MODULE-5

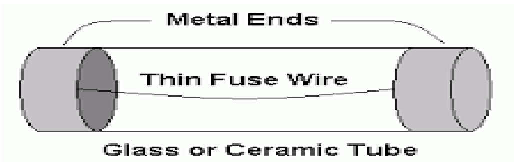
PROTECTIVE DEVICES

Protection for electrical installation must be provided in the event of faults such as short circuit, overload and earth faults. The protective circuit or device must be fast acting and isolate the faulty part of the circuit immediately. It also helps in isolating only required part of the circuit without affecting the remaining circuit during maintenance. The following devices are usually used to provide the necessary protection:

- Fuses
- Miniature circuit breakers(MCB)
- Earth leakage circuit breakers(ELCB)
- Residual Current Circuit Breaker (RCCB)

Fuse

A fuse is a safety device, a weak link connected in series with the circuit, which melts whenever the current in the circuit exceeds the value of the fuse provided, either due to overload or short circuit, thus opening the circuit and protecting other material in the circuit.



- 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.

Definitions

1. Fuse element

The part of the fuse which melts when excessive current flows through it is called fuse element or fuse wire.

2. Fusing current

The minimum value of the current at which the fuse element melts to interrupt the circuit current is called fusing current. Its value is always more than the current rating of the fuse.

3. Fusing Factor

The ratio of the minimum fusing current and the current rating of the fuse is called the fusing factor. As minimum fusing current is more than the current rating, the fusing factor is always greater than one.

$$\text{Fusing Factor} = \frac{\text{minimum fusing current}}{\text{current rating of the fuse}}$$

4. Rated current of fuse

It is that maximum current which fusing element can normally carry without any overheating or melting. It depends on,

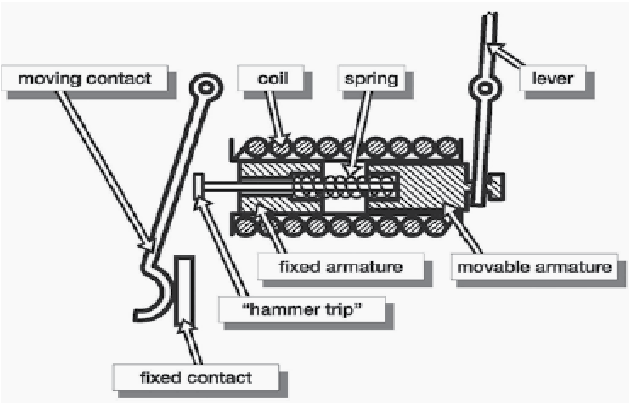
1. Temperature rise of fuse contact of fuse holder
2. Fusing element material
3. Deterioration of fuse to oxidation

Miniature Circuit Breaker (MCB)

- **MCB**s or **Miniature Circuit Breakers** are electromechanical devices which protect an electrical 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 reset and thus offers improved operational safety and greater convenience without incurring large operating cost.

An MCB functions by interrupting the continuity of electrical flow through the circuit once a fault is detected.

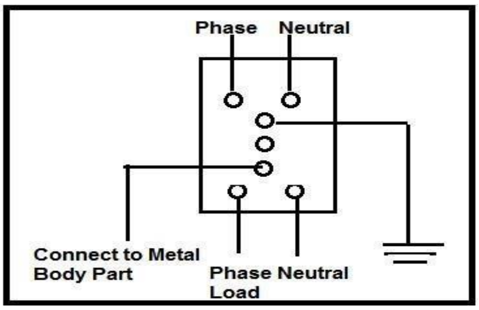
- In simple terms MCB is a switch which automatically turns off when the current flowing through it passes the maximum allowable limit.
- enerally MCB are designed to protect against over current and over temperature faults (over heating).
- There are two contacts one is fixed and the other moveable.
- When the current exceeds the predefined limit a solenoid forces the moveable contact to open (i.e., disconnect from the fixed contact) and the MCB turns off thereby stopping the current to flow in the circuit.
- In order to restart the flow of current the MCB is manually turned on.
- This mechanism is used to protect from the faults arising due to over current or over load.



- To protect against fault arising due to over heating or increase in temperature a bi-metallic strip is used.
- MCBs are generally designed to trip within 2.5 millisecond when an over current fault arises.
- In case of temperature rise or over heating it may take 2 seconds to 2 minutes for the MCB to trip.

Earth Leakage Circuit Breaker (ELCB)

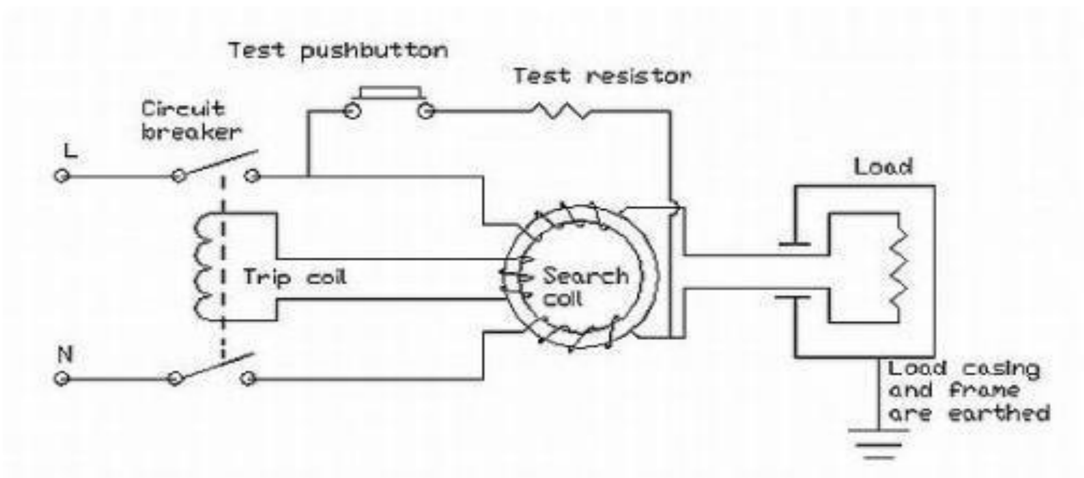
- There are certain situations where leakage current flows through the metal bodies of appliances. Thus person touching such appliances may get a shock.
- There is a risk of fire due to such leakage current flowing to the earth.
- The MCB and fuse cannot provide protection against earth leakage current.
- Hence there is a need of a device which can directly detect the earth leakage currents and cut the supply if such currents exceed a preset value. Such a device is called Earth Leakage Circuit Breaker (ELCB).



- Voltage Operate ELCB contains a relay coil or ELCB coil.
- One end of the ELCB coil is given connection to the load and the other end to the earth wire.
- When the voltage of the load rises, there will be a difference in voltage between the load and the earth wire resulting in electric shock.
- This potential or voltage difference causes a current to flow from the load to the ground through the relay coil loop.
- When the voltage difference becomes greater than 50 volt, current through the loop moves the relay and hence disconnect the supply. In other words, the trip mechanism operates.
- Voltage Operate ELCB detects only the electric faults from the phase to the earth wire within the load it protects.
- It cannot detect the fault currents that flow between the phase and any other earth (person, ground water pipes etc.).
- In such a case, the ELCB cannot protect against electric shock.

Residual Current Circuit Breaker (RCCB)

- Current operated ELCBs are generally known as Residual current devices (RCD).
- These also protect against earth leakage.
- Both circuit conductors (supply and return) are run through a sensing coil; any imbalance of the currents means the magnetic field does not perfectly cancel.
- The device detects the imbalance and trips the contact



- The supply coil, the neutral coil and the search coil all wound on a common transformer core.

- On a healthy circuit the same current passes through the phase coil, the load and return back through the neutral coil.
- Both the phase and the neutral coils are wound in such a way that they will produce an opposing magnetic flux.
- With the same current passing through both coils, their magnetic effect will cancel out under a healthy circuit condition.
- In a situation when there is fault or a leakage to earth in the load circuit, or anywhere between the load circuit and the output connection of the RCB circuit, the current returning through the neutral coil has been reduced. Then the magnetic flux inside the transformer core is not balanced anymore.
- The total sum of the opposing magnetic flux is no longer zero. This net remaining flux is what we call a residual flux.
- The periodically changing residual flux inside the transformer core crosses path with the winding of the search coil.
- This action produces an electromotive force (e.m.f.) across the search coil.
- An electromotive force is actually an alternating voltage.
- The induced voltage across the search coil produces a current inside the wiring of the trip circuit.
- It is this current that operates the trip coil of the circuit breaker.
- Since the trip current is driven by the residual magnetic flux (the resulting flux, the net effect between both fluxes) between the phase and the neutral coils, it is called the residual current device
- With a circuit breaker incorporated as part of the circuit, the assembled system is called residual current circuit breaker (RCCB) or residual current devise (RCD).
- The incoming current has to pass through the circuit breaker first before going to the phase coil.
- The return neutral path passes through the second circuit breaker pole.
- During tripping when a fault is detected, both the phase and neutral connection is isolated.

Electric Shock

- A sudden agitation of the nervous system of a body, due to the passage of an electric current is called an electric shock.
- The factors affecting the severity of the shock are
  - Magnitude of current through the body
  - Path of the current through the body
  - Time for which the current is passed through the body
  - Frequency of the current
  - Physical and psychological condition of the person

Elementary first aid against shock

The first aid can save the life and reduce severity of the accidents. Hence elementary first aid is important. The first aid against the electric shock involves following steps,

1. Do not panic
2. Carry the affected person and lay him in a comfortable position and call the doctor immediately.
3. Look for stoppage of breathing
4. Start giving him artificial respiration if breathing is stopped.
5. Never give anything to the person to drink when the person is unconscious.
6. The artificial respiration should be continued for longer time.
7. The burns caused due to electric flashes should be covered with sterile dressing and then bandaged.
8. Do not crowd and let the person get fresh air.

Safety precaution against electric shock

9. Insulation of the conductor used must be proper and in good condition. If it is not so the current carried by the conductor may leak out. The person coming in contact with such faulty insulated conductors may receive a shock.
10. Megger test should be conducted and insulation must be checked. With the help of megger all the test must be performed, on the new wiring before starting use of it.
11. Earth connection should be always maintained in proper condition.
12. Switch off the main supply and remove the fuses before starting to work with any installation.
13. Fuses must have correct rating.
14. Use rubber soled shoes while working. Use some wooden supper under the feet, this removes the contact with earth.
15. Use rubber gloves while touching any terminal or removing insulation layer from the conductor.
16. Use a line tester to check whether a live terminal carries any current.
17. Always use insulated screw driver, pliers etc
18. Never touch two different terminals at the same time.
19. Never remove the plug by pulling the wires connected to it.
20. The sockets should be fixed at a height beyond the reach of the children.

Earthing

The potential of the earth is considered to be at zero for all practical purposes as the generator (supply) neutral is always earthed. The body of any electrical equipment is connected to the earth by means of a wire of negligible resistance to safely discharge electric energy, which may be due to failure of the insulation, line coming in contact with the casing etc. Earthing brings the potential of the body of the equipment to ZERO i.e. to the earth's potential, thus protecting the operating personnel against electrical shock. The body of the electrical equipment is not connected to the supply neutral because due to long transmission lines and intermediate substations, the same neutral wire of the generator will not be available at the load end. Even if the same neutral wire is running it will have a self resistance which is higher than the human body resistance. Hence, the body of the electrical equipment is connected to earth only.

Thus earthing is to connect any electrical equipment to earth with a very low resistance wire, making it to attain earth's potential. The wire is usually connected to a copper plate placed at a depth of 2.5 to 3meters from the ground level.

Necessity of Earthing:

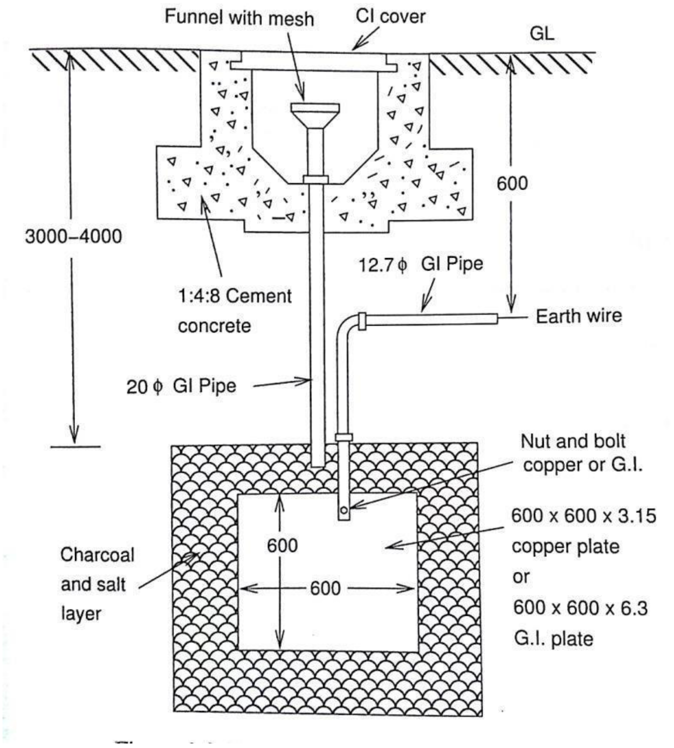
1. To protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation.
2. To maintain the line voltage constant under unbalanced load condition.
3. Protection of the equipments
4. Protection of large buildings and all machines fed from overhead lines against lightning.

Methods of Earthing:

The important methods of earthing are the plate earthing and the pipe earthing. The earth resistance for copper wire is 1 ohm and that of G I wire less than 3 ohms. The earth resistance should be kept as low as possible so that the neutral of any electrical system which is earthed is maintained almost at the earth potential. The typical value of the earth resistance at power house is 0. 5 ohm and that at substation is 1 ohm

Plate Earthing

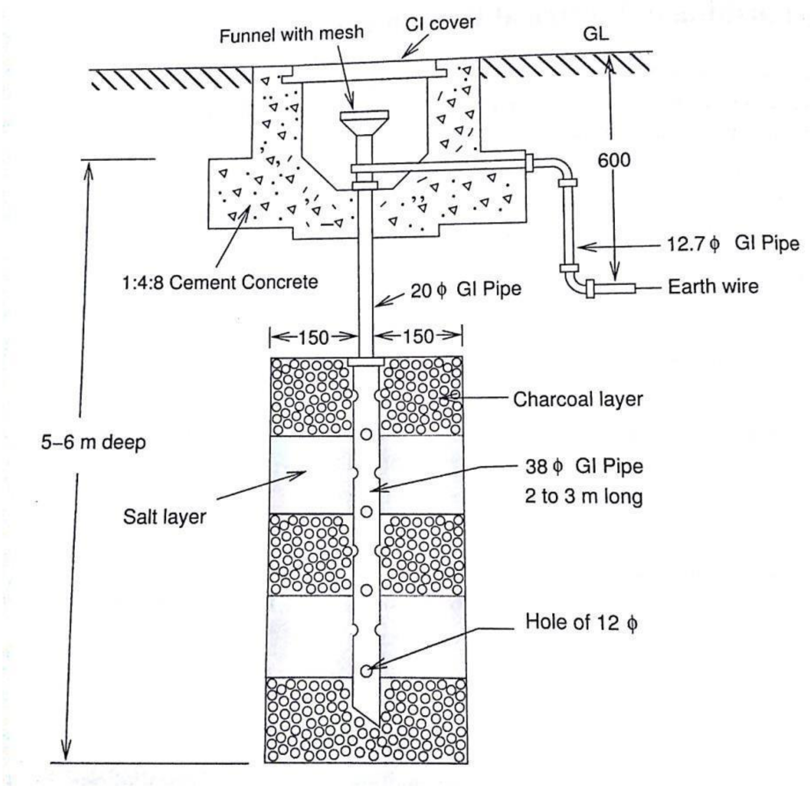
In this method a copper plate of 60cm x 60cm x 3.15cm or a GI plate of the size 60cm x 60cm x 6.35cm is used for earthing. The plate is placed vertically down inside the ground at a depth of 3m and is embedded in alternate layers of coal and salt for a thickness of 15 cm. In addition, water is poured for keeping the earth electrode resistance value well below a maximum of 5 ohms. The earth wire is securely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.



Pipe Earthing

Earth electrode made of a GI pipe of 38mm diameter and 2m length (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of

the earth resistance at the desired level, the area(15 cms) surrounding the GI pipe is filled with a mixture of salt and coal.. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross- sectional area are run through a 12.7mm diameter pipe (at 60cms below) from the 19mm diameter pipe and secured tightly at the top as shown in the following figure.



When compared to the plate earth system the pipe earth system can carry larger leakage currents as a much larger surface area is in contact with the soil for a given electrode size. The system also enables easy maintenance as the earth wire connection is housed at the ground level.

DOMESTIC WIRING

Introduction

Wiring done in domestic premises for providing power for lighting, fans and domestic appliances is called domestic wiring.

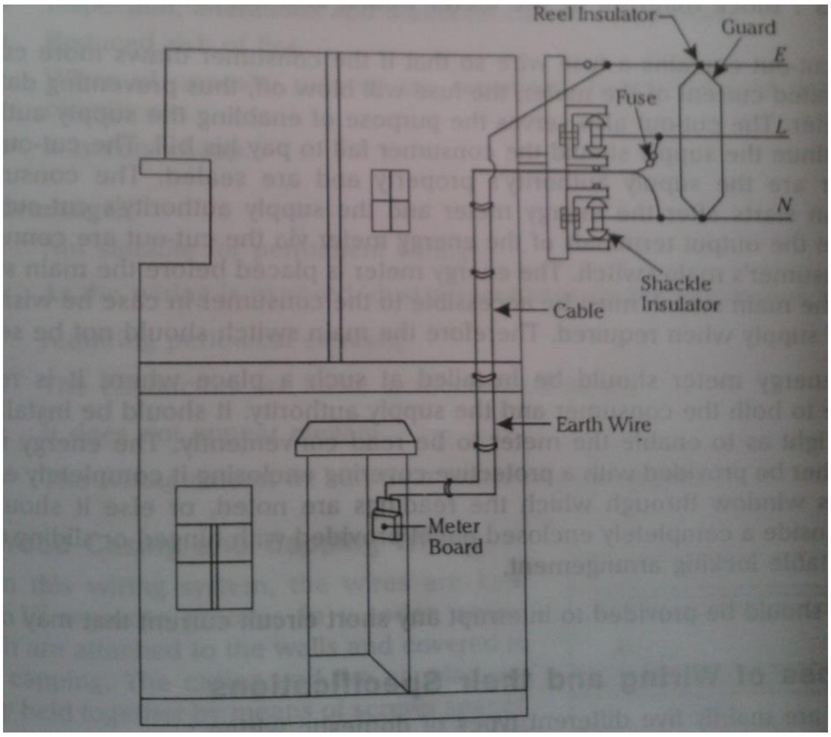
The primary objective of wiring system is to distribute electrical energy to the various points at which it is required, duly considering the following

1. **Electrical safety**: This is the most important aspects – there must be no danger of leakage or of electric shock to persons using the supply.

2. **Mechanical immunity**: A wiring system which is suitable for one type of building may not be suitable for another. The wiring selected for a particular type of building should be able to withstand weather changes for a long period and should be protected from physical damage during its usage.
3. **Permanence**: There should not be any undue deterioration in wiring due to action of dampness, fumes, weather etc.
4. **Appearance**: In certain cases appearance or invisibility is important. However in case of factory wiring, appearance apart from neatness is usually not important.
5. **Cost**: the cost of wiring installation is an important consideration. The system chosen should depend upon the type of building and the purpose for which it is used, keeping economy in view.

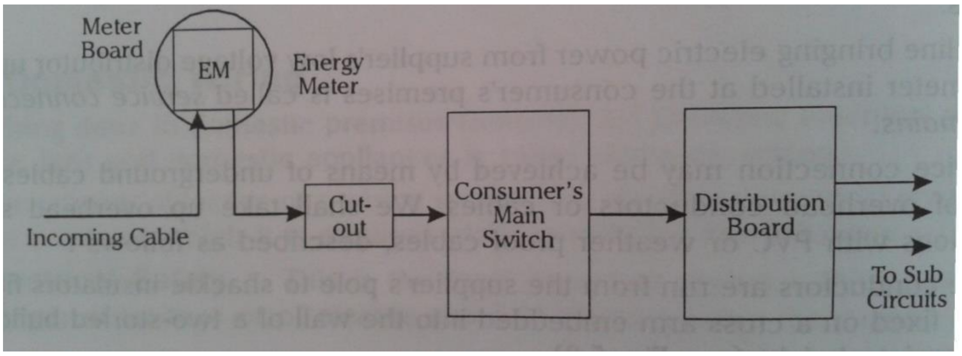
Service Mains

- The supplier`s distribution system brings power to the consumers through overhead lines or by means of underground cables to a spot outside the consumer`s premises.
- The line bringing electrical power from supplier`s low voltage distributor upto the energy meter installed at the consumer`s premises is called service connection or service mains.
- Service connection may be achieved by means of underground cables or by means of overhead conductors or cables.
- Bare conductors are run from the supplier`s pole to shackle insulators fitted to brackets fixed on a cross arm embedded into the wall of a two storied building at an appropriate height.
- Thereafter service connections are taken from the bare conductors by means of PVC or weather proof cables run on wooden battens or through GI pipe



3.2 Meter board and Distribution board

- The supplier service line which is brought to the consumers premises, is now connected to the consumer`s internal wiring.
- The supply authority has to charge the consumer for the electrical energy consumed.
- For this purpose the supplier's service will be connected to the input terminal of the energy meter, which has to be provided by the supply authority.
- After the energy meter the service line is connected to the cut-out.
- The cut-out contains the fuse wire so that if the consumer draws more current than the rated current of the meter, the fuse will blow off, thus preventing damage to the meter.
- The cut-out also serves the purpose of enabling the supply authority to discontinue the supply should the customer failed to pay his bill.
- The cut-out and the meter are the supply authorities' property and are sealed.
- The consumer`s distribution starts after the energy meter and the supply authority`s cut out.

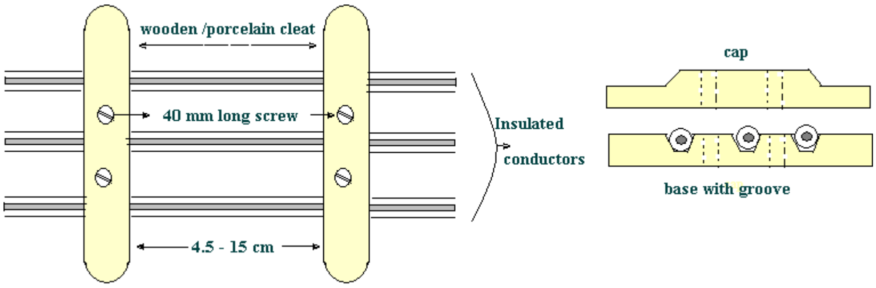


- The leads from the output terminals of the energy meter via the cut out are connected to the consumer's main switch.
- The energy meter is placed before the main switch because the main switch must be accessible to the consumer in case he wishes to switch off the supply when required. Therefore the main switch should not be sealed.
- The energy meter should be installed in such a place where it is readily accessible to both the consumer and the supply authority.

3.3 Types of wiring and their specification

3.4.1. <u>Cleat wiring:</u>

In this type of wiring, insulated conductors (usually VIR, Vulcanized Indian Rubber) are supported on porcelain or wooden cleats. The cleats have two halves one base and the other cap. The cables are placed in the grooves provided in the base and then the cap is placed. Both are fixed securely on the walls by 40mm long screws. The cleats are easy to erect and are fixed 4.5 – 15 cms apart. This wiring is suitable for temporary installations where cost is the main criteria but not the appearance.



Three Groove cleat

Advantages:

1. Easy installation
2. Materials can be retrieved for reuse
3. Flexibility provided for inspection, modifications and expansion.
4. Relatively economical
5. Skilled manpower not required.

Disadvantages:

1. Appearance is not good
2. Open system of wiring requiring regular cleaning.
3. Higher risk of mechanical injury

3.6 PROTECTIVE DEVICES

Protection for electrical installation must be provided in the event of faults such as short circuit, overload and earth faults. The protective circuit or device must be fast acting and isolate the faulty part of the circuit immediately. It also helps in isolating only required part of the circuit without affecting the remaining circuit during maintenance. The following devices are usually used to provide the necessary protection:

- Fuses
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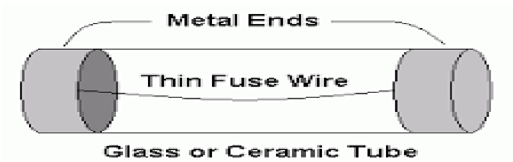
- Earth leakage circuit breakers(ELCB)
- Residual Current Circuit Breaker (RCCB)



Fuse

A fuse is a safety device, a weak link connected in series with the circuit, which melts whenever the current in the circuit exceeds the value of the fuse provided, either due to overload or short circuit, thus opening the circuit and protecting other material in the circuit.

- 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.
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- 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.
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Definitions

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The minimum value of the current at which the fuse element melts to interrupt the circuit current is called fusing current. Its value is always more than the current rating of the fuse.

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The ratio of the minimum fusing current and the current rating of the fuse is called the fusing factor. As minimum fusing current is more than the current rating, the fusing factor is always greater than one.

$$\text{Fusing Factor} = \frac{\text{minimum fusing current}}{\text{current rating of the fuse}}$$

4. Rated current of fuse

It is that maximum current which fusing element can normally carry without any overheating or melting. It depends on,

1. Temperature rise of fuse contact of fuse holder
2. Fusing element material
3. Deterioration of fuse to oxidation

3.7.1 Miniature Circuit Breaker (MCB)

- **MCB**s or **Miniature Circuit Breakers** are electromechanical devices which protect an electrical circuit from an over current.
- The over current, in an electrical circuit, may result from short circuit, overload or faulty design.
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- Unlike fuse, an MCB can be easily reset and thus offers improved operational safety and greater convenience without incurring large operating cost.
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- In simple terms MCB is a switch which automatically turns off when the current flowing through it passes the maximum allowable limit.
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- There are two contacts one is fixed and the other moveable.
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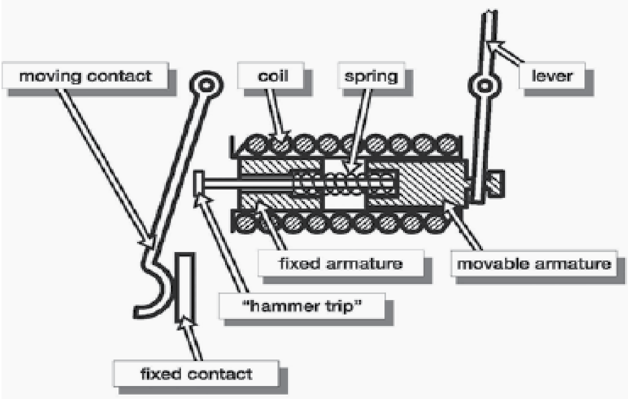
- In order to restart the flow of current the MCB is manually turned on.
- This mechanism is used to protect from the faults arising due to over current or over load.

- To protect against fault arising due to over heating or increase in temperature a bi-metallic strip is used.
- MCBs are generally designed to trip within 2.5 millisecond when an over current fault arises.
- In case of temperature rise or over heating it may take 2 seconds to 2 minutes for the MCB to trip.



3.7.2 Earth Leakage Circuit Breaker (ELCB)

- There are certain situations where leakage current flows through the metal bodies of appliances. Thus person touching such appliances may get a shock.
- There is a risk of fire due to such leakage current flowing to the earth.
- The MCB and fuse cannot provide protection against earth leakage current.
- Hence there is a need of a device which can directly detect the earth leakage currents and cut the supply if such currents exceed a preset value. Such a device is called Earth Leakage Circuit Breaker (ELCB).

- Voltage Operate ELCB contains a relay coil or ELCB coil.
- One end of the ELCB coil is given connection to the load and the other end to the earth wire.
- When the voltage of the load rises, there will be a difference in voltage between the load and the earth wire resulting in electric shock.
- This potential or voltage difference causes a current to flow from the load to the ground through the relay coil loop.
- When the voltage difference becomes greater than 50 volt, current through the loop moves the relay and hence disconnect the supply. In other words, the trip mechanism operates.
- Voltage Operate ELCB detects only the electric faults from the phase to the earth wire within the load it protects.
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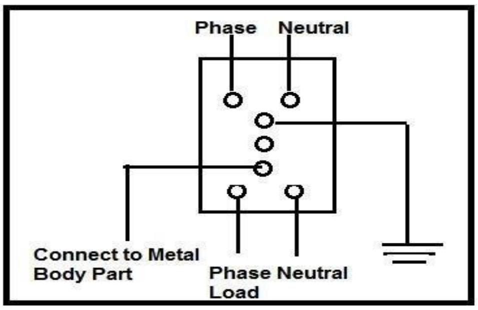
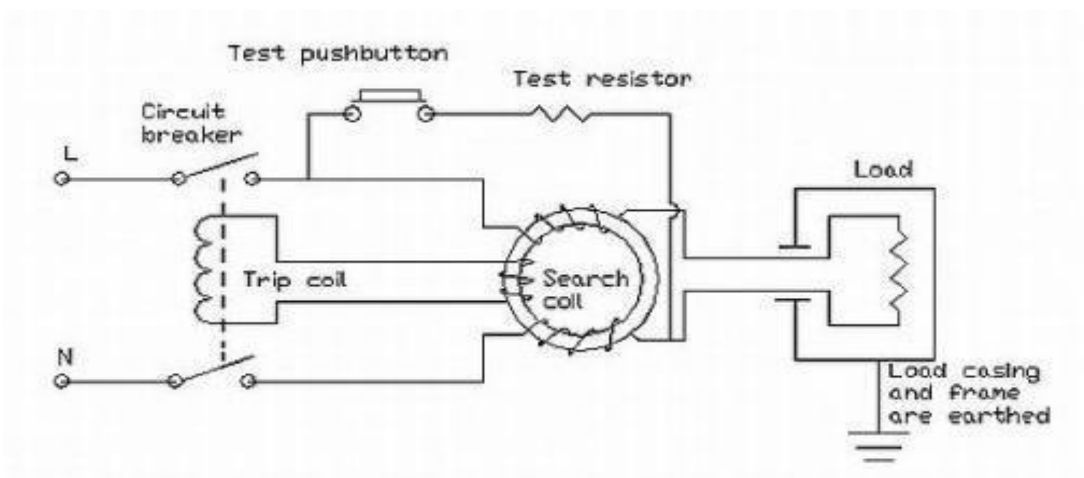


3.7.3 Residual Current Circuit Breaker (RCCB)

- Current operated ELCBs are generally known as Residual current devices (RCD).
- These also protect against earth leakage.
- Both circuit conductors (supply and return) are run through a sensing coil; any imbalance of the currents means the magnetic field does not perfectly cancel.
- The device detects the imbalance and trips the contact



- The supply coil, the neutral coil and the search coil all wound on a common transformer core.
- On a healthy circuit the same current passes through the phase coil, the load and return back through the neutral coil.
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- With the same current passing through both coils, their magnetic effect will cancel out under a healthy circuit condition.
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- The incoming current has to pass through the circuit breaker first before going to the phase coil.
- The return neutral path passes through the second circuit breaker pole.
- During tripping when a fault is detected, both the phase and neutral connection is isolated.

3.9 Electric Shock

- A sudden agitation of the nervous system of a body, due to the passage of an electric current is called an electric shock.
- The factors affecting the severity of the shock are
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2. To maintain the line voltage constant under unbalanced load condition.
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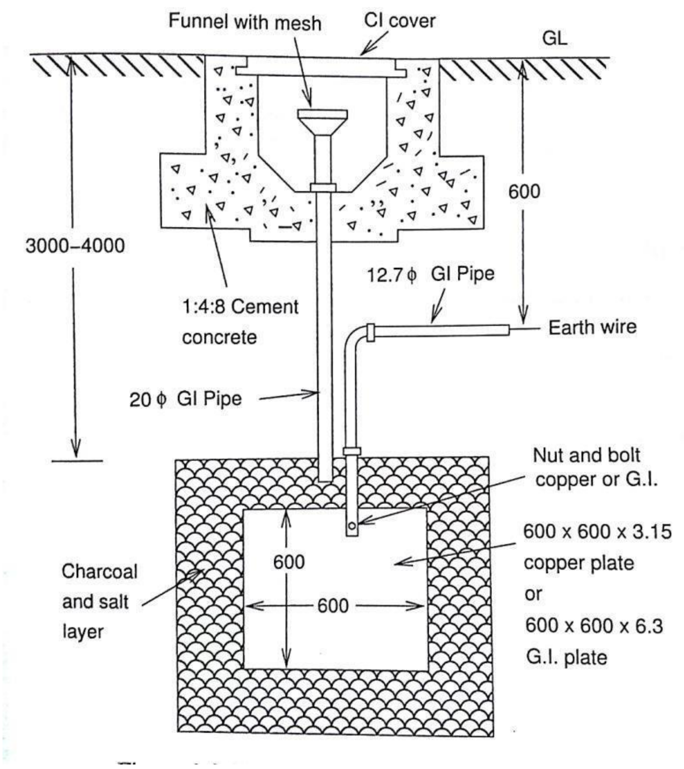
4. Protection of large buildings and all machines fed from overhead lines against lightning.

3.9.2 Methods of Earthing:

The important methods of earthing are the plate earthing and the pipe earthing. The earth resistance for copper wire is 1 ohm and that of G I wire less than 3 ohms. The earth resistance should be kept as low as possible so that the neutral of any electrical system which is earthed is maintained almost at the earth potential. The typical value of the earth resistance at power house is 0. 5 ohm and that at substation is 1 ohm

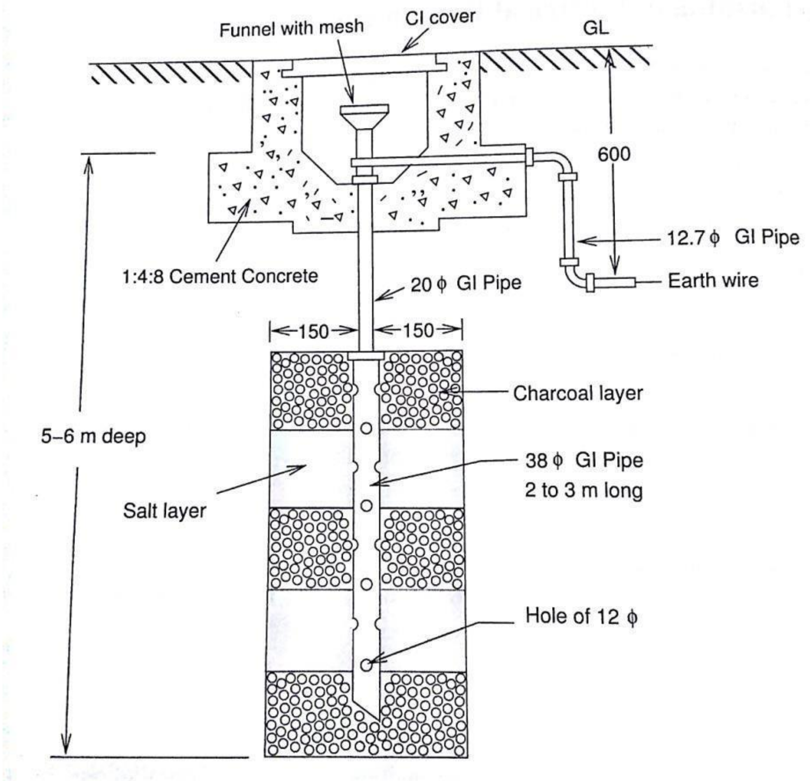
3.9.2.1 Plate Earthing

In this method a copper plate of 60cm x 60cm x 3.15cm or a GI plate of the size 60cm x 60cm x 6.35cm is used for earthing. The plate is placed vertically down inside the ground at a depth of 3m and is embedded in alternate layers of coal and salt for a thickness of 15 cm. In addition, water is poured for keeping the earth electrode resistance value well below a maximum of 5 ohms. The earth wire is securely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.



3.9.2.2 Pipe Earthing

Earth electrode made of a GI pipe of 38mm diameter and 2m length (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area(15 cms) surrounding the GI pipe is filled with a mixture of salt and coal.. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross- sectional area are run through a 12.7mm diameter pipe (at 60cms below) from the 19mm diameter pipe and secured tightly at the top as shown in the following figure.



When compared to the plate earth system the pipe earth system can carry larger leakage currents as a much larger surface area is in contact with the soil for a given electrode size. The system also enables easy maintenance as the earth wire connection is housed at the ground level.