UNIT 5
Electrical Installation

5.1 Types of Insulated Wires

Various types of wires are used for electrical wiring. The commonly used types are as follows:

(a) V.I.R. (Vulcanized India Rubber) Wires: This type of wire consists of a tinned conductor coated with rubber insulation. The thickness of rubber varies with the voltage for which the wire is designed i.e. 250 or 660 volts. This rubber insulation is not moisture or heatproof. Therefore, the conductor is further covered with protective cotton braiding saturated with heat and moisture resistant bitumen compound. For cleanliness and smoothness, it is finally finished with wax. These wires always have a single core. Because of their tendency to absorb the moisture quickly and the availability of other superior varieties at a cheaper cost, these wires are rarely used now days.

(b) C.T.S. (Cab Tyre Sheathed) / T.R.S. (Tough Rubber Sheathed) Wires: In this, ordinary rubber insulated conductors are provided with an additional tough rubber sheath. Apart from providing extra insulation, this covering provides protection against moisture, chemical fumes and wear and tear. T.R.S. wires are available in single core, twin core and three core varieties.

(c) Lead Sheathed Wires: Similar to T.R.S. wires, in this variety also, ordinary rubber or paper insulated conductors are provided with an outer sheath of lead or lead alloy. It gives protection against moisture, atmospheric corrosion and wear and tear. These wires are available in single and multicore varieties. Being quite heavy and costlier, they are almost superseded by the C.T.S. / T.R.S. wires.

(d) P.V.C. (Poly Vinyl Chloride) Wires: These wires which are in most common use have conductors with P.V.C. insulation. P.V.C. is non-hygroscopic, tough, durable, resistant to corrosion and chemically inert, therefore, eminently suitable for general wiring work. P.V.C. insulation, being tough to give mechanical protection, cotton taping or braiding is not essential as in the ordinary rubber insulated conductors. P.V.C. being a thermoplastic softens at high temperature. Therefore, its use, where, extremes of temperatures are likely to occur, should be For example, it should not be used for giving connection to heating appliances.

(e) Weather Proof Wires: For outdoor service lines which are run at sufficient height and where ability of anyone coming in contact with it is very small, costly wires like T.R.S. are not
essential. Therefore, in such cases, weather proof wires consisting of conductors with three braids us yarn, thoroughly saturated with a water-proof compound are used. These wires are cheap & at the same time, they are resistant to varying atmospheric conditions.

(f) **Flexible Wires:** These wires are normally used for pendant holders, household portable appliances such as heaters, irons, table lamps, etc. and wiring of temporary nature. The flexible wire normally consists of two separately insulated stranded conductors. The stranded conductors are used for flexibility and insulation used is either rubber or P.V.C. Cotton and silk braiding or T.R.S. sheathing is sometimes used in the case of rubber insulated conductors. Flexible wires are commonly available in the parallel twin and twisted twin forms. The great advantage of wire is the flexibility which makes the handling easy.

### 5.2 SYSTEMS OF WIRING

The electrical load in a given place will consist of a number of electrical appliances and each of these has to be supplied with electrical power. This means that the electric supply authority must provide electric supply up to a point outside the consumer’s premises. From there the consumer will take a connection to his main switchboard. Electric wires will then run along the consumer’s building and other premises to distribute power to all the points where his load is situated. This is the consumer’s internal distribution system. For distributing power within the consumer’s premises electric wiring is required. The wiring system selected will depend to a large extent on the types of service required.

The points to be considered in selecting the type of wiring will include:

(i) Expected life of the installation
(ii) Expected future alterations or extensions
(iii) Types of construction of the building
(iv) Fire hazards.
(v) Atmospheric hazards like fumes, dampness, etc.

The cost of installation will often play an important part in determining the type of wiring to be preferred.

The various types of internal wiring are:

(i) Cleat wiring
(ii) Wood casing wiring
(iii) Batten wiring
(iv) Conduit wiring.
5.2.1 Cleat Wiring

In this type of wiring the cables are run over cleats. The cleats made of porcelain must be of approved design and consist of two parts, viz., a base piece and a cap. A special pattern of cleat may be used where conductors pass round corners, so that there may be no risk of conductors touching the wall. Cleats are fixed at regular intervals not exceeding 0.6 m.

Where cleat wiring is on a metal portion along its run. The space between such metal and the porcelain cleats should be filled either with varnished wood fillet or varnished wood clamp securely fixed so as to prevent conductors coming in contact with the metal along which they are passing.

The wire used for cleat wiring should be vulcanized rubber insulated cable, PVC cable, or any other approved insulated cable. Cleat wiring should not be employed for wiring on damp walls or ceilings.

Cleats are fixed to the wall or the ceiling by means of plugs (ghitti). Plugs for ordinary walls or ceiling should be of well seasoned teak or other hard wood not less than 5 cm long, 2.5 cm sq on the inner end and 2 cm. sq. on the outer end. They should be cemented into walls (or ceiling) to within 6.5 mm of the surface; the remainder should be finished according to the nature of the surface with plaster or lime punning. Cleat wiring is cheap and is used only for temporary installations.

![Cheat Wiring Diagram](image)

**Figure 5.1: Cheat Wiring**

5.2.2 Wood Casing & Capping Wiring

Casing is a rectangular strip made from seasoned teak wood & usually has two or three grooves. It is fixed with countersunk wood screws using rawl-plugs or wood plugs on the wall or ceiling. Porcelain round cleats are used to keep the casing away from the walls or ceiling in order to protect it from dampness. The V.I.R OR P.V. C. wires are run in grooves in a wooden casing. Casing is then finally covered at the top by a rectangular wooden strip of the same width as that are casing. This strip known as capping, is then screwed to the casing. He casing and capping are
given a double coating of shellac varnish from inside and at the back. They are painted, varnished from the outside after erection.

**Application:** This system is now almost superseded by other types of wiring even though it was popularly used for residential and commercial buildings in the early days. However, it is still in for special situations and in places to fit in with the internal decorations of a room.

**Advantages:**
1. Gives good mechanical protection to the conductors.
3. Installation and repairs are easy in comparison with conduit wiring.

**Disadvantages:**
1. The system is costly since it involves highly skilled labour.
2. Wood being inflammable, it is quite susceptible to fire hazards.
3. In spite of coating with varnish, it cannot be used in damp situations.

### 5.2.3 Metal Sheathed or Lead Sheathed Wiring

This system employs rubber or paper insulated conductors with a lead sheath. These wires are run on the wooden battens fixed to the brick or concrete walls by means of rawl plugs or wood-plugs. The metal clips spaced at regular intervals are used to clamp wires to the batten. The lead sheath is efficiently earthed to provide a safety against the metal sheath becoming a and to avoid electrolytic action due to leakage current on it.
Application: This system is also superseded by the C.T.S. system, but still preferred in damp actions as on ships.

Advantages:
1. Neat appearance.
2. Lead sheath provides protection against fires, high temperature, moisture and to some extent against mechanical injuries. Due to this feature, this type of wiring can be used for out-door work.
3. It is particularly suitable in damp situations.

Disadvantages:
1. Lead sheathed wires are costly.
2. The lead sheath is to be effectively earthed to avoid any possibility of electrical shocks and to prolong the life of the lead sheath which otherwise is reduced due to the electrolytic action of leakage current.
3. Sharp bends sometimes cause breaking of the lead cover.

5.2.4 Tough Rubber Sheathed (T.R.S.) OR Cab-Tyre Sheathed(C.T.S) Wiring: This wiring is similar to lead sheathed wiring except that C.T.C or T.R.S. wires are used in place of lead sheathed wires. Initially the wooden batten are fixed to the brick or concrete walls by means of screws and rawl-plugs or wood –plugs. The wires are run on these battens and clamped with the help of metal clips spaced at regular intervals.

![Diagram](image-url)

Figure 5.4: Tough Rubber Sheathed (T.R.S.) OR Cab-Tyre Sheathed (C.T.S) Wiring

Application: It is most widely used for indoor wiring for houses, shops, offices, etc.

Advantages:
1. Neat appearance.
2. Tough rubber sheath or cab type sheath gives good mechanical protection and is unaffected by moisture, chemical fumes, paint or wet plaster.
3. Being cheaper, more rapid and easier to erect than the wooden casing –capping and lead sheathed wiring, it is the most widely used system of surface wiring.

**Disadvantages:**

It should not be used for out-door work where wiring is exposed to sun as it cannot withstand much heat.

5.2.5 Conduit Wiring: In this system V.I.R or P.V.C. wires are run through black enameled or galvanized metallic tubing called conduits.

**Types of conduits:** The following two types of conduits are normally used for this type of wiring.

1. **Thin Wall Conduits:** These are the light gauge iron conduits with a seam along its length. The seam may be an open type with no. mechanical adhesion between its two edges as in spits conduits or sometimes these edges are brazed together which makes the conduits damp proof. Friction tight slip fittings are normally used to join conduit ends.

2. **Rigid Conduits:** These are the heavy gauge iron conduits either solid drawn or with welded seam. The ends of conduit length and various fittings to join them are always threaded. These conduits being more costly are normally used for all medium pressure (250 to 600) circuits and in places where a good degree of mechanical protection and absolute protection from moisture is required.

5.2.6. **Type Of Conduit Wiring:** Depending upon whether the conduits are laid inside the walls or the walls, there are two types of conduit wiring:

(a)**Surface Conduit Wiring:** In this method, conduits are fixed on the walls by means of saddles screwed to rawl-plugs or wood plugs embedded in the wall in damp situations, these conduits are apart from the wall surface by small wooden blocks fixed below the pipe at regular intervals.
(b) Concealed Conduit Wiring:
This method employs heavy gauge rigid conduits buried under wall plaster. Such wiring is used in cases where beauty is the main consideration irrespective of cost. In both the above types, it is essential that the whole length of the conduit piping is kept at earth potential by or proper earthing.

Wiring of the Conduits: The drawing in method of wiring the conduit is most commonly adopted. After planning the layout carefully, the conduits are erected in position with a number of draw-in inspection) fittings provided along the length. Then V. I.R or P. V. C wires are drawn through the conduits by means of a steel draw wire. In order that the wires may be easily pulled, they are sometimes rubbed with French chalk.

Application: Surface conduit wiring is mainly used for all indoor and outdoor wiring of permanent for light and power e.g. in godowns, workshops and public buildings. The concealed type is preferably used in public buildings, offices, shops and houses for its nice appearance.

Advantages:
1. Very long life.
2. Provides good protection against mechanical injury, moisture and fire-hazards.
3. Neat appearance. Particularly, the concealed type of conduit wiring adds to the beauty of the building.
4. Less maintenance.

Disadvantages:
1. Most costly system of wiring
2. Erection requires highly skilled labor and time.
3. Repairs particularly with concealed wiring are difficult and take long time.
4. In the absence of earth continuity on all conduit joints, there is the possibility of an electrical shock.
5. If proper precautions are not taken to file sharp edges of the conduits, there is possibility of damage to the wire insulation.

5.3 Concept of Fuses
A fuse is an electrical safety device that operates to provide overcorrect protection of an electrical circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, thereby interrupting the current. It is a sacrificial device; once a fuse has operated it is an open circuit, and it must be replaced or rewired, depending on type.
**Construction**

A fuse consists of a metal strip or wire fuse element, of small cross-section compared to the circuit conductors, mounted between a pair of electrical terminals, and (usually) enclosed by a non-combustible housing. The fuse is arranged in series to carry all the current passing through the protected circuit. The resistance of the element generates heat due to the current flow. The size and construction of the element is (empirically) determined so that the heat produced for a normal current does not cause the element to attain a high temperature. If too high a current flows, the element rises to a higher temperature and either directly melts, or else melts a soldered joint within the fuse, opening the circuit.

The fuse element is made of zinc, copper, silver, aluminum, or alloys to provide stable and predictable characteristics. The fuse ideally would carry its rated current indefinitely, and melt quickly on a small excess. The element must not be damaged by minor harmless surges of current, and must not oxidize or change its behavior after possibly years of service. The fuse elements may be shaped to increase heating effect. In large fuses, current may be divided between multiple strips of metal. A dual-element fuse may contain a metal strip that melts instantly on a short-circuit, and also contain a low-melting solder joint that responds to long-term overload of low values compared to a short-circuit. Fuse elements may be supported by steel or nichrome wires, so that no strain is placed on the element, but a spring may be included to increase the speed of parting of the element fragments.

The fuse element may be surrounded by air, or by materials intended to speed the quenching of the arc. Silica sand or non-conducting liquids may be used.
11.4.1 Fuses:

An electrical circuit must be safeguarded against the harmful effects of excessive currents. These excessive currents may be because of overloading or short circuit faults. When an electrical motor is overloaded, it draws an excessive current. If proper precautions are not taken, this excessive current results in the overheating of the motor which ultimately leads to its damage. In case of domestic installation, short circuiting takes place when there is direct connection between the live and neutral conductor. Under these circumstances, the resistance to the supply being very low, enormous current will flow through the conductors. Such a high current leads to an excessive heat rise which, if adjacent to inflammable materials will almost certainly cause an outbreak of fire. In all such cases therefore, it is necessary to interrupt these excessive currents before they cause any damage. Fuse is the simplest current interrupting device for the protection against excessive currents.

**General Construction of the Fuse**: In general, the fuse consists of a small piece of metal connected in between two terminals mounted on the insulated base.

**Function of the Fuse**: When the fuse is inserted in a circuit to be protected, it carries the normal working current safely without heating. But when the current exceeds the predetermined value it melts due to its rapid overheating. The circuit is then interrupted thereby preventing any damage due to excessive current. Thus the fuse is in effect a safety valve for the electrical circuit.

**Fuse Element Material**: Metal like, tin, lead, zinc, silver, antimony, copper and aluminium can be used for fuse elements. However, metals with low melting points like tin, lead, zinc or lead-tin alloys are found more suitable for this purpose. The main objection for the lead-tin alloys is that these alloys being soft are apt to spread under pressure. The most preferred lead-tin alloys for a fuse element contains 37% lead and 63% tin. Normally lead-tin alloy wire is not used beyond 10 amperes because with higher currents, a wire with a large diameter will be required and after fusing, the metal released will be excessive. Copper wire is most suitable for higher currents. The present trend however, is to use
silver for higher currents despite its higher cost as it is comparatively free from oxidation.

Types of Fuses: Following two types of fuses are commonly used in practice.

(a) Semi-enclosed or Rewirable Type Fuses:

Construction: In this type of fuses, the fuse element is semi-enclosed i.e. neither open nor totally closed. They are available in various forms. Fig. 11.8 illustrates a typical rewirable fuse bridge and base (also known as a Kit-kat type fuse unit).

![Fig. 11.8: Rewirable fuse bridge and base](image)

The fuse element (E) consists of a short length of fuse wire of diameter depending upon the current rating of the circuit the fuse is protecting. The wire is threaded through a small hole in the porcelain fuse bridge (B₁) and secured to the contacts (C) by means of screws (S). The incoming and outgoing live or phase wires are connected permanently with the help of connecting terminals to the base (B₂). These terminals of the base are bridged by the contacts of the bridge through the fuse element when the bridge fits into the base.

Operation: The fuse is wired in series with the circuit to be protected. At the fuse, because of the highest resistance, more heat is developed than at any other point in the circuit. During the fault, the circuit current rises in value. Therefore, the heat produced at the fuse causes temperature of the fuse wire to rise to a value high enough to melt the wire and thus break the circuit.

Application: Commonly used in domestic installations and the other circuits where very low values of fault currents are to be handled.

Advantages:

(i) They are cheaper.

(ii) After blowing off the fuse element, the bridge can be pulled out and again rewired with a new fuse wire. Thus service can be restored very quickly with negligible additional expenditure.

Disadvantages:

(i) Cannot be used for higher values of fault current.

(ii) Protection is not reliable due to inaccurate characteristics.
(iii) Since the wire is exposed to air, it is subjected to deterioration due to oxidation caused by heating. This decreases the effective diameter of the wire. Heating due to increased resistance causes premature failure under normal load.

(iv) Slow speed i.e. current interruption is not quick in comparison with other interrupting devices.

(v) Risk of fire-hazards due to external flash on blowing.

(b) High Rupturing Capacity (H.R.C.) Cartridge Fuses:

With the increase in fault current level, the fuse clearing the fault would be called upon to withstand extremely heavy stresses in the process. A rewirable fuse would not be able to withstand these stresses and would probably disintegrate violently. The totally enclosed type high rupturing capacity cartridge fuses specially designed for extremely rapid operation are, therefore, used for such duties.

Construction: H. R. C. Cartridge fuse in its simplest form is shown in Fig. 11.9.

![Fig. 11.9 : H. R. C. Cartridge fuse](image)

Fuse element (E), either of silver or copper is totally enclosed and hermetically sealed inside the container known as cartridge (C). The body of the cartridge is of a ceramic material or epoxy-resins having good mechanical strength. The ends of the enclosed fuse element are connected to the metal end caps (M) normally of brass. The contact blades (B) of some conducting material are welded to the metal end caps. The fuse body is filled with powdered pure quartz (P) and some form of indicator is provided on it to provide an indication of the blowing up to the fuse element. The cartridge is bolted on the stationary terminals of the fuse base.

Operation: When the fuse is inserted in a circuit to be protected, it carries the normal working current safely without heating. When a fault occurs, the large current passing through the fuse element produces heat to such an extent that it causes melting of the fuse element. The metal released in the vapour form diffuses with the quartz powder. The chemical reaction between the two produces a substance of high electrical resistance like an insulator. This
substance, which is in the form of glass beads, helps in quenching the arc quickly.

An indicator may consist of a resistance wire of fine gauge connected in parallel with the fuse element and led through a small quantity of a mild explosive held in a pocket in the side of the fuse and covered by a label. The fine wire is automatically fused when the fuse operates and the resulting combustion of the explosive material chars the label. Thus the charred label will indicate the blowing up of the fuse.

**Application**: With the increasing loads and sizes of the networks, H.R.C. cartridge fuses are now gradually replacing the rewirable types, particularly in industrial installations. They are also frequently used in low voltage distribution systems.

**Advantages**:

(i) Being totally closed, there is no deterioration of the fuse element.
(ii) Due to accurate characteristics and consistent performance protection is reliable.
(iii) High speed operation.
(iv) Ability to clear high values of fault current.
(v) Its operation is silent and without flame, gas or smoke. Hence safe from the point of view of fire hazards.

**Disadvantages**:

(i) Costly in comparison with rewirable type fuses.
(ii) The cartridge is to be replaced by a new one after each operation.
(iii) Overheating of the adjacent contacts is possible during the operation of the fuse.

**Current Rating and Minimum Fusing Current**:

These are the terms which are very commonly used in respect of fuses. They are defined as follows:

**Current Rating of Fusing Element**: It is that value of continuous current which the fusing element can carry safely without undue heating, melting and deterioration.

**Minimum Fusing Current**: It is that minimum value of current which causes melting of the fuse.

**Fusing Factor**: It is defined as the ratio of minimum fusing current to the current rating of the fusing element i.e.

\[
Fusing \ factor = \frac{Minimum \ fusing \ current}{Current \ rating \ of \ the \ fusing \ element}
\]

Its value is always more than 1.
5.4 Circuit Breakers:

5.4.1 MCB (Miniature Circuit Breaker)

MCBs or Miniature Circuit Breakers are electromechanical devices which protect an electric circuit from an over current. The over current, in an electrical circuit, may result from short circuit, overload or faulty design. An MCB is a better alternative to a Fuse since it does not require replacement once an overload is detected. Unlike fuse, an MCB can be easily operated and thus offers improved operational safety and greater convenience without incurring large operating cost.

Miniature Circuit Breakers are used to protect lower current circuits and have the following Specifications.

- Current rating - Amperes
- Short Circuit Rating - Kilo Amperes (kA)
- Operating Characteristics - B, C or D Curves

Miniature Circuit Breakers are usually available in the range of 0.5A to 100A. An MCB's Short circuit rating is given in Kilo amps (kA), and this indicates the level of its ability to work. For example a domestic MCB would normally have a 6kA fault level, whereas one used in an industrial application may need a unit with a 10kA fault capability.

**Working Principle of MCB**

MCB’s are protective devices that are made to break the circuit in case of overload or Short circuit. For Overload protection they have Bi-metallic strip which causes the circuit to open. For short circuit it is Electromagnetic kind of thing. There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over electric current and due to electromagnetic effect of over current.

The thermal operation of miniature circuit breaker is achieved with a bimetallic strip. Whenever continuous over electric current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts.
But during short circuit condition, sudden rising of electric current, causes electro-mechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts. This was a simple explanation of miniature circuit breaker working principle.

- **Types of MCB based on Tripping Characteristics**

  MCBs are classified according to tripping over range of fault current as follows:
  
  - Type B MCB
  - Type C MCB
  - Type D MCB

- **Type B MCB:**

  This type of MCB trips between 3 and 5 times full load current. Type B devices are mainly used in residential applications or light commercial applications where connected loads are primarily lighting fixtures, domestic appliances with mainly resistive elements. The surge current levels in such cases are relatively low.

- **Type C MCB:**

  This type of MCB trips between 5 and 10 times full load current. This is used in commercial or industrial type of applications where there could be chances of higher values of short circuit currents in the circuit. The connected loads are mainly inductive in nature (e.g. induction motors) or fluorescent lighting.
• **Type D MCB:**
This type of MCB trips between 10 and 20 times full load current. These MCBs are use in specialty industrial / commercial uses where current inrush can be very high. Examples include transformers or X-ray machines, large winding motors etc.

All the above three types of MCBs provide tripping protection within one tenth of a second.

• **Types of MCB based on Number of Poles**
  Another practical way of distinguishing MCBs is by way of the number of poles supported by the circuit breaker. Based on that, following types exist:

Single Pole (SP) MCB: A single pole MCB provides switching and protection only for one single phase of a circuit.

Double Pole (DP) MCB: A two Pole MCB provides switching and protection both for a phase and the neutral.

Triple Pole (TP) MCB: A triple/three phase MCB provides switching and protection only to three phases of the circuit and not to the neutral.

3 Pole with Neutral [TPN (3P+N) MCB]: A TPN MCB, has switching and protection to all three phases of circuit and additionally Neutral is also part of the MCB as a separate pole. However, Neutral pole is without any protection and can only be switched.

4 Pole (4P) MCB: A 4 pole MCB is similar to TPN but additionally it also has protective release for the neutral pole. This MCB should be used in cases where there is possibility of high neutral current flow through the circuit as in cases of an unbalanced circuit.

5.4.2 **RCCB (Residual Current Circuit Breaker)**

• **Introduction**

  A Residual Current Circuit Breakers is another different class of Circuit Breakers. A Residual Current Circuit Breaker (RCCB) is essentially a current sensing device used to protect a low voltage circuit in case of a fault. It contains a switch device that switches off whenever a fault occurs in the connected circuit. Residual Current Circuit Breakers are aimed at protecting an individual from the risks of electrical shocks, electrocution and fires that are caused due to faulty wiring or earth faults.

RCCB is particularly useful in situations where there is a sudden earth fault occurring in the circuit. e.g. A person accidentally comes in contact with an open live wire in the circuit.
In such situation, in absence of an RCCB in the circuit, an earth fault may occur and the person is at the risk of receiving an electrical shock. However, if the same circuit is protected with RCCB, it will trip the circuit in fraction of a second thus preventing the person from receiving an electrical shock. Therefore, it is a good and safe practice to install RCCB in your electrical circuit.

- **Working:**

  As explained above, RCCB is meant for protection from earth faults and associated risk to human life such as electrical shocks. The underlying fundamental principle behind operation of RCCB is that in ideal situations the current flowing into the circuit through live (hot) wire should be same as the returning current from the neutral.

  In case of an earth fault, the current finds a passage to earth through accidental means (such as accidental contact with an open wire etc.). As a result the returning current from neutral is reduced. This differential in the current is also known as “Residual Current”.

  RCCB is designed such way that it continuously senses and compares for difference (residual current value) in current values between the live and neutral wires. Any small change in the current value on account of such event would trigger the RCCB to trip off the circuit.

- **Types of RCCBs**

  2 Pole RCCB: It is used in case of a single phase supply that involves only a live and neutral wire. It is as displayed in image below. It contains two ends where the live and neutral wires are connected. A Rotary switch is used to switch the RCCB back to ON or OFF positions. A test button helps to periodically test the RCCB functionality.

![RCCB 2 Pole](image)

  4 Pole RCCB: It is used in cases of a three phase supply connection involving three phase wires and a neutral. It is as displayed in image below. It consists of two ends where the three phases and neutral wire is connected. Besides this it is similar in construction and
operation as 2 Pole RCCB. RCCBs come in different ratings like: 30 mA, 100 mA, 300 mA

- **Residual Current Sensitivity**

  RCCB is primarily designed for protection from earth fault and its consequence to human life such as electrical shocks. As per studies, a person is able to sustain electrical shocks only to the magnitude of 30 mA. Thus, RCCBs in low voltage protection are designed such a way that they will trip off the circuit even for small change in residual current value of up to 30 mA. The response time is usually within 40 mSec, thus ensuring that the person is fully protected from electrical shocks at all times. Higher values of 300 mA are used in cases where a protection from fire hazard is sought. This is useful in places where a lot of flammable material is stored.

5.4.3 **Earth Leakage Circuit Breaker or ELCB:**

- **Introduction:**

  If any current leaks from any electrical installation, there must-be any insulation failure in the electrical circuit, it must be properly detected and prevented otherwise there may be a high chance of electrical shock if-anyone touches the installation. An earth leakage circuit breaker does it efficiently. Means it detects the earth leakage current and makes the power supply off by opening the associated circuit breaker. There are two types of earth leakage circuit breaker, one is voltage ELCB and other is current ELCB.

**Voltage Earth Leakage Circuit Breaker**

  The working principle of voltage ELCB is quite simple. One terminal of the relay coil is connected to the metal body of the equipment to be protected against earth leakage and other terminal is connected to the earth directly. If any insulation failure occurs or live phase wire
touches the metal body, of the equipment, there must be a voltage difference appears across the terminal of the coil connected to the equipment body and earth. This voltage difference produces a current to flow the relay coil.

If the voltage difference crosses, a predetermined limit, the current through the relay becomes sufficient to actuate the relay for tripping the associated circuit breaker to disconnect the power supply to the equipment. The typicality of this device is, it can detect and protect only that equipment or installation with which it is attached. It cannot detect any leakage of insulation in other installation of the system.

- **Current ELCB or RCCB or Residual Current Circuit Breaker**

  The working principle of current earth leakage circuit breaker or RCCB is also very simple as voltage operated ELCB but the theory is entirely different and residual current circuit breaker is more sensitive than ELCB. Actually, ELCBs are of two kinds, but it is general practice to refer voltage based ELCB as simple ELCB. And current based ELCB is referred as RCD or RCCB. Here one CT core is energized from both phase and neutral wire.
Single Phase Residual Current EL CB. The polarity of the phase winding and neutral winding on the core is so chosen that, in normal condition mmf of one winding opposes that of another. As it is assumed that, in normal operating conditions the current goes through the phase wire will be returned via neutral wire if there's no leakage in between. As both currents are same, the resultant mmf produced by these two currents is also zero-ideally. The relay coil is connected with another third winding wound on the CT core as secondary. The terminals of this winding are connected to a relay system. In normal operating condition there would not be any current circulating in the third winding as here is no flux in the core due to equal phase and neutral current. When any earth leakage occurs in the equipment, there may be part of phase current passes to the earth, through the leakage path instead of returning via mental wire. Hence the magnitude of the neutral current passing through the RCCB is not equal to phase current passing through it.

Three Phase Residual Current Circuit Breaker or Current ELCB. When this difference crosses a predetermined value, the current in the third secondary winding of the core becomes sufficiently high to actuate the electromagnetic relay attached to it. His relay causes tripping of the associated circuit breaker to disconnect the power supply to the equipment under protection. Residual current circuit breaker is sometimes also referred as residual current device (RCD) when we consider the device by disassociating the circuit breaker attached to RCCB. That means, the entire parts of RCCB except circuit breaker are referred as RCD.
5.5 Electrical Earthing

**Definition:** The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground.

Mostly, the galvanised iron is used for the earthing. The earthing provides the simple path to the leakage current. The short circuit current of the equipment passes to the earth which has zero potential. Thus, protects the system and equipment from damage.

- **Types of Electrical Earthing**

The electrical equipment mainly consists of two non-current carrying parts. These parts are neutral of the system or frame of the electrical equipment. From the earthing of these two non-current carrying parts of the electrical system earthing can be classified into two types.

1. Neutral Earthing
2. Equipment Earthing.

**Neutral Earthing**

In neutral earthing, the neutral of the system is directly connected to earth by the help of the GI wire. The neutral earthing is also called the system earthing. Such type of earthing is mostly provided to the system which has star winding. For example, the neutral earthing is provided in the generator, transformer, motor etc.

**Equipment Earthing**

Such type of earthing is provided to the electrical equipment. The non-current carrying part of the equipment like their metallic frame is connected to the earth by the help of the conducting wire. If any fault occurs in the apparatus, the short-circuit current to pass the earth by the help of wire. Thus, protect the system from damage.

- **Importance of Earthing**

The earthing is essential because of the following reasons

1. The earthing protects the personnel from the short-circuit current.
2. The earthing provides the easiest path to the flow of short-circuit current even after the failure of the insulation.
3. The earthing protects the apparatus and personnel from the high voltage surges and lightning discharge.

Earthing can be done by electrically connecting the respective parts in the installation to some
system of electrical conductors or electrodes placed near the soil or below the ground level. The earthing mat or electrode under the ground level have flat iron riser through which all the non-current-carrying metallic parts of the equipment are connected.

- **Methods of Earthing**

There are several methods of earthing like wire or strip earthing, rod earthing, pipe earthing, plate earthing or earthing through water mains. Most commonly used methods of earthing are pipe earthing and plate earthing. These methods are explained below in details.

**5.5.1 Pipe Earthing**

This is the most common and best system of earthing as compared to other systems suitable for the same earth and moisture conditions. In this method the galvanized steel and perforated pipe of approved length and diameter in place upright in a permanently wet soil, as shown below. The size of the pipe depends upon the current to be carried and type of soil.

Normally, the size of the pipe uses for earthing is of diameter 40 mm and 2.5 meters in length for ordinary soil or of greater length in case of dry and rocky soil. The depth at which the pipe must be buried depends on the moistures of the ground. The pipe is placed at 3.75 meters. The bottom of the pipe is surrounded by small pieces of coke or charcoal at a distance of about 15 cm. Alternate layers of coke and salt are used to increase the effective area of the earth and to
decrease the earth resistance respectively. Another pipe of 19 mm diameter and minimum length 1.25 meters is connected at the top of GI pipe through reducing socket. During summer the moisture in the soil decreases, which causes an increase in earth resistance. So a cement concrete work is done to keep the water arrangement accessible, and in summer to have an effective earth, 3 or 4 buckets of water are put through the funnel connected to 19 mm diameter pipe, which is further connected to GI pipe. The earth wire either GI or a strip of GI wire of sufficient cross section to carry faulty current safely is carried in a GI pipe of diameter 12 mm at a depth of about 60 cm from the ground.

5.5.2 Plate Earthing

In Plate Earthing an earthing plate either of copper of dimension 60 cm × 60 cm × 3 m of galvanized iron of dimensions 60 cm × 60 cm × 6 mm is buried into the ground with its face vertical at a depth of not less than 3 meters from ground level.

![Diagram of Plate Earthing](image.png)

The earth plate is inserted into auxiliary layers of coke and salt for a minimum thickness of 15 cm. The earth wire (GI or copper wire) is tightly bolted to an earth plate with the help of nut or bolt. The copper plate and copper wire are usually not employed for grounding purposes because of their higher cost.
5.6 Energy Bill Calculations

Residential Tariff LT I BILL

Consumer Number : 110012279361
Reading Dates : 30/6/2017 30/7/2017
Bill Duration : 1 Month
Total Consumption : 190
Sanction Load : 0.60 KW

Bill Calculation

Energy Charge Calculation

<table>
<thead>
<tr>
<th>Slab no</th>
<th>Slab Units</th>
<th>Units</th>
<th>Rate in Rs</th>
<th>EC Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 to 100</td>
<td>100</td>
<td>3.00</td>
<td>300.00</td>
</tr>
<tr>
<td>2</td>
<td>101-300</td>
<td>90</td>
<td>6.73</td>
<td>605.70</td>
</tr>
<tr>
<td>3</td>
<td>301-500</td>
<td>0</td>
<td>9.70</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>501-1000</td>
<td>0</td>
<td>11.20</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&gt; 1000</td>
<td>0</td>
<td>12.48</td>
<td></td>
</tr>
</tbody>
</table>

Total EC 905.70

Energy Charge 905.70
Fix Charge 60.00
Wheeling Charges @1.21 Rs./U 229.90
Electricity Duty @ 16 % 176.46
Fuel Adjustment Charges -92.70

Total 1279.36
5.7 Lamps

### 11.11 Electric Lamps:

The lamp, whether oil, gas, electric or any other type, may be regarded as a piece of equipment for converting a certain form of energy into light waves. Electric lamps produce light using electrical energy and have almost replaced other types of lamps due to their cleanliness, ease of control and low cost. Their application has particularly helped industries in reducing the accidents and increasing the outputs. The following types of electric lamps are in common use in our day to day life.

(a) **Incandescent Lamps**: Incandescent lamps work on the principle that when a filament of fine wire is maintained at incandescence (white-hot condition) by the passage of current it emits sufficient energy in the form of light.

**Construction**: Fig. 11.27 (a) shows the construction of the modern type of gas filled incandescent lamp.

It consists of a tungsten filament (F) placed in a glass bulb (B). Tungsten is used as filament material because it has a high melting point (3500°C), high specific resistance and a low rate of evaporation in addition to ductility and good mechanical strength. The glass bulb is filled with a chemically inert gas such as argon or krypton at about atmospheric pressure to further reduce the rate of