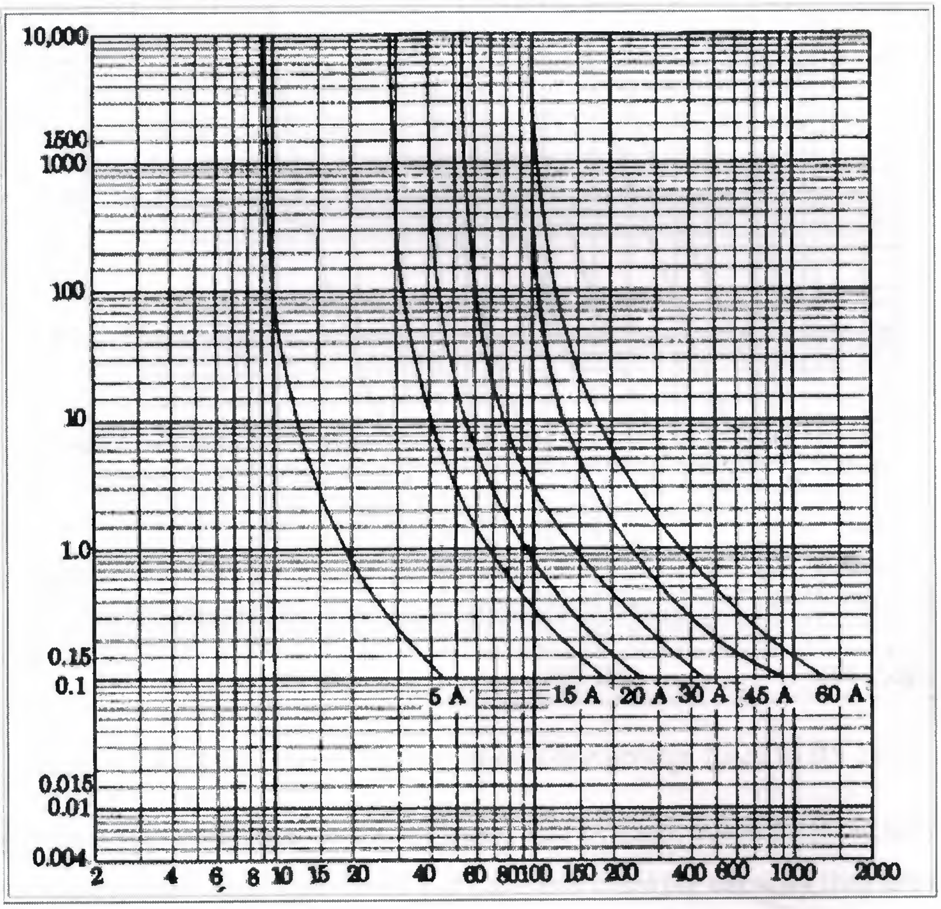


Figure 2.7 - Time/current characteristics of semi-enclosed fuses to BS 3036

A graph with linear axes would need to be very large indeed if the high current/short time and the low current/long time ends of the characteristic were to be used to read the time to operate for a given current. The problem is removed by using logarithmic scales, which open out the low current and short time portions of the scales, and compress the high current and long time portions.

This means that the space between two major lines on the axes of the graph represents a change of ten times that represented by the two adjacent lines. In other words, a very much increased range of values can be accommodated on a graph of a given size.

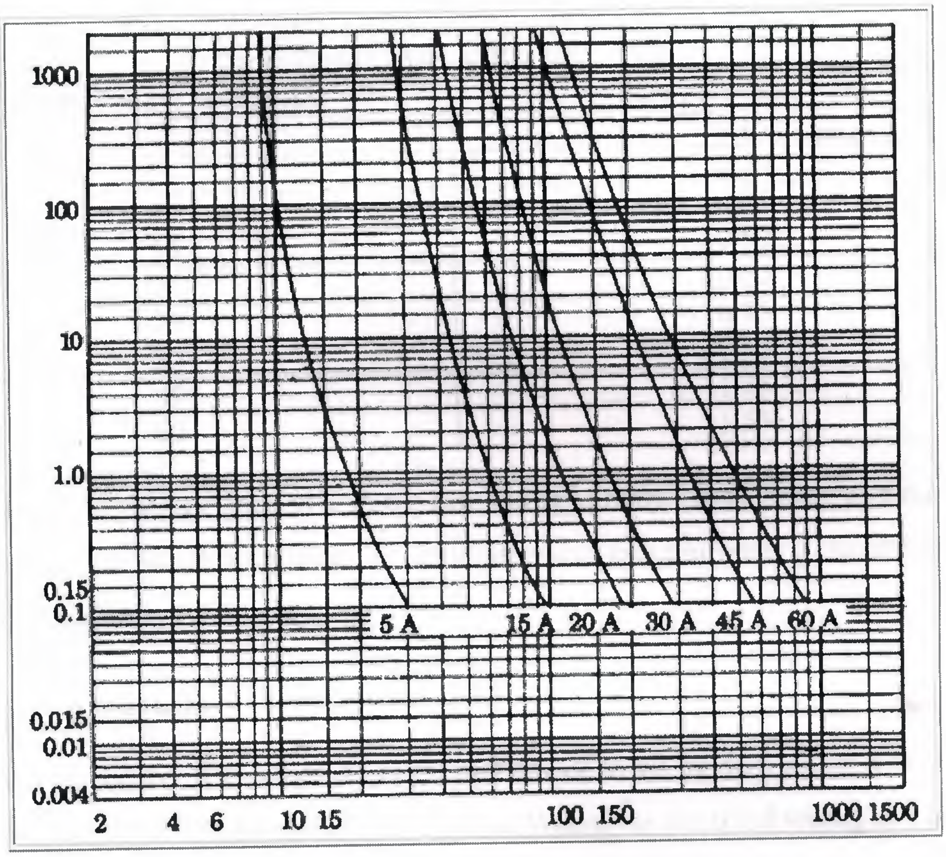


Figure 2.8 - Time/current characteristics of cartridge fuses to BS 1361

Rewirable (semi-enclosed) fuses to BS 3036 may still be used, but as they can easily have the wrong fuse element (fuse wire) fitted and have low breaking capacity they are not recommended for other than small installations. Where used, they are subject to the derating requirements which are explained in the diameter of copper wires for use as elements in such fuses is shown in {Table 2.2}.

Table 2.2 - Sizes of tinned copper wire fuse elements (from [Table 53A] of BS 7671: 1992)	
Fuse element rating (A)	*Wire diameter (mm)*
3	0.15
5	0.20
10	0.35
15	0.50
20	0.60
25	0.75
30	0.85
45	1.25
60	1.53

All fuses must be clearly labelled with the fuse rating to make replacement with the wrong fuse as unlikely as possible. It must not be hazardous to make or break a circuit by insertion or removal of a fuse.

2.5.4 - Circuit breakers

The circuit breaker is an absolutely essential device in the modern world, and one of the most important safety mechanisms in your home. Whenever electrical wiring in a building has too much current flowing through it, these simple machines cut the power until somebody can fix the problem. Without circuit breakers (or the alternative, fuses), household electricity would be impractical because of the potential for fires and other mayhem resulting from simple wiring problems and equipment failures.

2.5.5 - Types of circuit breaker

There are many different technologies used in circuit breakers and they do not always fall into distinct categories. The following types are common in domestic, commercial and light industrial applications for low voltage (less than 1000V) use.

- MCB - Miniature Circuit Breaker - rated current not more than 100A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
- MCCB - Moulded Case Circuit Breaker - rated current up to 1000A. Thermal or thermal-magnetic operation. Trip current may be adjustable.

- Air Circuit Breaker - Rated current up to 10,000A. Trip characteristics often fully adjustable including configurable trip thresholds and delays. Usually electronically controlled - some models are microprocessor controlled. Often used for main power distribution in large industrial plant, where the breakers are arranged in draw-out enclosures for ease of maintenance.
- Vacuum Circuit Breaker - With rated current up to 3000 A, these breakers interrupt the arc in a vacuum bottle. These can also be applied at up to 35,000 V. Vacuum breakers tend to have longer life expectancies between overhaul than do air circuit breakers.

Circuit breakers operate using one or both of two principles. They are:

1. - Thermal operation relies on the extra heat produced by the high current warming a bimetal strip, which bends to trip the operating contacts,

2. - Magnetic operation is due to the magnetic field set up by a coil carrying the current, which attracts an iron part to trip the breaker when the current becomes large enough.

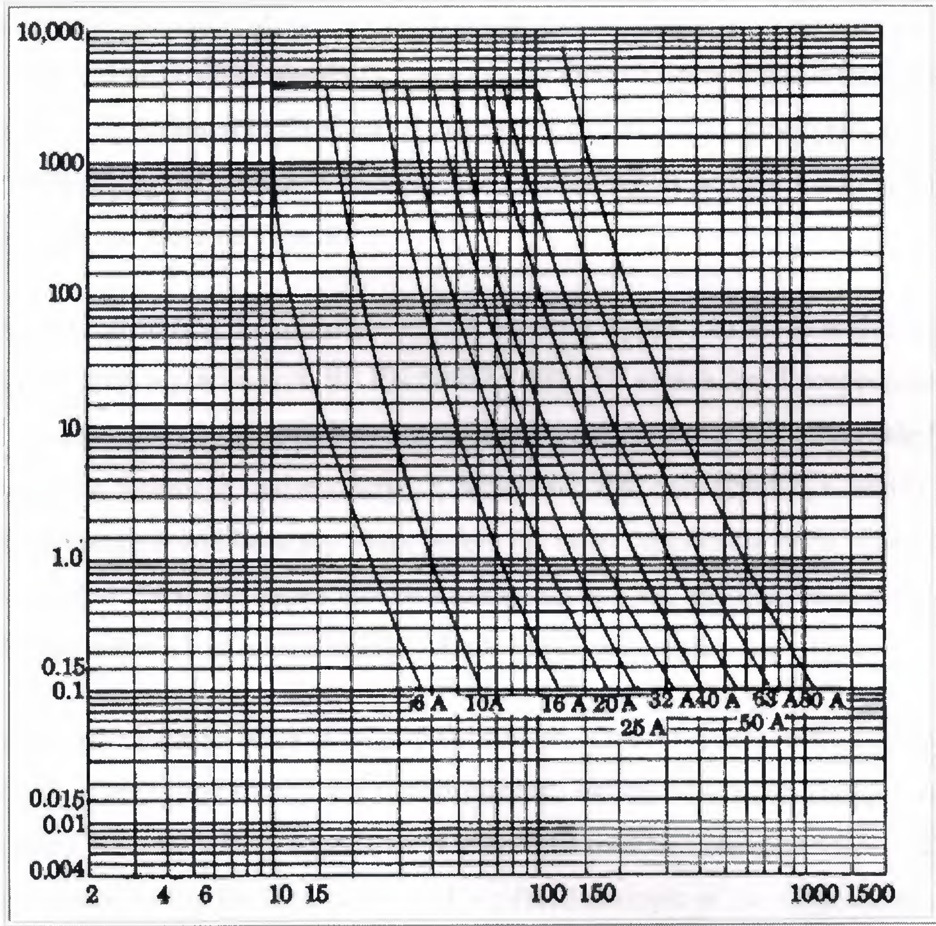


Figure 2.9 - Time/current characteristics of cartridge fuses to BS 88 Part 2

Thermal operation is slow, so it is not suitable for the speedy disconnection required to clear fault currents. However, it is ideal for operation in the event of small but prolonged overload currents. Magnetic operation can be very fast and so it is used for breaking fault currents; in many cases, both thermal and magnetic operation are combined to make the circuit breaker more suitable for both overload and fault protection. It must be remembered that the mechanical operation of opening the contacts takes a definite minimum time, typically 20 ms, so there can never be the possibility of truly instantaneous operation.

All circuit breakers must have an indication of their current rating. Miniature circuit breakers have fixed ratings but moulded case types can be adjusted. Such adjustment must require the use of a key or a tool so that the rating is unlikely to be altered except by a skilled or instructed person.

There are many types and ratings of moulded case circuit breakers, and if they are used, reference should be made to supplier's literature for their characteristics. Miniature circuit breakers are manufactured in fixed ratings from 5 A to 100 A for some types, and in six types, type B giving the closest protection. The characteristics of Type C circuit breakers are very similar to those of Type 3.

BS3871, which specified the miniature circuit breakers Types 1 to 4 was withdrawn in 1994 and has been replaced with BS EN 60898:1991 (EN stands for "European norm"), although it is possible that circuit breakers to the old standard will still be on sale for five years from its withdrawal. In due course, it is intended that only types B, C and D will be available, although it will be many years before the older types cease to be used. Short circuit ratings for the newer types will be a minimum of 3 kA and may be as high as 25 kA - the older types had short circuit ratings which were rarely higher than 9 kA.

The time/current characteristics of all circuit breakers have a vertical section where there is a wide range of operating times for a certain current. Hence, with a fixed supply voltage, the maximum earth fault loop impedance is also fixed over this range of time. The operating current during the time concerned is a fixed multiple of the rated current. For example, a Type 2 MCB has a multiple of 7 (from {Table 2.3}) so a 30 A device of this type will operate over the time range of 0.04 s to 8 s at a current of 7 x 30 A = 210 A.

Table 2.3 - Operating time ranges and current multiples for MCBs over fixed current section of characteristic

MCB Type	*Range of operating times (s)*	*Current multiple of rating*
1	0.04 to 20	x4
2	0.04 to 8	x7
3	0.04 to 5	x10
B	0.04 to 13	x5
C	0.04 to 5	x10
D	0.05 to 3	x20

Table 2.4 - A comparison of types of protective device

Semi-enclosed fuses	*HBC fuses*	*Miniature circuit breakers*
Very low initial cost	Medium initial cost	High initial cost
Low replacement cost	Medium replacement cost	Zero replacement cost
Low breaking capacity	Very high breaking capacity	Medium breaking capacity

Table 2.5 - Comparison of miniature circuit breaker types

Type	Will not trip in 100ms at rating	Will trip in 100ms at rating	Typical application
1	2.7 x	4 x	Low inrush currents (domestic installations)
2	4 x	7 x	General purpose use
3	7 x	10 x	High inrush currents (motor circuits)
B	3 x	5 x	General purpose use (close protection)
C	5 x	10 x	Commercial and industrial applications with fluorescent fittings
D	10 x	50 x	Applications where high in-rush currents are likely (transformers, welding machines)

{Table 2.4} shows a comparison of the three main types of protective device in terms of cost, whilst {Table 2.5} compares the available types of MCB.

2.5.6 - Protecting conductors

The prime function of overload protection is to safeguard conductors and cables from becoming too hot. Thus the fuse or circuit breaker rating must be no greater than that of the smallest cable protected. Reference to the time/current characteristics of protective devices shows that a significantly greater current than the rated value is needed to ensure operation.

Thus, the current at which the protective device operates must never be greater than 1.45 times the rating of the smallest cable protected. For example, consider a cable system rated at 30 A and protected by a miniature circuit breaker type 3, rated at 32 A. that a prolonged overload of about 38 A will open the breaker after about 104 seconds (about two and a half hours!). The ratio of operating current over rated current is thus 38/30 or 1.27; significantly lower than the maximum of 1.45.will comply with the Regulations as long as their rating does not exceed that of the smallest cable protected.

Semi-enclosed (rewirable) fuses do not operate so closely to their ratings as do circuit breakers and HBC fuses. For example, the time/current characteristics of

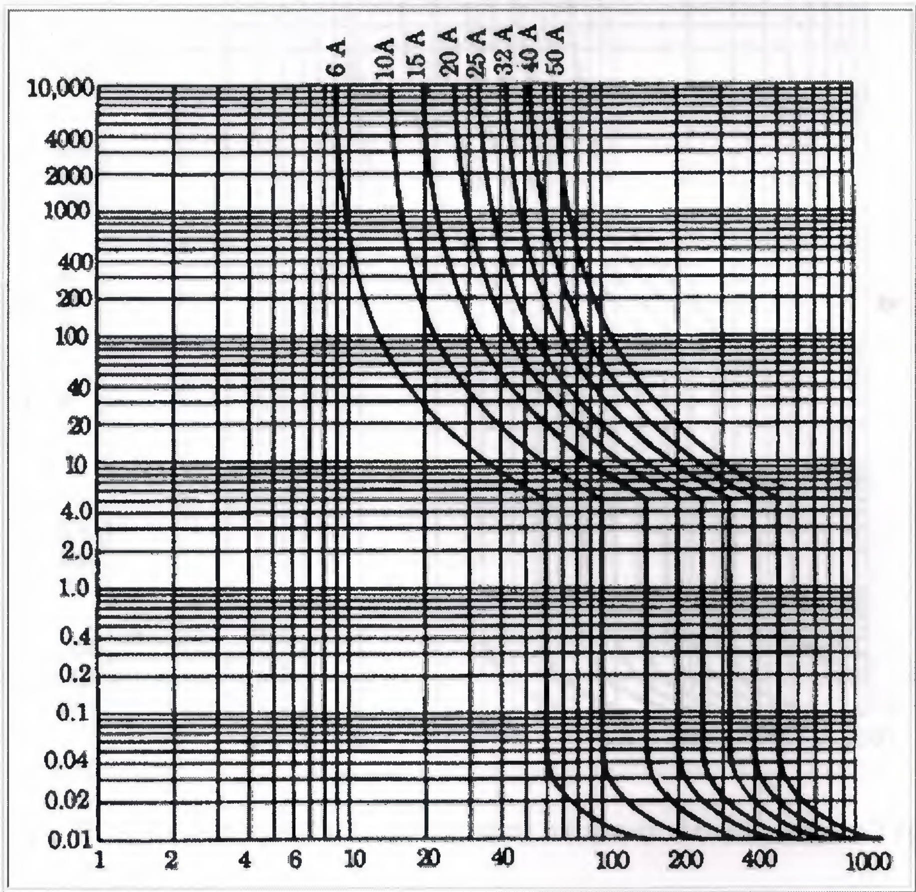


Figure 2.10 - Time/current characteristics for some miniature circuit breakers Type 1

For rewirable fuses, the Regulations require that the fuse current rating must not exceed 0.725 times the rating of the smallest cable protected. Considering the 30 A cable protected by the 32 A miniature circuit breaker above, if a rewirable fuse replaced the circuit breaker, its rating must not be greater than 0.725 x 30 or 21.8 A.

Since overload protection is related to the current-carrying capacity of the cables protected, it follows that any reduction in this capacity requires overload protection at the point of reduction. Reduced current-carrying capacity may be due to any one or more of:

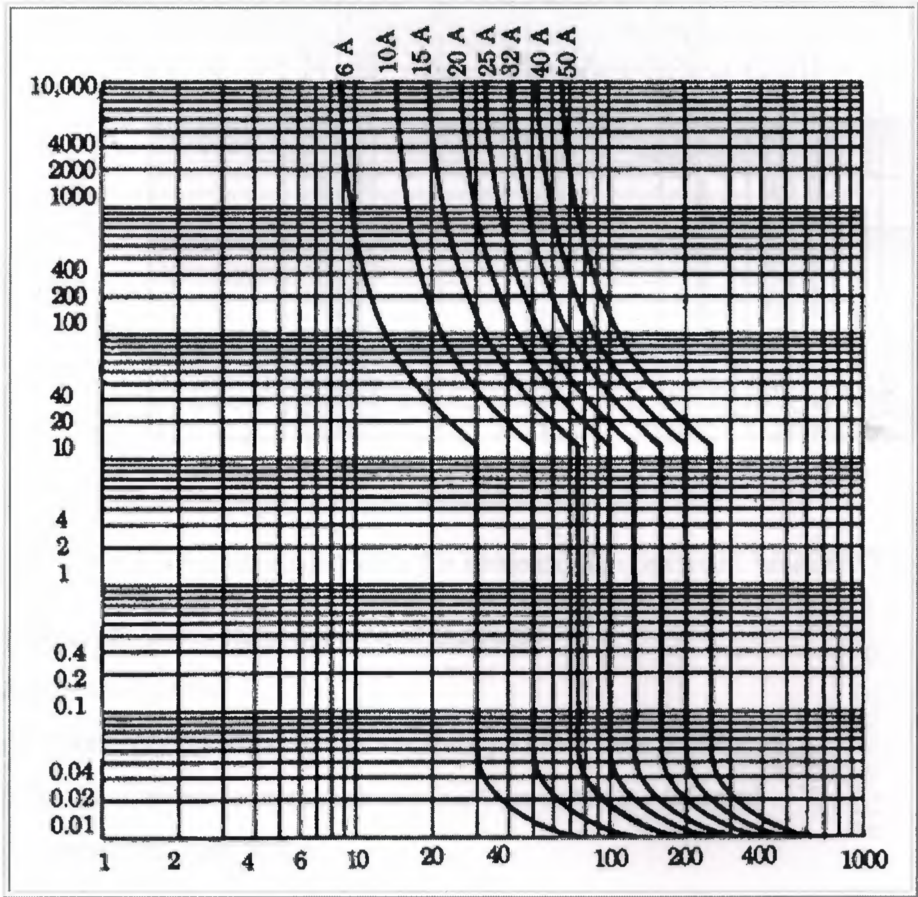


Figure 2.11 - Time/current characteristics for some miniature circuit breakers Type B

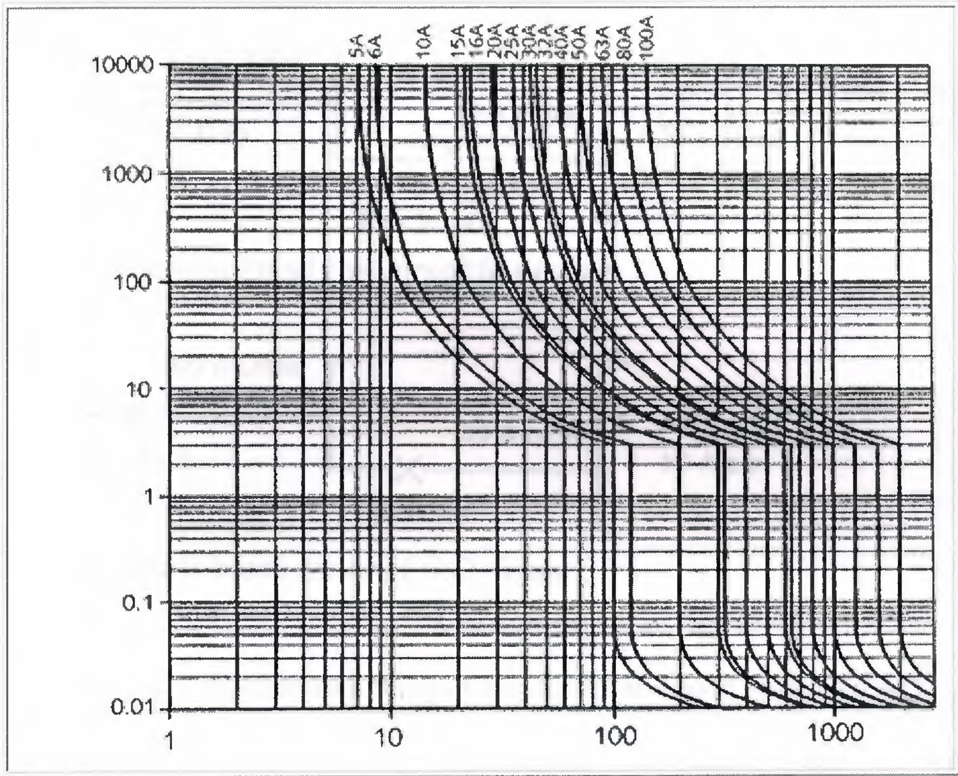


Figure 2.12 - Time/current characteristics for some miniature circuit breakers Type D

1.-a reduction in the cross-sectional area of the cable

2.-a different type of cable

3.-the cable differently installed so that its ability to lose heat is reduced

4.-a change in the ambient temperature to which the cable is subjected

5.-the cable is grouped with others.

{Figure 2.13} shows part of a system to indicate how protection could be applied to conductors with reduced current carrying capacity.

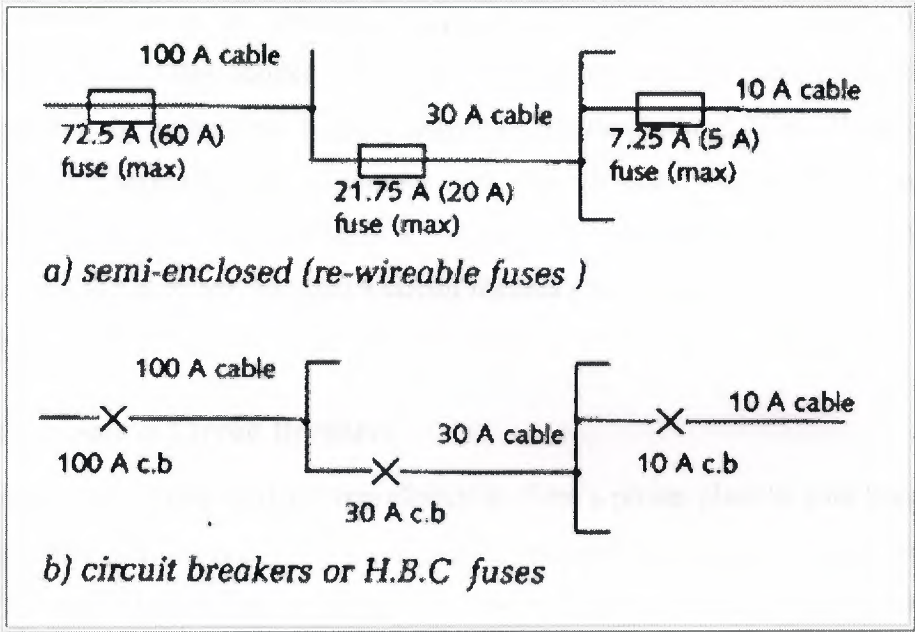


Figure 2.13 - Position and rating of devices for overload protection – [5]

In fact, the calculated fuse sizes for {Figure 2.13a)} of 72.5 A, 21.75 A and 7.25 A are not available, so the next lowest sizes of 60 A, 20 A and 5 A respectively must be used. It would be unwise to replace circuit breakers with semi-enclosed fuses because difficulties are likely to arise. For example, the 5 A fuse used as the nearest practical size below 7.25 to operate in 100 5 when carrying a current of 10 A. Thus, if the final circuit is actually carrying 10 A, replacing a 10 A circuit breaker with a 5 A fuse will result in the opening of the circuit. The temptation may be to use the next semi-enclosed fuse size of 15 A, but that fuse takes nearly seven minutes to operate at a current of 30 A. Clearly, the cable could well be damaged by excessive temperature if overloaded.

The device protecting against overload may be positioned on the load side of (downstream from) the point of reduction, provided that the unprotected cable length does not exceed 3 m, that fault current is unlikely, and that the cable is not in a position that is hazardous from the point of view of ignition of its surroundings. This Regulation is useful when designing switchboards, where a short length of cable protected by conduit or trunking feeds a low-current switch fuse from a high current fuse.

All phase conductors must be protected, but attention must be paid to the need to break at the same time all three line conductors to a three-phase motor in the event of a fault on one phase, to prevent the motor from being damaged by 'single-phasing'. Normally the neutral of a three phase system should not be broken, because this could lead to high voltages if the load is unbalanced. Where the neutral is of reduced size, overload protection of the neutral conductor may be necessary, but then a circuit breaker must be used so that the phases are also broken.

2.5.7 - Advantages of Circuit Breakers

The power distribution grid delivers electricity from a power plant to your house. Inside your house, the electric charge moves in a large circuit, which is composed of many smaller circuits. One end of the circuit, the hot wire, leads to the power plant. The other end, called the neutral wire, leads to ground. Because the hot wire connects to a high energy source, and the neutral wire connects to an electrically neutral source (the earth), there is a voltage across the circuit -- charge moves whenever the circuit is closed. The current is said to be alternating current, because it rapidly changes direction.

The power distribution grid delivers electricity at a consistent voltage (120 and 240 volts in the United States), but resistance (and therefore current) varies in a house. All of the different light bulbs and electrical appliances offer a certain amount of resistance, also described as the load. This resistance is what makes the appliance work. A light bulb, for example, has a filament inside that is very resistant to flowing charge. The charge has to work hard to move along, which heats up the filament, causing it to glow.

In building wiring, the hot wire and the neutral wire never touch directly. The charge running through the circuit always passes through an appliance, which acts as a resistor. In this way, the electrical resistance in appliances limits how much charge can flow through a circuit (with a constant voltage and a constant resistance, the current must also be constant). Appliances are designed to keep current at a relatively low level for safety purposes. Too much charge flowing through a circuit at a particular time would heat the appliance's wires and the building's wiring to unsafe levels, possibly causing a fire.

This keeps the electrical system running smoothly most of the time. But occasionally, something will connect the hot wire directly to the neutral wire or something else leading to ground. For example, a fan motor might overheat and melt, fusing the hot and neutral wires together. Or someone might drive a nail into the wall, accidentally puncturing one of the power lines. When the hot wire is connected directly to ground, there is minimal resistance in the circuit, so the voltage pushes a huge amount of charge through the wire. If this continues, the wires can overheat and start a fire.

The circuit breaker's job is to cut off the circuit whenever the current jumps above a safe level. In the following sections, we'll find out how it does this.

2.5.8 - Fuses compared with circuit breakers

Fuses have the advantages of often being less costly and simpler than a circuit breaker for similar ratings. High rupturing capacity fuses can be rated to safely interrupt up to 300,000 amperes at 600 V AC. Fuses can be selected that operate so quickly they limit the "let-through" energy into the circuit, helping to protect downstream equipment from damage. However, fuses are inherently a one-time-only device, requiring replacement after they've served their function. In a three-phase power circuit, if only one of the three fuses operates, the remaining phases will be unbalanced, with possible damage to motors. Fuses only sense over current, or to a degree, over temperature, and cannot usually be used with protective relaying to provide more advanced protective functions, for example, ground fault detection.

2.6 - Short circuit and overload protection

2.6.1 - Combined protection

In many practical applications, most types of fuses and circuit breakers are suitable for both overload and short circuit protection. Care must be taken, however, to ensure that the forms of protection are chosen so that they are properly co-coordinated to prevent problems related to excessive let-through of energy or to lack of discrimination.

2.6.2 - Current limited by supplied characteristic

If a supply has a high impedance, the maximum current it can provide could be less than the current carrying capacity of the cables in the installation. In such a case, no overload or short circuit protection is required.

This situation is very unlikely with a supply taken from an Electricity Company, but could well apply to a private generating plant.

2.6.3 - Protection omitted

There are cases where a break in circuit current due to operation of a protective device may cause more danger than the overload or fault. For example, breaking the supply to a lifting electromagnet in a scrap yard will cause it to drop its load suddenly, possibly with dire consequences. If the field circuit of a dc motor is broken, the reduction in field flux may lead to a dangerous increase in speed. A current transformer has many more secondary than primary turns, so dangerously high voltages will occur if the secondary circuit is broken.

In situations like these the installation of an overload alarm will give warning of the faulty circuit, which can be switched off for inspection when it is safe to do so. The possibility of short circuits in such cables will be reduced if they are given extra protection.

Probably the most usual case of omission of protection is at the incoming mains position of a small installation. Here, the supply fuse protects the installation tails and the consumer's unit. The unprotected equipment must, however, comply with the requirements for otherwise unprotected systems.

2.6.4 - Protection of conductors in parallel

The most common application of cables in parallel is in ring final circuits for socket outlets. Cables may otherwise be connected in parallel provided that they are of exactly the same type, run together throughout their length, have no branches and are expected to share the total circuit current in proportion to their cross-sectional area. It is not recommended that cables are connected in parallel at all except in ring final circuits.

Overload protection must then be provided for the sum of the current-carrying capacities of the cables. If, for example, two cables with individual current ratings of 13 A are connected in parallel, overload protection must be provided for 26 A.

Account must also be taken of a short circuit which does not affect all the cables: this is made less likely by the requirement that they should run close together. In {Figure 2.14}, for example, the 30 A cable with the short circuit to neutral must be able to carry more than half the short circuit current without damage until the protection opens.

Fault current sharing in these circumstances depends on the inverse of the ratio of the conductor resistance's. If, for example, the fault on one cable were to occur close to the connection to the protective device, almost all of the fault current would be carried by the short length from the protection to the fault.

In these circumstances there would be little protection for the faulty cable, and it would be prudent to provide protection with the installation of a suitable RCD.

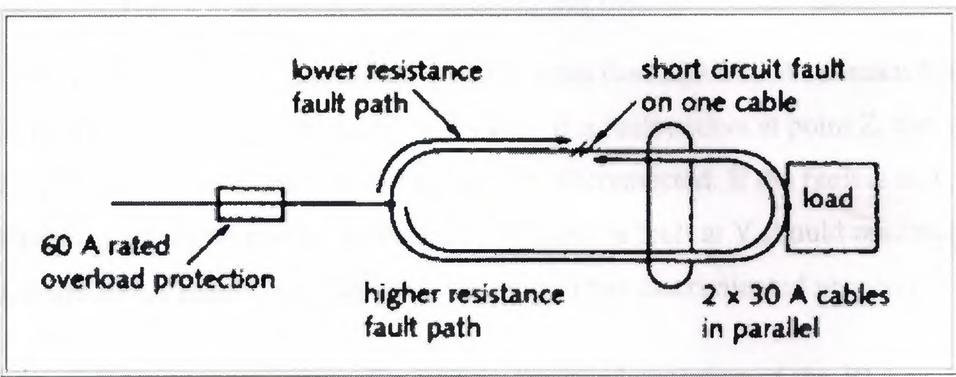


Figure 2.14 - Cables in parallel the lower resistance path will carry the higher fault current

2.6.5 - Absence of protection

The protection described in this Chapter applies to conductors, but not necessarily to the equipment fed. This is particularly true where flexible cords are concerned. For example, a short circuit in an appliance fed through a 0.5 mm2 flexible cord from a 13 A plug may well result in serious damage to the cord or the equipment before the fuse in the plug can operate.

2.6.6 - Discrimination

Most installations include a number of protective devices in series, and they must operate correctly relative to each other if healthy circuits are not to be disconnect ed. Discrimination occurs when the protective device nearest to the fault operates, leaving all other circuits working normally.

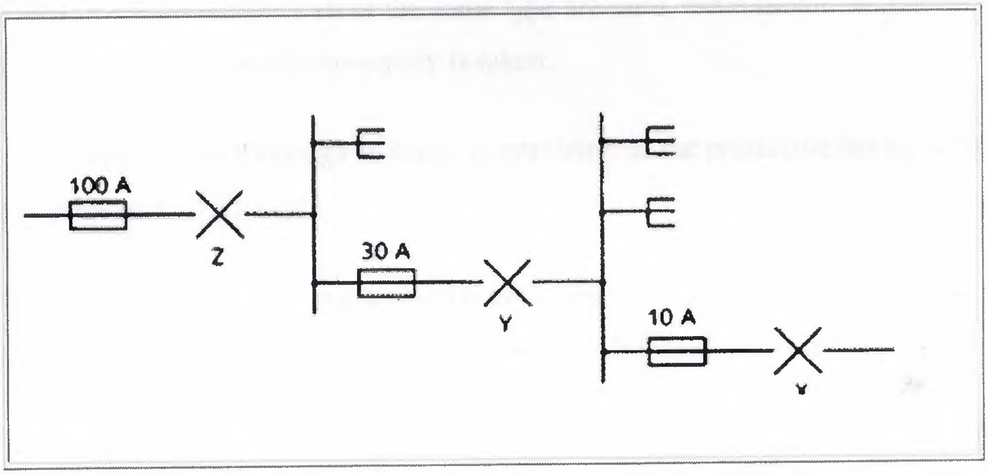


Figure 2.15 - System layout to explain discrimination – [2]

{Figure 2.15} shows an installation with a 100 A main fuse and a 30 A submain fuse feeding a distribution board containing 10 A fuses. If a fault occurs at point Z, the 100 A fuse will operate and the whole installation will be disconnected. If the fault is at X, the 10 A fuse should operate and not the 30 A or 100 A fuses. A fault at Y should operate the 30 A, and not the 100 A fuse. If this happens, the system has discriminated properly.

Lack of discrimination would occur if a fault at X caused operation of the 30 A or 100 A fuses, but not the 10 A fuse. This sounds impossible until we remember the time/current fuse characteristics. For example, {Figure 2.16} shows the superimposed characteristics of a 5 A semi-enclosed fuse and a 10 A miniature circuit breaker which we shall assume are connected in series.

If a fault current of 50 A flows, the fuse will operate in 0.56 s whilst the circuit breaker would take 24 s to open. Clearly the fuse will operate first and the devices have discriminated. However, if the fault current is 180 A, the circuit breaker will open in 0.016

s, well before the fuse would operate, which would take 0.12 s. In this case, there has been no discrimination.

To ensure discrimination is a very complicated matter, particularly where an installation includes a mixture of types of fuse, or of fuses and circuit breakers. Manufacturers' operating characteristics must be studied to ensure discrimination. As a rule of thumb where fuses or circuit breakers all of the same type are used, there should be a doubling of the rating as each step towards the supply is taken.

When fault current is high enough to result in operation of the protective device within 40 ms (two cycles of a 50 Hz supply).

When RCDs are connected in series, discrimination between them is also important, the rule here being that a trebling in rating applies with each step towards the supply.

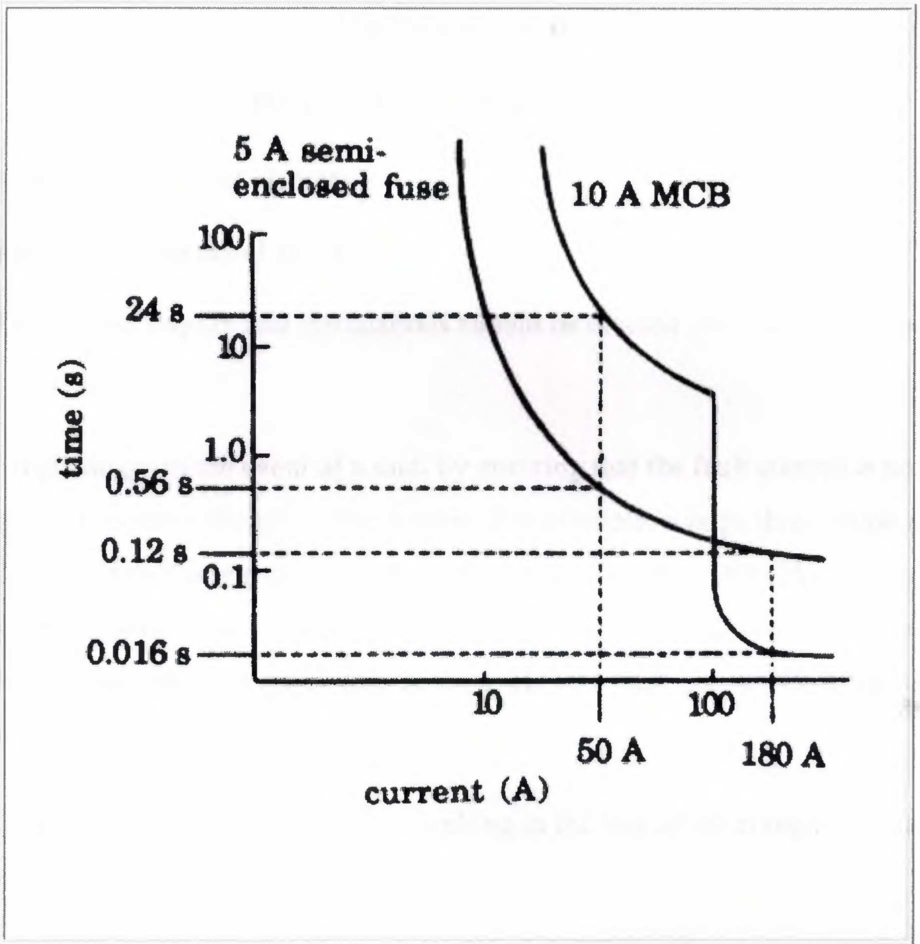


Figure 2.16 - To illustrate a lack of discrimination – [5]

CHAPTER THREE

BASIC REQUIREMENTS OF CIRCUITS

3.1 - Basic requirements of circuits

3.1.1 - Basic requirements of circuits

The Regulations require that installations should be divided into circuits, the purposes being:

1. - to prevent danger in the event of a fault by ensuring that the fault current is no greater than necessary to operate the protective system. For example, a large three-phase motor must be connected to a single circuit because the load cannot be subdivided. If, however, a load consisted of three hundred lamps, each rated at 100 W, it would be foolish to consider putting all this load onto a single circuit. In the event of a fault, the whole of the lighting would the rest of the system.

3. - to prevent a fault on one circuit from resulting in the loss of the complete installation on the subject of discrimination).

The number of final circuits will depend on the types of load supplied, and must be designed to comply with the requirements for over current protection, switching and the current-carrying capacity of conductors. Every circuit must be separate from others and must be connected to its own over current protective fuse or circuit breaker in a switch fuse, distribution board, consumer's unit, etc. See {Figure 3.1 and Figure 3.2}.

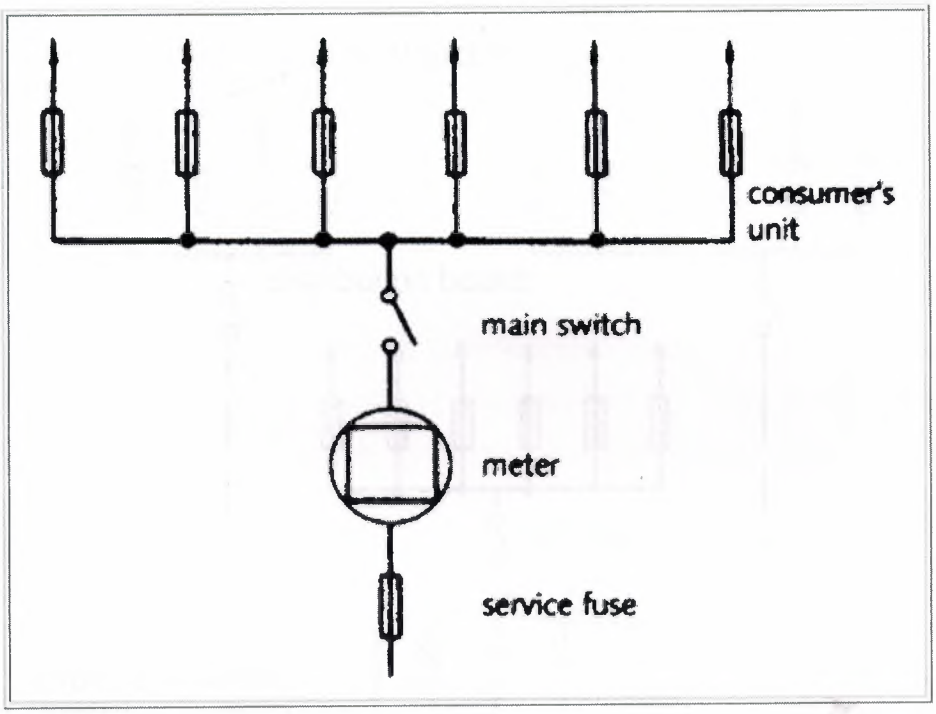


Figure 3.1 - Typical arrangement for feeding final circuits in a domestic installation

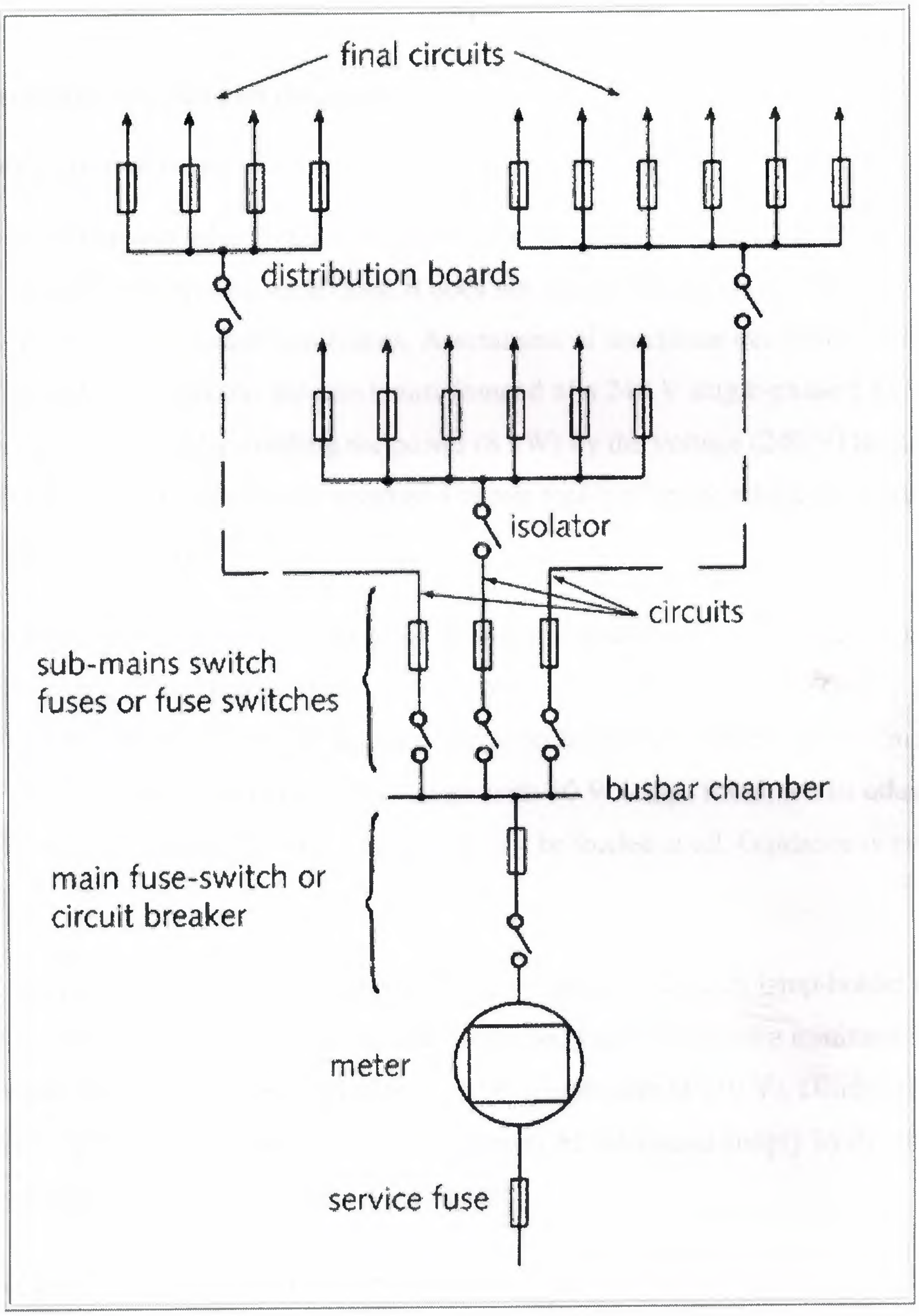


Figure 3.2 - An arrangement for main and final circuits in a large installation – [6]

A durable notice giving details of all the circuits fed is required to be posted in or near each distribution board. The data required is the equipment served by each circuit, its rating, its design current and its breaking capacity. When the occupancy of the premises changes, the new occupier must be provided with full details of the installation.

3.2 - Maximum demand and diversity

3.2.1 - Maximum demand

Maximum demand (often referred to as MD) is the largest current normally carried by circuits, switches and protective devices; it does not include the levels of current flowing under overload or short circuit conditions, Assessment of maximum demand is sometimes straightforward. For example, the maximum demand of a 240 V single-phase 8 kW shower heater can be calculated by dividing the power (8 kW) by the voltage (240 V) to give a current of 33.3 A. This calculation assumes a power factor of unity, which is a reasonable assumption for such a purely resistive load.

There are times, however, when assessment of maximum demand is less obvious. For example, if a ring circuit feeds fifteen 13 A sockets, the maximum demand clearly should not be 15 x 13 = 195 A, if only because the circuit protection will not be rated at more than 32 A. Some 13 A sockets may feed table lamps with 60 W lamps fitted, whilst others may feed 3 kW washing machines; others again may not be loaded at all. Guidance is given in {Table 3.1}.

Lighting circuits pose a special problem when determining MD. Each lamp-holder must be assumed to carry the current required by the connected load, subject to a minimum loading of 100 W per lampholder (a demand of 0.42 A per lampholder at 240 V). Discharge lamps are particularly difficult to assess, and current cannot be calculated simply by dividing lamp power by supply voltage. The reasons for this are:

1. -control gear losses result in additional current,

2. -the power factor is usually less than unity so current is greater, and

3. -chokes and other control gear usually distort the waveform of the current so that it contains harmonics which are additional to the fundamental supply current.

So long as the power factor of a discharge lighting circuit is not less than 0.85, the current demand for the circuit can be calculated from:

Current (A) = (lamp power (W) x 1.8) / (supply voltage (V))

For example, the steady state current demand of a 240 V circuit supplying ten 65 W fluorescent lamps would be:

I = (10 x 65 x 1.8 A) / 240 = 4.88A

Switches for circuits feeding discharge lamps must be rated at twice the current they are required to carry, unless they have been specially constructed to withstand the severe arcing resulting from the switching of such inductive and capacitive loads.

Table 3.1 - Current demand of outlets

Type of outlet	*Assumed current demand*
2 A socket outlet	At least 0.5A
Other socket outlets	Rated current
Lighting point	Connected load, with minimum of 100 W
Shaver outlet, bell transformer or any equipment of 5 W or less	May be neglected
Household cooker	10A + 30% of remainder + 5A for socket in cooker unit

When assessing maximum demand, account must he taken of the possible growth in demand during the life of the installation. Apart from indicating that maximum demand must be assessed, the Regulations themselves give little help. Suggestions for the assumed current demand of various types of outlet are shown in {Table 3.1}.

3.2.2 - Diversity

A domestic ring circuit typically feeds a large number of 13 A sockets hut is usually protected by a fuse or circuit breaker rated at 30 A or 32 A. This means that if sockets were feeding 13 A loads, more than two of them in use at the same time would overload the circuit and it would be disconnected by its protective device.

In practice, the chances of all domestic ring sockets feeding loads taking 13 A is small. Whilst there maybe a 3 kW washing machine in the kitchen, a 3 kW heater in the living room and another in the bedroom, the chance of all three being in use at the same time is remote. If they are all connected at the same time, this could be seen as a failure of the designer when assessing the installation requirements; the installation should have two ring circuits to feed the parts of the house in question.

Most sockets, then, will feed smaller loads such as table lamps, vacuum cleaner, television or audio machines and so on. The chances of all the sockets being used simultaneously is remote in the extreme provided that the number of sockets (and ring circuits) installed is large enough. The condition that only a few sockets will be in use at the same time, and that the loads they feed will be small is called diversity.

By making allowance for reasonable diversity, the number of circuits and their rating can be reduced, with a consequent financial saving, but without reducing the effectiveness of the installation. However, if diversity is over-estimated, the normal current demands will exceed the ratings of the protective devices, which will disconnect the circuits - not a welcome prospect for the user of the installation! Overheating may also result from overloading which exceeds the rating of the protective device, but does not reach its operating current in a reasonably short time. The Regulations require that circuit design should prevent the occurrence of small overloads of long duration.

The sensible application of diversity to the design of an installation calls for experience and a detailed knowledge of the intended use of the installation. Future possible increase in load should also be taken into account. Diversity relies on a number of factors which can only be properly assessed in the light of detailed knowledge of the type of installation, the industrial process concerned where this applies, and the habits and practices of the users, Perhaps a glimpse into a crystal ball to foresee the future could also be useful!

In many situations there is a need for socket outlets to be closely spaced so that they are available to feed appliances and equipment without the need to use long and potentially dangerous leads. For example, the domestic kitchen worktop should be provided with ample sockets to feed the many appliances (deep fat fryer, kettle, sandwich toaster, carving knife, toaster, microwave oven, coffee maker, and so on) which are likely to be used. Similarly, in the living room we need to supply television sets, video recorders, stereo players, table lamps, room heaters, etc. In this case, more outlets will he needed to allow for occasional rearrangement of furniture, which may well obstruct access to some outlets.

3.3 - BS1363 socket outlet circuits

3.3.1 - The fused plug

If each one of these socket outlets were wired back to the mains position or to a local distribution board, large numbers of circuits and cables would be necessary, with consequent high cost. The alternative is the provision of fewer sockets with the penalties of longer leads and possibly the use of multi-outlet adaptors. Because the ideal situation will have closely-spaced outlets, there is virtually no chance of more than a small proportion of them being in use at the same time, so generous allowance can be made for diversity. Thus, cables and protective devices can safely he smaller in size than would he needed if it were assumed that all outlets were simultaneously fully loaded.

Thus a ring circuit protected by a 30 A or 32 A device may well feed twenty socket outlets. It follows that judgement must be used to make as certain as possible that the total loading will not exceed the protective device rating, or its failure and inconvenience will result. Two basic steps will normally ensure that a ring circuit is not overloaded.

1. - Do not feed heavy and steady loads (the domestic immersion heater is the most obvious example) from the ring circuit, but make special provision for them on separate circuits.

2. -Make sure that the ring circuit does not feed too great an area. This is usually ensured by limiting a single ring circuit to sockets within an area not greater than one hundred square metres.

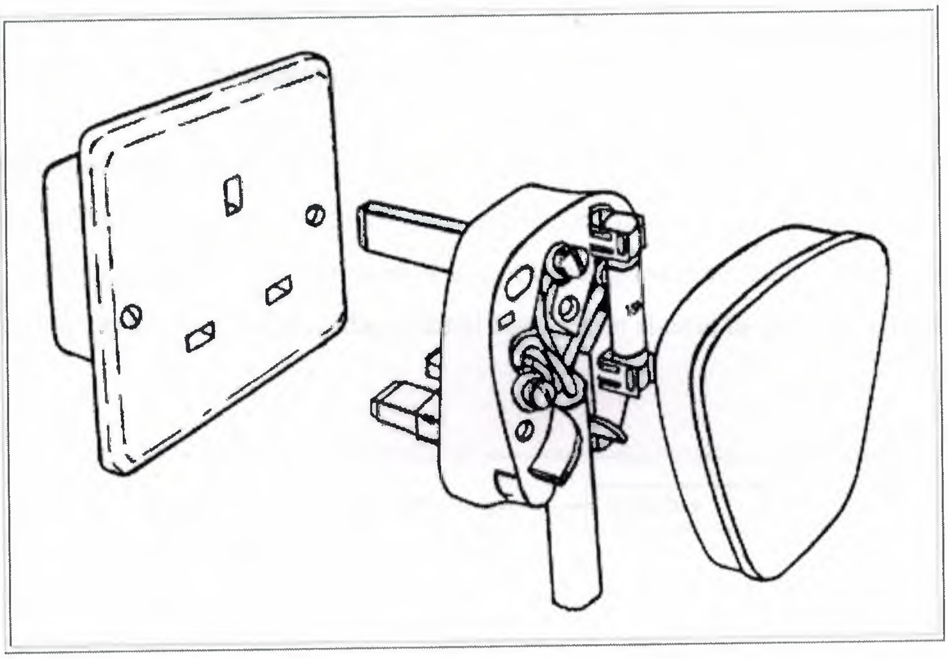


Figure 3.3 - Plug and socket– [6]

We have already indicated that a 30 A or 32 A fuse or circuit breaker is likely to protect a large number of outlets. If this were the only method of protection, there could be a dangerous situation if, for example, a flexible cord with a rating of, say, 5 A developed a fault between cores. The fuse is inside the BS 1363 plug, and is rated at 13 A or 3 A, although many other ratings up to 12 A, which are not recognised in the BSS, are available.

A plug to BS 1363 without a fuse is not available. The circuit protection in the distribution board or consumer's unit covers the circuit wiring, whilst the fuse in the plug protects the appliance and its cord as shown in {Figure 3.4}. In this way, each appliance can be protected by a suitable fuse, for example, a 3 A fuse for a table lamp or a 13 A fuse for a 3 kW fan heater.

Whilst the installer of the wiring is seldom concerned with the flexible cords of appliances connected to it, he must still offer guidance to users. This will include fitting 3 A fuses in plugs feeding low rated appliances, and the use of flexible cords which are of sufficient cross-section and are as short as possible in the circumstances concerned. Generally, 0.5 mm^2 cords should be the smallest size connected to plugs fed by 30 A or 32 A ring circuits.

Where the cord length must he 10 m or greater, the minimum size should be 0.75 mm² and rubber-insulated cords are preferred to those that are PVC insulated.

This type of outlet is not intended for use at high ambient temperatures. A common complaint is the overheating of a fused plug and socket mounted in an airing cupboard to feed an immersion beater; as mentioned above, it is not good practice to connect such a load to a ring circuit, and if unavoidable, final connection should be through a fused spur outlet.

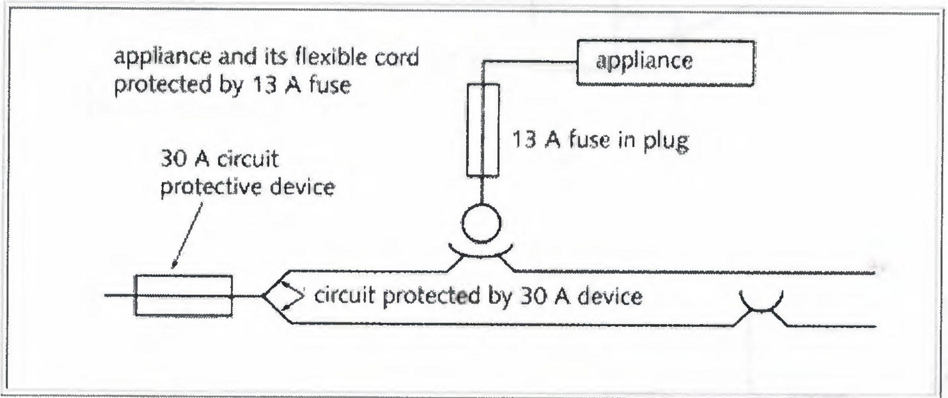


Figure 3.4 - Principle of appliance protection by plug fuse – [6]

The British fused plug system is probably the biggest stumbling block to the introduction of a common plug for the whole of Europe (the 'europlug'). The proposed plug is a reversible two pin type, so would not comply with the Regulations in terms of correct polarity. If we were to adopt it, every plug would need adjacent fuse protection, or would need to be rewired back to its own protective device. In either case, the cost would be very high.

Ring circuits fed from systems where no earth terminal is provided by the Electricity Supply Company (TT systems) must be protected by an RCD rated at 30 mA, In all installations, a socket intended to feed equipment outdoors must be individually protected by a 30 mA RCD.

Where a socket is mounted on a vertical wall, its height above the floor level or

The working surface level must be such that mechanical damage is unlikely. A minimum mounting height of 150 mm is recommended.

3.3.2 - The ring final circuit

The arrangement of a typical ring circuit is shown in {Figure 3.5} and must comply with the following requirements.

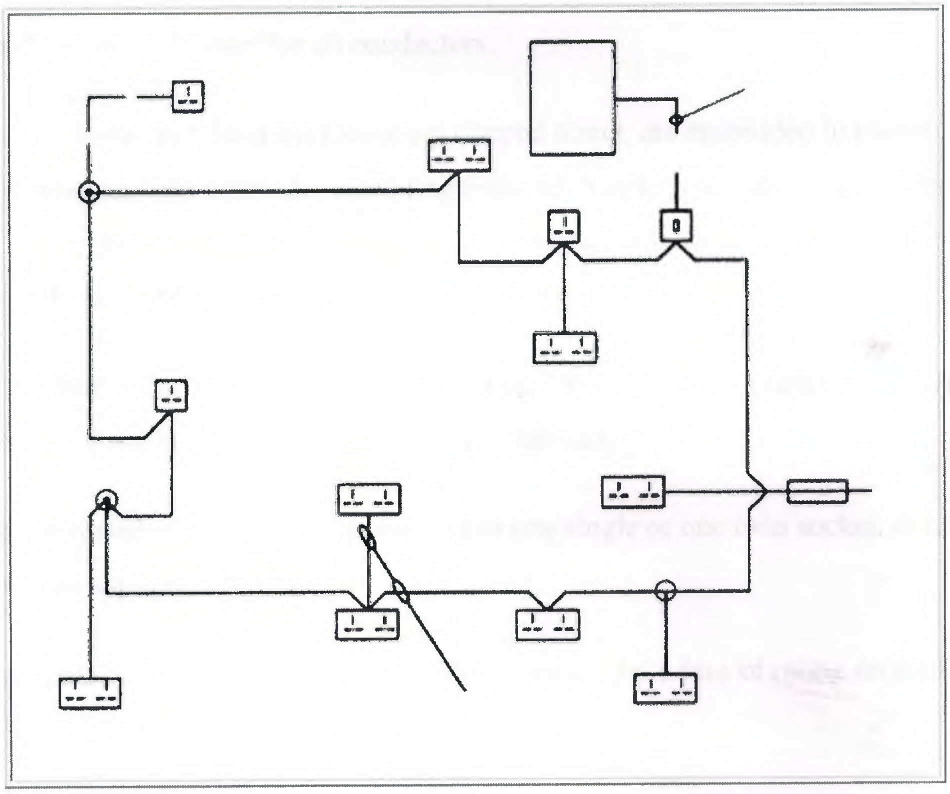


Figure 3.5 - Ring circuit feeding socket outlets – [6]

1. - The floor area served by each ring must not exceed 100 m² for domestic situations, Where ring circuits are used elsewhere (such as in commerce or industry) the diversity must be assessed to ensure that maximum demand will not exceed the rating of the protective device.

2. - Consideration should be given to the provision of a separate ring (or radial) circuit in a kitchen.

3. -Where there is more than one ring circuit in the same building, the installed sockets should be shared approximately evenly between them.

4. - Cable sizes for standard circuits are as follows:

a) p.v.c. insulated cable are 2.5 mm^2 for live (phase and neutral) conductors and 1.5mm^2 for the CPC.

b) Mineral insulated: 1.5$mm^2$for all conductors.

These sizes assume that sheathed cables are clipped direct, are embedded in plaster, or have one side in contact with thermally insulating material. Single core cables are assumed to be enclosed in conduit or trunking. No allowance has been made for circuits which are bunched, and the ambient temperature is assumed not to exceed 30°C.

5. - The number of unfused spurs fed from the ring circuit must not exceed the number of sockets or fixed appliances connected directly in the ring.

6. - Each non-fused spur may feed no more than one single or one twin socket, or no more than one fixed appliance.

7. - Fixed loads fed by the ring must be locally protected by a fuse of rating no greater than 13 A or by a circuit breaker of maximum rating 16 A.

8. - Fixed equipment such as space heaters, water heaters of capacity greater than 15 litres, and immersion heaters, should not be fed by a ring, but provided with their own circuits.

3.3.3 - The radial circuit

Two types of radial circuit are permitted for socket outlets. In neither case is the number of sockets to be supplied specified, so the number will be subject to the constraints of load and diversity. The two standard circuits are:

1. - 20 A fuse or miniature circuit breaker protection with 2.5 mm^2 live and 1.5mm^2 protective conductors (or 1.5 mm^2 if m.i. cable) feeding a floor area of not more than 50 m^2.

If the circuit feeds a kitchen or utility room, it must be remembered that a 3 kW device such as a washing machine or a tumble dryer takes 12.5 A at 240 V and that this leaves little capacity for the rest of the sockets.

2. - 32 A cartridge fuse to B888 or miniature circuit breaker feeding through 4 mm² live and 2.5 mm² protective conductors (or 2.5 mm² and 1.5 mm² if m.i. Cable) to supply a floor area no greater than 75m².

The arrangement of the circuits is shown in (Figure3.6). 4mm² may seem to be a large cable size in a circuit feeding 13 A sockets. It must be remembered, however, that the 2.5 mm² ring circuit allows current to be fed both ways round the ring, so that two conductors are effectively in parallel, whereas the 4 mm² cable in a radial circuit must carry all the current.

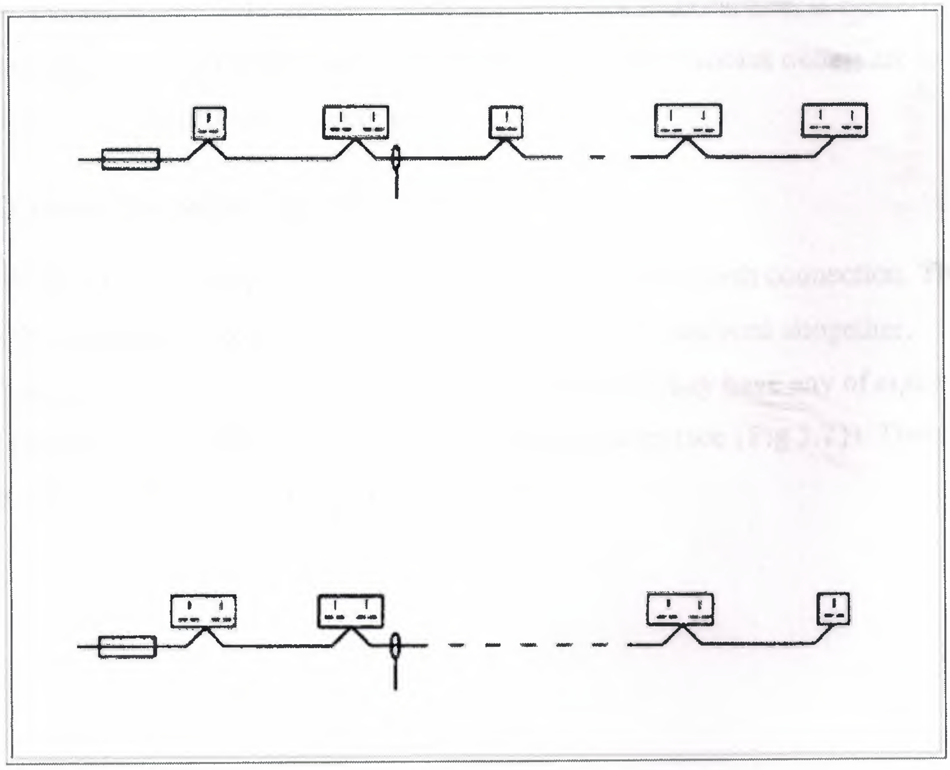


Figure 3.6 - Radial circuits – [6]

Radial circuits can be especially economic in a long building where the completion of a ring to the far end could effectively double the length of cable used. As for ring circuits, danger can occur if flexible cords are too small in cross-section, or are too long, or if 3 A fuses are not used where appropriate.

The minimum cross-sectional area for flexible cords should be:

$0.5mm^2$ where the radial circuit is protected by a 16 A fuse,
$0.75mm^2$ for a 20 A fuse,
or $1.0mm^2$ for a 30 A or 32 A fuse.

3.4 - Industrial socket outlet circuits

3.4.1 - Introduction

There is no reason at all to prevent the installation of (13 A) socket outlets in industrial situations. Indeed, where light industry, such as electronics manufacture, is concerned, these sockets are most suitable. However, heavy duty industrial socket outlets are available, and this type is the subject of this section.

3.4.2 - BS 196 socket outlet circuits

BS 196 sockets are two-pin, non-reversible, with a scraping earth connection. The fusing in the plug can apply to either pole, or the plug may be unfused altogether. Interchangeability is prevented by means of a keyway which may have any of eighteen different positions, identified by capital letters of the alphabet (see {Fig 3.7}). They are available with current ratings of 5 A, 15 A or 30 A.

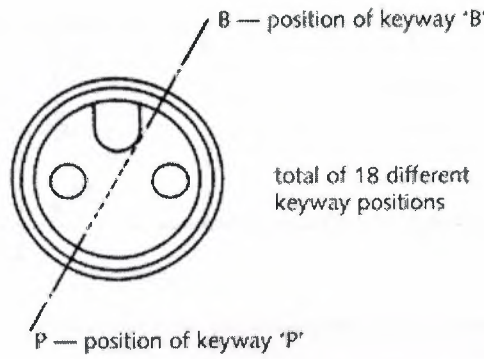


Figure 3.7 - Arrangement of socket outlet.
Two of the eighteen possible keyway positions are shown

Circuit details for wiring ES 196 outlets can be summarised as:

1. - the maximum protective device rating is 32 A

2. - all spurs must be protected by a fuse or circuit breaker of rating no larger than 16 A - this means that 30 A outlets cannot be fed from spurs

3. - the number of sockets connected to each circuit is unspecified, but proper judgement must be applied to prevent failure of the protective device due to overload

4. - cable rating must be no less than that of the protective device for radial circuits, or two thirds of the protective device rating for a ring circuit

5. - on normal supplies with an earthed neutral, the phase pole must be fused and the keyway must be positioned at point B (see {Figure 3.7})

6. - when the socket is fed at reduced voltage from a transformer with the centre tap on its secondary winding earthed {Figure 3.8}, both poles of the plug must be fused and the keyway must be positioned at P.

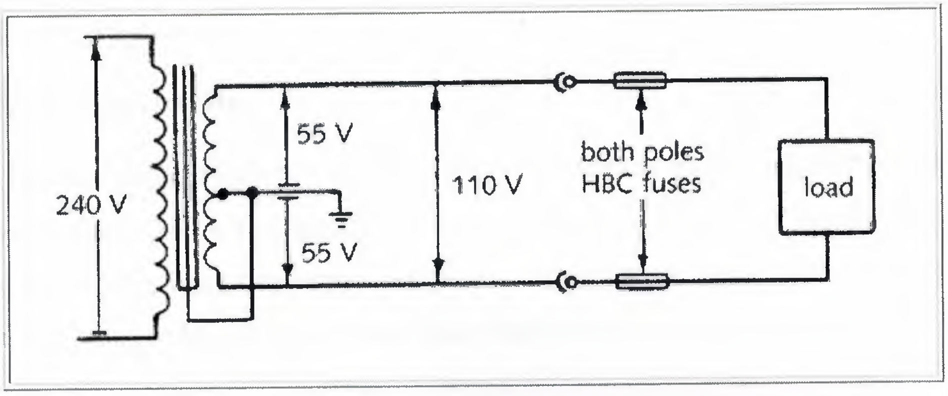


Figure 3.8 - Circuit fed from a transformer with a centre-tapped secondary winding – [5]

3.4.3 - BS EN 60309-1 (BS 4343) socket outlet circuits

Plugs and sockets to BS EN 60309-1 are for industrial applications and are rated at 16 A, 32 A, 63 A and 125 A. All but the smallest size must be wired on a separate circuit, but 16 A outlets may be wired in unlimited numbers on radial circuits where diversity can be justified. However, since the maximum rating for the protective device is 20 A, the number of sockets will be small except where loads are very light or where it is certain that few loads will be connected simultaneously. An arrangement of BS EN 60309-2 plugs and sockets is shown in {Figure 3.9}.

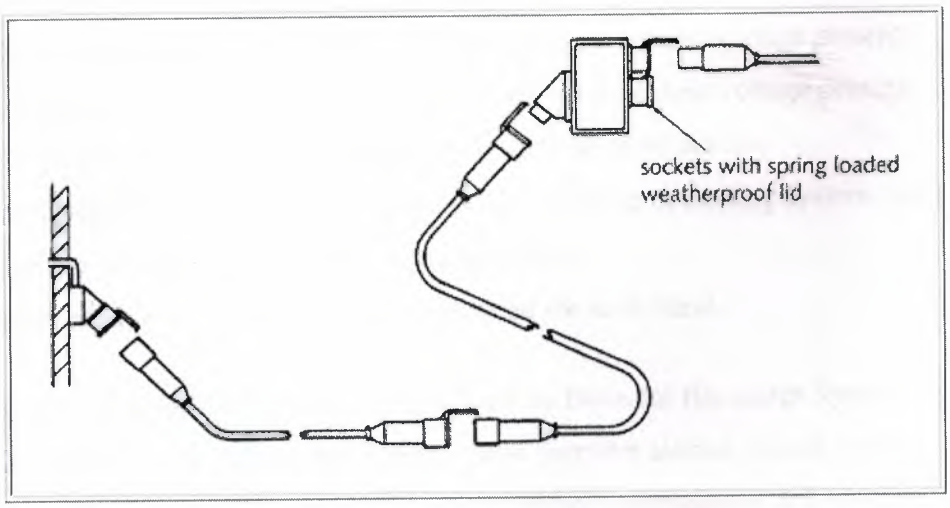


Figure 3.9 - Plugs and sockets – [1]

3.5 - Circuit segregating

3.5.1 - Segregating circuits

The 15th and 16th editions of the IEE Wiring Regulations applied segregation of circuits which need to be kept apart by classifying them in four separate categories (the Regs themselves only mentioned three categories, but since two types of circuit both categorised as 3 had to be separated from each other, there were effectively four categories).

The second amendments to BS 7671 (published in 1997) have simplified the situation. There are now only two categories, which are known as voltage bands.

Voltage Band I is defined as levels of voltage which are too low to provide serious electric shocks; effectively this limits the band to extra-low voltage (ELV), including telecommunications, signalling, bell, and control and alarm circuits.

Voltage Band II covers all voltages used in electrical installations not included in Band I. This means that all 230/400 V (240/415 V) supplies are included in Band II.

As expected, BS 7671 prohibits Band I and Band II cables sharing the same cable enclosure or multicore cable unless: every cable is insulated for the highest voltage present,
or each conductor in a multicore cable is insulated for the highest voltage present, unless conductors of the two bands are separated by an earthed metal screen,
or they are installed in separate compartments of a trunking or ducting system, or they are installed on a tray with a partition providing separation,
or a separate conduit or ducting system is provided for each band.

This does mean that BS 7671 allows circuits such as those for fire alarm Systems, emergency lighting, telephones, data transmission, intruder alarms, sound systems, and bell and calls systems, etc., may now be run together without segregation. BS 5838: 1988, on the other hand. Makes it clear that fire alarm cables must be separated from all others, and IEE Guidance Note 4 requires that escape lighting cables should be mineral insulated or separated from all others by at least 300 mm. Care must be taken to ensure that circuits are not affected by electrical interference, both electrostatic (due to electric fields) or electro-magnetic (due to electro-magnetic fields). In some ways this makes the circuit designer's task more difficult, because he must now ensure that there will be no interference, whereas before, he simply had to ensure that the required segregation was employed.

In some instances it will be necessary for circuit outlets for both voltage bands to share a common box; switchplate or block. In such a case, the connections of circuits of differing bands must be segregated by a partition, which must be earthed if of metal.

3.5.2 - Electromagnetic compatibility

All electrical equipment must be selected and installed so that it will not affect the supply or cause harmful effects to other equipment. One of the harmful effects is electromagnetic interference (EMI). Whenever current flows in a conductor it sets up a magnetic field; a change in the current will result in a corresponding change in the magnetic field, which will result in the induction of electromotive force (voltage) in any conducting system subject to the field. Whilst induced voltages will usually be very small, they may be considerable when rates of change of current are heavy (for example, circuits feeding lift motors) or when there is a lightning strike in the vicinity.

The effects are most pronounced when large metal loops are formed by circuits (perhaps power and data circuits) which are run at a distance from each other but have common earthing and bonding. Power and data cables need to follow common routes to prevent aerial loops which will be subject to induced e.m.f., but with sufficient spacing to prevent interference between them (see {Table 3.2}). The emission standard is BS EN 50081 and the immunity standard BS EN 50082.

The designer needs to consider EMC when planning an installation, and may decide that some of the following measures are appropriate:

providing surge protectors and filters for sensitive equipment, proper separation of power and other cables to limit electro-magnetic interference (EMI),
using bonding connections which are as short as possible, screening sensitive equipment

and bonding of metal enclosures, and avoiding inductive loops by using the same route for cables of different systems.

This list is far from exhaustive.

Table 3.2 - Proposed EMI cable separation distances

Power cable voltage	Min. separation btw power & signal cables, m	Power cable current	Min separation btw power & signal cables, m
115 V	0.25	5 A	0.24
240 V	0.45	15 A	0.35
415 V	0.58	50 A	0.50
3.3 kV	1.10	100 A	0.60
6.6 kV	1.25	300 A	0.85
11 kV	1.40	600 A	1.05

3.5.3 - lift or hoist shaft circuits

A lift shaft may well seem to be an attractive choice for running cables, but this is not permitted except for circuits which are part of the lift or hoist installation (see {Figure 3.10}). The cables of the lift installation may be power cables fixed in the shaft to feed the motor(s), or control cables which feed call buttons, position indicators, and so on. Trailing cables will feed call buttons, position indicators, lighting and telephones in the lift itself.

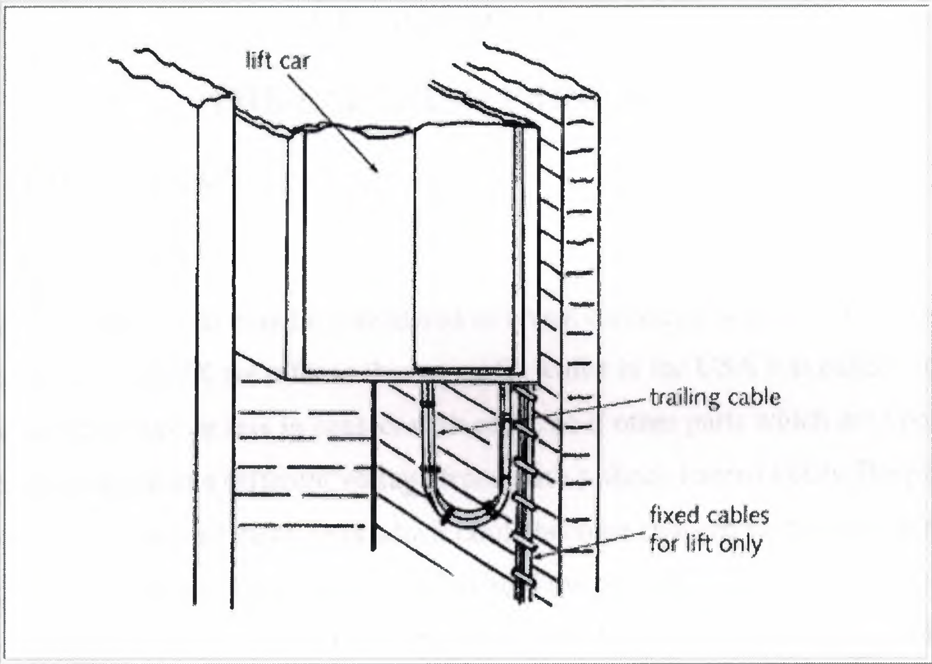


Figure 3.10 - Cables installed in lift or hoist shafts – [2]

CHAPTER FOUR

THE EARTHING PRINCIPLE

4.1 - The earthing principle

4.1.1 - What is earthing?

The whole of the world may be considered as a vast conductor which is at reference (zero) potential. In the UK we refer to this as 'earth' whilst in the USA it is called 'ground'. People are usually more or less in contact with earth, so if other parts which are open to touch become charged at a different voltage from earth a shock hazard exists.The process of earthing is to connect all these parts which could become charged to the general mass of earth, to provide a path for fault currents and to hold the parts as close as possible to earth potential. In simple theory this will prevent a potential difference between earth and earthed parts, as well as permitting the flow of fault current which will cause the operation of the protective systems.

The standard method of tying the electrical supply system to earth is to make a direct connection between the two. This is usually carried out at the supply transformer, where the neutral conductor (often the star point of a three-phase supply) is connected to earth using an earth electrode or the metal sheath and armouring of a buried cable. {Figure 4.1} shows such a connection. Lightning conductor systems must be bonded to the installation earth with a conductor no larger in cross-sectional area than that of the earthing conductor.

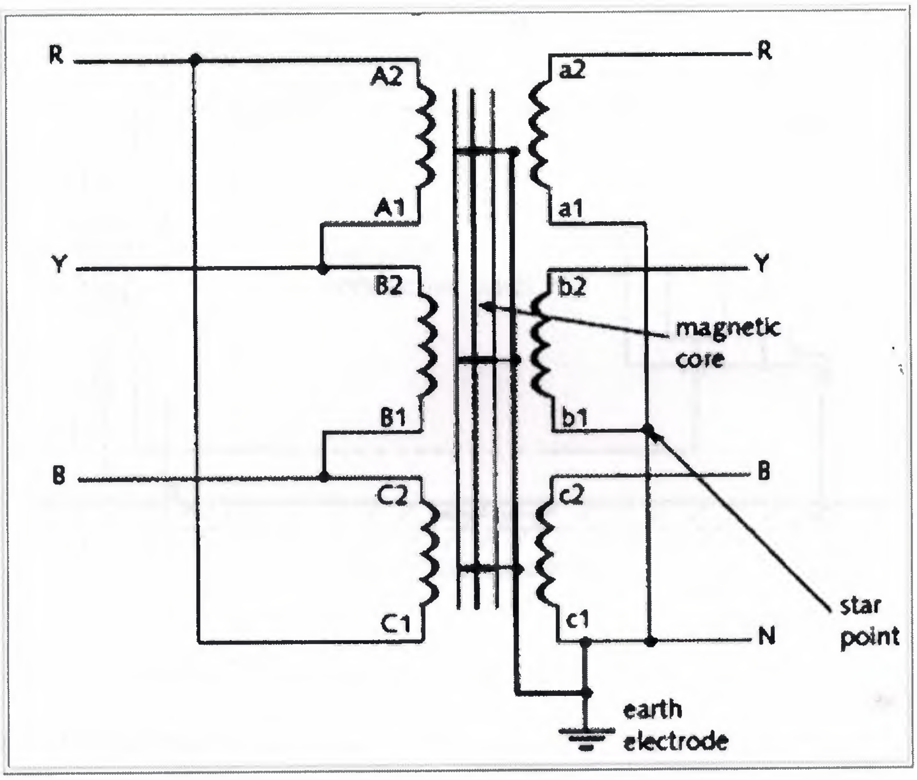


Figure 4.1 - Three-phase delta/star transformer
showing earthing arrangements – [2]

4.1.2 - The advantages of earthing

The practice of earthing is widespread, but not all countries in the world use it.

There is certainly a high cost involved, so there must be some advantages. In fact there are two. They are:

1. - The whole electrical system is tied to the potential of the general mass of earth and cannot 'float' at another potential. For example, we can be fairly certain that the neutral of our supply is at, or near, zero volts (earth potential) and that the phase conductors of our standard supply differ from earth by 240 volts.

2. - By connecting earth to metalwork not intended to carry current (an extraneous conductive part or a an exposed conductive part) by using a protective conductor, a path is provided for fault current which can be detected and, if necessary, broken. The path for this fault current is shown in {Figure 4.2}.

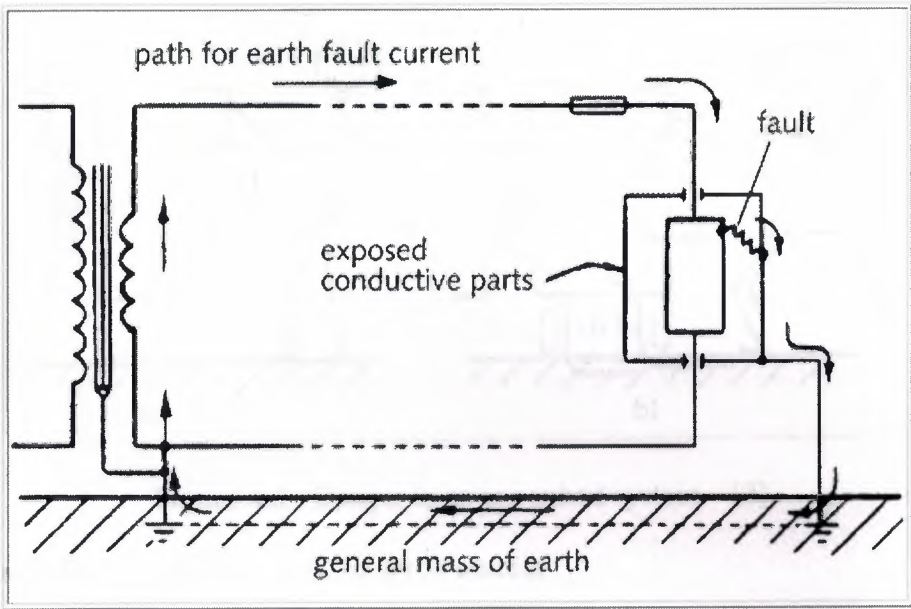


Figure 4.2 - Path for earth fault current (shown by arrows) – [2]

4.1.3 - The disadvantages of earthing

The two important disadvantages are:

1. - Cost: the provision of a complete system of protective conductors, earth electrodes, etc. is very expensive.

2. - Possible safety hazard: It has been argued that complete isolation from earth will prevent shock due to indirect contact because there is no path for the shock current to return to the circuit if the supply earth connection is not made (see {Figure 4.3(a)}). This approach, however, ignores the presence of earth leakage resistance (due to imperfect insulation) and phase-to-earth capacitance (the insulation behaves as a dielectric). In many situations the combined impedance due to insulation resistance and earth capacitive reactance is low enough to allow a significant shock current (see {Figure 4.3(b)}).

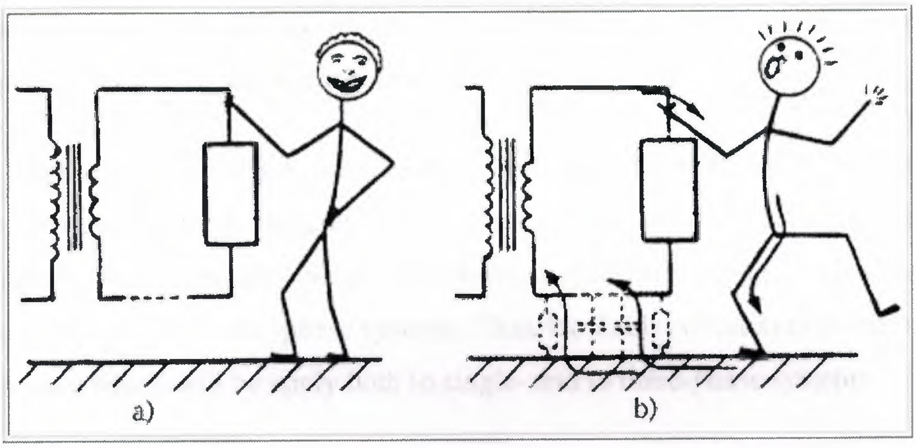


Figure 4.3 - Danger in an unearthed system – [2]

a) apparent safety: no obvious path for shock current

b) actual danger: shock current via stray resistance and capacitance

4.2 – Earth fault loop impedance

4.2.1 - The importance of loop impedance

The earth fault loop impedance can be used with the supply voltage to calculate the earth-fault current.

IF = Uo / Zs

Where IF = fault current, A Uo = phase voltage, V Zs = loop impedance

For example, if a 240 V circuit is protected by a 15 A semi-enclosed fuse and has an earth-fault loop impedance of 1.6 Ohms, the earth-fault current in the event of a zero impedance earth fault will he:

IF = Uo / Zs = 240 A /150 A =1, 6

This level of earth-fault current will cause the fuse to operate quickly. The time taken for the fuse to operate will be about 0.15 s. Any load current in the circuit will be additional to the fault current and will cause the fuse to operate slightly more quickly. However, such load current must not be taken into account when deciding disconnection time, because it is possible that the load may not be connected when the fault occurs.

Note that there is no such thing as a three-phase line/earth fault, although it is possible for three faults to occur on the three lines to earth simultaneously. As far as calculations for fault current are concerned, the voltage to earth for standard UK supplies is always 240 V, for both single-phase and three-phase systems. Thus the Tables of maximum earth-fault loop impedance which will be apply both to single- and to three-phase systems.

4.2.2 – Earth-fault loop impedance values

The over-riding requirement is that sufficient fault current must flow in the event of an earth fault to ensure that the protective device cuts off the supply before dangerous shock can occur. For normal 240 V systems, there are two levels of maximum disconnection time. These are:

For socket outlet circuits where equipment could be tightly grasped: 0.4 s

For fixed equipment where contact is unlikely to be so good: 5 s

The maximum disconnection time of 5 s also applies to feeders and sub-mains.

It must be appreciated that the longest disconnection times for protective devices, leading to the longest shock times and the greatest danger, will be associated with the lowest levels of fault current, and not, as is commonly believed, the highest levels.

Where the voltage is other than 240 V, [Table 41A] gives a range of disconnection times for socket outlet circuits, of which the lowest is 0.1 s for voltages exceeding 400 V.

In general, the requirement is that if a fault of negligible impedance occurs between a phase and earth, the earth-fault loop impedance must not be greater than the value calculated from.

$Zs < Uo / Ia$

Where Zs = the earth fault loop impedance (Ohms), Uo = the system voltage to earth (V) and Ia = the current causing automatic disconnection (operation of the protective device) in the required time [A]).

The earth fault loop values shown in (Tables 4.1, 4.2 and 4.4) depend on the supply voltage and assume, as shown in the Tables, a value of 240 V. Whilst it would appear that 240 V is likely to be the value of the supply voltage in Great Britain for the foreseeable future, it is not impossible that different values may apply. In such a case, the tabulated value for earth fault loop impedance should be modified using the formula:-

Zs = Zt x (U / U240)

Where Zs = is the earth fault loop impedance required for safety Zt = is the tabulated value of earth fault loop impedance U = is the actual supply voltage U240 = is the supply voltage assumed in the Table.

As an alternative to this calculation, a whole series of maximum values of earth fault loop impedance is given in (Table 5.1) for disconnection within 0.4 s. The reader should not think that these values are produced in some mysterious way - all are easily verified using the characteristic curves

For example, consider a 20 A HRC fuse to BS88 used in a 240 V system. And indicates that disconnection in 0.4 s requires a current of about 130 A. It is difficult (if not impossible) to be precise about this value of current, because it is between the 100 A and 150 A current graduations.

Using these values,

Zs = Uo / Ia = 240/130 = 1.84 Ohms.

Reference to (Table 4.1) shows that the stated value is 1.8 Ohms, the discrepancy being due to the difficulty in reading the current with accuracy. (Tables 4.1 and 4.2) give maximum earth-fault loop impedance values for fuses and for miniature circuit breakers to give a minimum disconnection time of 0.4 s in the event of a zero impedance fault from phase to earth.

The reason for the inclusion of fixed equipment as well as distribution circuits in (Table 4.2) will become apparent later in this sub-section.

Table 4.1 - Maximum earth-fault loop impedance for 240 V socket outlet circuits protected by fuses			
Fuse rating (A)	Maximum earth-fault loop impedance (Ohms)		
-	Cartridge BS 88	Cartridge BS 1361	Semi-enclosed BS3036
5	-	10.9	10.0
6	8.89	-	-
10	5.33	-	-
15	-	3.43	2.67
20	1.85	1.78	1.85
30	-	1.20	1.14
32	1.09	-	-
40	0.86	-	-
45	-	0.60	0.62

Table 4.2 - Maximum earth-fault loop impedance for 240 V circuit protected by miniature circuit breakers to give compliance with 0.4 s disconnection time					
	Maximum earth-fault loop impedance (Ohms)				
Device rating (A)	MCB type 1	MCB type 2	MCB type 3 and type C	MCB type B	MCB type D
5	12.00	6.86	4.80	-	2.40
6	10.00	5.71	4.00	8.00	2.00
10	6.00	3.43	2.40	4.80	1.20
15	4.00	2.29	1.60	-	0.80
16	3.75	2.14	1.50	3.00	0.75
20	3.00	1.71	1.20	2.40	0.60
25	2.40	1.37	0.96	1.92	0.48
30	2.00	1.14	0.80	-	0.40
32	1.88	1.07	0.75	1.50	0.36
40	1.5	0.86	0.60	1.20	0.30

The severity of the electric shock received when there is a phase to earth fault (indirect contact) depends entirely on the impedance of the circuit protective conductor. We saw how the volt drop across the protective conductor is applied to the person receiving the shock. Since this volt drop is equal to fault current times protective conductor impedance, if the protective conductor has a lower impedance the shock voltage will he less. Thus it can be sustained for a longer period without extreme danger.

Socket outlet circuits can therefore have a disconnection time of up to 5 s provided that the circuit protective conductor impedance's are no higher than shown in {Table 4.3} for various types of protection.

The reasoning behind this set of requirements becomes clearer if we take an example. {Table 4.3} shows that a 40 A cartridge fuse to BS 88 must have an associated protective conductor impedance of no more than 0.29 Ohms if it is to comply. Now look at the time/current characteristic for the fuse from which we can see that the current for operation in 5 s is about 170 A. The maximum volt drop across the conductor (the shock voltage) is thus 170 x 0.29 or 49.3 V.

Table 4.3 - Maximum impedance of circuit protective conductors to allow 5 s disconnection time for socket outlets

	Maximum impedance of circuit protective conductor							
	Fuse BS 88	Fuse BS 1361	Fuse BS 3036	MCB type 1	MCB type 2	MCB type 3 & C	MCB type B	MCB type D
5	-	3.25	3.25	2.50	1.43	1.00	-	0.50
6	2.48	-	-	2.08	1.19	0.83	1.67	0.42
10	1.48	-	-	1.25	0.71	0.50	1.00	0.25
15	-	0.96	0.96	0.83	0.48	0.33	-	-
16	0.83	-	-	0.78	0.45	0.31	0.63	0.16
20	0.55	0.55	0.63	0.63	0.36	0.25	0.50	0.12
25	0.43	-	-	-	-	-	-	0.10
30	-	0.36	0.43	0.42	0.24	0.17	-	-
32	0.34	-	-	0.39	0.22	0.16	0.31	0.08
40	0.26	-	-	0.31	0.18	0.13	0.25	0.06
45	-	0.18	0.24	0.28	0.16	0.11	0.22	0.06

Table 4.4 - Maximum earth-fault loop impedance for 240 V fixed equipment distribution circuits protected by fuses			
-	Maximum earth-fault loop impedance		
Device rating (A)	Cartridge BS 88	Cartridge BS 1361	Semi-enclosed BS 3036
5	-	17.1	-
6	14.1	-	-
10	7.74	-	-
15	-	5.22	5.58
16	4.36	-	-
20	3.04	2.93	4.00
30	-	1.92	2.76
32	1.92	-	-
40	1.41	-	-
45	-	1.00	1.66
50	1.09	-	-

Application of the same reasoning to all the figures gives shock voltages of less than 50 V. This limitation on the impedance of the CPC is of particular importance in TT systems where it is likely that the resistance of the earth electrode to the general mass of earth will be high.

The breaking time of 5 s also applies to fixed equipment, so the earth-fault loop impedance values can be higher for these circuits, as well as for distribution circuits. For fuses, the maximum values of earth-fault loop impedance for fixed equipment are given in {Table 4.4}.

No separate values are given for miniature circuit breakers. Examination of the time/current characteristics will reveal that there is no change at all in the current causing operation between 0.4 s and 5 s in all cases except the Type 1. Here, the vertical characteristic breaks off at 4 s, but this makes little difference to the protection. In this case, the values given in (Table 4.2) can be used for fixed equipment as well as for socket outlet circuits. An alternative is to calculate the loop impedance as described above.

4.2.3 – Protective conductors impedance

It has been shown in the previous sub-section how a low-impedance protective conductor will provide safety from shock in the event of a fault to earth. This method can only be used where it is certain that the shock victim can never be in contact with conducting material at a different potential from that of the earthed system in the zone he occupies. Thus, all associated exposed or extraneous parts must be within the equipotential zone. When over current protective devices are used as protection from electric shock, the protective conductor must be in the same wiring system as, or in close proximity to, the live conductors. This is intended to ensure that the protective conductor is unlikely to he damaged in an accident without the live conductors also being cut.

{Figure 4.4} shows a method of measuring the resistance of the protective conductor, using a line conductor as a return and taking into account the different cross-sectional areas of the phase and the protective conductors.

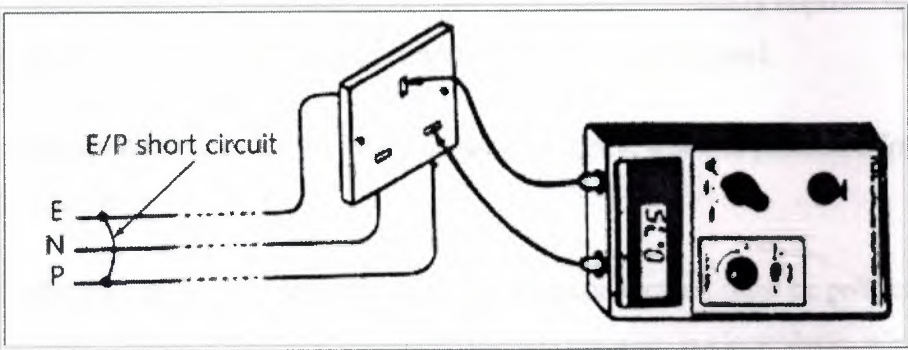


Figure 4.4 - Measurement of protective conductor resistance – [5]

Taking the cross-sectional area of the protective conductor as Ap and that of the line (phase or neutral) conductor as Al, then

$$Rp = \text{resistance reading} \times (Al / (Al + Ap))$$

4.3 - protective conductors

4.3.1 – Earthing conductors

The earthing conductor is commonly called the earthing lead. It joins the installation earthing terminal to the earth electrode or to the earth terminal provided by the Electricity Supply Company. It is a vital link in the protective system, so care must be taken to see that its integrity will be preserved at all times. Aluminium conductors and cables may now be used for earthing and bonding, but great care must be taken when doing so to ensure that there will be no problems with corrosion or with electrolytic action where they come into contact with other metals.

Where the final connection to the earth electrode or earthing terminal is made there must be a clear and permanent label Safety Electrical Connection - Do not remove Where a buried earthing conductor is not protected against mechanical damage but is protected against corrosion by a sheath, its minimum size must be 16 mm² whether made of copper or coated steel. If it has no corrosion protection, minimum sizes for mechanically unprotected earthing conductors are 25 mm² for copper and 50 mm² for coated steel.

If not protected against corrosion the latter sizes again apply, whether protected from mechanical damage or not.

Earthing conductors, as well as protective and bonding conductors, must be protected against corrosion. Probably the most common type of corrosion is electrolytic, which is an electro-chemical effect between two different metals when a current passes between them whilst they are in contact with each other and with a weak acid. The acid is likely to be any moisture which has become contaminated with chemicals carried in the air or in the ground. The effect is small on ac supplies because any metal removed whilst current flows in one direction is replaced as it reverses in the next half cycle. For dc Systems, however, it will be necessary to ensure that the system remains perfectly dry (a very difficult task) or to use the 'sacrificial anode' principle.

A main earth terminal or bar must be provided for each installation to collect and connect together all protective and bonding conductors. It must be possible to disconnect the earthing conductor from this terminal for test purposes, but only by the use of a tool. This requirement is intended to prevent unauthorised or unknowing removal of protection.

4.3.2 - Bonding conductors

The purpose of the protective conductors is to provide a path for earth fault current so that the protective device will operate to remove dangerous potential differences, which are unavoidable under fault conditions, before a dangerous shock can be delivered. Equipotential bonding serves the purpose of ensuring that the earthed metalwork (exposed conductive parts) of the installation is connected to other metalwork (extraneous conductive parts) to ensure that no dangerous potential differences can occur. The resistance of such a bonding conductor must be low enough to ensure that its volt drop when carrying the operating current of the protective device never exceeds 50 V.

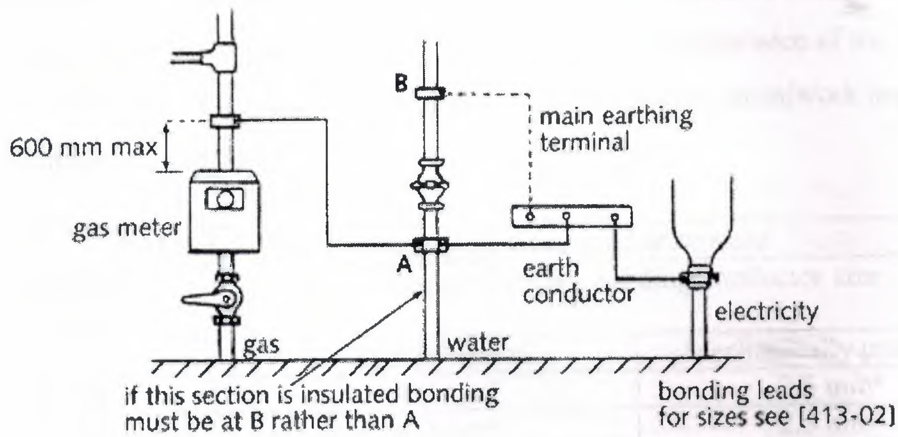


Figure 4.5 - Main bonding connections – [2]

Thus R < (50/ Ia)

Where R is the resistance of the bonding conductor and Ia is the operating current of the protective device.

Two types of equipotential bonding conductor are specified.

1. - Main equipotentiol bonding conductors

These conductors connect together the installation earthing system and the metalwork of other services such as gas and water. This bonding of service pipes must be effected as close as possible to their point of entry to the building, as shown in {Figure 4.5}. Metallic sheaths of telecommunication cables must be bonded, but the consent of the owner of the cable must he obtained before doing so. The minimum size of bonding conductors is related to the size of the main supply conductors (the tails) and is given in (Table 4.5).

2. - Supplementary bonding conductors

These conductors connect together extraneous conductive parts - that is, metalwork which is not associated with the electrical installation but which may provide a conducting path giving rise to shock. The object is to ensure that potential differences in excess of 50 V between accessible metalwork cannot occur; this means that the resistance of the bonding conductors must be low (Figure 4.6) shows some of the extraneous metalwork in a bathroom which must be bonded.

Table 4.5 - Supplementary bonding conductor sizes

Circuit protective conductor size	Supplementary bonding conductor size	
	Not protected	Mechanically protected
1.0 mm^2	4.0 mm^2	2.5 mm^2
1.5 mm^2	4.0 mm^2	2.5 mm^2
2.5 mm^2	4.0 mm^2	2.5 mm^2
4.0 mm^2	4.0 mm^2	2.5 mm^2
6.0 mm^2	4.0 mm^2	4.0 mm^2
10.0 mm^2	6.0 mm^2	6.0 mm^2

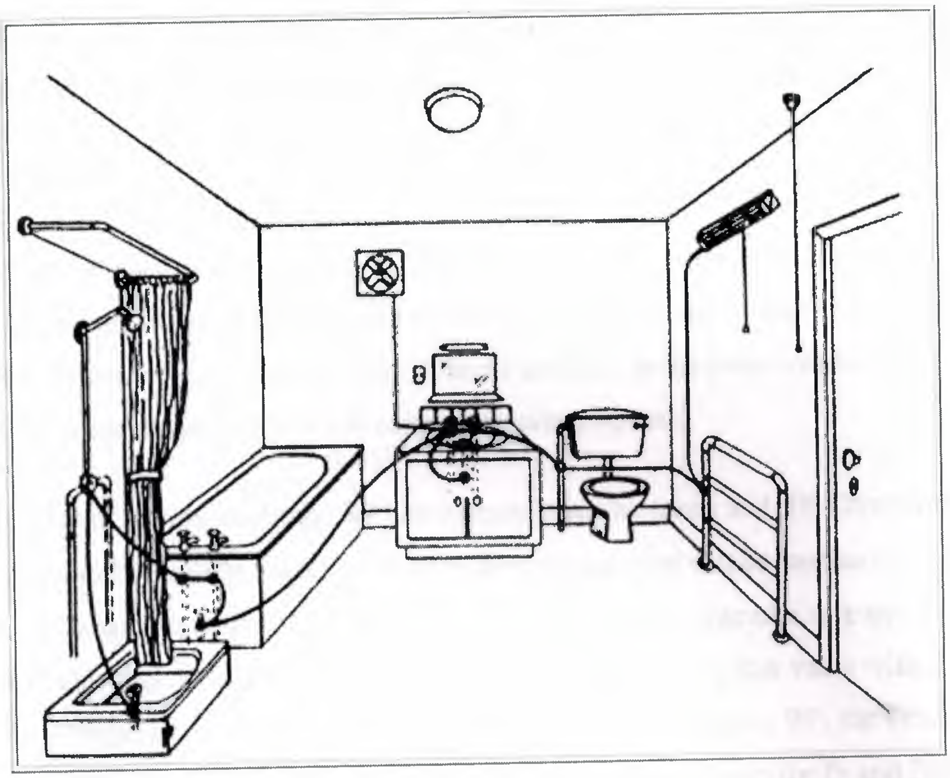


Figure 4.6 - Supplementary bonding in a bathroom – [7]

The cross-sectional areas required for supplementary bonding conductors are shown in {Table 4.5}. Where connections are between extraneous parts only, the conductors may be 2.5 mm² if mechanically protected or 4 mm²if not protected. If the circuit protective conductor is larger than 10 mm², the supplementary bonding conductor must have have at least half this cross-sectional area. Supplementary bonding conductors of less than 16 mm² cross sectional area must not be aluminium. {Figure 4.7} shows the application of a supplementary bonding conductor to prevent the severe shock which could otherwise occur between the live case of a faulty electric kettle and an adjacent water tap.

There will sometimes be doubt if a particular piece of metalwork should be bonded. The answer must always be that bonding will be necessary if there is a danger of severe shock when contact is made between a live system and the metal work in question. Thus if the resistance between the metalwork and the general mass of earth is low enough to permit the passage of a dangerous shock current, then the metalwork must be bonded.

The question can be resolved by measuring the resistance (Rx) from the metalwork concerned to the main earthing terminal. Using this value in the formula:

$$Ib = Uo / (Rp + Rx)$$

will allow calculation of the maximum current likely to pass through the human body where : Ib - is the shock current through the body (A) Uo - Is the voltage of the supply (V) RP - is the resistance of the human body (Ohms) and Rx - is the measured resistance from the metalwork concerned to the main earthing terminal (Ohms).

The resistance of the human body, RP can in most cases be taken as 1000 Ohms although 200 Ohms would be a safer value if the metalwork in question can be touched by a person in a bath. Although no hard and fast rules are possible for the value of a safe shock current, Ib, it is probable that 10 mA is seldom likely to prove fatal. Using this value with 240 V for the supply voltage, uo, and 1000 Ohms as the human body resistance, RP, the minimum safe value of RP calculates to 23 k Ohms. If the safer values of 5 mA for Ib and 200 Ohms for RP are used, the value of Rx would be 47.8 k Ohms for a 240 V supply.

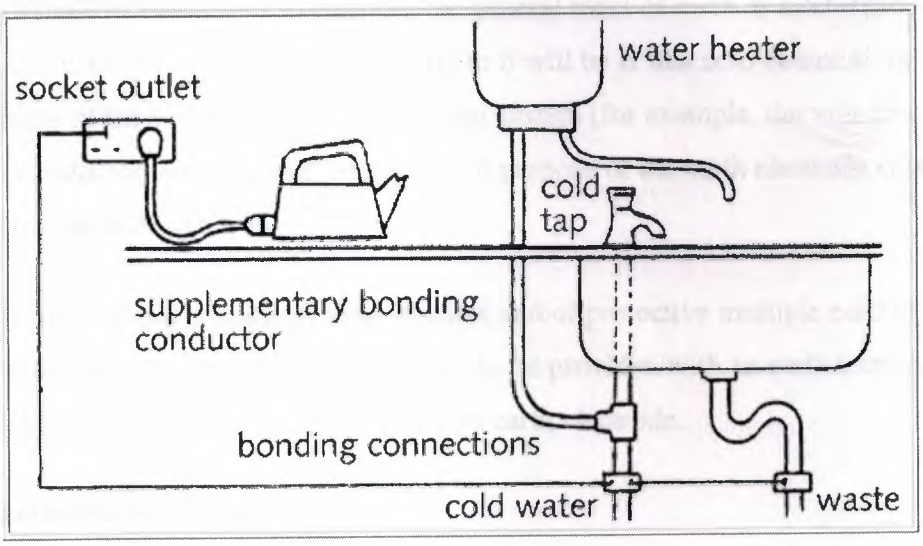


Figure 4.7 - Supplementary bonding conductor in a kitchen – [7]

To sum up when in doubt about the need to bond metalwork, measure its resistance to the main earthing terminal. If this value is 50 k Ohms or greater, no bonding is necessary. In a situation where a person is not wet, bonding could be ignored where the resistance to the main earthing terminal is as low as 25 k Ohms. To reduce the possibility of bonding conductors being disconnected by those who do not appreciate their importance, every bonding connection should be provided with a label.

4.3.3 - Unearthed metalwork

If exposed conductive parts are isolated, or shrouded in non-conducting material, or are small so that the area of contact with a human body is limited, it is permissible not to earth them. Examples are overhead line metalwork which is out of reach, steel reinforcing rods within concrete lighting columns, cable clips, nameplates, fixing screws and so on. Where areas are accessible only to skilled or instructed persons, and where unauthorised persons are unlikely to enter due to the presence of warning notices, locks and so on, earthing may be replaced by the provision of obstacles which make direct contact unlikely, provided that the installation complies with the Electricity at Work Regulations, 1989.

4.4 – earth electrodes

4.4.1 - Why we must have earth electrodes?

The principle of earthing is to consider the general mass of earth as a reference (zero) potential. Thus, everything connected directly to it will be at this zero potential, or above it by the amount of the volt drop in the connection system (for example, the volt drop in a protective conductor carrying fault current). The purpose of the earth electrode is to connect to the general mass of earth.

With the increasing use of underground supplies and of protective multiple earthing (PME) it is becoming more common for the consumer to be provided with an earth terminal rather than having to make contact with earth using an earth electrode.

4.4.2 – Earth electrode types

Acceptable electrodes are rods, pipes, mats, tapes, wires, plates and structural steelwork buried or driven into the ground. The pipes of other services such as gas and water must not be used as earth electrodes although they must be bonded to earth as described in The sheath and armour of a buried cable may be used with the approval of its owner and provided that arrangements can be made for the person responsible for the installation to be told if the cable is changed, for example, for a type without a metal sheath.

The effectiveness of an earth electrode in making good contact with the general mass of earth depends on factors such as soil type, moisture content, and so on. A permanently-wet situation may provide good contact with earth, but may also limit the life of the electrode since corrosion is likely to be greater. If the ground in which the electrode is placed freezes, there is likely to be an increase in earth resistance. In most parts of the UK an earth electrode resistance in the range 1 Ohm to 5 Ohms is considered to be acceptable.

The method of measuring the resistance of the earth electrode will be considered in the resistance to earth should be no greater than 220 Ohms. The earthing conductor and its connection to the earth electrode must be protected from mechanical damage and from corrosion. Accidental disconnection must be avoided by fixing a permanent label as shown in {Figure 4.8} which reads:

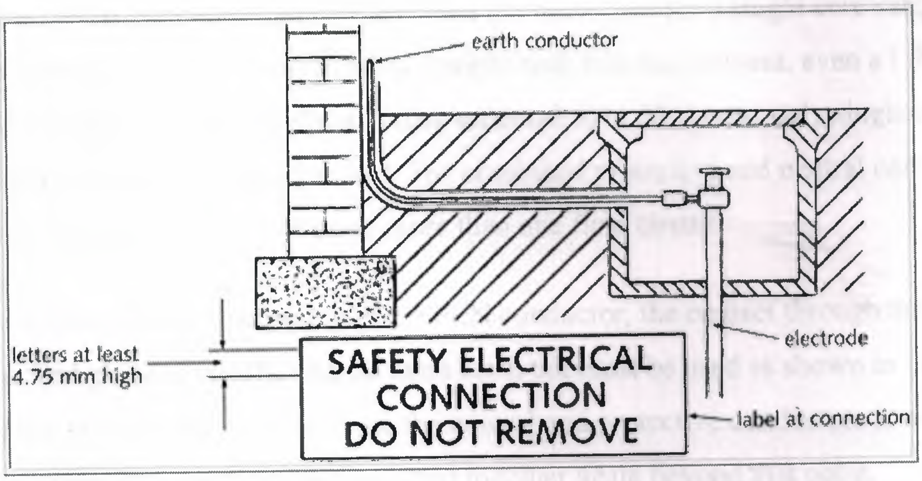


Figure 4.8 - Connection of earthing conductor to earth electrode – [1]

4.5 – Earthed concentric wiring

4.5.1 – What is earth concentric wiring?

This is the TN-C system where a combined neutral and earth (PEN) conductor is used throughout the installation as well as for the supply. The PEN conductor is the sheath of a cable and therefore is concentric with (totally surrounds) the phase conductor(s). The system is unusual, but where employed almost invariably uses mineral insulated cable, the metallic copper sheath being the combined neutral and earth conductor.

4.5.2 – Requirements for earthed concentric wiring

Earthed concentric wiring may only be used under very special conditions, which usually involve the use of a private transformer supply or a private generating plant. Since there is no separate path for earth currents, it follows that residual current devices (RCDs) will not be effective and therefore must not be used. The cross-sectional area of the sheath (neutral and earth conductor) of a cable used in such a system must never be less than 4 mm² copper, or 16 mm² aluminium or less than the inner core for a single core cable. All multicore copper mineral insulated cables comply with this requirement, even a I mm² two core cable having the necessary sheath cross-sectional area. However, only single core cables of 6 mm² and below may be used. The combined protective and neutral conductors (sheaths) of such cables must not serve more than one final circuit.

Wherever a joint becomes necessary in the PEN conductor, the contact through the normal sealing pot and gland is insufficient; an extra earth tail must be used as shown in {Figure 4.9}. If it becomes necessary to separate the neutral and protective conductors at any point in an installation, they must not be connected together again beyond that point.

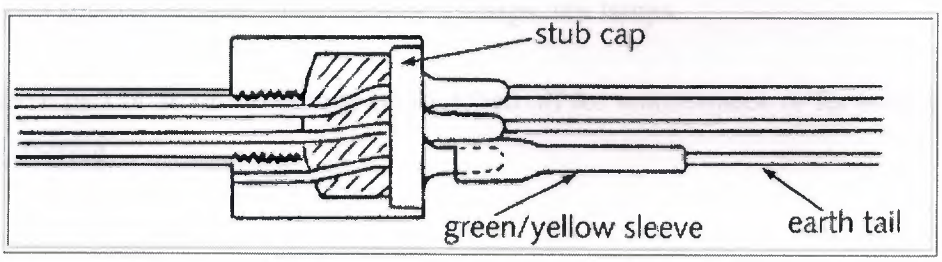


Figure 4.9 - Earth tail seal for use in earthed concentric wiring – [1]

4.6 – Combined functional and protective earthing

The previous section has made it clear that high earth leakage currents can cause difficulties in protection. The increasing use of data processing equipment such as computers has led to the need for filters to protect against transients in the installation which could otherwise result in the loss of valuable data. Such filters usually include capacitors connected between live conductors and earth. This has led to large increases in normal earth currents in such installations, and to the need for special regulations for them. Since these are special situations, they will be considered in.

Electrical disturbances on the earth system (known as 'earth noise') may cause malfunctions of computer based systems, and 'clean' mains supplies and earth systems may be necessary. A separate earthing system may be useful in such a case provided that:

1. - the computer system has all accessible conductive parts earthed,

2. - the main earthing terminal of the computer earth system is connected directly to the main earthing terminal,

3. - all extraneous conductive parts within reach of the computer system are earthed to the main earthing terminal and not to the separate computer earth.

Supplementary bonding between the computer earth system and extraneous conductive parts is not necessary.be lost, and the fault current needed to operate the protective device (single-phase circuit current would be 125 A at 240 V) would be high enough to cause a fire danger at the outlet where the fault occurred. The correct approach would be to divide the load into smaller circuits, each feeding, perhaps, ten lamps.

2. - to enable part of an installation to be switched off for maintenance or for testing without affecting.

CHAPTER FIVE

ELECTRICAL INSTALLATION SERIES

5.1 - Introduction

The distinction between terms used in illumination often presents difficulties. The following table shows units definitions.

Term	*Definition*	*unit*
Luminous intensity	Light source	Candela
Luminous flux	Light emitted from a source	Lumen
Illumination	Density of luminous flux falling on a working plane	Lumen/m^2 or Lux

5.2 - Inverse Square Law

The illumination falling on a working plane varies inversely as the square of the distance of that surface from the light source.

The illumination (in lumens per square meter) at a point below a light source on a horizontal work plane is calculated as follows:

$E = I/d^2$

Where E = illumination in lumens per square meter, I = luminous intensity in candelas, and d = distance from light source in meters.

5.3 - Cosine Law

The illumination at a point on a horizontal working plane which is at an angle to the light source is calculated as follows:

$E = (I \times \cos) / d^2$.

5.4 - Other Factors in Illumination

1 Maintenance Factor. This factor (a number without units) takes into consideration losses in light output due to (a) ageing of lamps and (b) dirt collecting on lamps and fittings. The maintenance factor recommended by the Illumination Engineering Society is 1.25, for fittings cleaned every six weeks.

2 Coefficient of Utilization. The level of illumination in a factory or office is affected by (a) light output of lamp (lumens), (b) the type of reflector used, (c) height and spacing of fittings, and (d) the colouring of the walls, ceiling, and floor. These factors are taken into consideration in the coefficient of utilization (a number without units)

Coefficient of utilization = light received on working plane / light output of lamps

5.5 - Calculation

Here we will find out the calculations of how many flourcent lamps are needed in rooms which have differences in cross sectional area, illumination, and on how much watt will contain.

First of all we should know about the place where we want to fix the flourcent, because for example some places needs more luminosity than others, one more thing is the maintenance factor its a number without unit, constant and its equal to1.25.

First thing we should do is to find the index room then we look at the table to find number of utilization factors which it is number without unit, another thing we should do is to find the total number of luminous flux, finally we get the result of how many flourcent by dividing the total number of luminous flux with the luminous flux. The luminous flux depends on the type of the flourcent lamp and how much watt. On our plan we used the flourcent lamp that has (2x80w) now as we have seen in the table of luminous flux every 80w equals to 5600 lumen, but we used in our plan (2x80w) so what we should is just to multiply 5600 by 2 . Here are below some examples of illumination calculation for some room that has different situations.

1-Classroom

Dimension of the room A = 6.8m, B = 12m, H = 3.5m

Maintenance factors = 1.25m, E = 200lux, flourcent (2x80w)

$\Phi = 2\times5600 = 11200$ lumen, working plane = 0.85m

$K = \frac{A\times B}{H(A+B)} = \frac{6.8\times12}{2.65(6.8+12)} = 1.637$

$\eta = \frac{1.637\times0.45}{1.5} = 0.4911$

$\Phi tot = \frac{E\times A\times D}{\eta} = \frac{200\times(6.8\times12)\times1.25}{0.4911} = 41539.4$ lumen

$n = \frac{\Phi tot}{\Phi} = \frac{41539.4}{11200} = 4$ FLO.

2- Doctor office

Dimension of the room A = 6.8m, B = 4.8m, H = 3.5m

Maintenance factors = 1.25m, E = 200lux, flourcent (2x80w)

$\Phi = 2\times5600 = 11200$ lumen, working plane = 0.85m

$K = \frac{A\times B}{H(A+B)} = \frac{6.8\times4.8}{2.65(6.8+4.8)} = 1$

$\eta = 0.36$

$\Phi tot = \frac{E\times A\times D}{\eta} = \frac{200\times(6.8\times4.8)\times1.25}{0.36} = 22666.6$ lumen

$n = \frac{\Phi tot}{\Phi} = \frac{22666.6}{11200} = 2$ FLO.

3- Secretary

Dimension of the room A = 6.8m, B = 3.3713m, H = 3.5m

Maintenance factors = 1.25m, E = 200lux, flourcent (1x80w)

$\Phi = 1\times5600 = 5600$ lumen, working plane = 0.85m

$K = \frac{A\times B}{H(A+B)} = \frac{6.8\times3.3713}{2.65(6.8+3.3713)} = 0.85$

$\eta = 0.31$

$\Phi tot = \frac{E\times A\times D}{\eta} = \frac{200\times(6.8\times3.3713)\times1.25}{0.31} = 18487.7$ lumen

$n = \frac{\Phi tot}{\Phi} = \frac{18487.7}{5600} = 3$ FLO.

4- Laboratory computer

Dimension of the room A = 6.8m, B = 12m, H = 3.5m

Maintenance factors = 1.25m, E = 250lux, flourcent (2x80w)

$\Phi = 2\times5600 = 11200$ lumen, working plane = 0.85m

$K = \frac{A\times B}{H(A+B)} = \frac{6.8\times12}{2.65(6.8+12)} = 1.637$

$\eta = \frac{1.637\times0.45}{1.5} = 0.4911$

$\Phi tot = \frac{E\times A\times D}{\eta} = \frac{250\times(6.8\times12)1.25}{0.4911} = 51924.2$ lumen

$n = \frac{\Phi tot}{\Phi} = \frac{51924.2}{11200} = 6$ FLO.

5- Laboratory Electrical

Dimension of the room A = 14.7707m, B = 6.7709m, H = 3.5m

Maintenance factors = 1.25m, E = 250lux, flourcent (2x80w)

$\Phi = 2\times5600 = 11200$ lumen, working plane = 0.85m

$K = \frac{A\times B}{H(A+B)} = \frac{6.7709\times14.7707}{2.65\times(6.7709+14.7707)} = 1.75$

$\eta = \frac{1.75\times0.51}{2} = 0.446$

$\Phi tot = \frac{E\times A\times D}{\eta} = \frac{250\times(6.7709\times14.7707)\times1.25}{0.446} = 70074.9$ lumen

$n = \frac{\Phi tot}{\Phi} = \frac{70074.9}{11200} = 6$ FLO.

6- Corridors besides the classroom

Dimension of the room A = 2.5m, B = 35.5472m, H = 3.5m

Maintance factors = 1.25m, E = 100lux, flourcent (4x20w)

$\Phi = 4\times2100 = 8400$ lumen, working plane = 0.85m

$K = \frac{A\times B}{H(A+B)} = \frac{2.5\times35.5472}{2.65\times(2.5+35.5472)} = 0.881$

$\eta = \frac{0.881\times0.36}{1} = 0.371$

$\Phi tot = \frac{E\times A\times D}{\eta} = \frac{100\times(2.5\times35.5472)\times1.25}{0.371} = 35042.5$ lumen

$n = \frac{\Phi tot}{\Phi} = \frac{35042.5}{8400} = 4$ FLO.

7- Corridors besides the doctors office

Dimension of the room A = 2.2m, B = 30m, H = 3.5m

Maintenance factors = 1.25m, E = 100lux, flourcent (4x20w)

$\Phi = 4 \times 2100 = 8400$ lumen, working plane = 0.85m

$K = \frac{A \times B}{H(A+B)} = \frac{30 \times 2.2}{2.65 \times (30+2.2)} = 0.77$

$\eta = 0.31$

$\Phi tot = \frac{E \times A \times D}{\eta} = \frac{100 \times (30 \times 2.2) \times 1.25}{0.31} = 26612.9$ lumen

$n = \frac{\Phi tot}{\Phi} = \frac{26612.9}{8400} = 3$ FLO.

8- Corridors besides the stairs

Dimension of the room A = 54.0967m, B = 3.9041m, H = 3.5m

Maintenance factors = 1.25m, E = 100lux, flourcent (4x20w)

$\Phi = 4 \times 2100 = 8400$ lumen, working plane = 0.85m

$K = \frac{A \times B}{H(A+B)} = \frac{54.0967 \times 3.9041}{2.65 \times (54.0967+3.9041)} = 1.374$

$\eta = \frac{1.374 \times 0.45}{1.5} = 0.41$

$\Phi tot = \frac{E \times A \times D}{\eta} = \frac{100 \times (54.0967 \times 3.9041) \times 1.25}{0.41} = 64389.9$lumen

$n = \frac{\Phi tot}{\Phi} = \frac{64389.9}{8400} = 7$ FLO.

5.6 – Calculation the voltage drop

All cables have resistance, and when current flows in them this result in a volt drop. Hence, the voltage at the load is lower than the supply voltage by the amount of this volt drop.

The volt drop may be calculated using the basic Ohm's law formula

U = I x R

Where **U** is the cable volt drop (V) **I** is the circuit current (A), and **R** is the circuit resistance (ohms).

Indicates that these requirements will he met if the voltage drop does not exceed 4% of the declared supply voltage. If the supply is single-phase at the usual level of 240 V, this means a maximum volt drop of 4% of 240 V which is 9.6 V, giving (in simple terms) a load voltage as low as 230.4 V. For a 415 V three-phase system, allowable volt drop will be 16.6 V with a line load voltage as low as 398.4 V.

o calculate the volt drop for a particular cable. Each current rating table has an associated volt drop column or table. For example, multicore sheathed non-armoured P.V.C. insulated cables are covered by for current ratings, and volt drops. The exception in the Regulations to this layout is for mineral insulated cables where there are separate volt drop tables for single- and three-phase operation.

To calculate the cable volt drop:

1- take the value from the volt drop table (mV/A/m)

2- multiply by the actual current in the cable (NOT the current rating)

3- multiply by the length of run in metres

4- divide the result by one thousand (to convert millivolts to volts).

The 'length of run' calculations carried out in these examples are often useful to the electrician when installing equipment at greater distances from the mains position.

The Regulations include a very complicated formula to be applied to cables of cross-sectional area 16 mm² and less which may show that the actual volt drop is less than that obtained from the tables. There some example about different type of cables that it has different voltage drop that shown below in the tables, that we are using in the plan and we find out the voltage drop from it.

Table 5.1 - Current ratings and volt drops for unsheathed single core p.v.c. insulated cables								
Cross sectional area	In conduit in thermal insulation	In conduit in thermal insulation	In conduit on wall	In conduit on wall	Clipped direct	Clipped direct	Volt drop	Volt drop
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)	(mV/A/m)
-	2 cables	3 or 4 cables	2 cables	3 or 4 cables	2 cables	3 or 4 cables	2 cables	3 or 4 cables
1.0	11.0	10.5	13.5	12.0	15.5	14.0	44.0	38.0
1.5	14.5	13.5	17.5	15.5	20.0	18.0	29.0	25.0
2.5	19.5	18.0	24.0	21.0	27.0	25.0	18..0	15.0
4.0	26.0	24.0	32.0	28.0	37.0	33.0	11.0	9.5
6.0	34.0	31.0	41.0	36.0	47.0	43.0	7.3	6.4
10.0	46.0	42.0	57.0	50.0	65.0	59.0	4.4	3.8
16.0	61.0	56.0	76.0	68.0	87.0	79.0	2.8	2.4

Table 5.2 - Current ratings and volt drops for sheathed multi-core p.v.c.-insulated cables								
Cross sectional area	In conduit in thermal insulation	In conduit in thermal insulation	In conduit on wall	In conduit on wall	Clipped direct	Clipped direct	Volt drop	Volt drop
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)	(mV/A/m)
-	2 core	3 or 4 core	2 core	3 or 4 core	2 core	3 or 4 core	2 core	3 or 4 core
1.0	11.0	10.0	13.0	11.5	15.0	13.5	44.0	38.0
1.5	14.0	13.0	16.5	15.0	19.5	17.5	29.0	25.0
2.5	18.5	17.5	23.0	20.0	27.0	24.0	18.0	15.0
4.0	25.0	23.0	30.0	27.0	36.0	32.0	11.0	9.5
6.0	32.0	29.0	38.0	34.0	46.0	41.0	7.3	6.4
10.0	43.0	39.0	52.0	46.0	63.0	57.0	4.4	3.8
16.0	57.0	52.0	69.0	62.0	85.0	76.0	2.8	2.4

Table 5.3 - Current ratings of mineral insulated cables clipped direct						
Cross-sectional area	Volt	p.v.c. sheath 2 x single or twin	p.v.c. Sheath 3 core	p.v.c. Sheath 3 x single or twin	Bare sheath 2 x single	Bare sheath 3 x single
(mm^2)		(A)	(A)	(A)	(A)	(A)
1.0	500v	18.5	16.5	16.5	22.0	21.0
1.5	500v	24.0	21.0	21.0	28.0	27.0
2.5	500v	31.0	28.0	28.0	38.0	36.0
4.0	500v	42.0	37.0	37.0	51.0	47.0
1.0	750v	20.0	17.5	17.5	24.0	24.0
1.5	750v	25.0	22.0	22.0	31.0	30.0
2.5	750v	34.0	30.0	30.0	42.0	41.0
4.0	750v	45.0	40.0	40.0	55.0	53.0
6.0	750v	57.0	51.0	51.0	70.0	67.0
10.0	750v	78.0	69.0	69.0	96.0	91.0
16.0	750v	104.0	92.0	92.0	127.0	119.0

Table 5.4 - Volt drops for mineral insulated cables				
Cross-sectional area	Single-phase p.v.c. Sheath	Single-phase bare	Three-phase p.v.c. Sheath	Three-phase bare
(mm^2)	(mV/A/m)	(mV/A/m)	(mV/A/m)	(mV/A/m)
1.0	42.0	47.0	36.0	40.0
1.5	28.0	31.0	24.0	27.0
2.5	17.0	19.0	14.0	16.0
4.0	10.0	12.0	9.1	10.0
6.0	7.0	7.8	6.0	6.8
10.0	4.2	4.7	3.6	4.1
16.0	2.6	3.0	2.3	2.6

1. These equations shown below calculated the voltage drop three phase in distribution boxes floor 1, we are using current rating and volt drops for sheathed multi-core P.V.C. – insulated cables.

- First five equations for socket outlets circuits:

$$\Delta U_1 = L_1 \times g_1 \times I_1 = \frac{15\times30\times34.82705}{1000} = 15.6721725 \text{ V}$$

$$\Delta U_2 = L_2 \times g_2 \times I_2 = \frac{15\times30\times27.040805}{1000} = 12.168362 \text{ V}$$

$$\Delta U_3 = L_3 \times g_3 \times I_3 = \frac{15\times30\times25.1435}{1000} = 11.314575 \text{ V}$$

$$\Delta U_4 = L_4 \times g_4 \times I_4 = \frac{30\times15\times17.61049}{1000} = 7.9247205 \text{ V}$$

$$\Delta U_5 = L_5 \times g_5 \times I_5 = \frac{15\times30\times34.576488}{1000} = 15.5594196 \text{ V}$$

- This equation for cooker circuit:

$$\Delta U_C = L_6 \times g_6 \times I_6 = \frac{6.4\times30\times13.353977}{1000} = 2.56396358 \text{ V}$$

- Last nine equations for lighting circuits:

$$\Delta U_1 = L_1 \times g_1 \times I_1 = \frac{5\times38\times56.649678}{1000} = 10.76343882 \text{ V}$$

$$\Delta U_2 = L_2 \times g_2 \times I_2 = \frac{5\times38\times20.417103}{1000} = 3.87924957 \text{ V}$$

$$\Delta U_3 = L_3 \times g_3 \times I_3 = \frac{5\times38\times18.176732}{1000} = 3.45357908 \text{ V}$$

$$\Delta U_4 = L_4 \times g_4 \times I_4 = \frac{5\times38\times57.3278}{1000} = 10.892282 \text{ V}$$

$$\Delta U_5 = L_5 \times g_5 \times I_5 = \frac{5\times38\times57.3183}{1000} = 10.889247 \text{ V}$$

$$\Delta U_6 = L_6 \times g_6 \times I_6 = \frac{5\times38\times34.865188}{1000} = 6.62438572 \text{ V}$$

$$\Delta U_7 = L_7 \times g_7 \times I_7 = \frac{5\times38\times16.548486}{1000} = 3.1442123 \text{ V}$$

$$\Delta U_8 = L_8 \times g_8 \times I_8 = \frac{5\times38\times14.23417}{1000} = 2.7044923 \text{ V}$$

$$\Delta U_9 = L_9 \times g_9 \times I_9 = \frac{5\times38\times86.162349}{1000} = 16.37084631 \text{ V}$$

2. These equations shown below calculate the voltage drop three phase in distribution boxes floor 2, we are using current rating and volt drops for sheathed multi-core P.V.C. – insulated cables.

- First six equations for socket outlets circuits:

$$\Delta U_6 = L_6 \times g_6 \times I_6 = \frac{30\times15\times29.912532}{1000} = 13.4606394 \text{ V}$$

$$\Delta U_7 = L_7 \times g_7 \times I_7 = \frac{15\times30\times13.854595}{1000} = 6.234567 \text{ V}$$

$$\Delta U_8 = L_8 \times g_8 \times I_8 = \frac{30\times15\times27.270564}{1000} = 12.2717538 \text{ V}$$

$$\Delta U_9 = L_9 \times g_9 \times I_9 = \frac{30\times15\times33.395991}{1000} = 15.0281959 \text{ V}$$

$$\Delta U_{10} = L_{10} \times g_{10} \times I_{10} = \frac{30\times15\times35.836985}{1000} = 16.12664325 \text{ V}$$

$$\Delta U_{11} = L_{11} \times g_{11} \times I_{11} = \frac{30\times15\times29.831857}{1000} = 13.424335 \text{ V}$$

- Last seven equations for lighting circuits:

$$\Delta U_{10} = L_{10} \times g_{10} \times I_{10} = \frac{5\times38\times20.956337}{1000} = 3.98170403 \text{ V}$$

$$\Delta U_{11} = L_{11} \times g_{11} \times I_{11} = \frac{38\times5\times20.77758}{1000} = 3.94772652 \text{ V}$$

$$\Delta U_{12} = L_{12} \times g_{12} \times I_{12} = \frac{38\times5\times14.896508}{1000} = 2.8303365 \text{ V}$$

$$\Delta U_{13} = L_{13} \times g_{13} \times I_{13} = \frac{38\times5\times20.150458}{1000} = 3.82858702 \text{ V}$$

$$\Delta U_{14} = L_{14} \times g_{14} \times I_{14} = \frac{38\times5\times20.49217}{1000} = 3.9885123 \text{ V}$$

$$\Delta U_{15} = L_{15} \times g_{15} \times I_{15} = \frac{38\times5\times27.89125}{1000} = 5.2993375 \text{ V}$$

$$\Delta U_{16} = L_{16} \times g_{16} \times I_{16} = \frac{38\times5\times45.132242}{1000} = 8.57512598 \text{ V}$$

3. These equations shown below calculate the voltage drop three phase in distribution boxes floor 3, we are using current rating and volt drops for sheathed multi-core P.V.C. – insulated cables.

- First six equations for socket outlets circuits:

$$\Delta U_{12} = L_{12} \times g_{12} \times L_{12} = \frac{30\times15\times35.101497}{1000} = 15.7956615 \text{ V}$$

$$\Delta U_{13} = L_{13} \times g_{13} \times L_{13} = \frac{30\times5\times17.166442}{1000} = 7.948989 \text{ V}$$

$$\Delta U_{14} = L_{14} \times g_{14} \times I_{14} = \frac{30\times15\times22.0954205}{1000} = 9.94293922 \text{ V}$$

$$\Delta U_{15} = L_{15} \times g_{15} \times I_{15} = \frac{30\times15\times15.51945}{1000} = 6.9837525 \text{ V}$$

$$\Delta U_{16} = L_{16} \times g_{16} \times I_{16} = \frac{30\times15\times35.7494478}{1000} = 16.08725151 \text{ V}$$

$$\Delta U_{17} = L_{17} \times g_{17} \times I_{17} = \frac{30\times15\times33.359068}{1000} = 15.0115806 \text{ V}$$

- Last seven equations for lighting circuits:

$$\Delta U_{18} = L_{18} \times g_{18} \times I_{18} = \frac{5\times38\times22.311249}{1000} = 4.23913731 \text{ V}$$

$$\Delta U_{19} = L_{19} \times g_{19} \times I_{19} = \frac{38\times5\times27.733863}{1000} = 5.26943397 \text{ V}$$

$$\Delta U_{20} = L_{20} \times g_{20} \times I_{20} = \frac{38\times5\times19.116724}{1000} = 3.63217756 \text{ V}$$

$$\Delta U_{21} = L_{21} \times g_{21} \times I_{21} = \frac{38\times5\times18.574989}{1000} = 3.52924791 \text{ V}$$

$$\Delta U_{22} = L_{22} \times g_{22} \times I_{22} = \frac{38\times5\times13.21752}{1000} = 2.5113288 \text{ V}$$

$$\Delta U_{23} = L_{23} \times g_{23} \times I_{23} = \frac{38\times5\times22.837565}{1000} = 4.33913735 \text{ V}$$

$$\Delta U_{24} = L_{24} \times g_{24} \times I_{24} = \frac{38\times5\times45.132242}{1000} = 8.57512598 \text{ V}$$

CONCLUSION

In a distributions boxes that we using in our plan three phases because the number of the socket outlets circuits and the lighting circuits is more than the parameter cause the maximum number of single phase (1x12). The distributions types are commonly used in our plan domestic, commercial and light industrial applications for low voltage (less than 1000V) use. MCB - Miniature Circuit Breaker - rated current not more than 100A, and MCCB - Moulded Case Circuit Breaker - rated current up to 1000A.

A conductor is a material which offers a low resistance to a flow of current. For example silver is better than copper but it is too expensive for practical purposes. Electrical conductors are usually made of copper, although aluminium is being used to a greater extent, particularly as the price of copper increases. The copper wire is then dipped into a tank containing molten tin. This done for two reasons: (a) to protect the copper if the wire is to be insulated with vulcanized rubber, as this contains sulphur which attacks the copper; and (b) to make the copper conductor easier to solder.

P.V.C. insulated copper and aluminium cables are gradually replacing this cables, expect in conditions where creosote is present as this attacks the p.v.c. insulation.

It is essential for the correct operation of the E L C B that the earth and frame connections are not reversed. A reversal of connection places voltage between the frame and the general mass of earth when the test button is pressed.

The fuses must be capable of protecting the smallest conductor in the circuit.

All fuses and switches must place in the conductor and metal lampholders must be earthed and the phase conductors should be terminated at the centre pin of Giant Edison Screw (G.E.S.) lampholders.

The 2- metre rule. In conditions where two separate phases (for example the red and blue phases) are brought into the same room:

(a) The controlling switch must be clearly marked 415 Volts.
(b) Switches and sockets outlets supplied from different phases must be placed at least 2 metres apart. This is particularly important where portable appliances are used. It avoids the danger of a voltage of 415 V appearing between appliances or switches which can be touched simultaneously.

The purpose of the ring circuit (a) To minimize trailing flexes. (b) To take advantages of the fact that all outlets in a domestic installation are not operated simultaneously this known as the diversity in an installation.

Ceiling roses must not used on circuits operating above 250 V and no more than one flexible cord is permitted from any one ceiling rose. The earthing terminal of every ceiling rose must be connected to the earth continuity conductor of the final sub-circuit.

The greatest care should be taken to protect temporary installation against mechanical damage and portable appliances (for example, drills) should be regularly checked. Low-voltage (e.g. 110 V) step-down transformers should be used wherever possible. To minimize the danger from the shock.

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