# Salahaddin University- Erbil

## College of Engineering

## Architecture Department

**Third Year Students**

## Electrical Installation

**Part Three**

ELECTRIC EARTHING

# ELECTRIC EARTHING

Definition of Earthing :

The meaning of the term Earthing or Grounding is the physically connected of electrical circuit for all equipment's to the general mass of earth which is Zero Volt Potential ,by wire of negligible resistance

A grounding system protects the user against being electrocuted during ground faults (a short that occurs when a hot wire touches aground or noncurrent carrying conductor). It is also protects both the user and the appliance against the build of induced Voltages and provides a safe discharge path for Surges.

Earthing is basically a TWO PART system. The first part consists of a wire present in all the branch circuit, electrical cables that connects the Frame of all appliances, tools, and metal outlet boxes back to the grounding Bus of a Fuse or Circuit Breaker Panel .This wire is called an equipment grounding conductor .It could be the armor of an (A.C.) cable if the metal conduit runs all the way back to the service Panel.

The Second Part in earth grounding system: composed of a large Copper wire, called GROUNDING ELECTRODE conductor, and a series of ground rods (or equivalent) that are buried in the earth.

The Earthing (grounding) brings the body of electrical equipment to ZERO potential and thus will avoid the shock to the Operator because also the neutral of the supply system is earthed to ensure its potential equal to ZERO.

There are many methods of Grounding , such as using structural steel, rebar or well casings .However , ground rods are used for most residential applications .But sometimes rods cannot give you a low resistance ground due to the earth low moisture or excessive Rock and little Soil .

Grounding offers life safety, equipment safety, and longer equipment life.

The equipment – Grounding conductor works like this ; If a hot wire touches a grounded appliance frame, , or the side of a grounded metal outlet box , the fault current will ride back to the service Panel via the equipment – Grounding conductor , complete the circuit , Fig (3.1), and trip the Breaker.

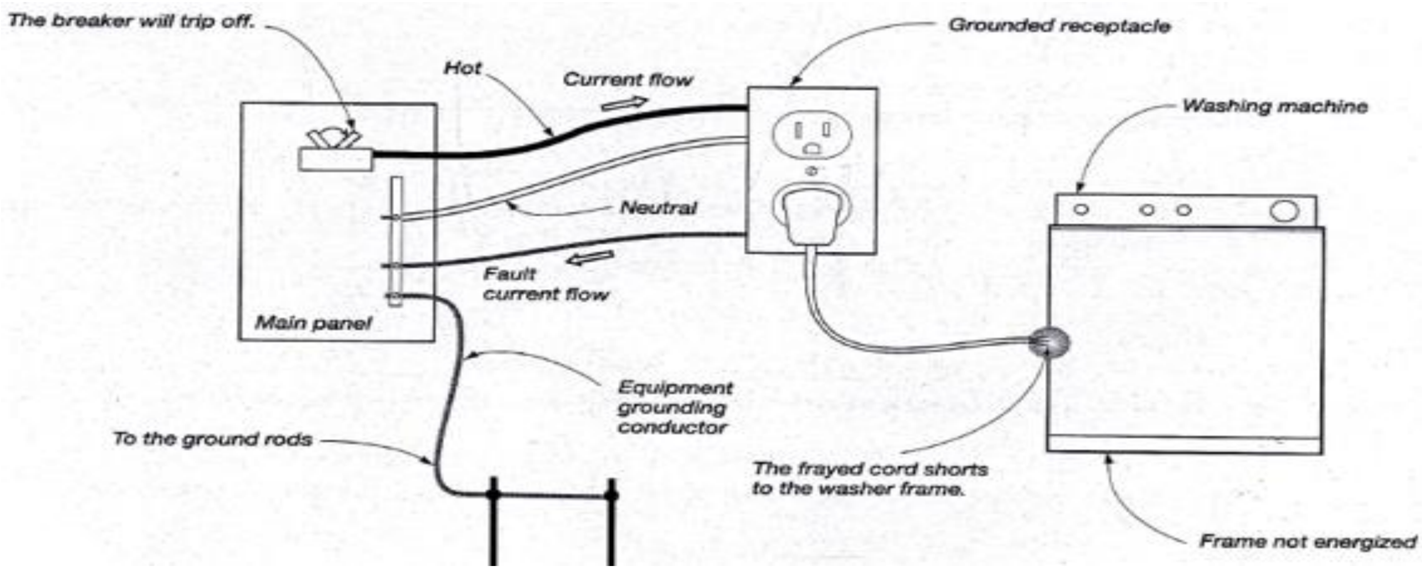
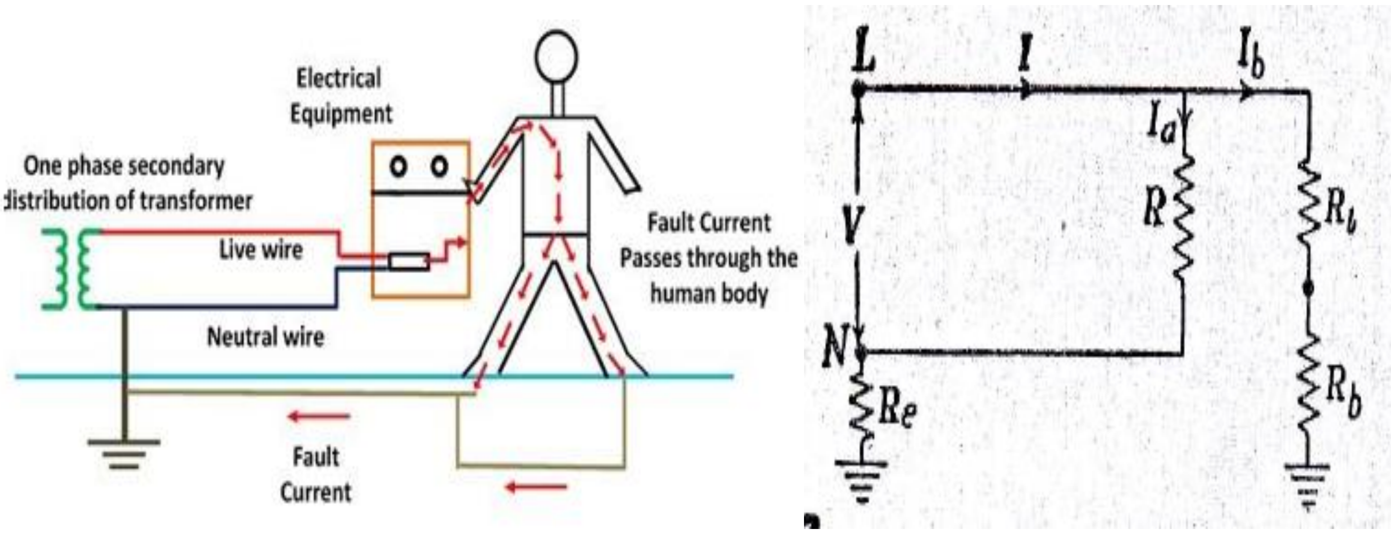



Fig (3.1) Ground Fault on a Grounded Appliance

The ground Rod and earth ground play no part in this system. The earth grounding system comes into play whenever there is any static Voltage buildup on an Appliance's frame. A typical example would be a Lightning Strike. The Strike putout a massive Electromagnetic Force (E.M.F.) pulse that induces a Voltage into metal Appliance Frame's. The equipment – Grounding conductor takes this surge back to the main Panel, where it transfers to Grounding Electrode conductor, which sends it to the Ground rods to bleed harmlessly into the earth .This same large ground rod is also used to transfer Surges pulses (caused by the utility company of opening and closing a circuit) to the earth that have been stripped off the line by ARRESTORS mounted at the Panel or at the point of use.

The necessity of earthing :

Let an electrical apparatus of a resistance R be connected across the supply mains and let it to be not earthed as shown in Fig (3. 2 a)




(a) (b) Equv. electrical CCT of getting a shock

**Fig (3.2) Electrical system without Earthing**

Let us assume that:

**V** – The potential between life wire and Neutral.

**$R_i$** – The insulation resistance between the electrical element of the apparatus and it's metal Case.

**$R_b$** – Resistance of the person body.

If the person who touches the apparatus standing on the earth ,then the current from the supply main will have alternative path through the insulation Resistance (**$R_i$** ) of the electrical apparatus and Resistance(**$R_b$** ) of the body to earth , and finally through the earth Resistance (**$R_e$**) to neutral of supply . Electrical circuit for the above is shown in Fig (3.2b).

The current **($I_b$)** in the second shunt path depends upon the insulation

Resistance **$R_i$** , **$R_b$** , **$R_e$** and the applied voltage **V .**

However, mostly it is dependent upon **$R_i$** , since it varies from infinity when there is a dead short (S.C) between the element and the metal case respectively . NO current will pass through alternative circuit, if the insulation resistance is Infinity:

$$(\mathbf{R_i}) = \text{Infinity} = \boldsymbol{\alpha} \qquad \text{........(3.1)}$$

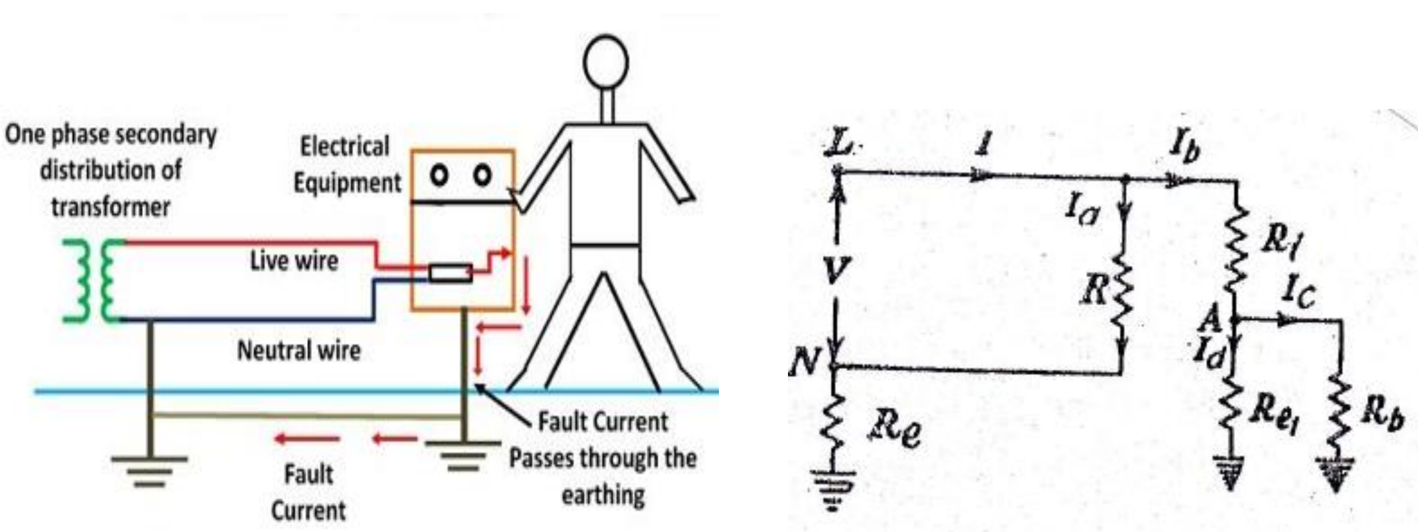
$$\mathbf{I_b = \ V / (R_i + Rb + Re) = V / (\alpha + Rb + Re)} \quad \rightarrow\rightarrow \; I_b = 0 \quad (3.2)$$

Hence NO current passes through the body and NO shock is experienced by the person.

When the insulation resistance of the element defective, the insulation resistance of the apparatus will approach ZERO and then the value of (**$I_b$**) will be much dependent upon the Resistance (**Rb**) of the body and it may be quite sufficient to give a fatal shock to person. **$I_b$** in this case:

$$\mathbf{I_b = \ V / ( Rb + Re)} \qquad \text{........(3.3)}$$

Now let the metal case be earthed as shown in Fig (3.3a)




(a) (b) electrical cct when apparatus is earthed

Fig (3.3) Electrical system with Earthing

Fig (3.3b) represents the electrical circuit when any person standing on the earth touches the apparatus .

Again the leakage current will largely be determined by the resistance (**$R_i$**) ; when the insulation of the element is sound ,the value of (**$R_i$**) will very high and the leakage current( **$I_b$**) will be almost negligible .

When the insulation deteriorates, the value of (**$R_i$**) approaches ZERO; the value of the leakage current no doubt will be not sufficient to give a fatal shock, but at junction (A) before it passes through the body, it divided into two paths open for it, one through the body offering resistance (**Rb**) and the other through the earth resistance **($R_{e1}$)** which is negligible.

The resistance **($R_{e1}$)** comprises the earth electrode resistance and resistance of the general mass of earth which is denoted as **($R_e$)**

As (**Rb**) and **($R_{e1}$)** are parallel, the effective resistance will be approximately equal to (**Rb**) .

Thus the equivalent resistance of the alternative path, Fig (3.3b), will be:

$$R = (R_i) + \{ (R_{e1} \times Rb) / (R_{e1} + Rb)\} \qquad \text{.........}(3.4)$$

The current **$I_b$** in view equation (3.4) ;

$$I_b = V / \{(R_i) + \{ (R_{e1} \times Rb) / (R_{e1} + Rb)\}\} \qquad \text{......}(3.5)$$

The current for which value has been arrived at junction (A), in equation **(**3.5) will be divided in two parts, If value of current through the body and earth be **$I_c$** and **$I_d$** Which adjust themselves in the inverse ratio of their resistance ,then :

$$I_c = \{ I_b / (R_{e1} + Rb)\} \times R_{e1} \qquad \text{.........}( 3.6 )$$

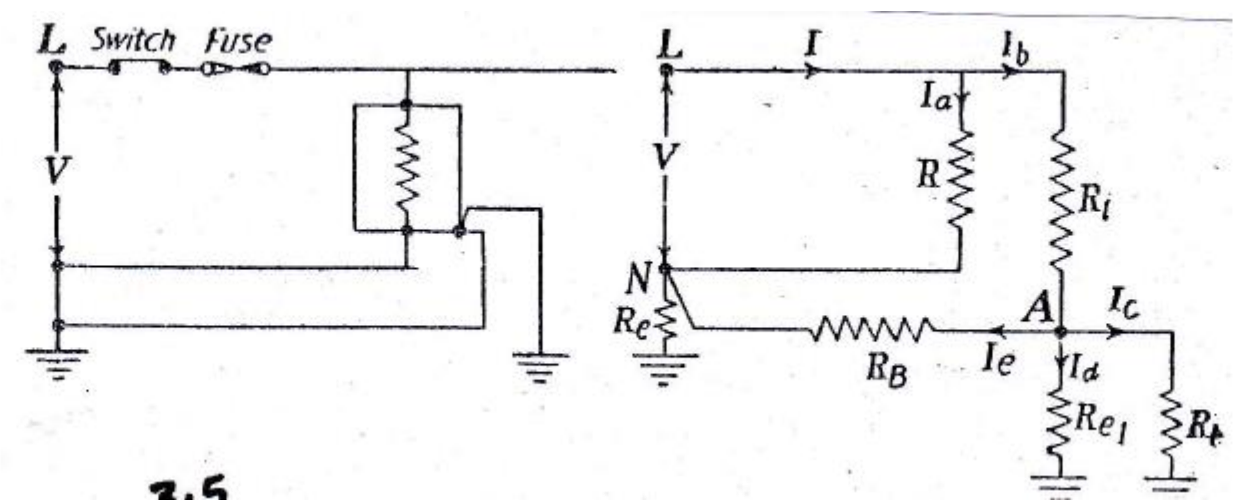
$$I_d = \{ I_b / (R_{e1} + Rb)\} \times Rb \qquad \text{........} (3.7)$$

Since the value of (**$R_{e1}$**) is of order( = 5**Ω**) according to S.I specification , **Rb** under worst condition will be 1000 **Ω** ,thus current( **$I_d$** ) will be much more than **$I_c$** and this current will not be sufficient to cause any shock . The value of leakage current (**$I_b$**) will be sufficiently high to cause the fuse in the circuit to melt and thus help to isolate the electrical appliance from the supply mains.

It will be observed from the above that the effective isolation of the plant from the supply mains depend upon the earth resistance comprising the resistance of earth electrodes and resistance of the general mass of the earth . If due to some reasons, the earth resistance rise above the safe limits, it will cause the current through the body to increase, thus the possibility of the shock further increases. Hence arrangement is not fool proof.

Absolutely safe from shock point of view, an alternative arrangement is to run an earth wire between the electrical apparatus to be protected and the neutral of the sources

In order to make the arrangement of supply called a BONDING CONNECTIONS, as shown in Fig (3.4)




(a) An earthed apparatus and Bonding connection (b) equivalent elec. cct

Fig (3.4) Bonding connections of earthing system

When any person touches the metal case of the electrical apparatus, current will not be sufficient to cause any shock .The circuit reduces as shown in Fig (3.4b), thus it will provide an alternative low resistance path to the neutral.

The salient feature of the bonding must be:

i) The earth wire acting as a Bonding Connection must be of sufficient Cross – section to carry the fault current under worst conditions.

ii)The Bonding must be continuous from the appliance to be protected to Neutral of the source .

iii)The resistance of the Bonding must be very low .

iv)The Bonding wire must be strong enough so that it can't be broken easily at any point .

v)The connection of the Bonding wire must be perfect at both ends .

vi)All bonding connection should be protected against corrosion .

**Comparison between Neutral and Earth Wire**

The color of Neutral all times is blue, while color of earth wire is green or green – yellow mixture.

| *S.No.* | *Neutral Wire* | *Earth Wire* |
| --- | --- | --- |
| 1. | It is directly connected to the neutral point of the supply system. | It may be directly connected to the neutral point to supply system. |
| 2. | It serves as a return conductor. | It may carry current only in case of a fault. |
| 3. | Its potential at some point may be substantially far from zero. It is therefore insulated from the pole on which it is supported. In this case, the insulator is smaller is size than the one supporting the phase conductors. | It is supposed to be at zero potential. it is not mounted on any insulator and is in direct m etalic contact with the support metals work. |
| 4. | It may not be connected to earth at an intermediate point in the line. | It must be connected to earth at least at 3 places in a Km or at 4 places an a mile. |

**Method of Earthing**

There are three methods of earthing;

1- Earthing through a Water Main:

Before making an earthing connection to the Water Main it must be ascertained that throughout conducting metal (e.g Stain – steel) pipe have used, otherwise if the cement – concrete pipes have been used, Earthing will not be effective,

when making an earthing connection , care must be taken to limit contact resistance to min. , for that purpose properly designed earthing Clamp should be used .

The stranded Copper lead is fanned out and Soldered to make it solid. Then the lead strip is bent round the pipe so that it may be seated properly over the pipe. The surface of the pipe is Cleaned properly, and all stuck or grease are removed and then over it is placed the Clamp. In between the clamp and pipe is inserted the lead and is tightened with screws as shown in Fig (3 .5). This method is however not popular as water mean are concrete or cement.

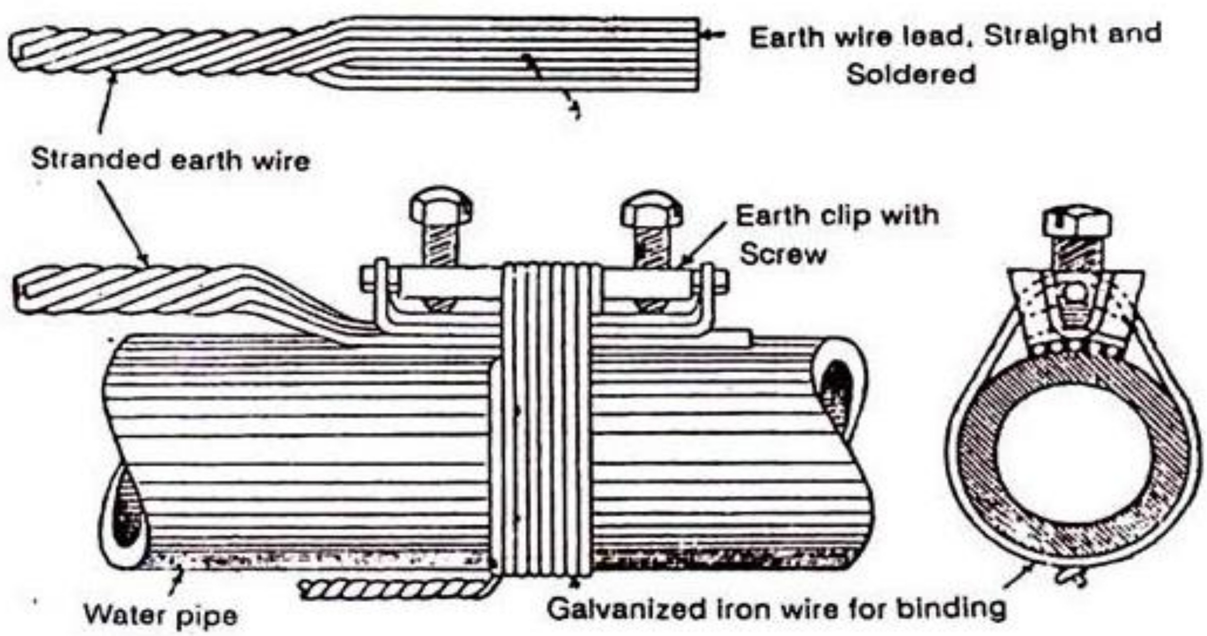



Fig (3 .5) earth connection with water main

2 – Pipe Earthing :

If the Water – pipe can't be used as an earth , a Galvanized - iron (G.I)pipe of approved length and diameter can be used .

The size of the pipe depends upon:

a) The current to be carried. b) The type of soil.

According to (S.I) standard, the Galvanized - iron pipe shall not be less than 38 m.m diameter and 2 m. long for ordinary soil, but if the soil is dry and rocky, the length of pipe should increase to 2.75 m.

The pipe is placed in a permanently wet ground. The depth at which the pipe should buried depend on the condition of ground moisture.

According to the standard, the pipe should place at a depth of 4.75 m.; it can be less if the soil provides sufficient moisture earlier. The pipe at the bottom should be surrounded by broken pieces of Coke or Charcoal for distance of about 15cm. around the pipe. The Coke increases the effective areas of earth practically to the outside of the Coke bed. Impregnating the Coke with Salt decrease the earth resistance, generally alternate layers of Salt and Coke are used for best results as represented in Fig (3.6).

At summer season the moisture in the soil will decrease to a large extent which increase the earth resistance, so in order to have an effective earth, whenever needed, 3 or 4 Buckets of water should be put into the funnel connected to the main pipe.

The earth lead used be a Galvanized wire (G.I) strip of sufficient Cross – sectional area to carry fault current safely ,it should be not less than

Electrical equivalent of Copper conductor, that mean about 13 $(m.m)^2$ , 8 $(m.m)^2$ according to (SWG). The earth wire from the (G.I) pipe of 9 m.m. diameter. Should be carried in a (G.I) pipe of 12.7 m.m. diameter at a depth of about 60cm. below the ground.

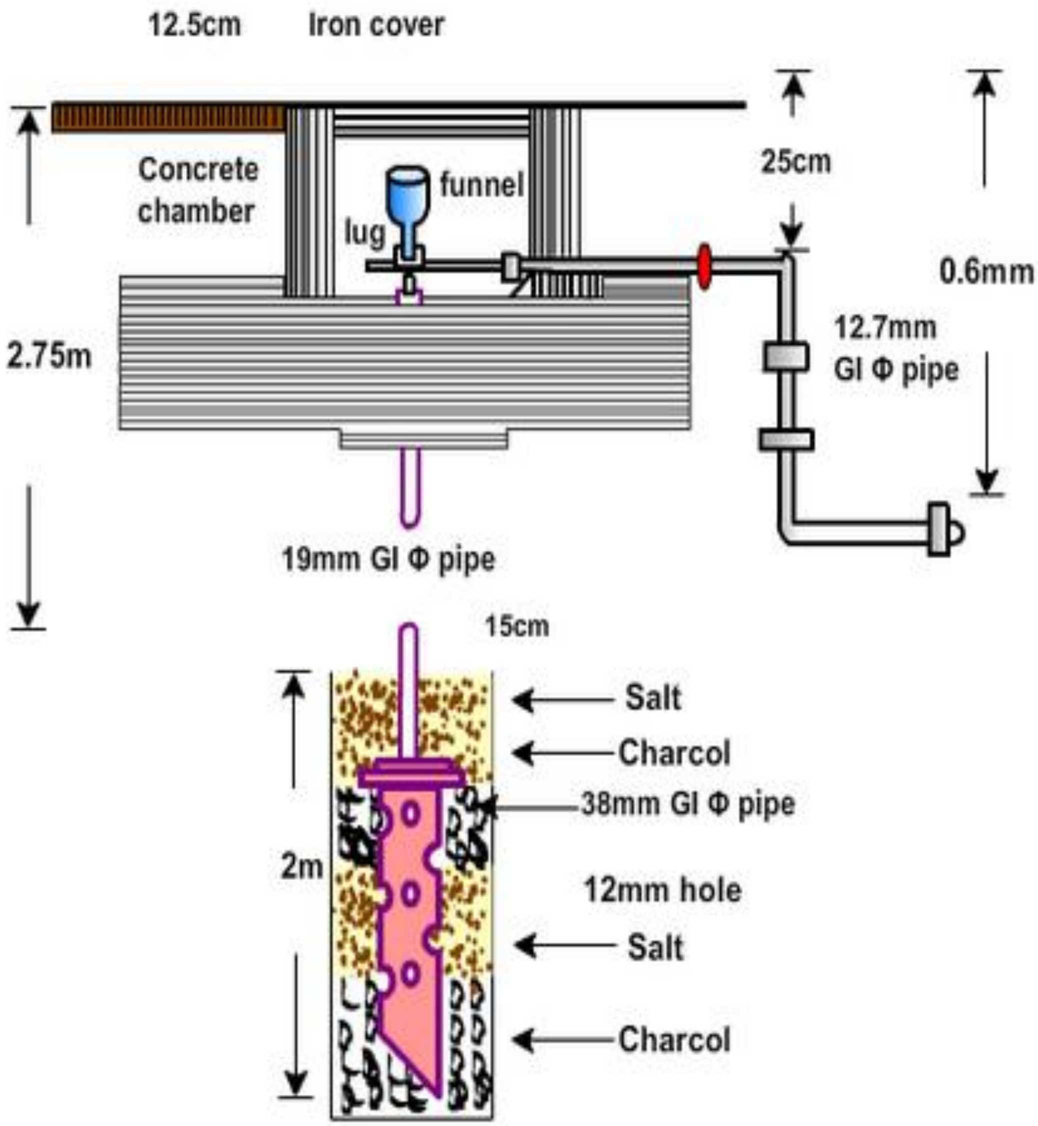



Fig (3.6) Pipe earthing

3 – Plate Earthing :

In case of plate earthing if galvanized iron plate is used as earth electrode, its size shall not be less than 60 cm x 60 cm x 6.35 mm according to Standard. With this plate galvanized iron wire is used as earth lead. If copper plate is used, its size must be at least 60 cm x 60 cm x 3.18 mm), and copper wire should be used as earth lead with this plate. In both cases plate is kept vertically in the earth pit at a depth of at least 3 meter (10 ft) below ground level.

The depth at which the plate is kept in the earth pit depends upon the condition of the soil. It must be placed in a permanently wet ground. If the soil surrounding the plate becomes dry and hard, the earthing itself becomes a source of danger. For this reason periodical testing of earthing arrangement is necessary.

Copper earth plate should be embedded in alternate layer of charcoal and salt and G.I. plate should be embedded in charcoal for a minimum thickness of about 15 cm around the plate. The filling earth is thoroughly moistened with saline water. This reduces the earth resistance further. The details of the earthing arrangement have been shown in Fig (3.7).

It should be remembered that that nuts and bolts must be of Copper for Copper plate and should of Galvanized – Iron for Galvanized plate the other details of plate earthing are same as that of (G.I) Pipe earthing.

**Types of Earth Electrode**:

There are three types of artificial electrodes, following the specifications of:

i)Driven Electrodes ( i.e pipe or rode electrodes ,see Fig (3.8) .

ii)Plate Electrodes .

iii)Strip Electrodes.

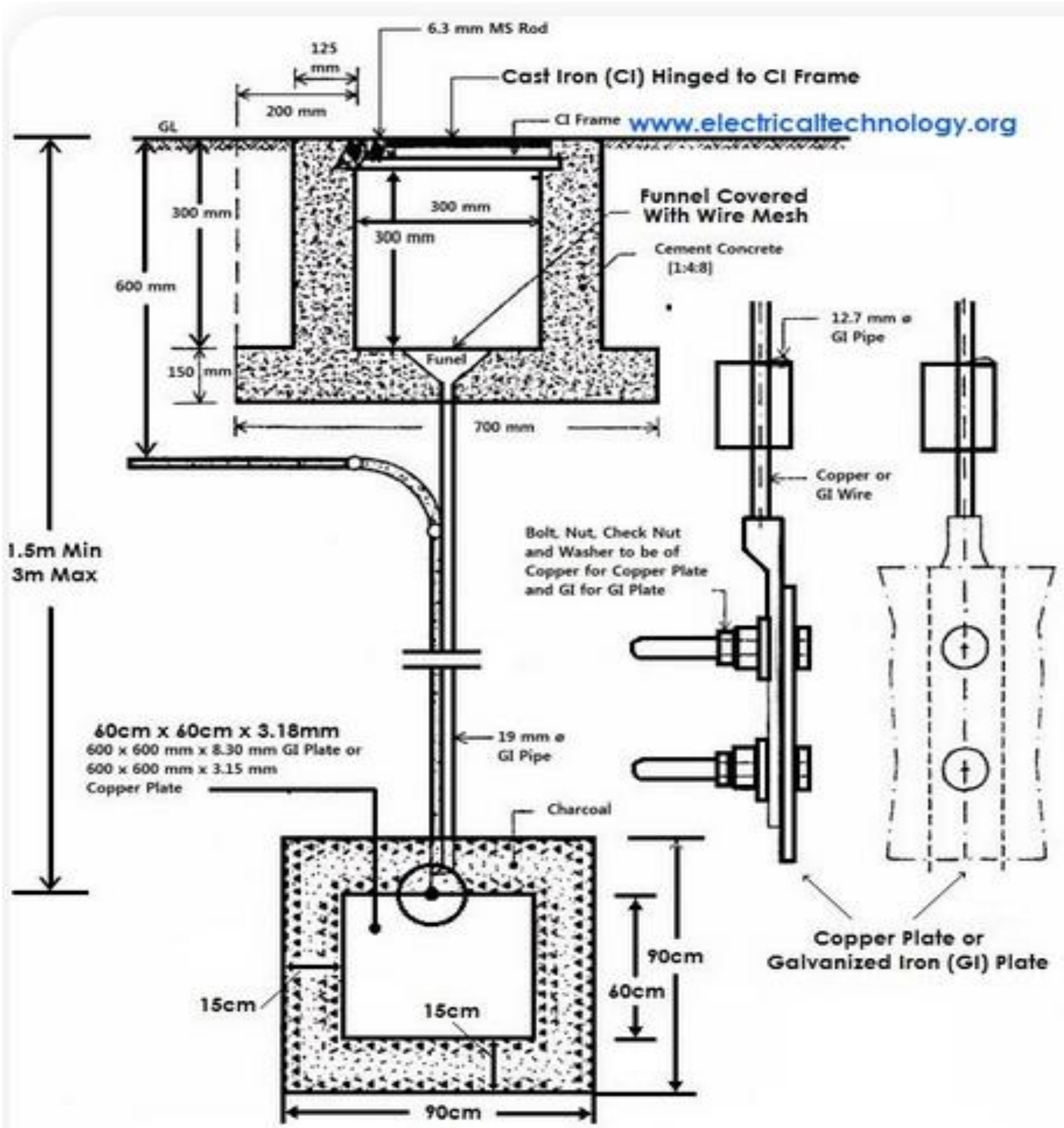



**Fig (3.7) Plate Earthing**

## i)Driven Electrodes ;

Electrodes is made of metal rode or Pipe having a clean surface not covered by any poorly conducting material such as paint .Rod electrodes of steel or iron shall have a minimum diameter of 16 m.m. and those of copper be at least 12.5 m.m.

Pipe electrodes shall not be less than 38 m.m. internal diameter, if it made of iron or steel (Galvanized).electrode length shall be not less than 2.5 m. The electrodes depth shall normally be at least 1 .25 m. But if rock is encountered, they may be buried in a horizontal trench with length not less than 2.5 m.

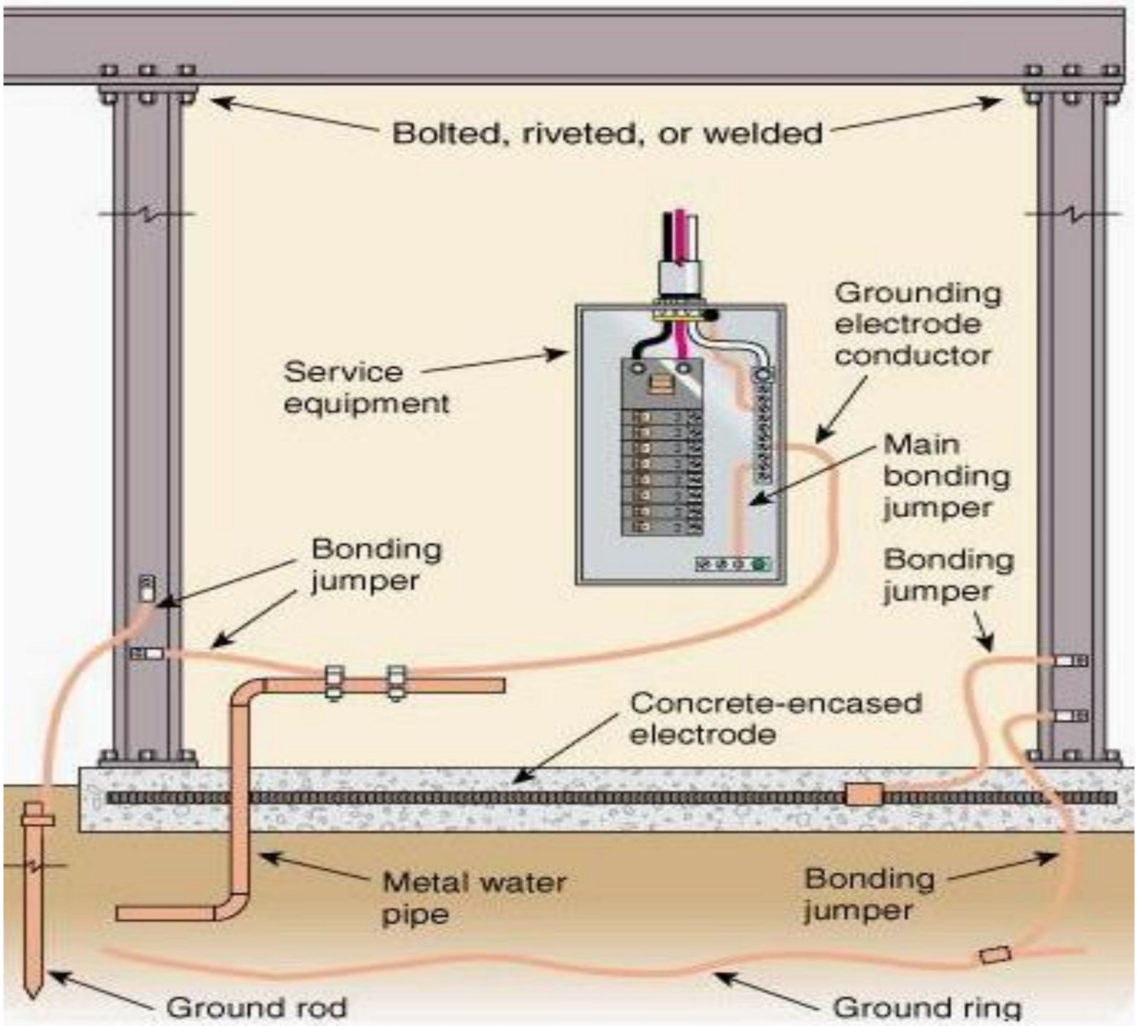



Fig (3.8) **Ground rod**

## ii)Plate Electrodes

Earthing plates are typically thin copper plates buried in direct contact with earth. National Electric Code requires that earth plates have at least 2 ft2 of surface area exposed to the surrounding soil. Ferrous materials must be at least .20 inches thick, while non-ferrous materials (copper) need only be .060 inches thick. Earthing plates are typically placed under poles or supplementing counterpoises.

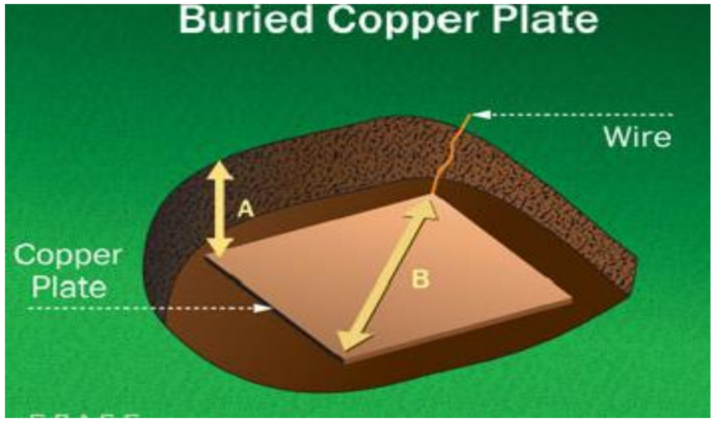



**Fig (3.9) Plate Electrode**

As shown Fig (3.9), earthing plates should be buried at least 30 inches below grade level. While the surface area of earthing plates is greatly increased over that of a driven rod, the zone of influence is relatively small as shown in "B". The zone of influence of an earthing plate can be as small as 17 inches. This ultra-small zone of influence typically causes earthing plates to have a higher resistance reading than other electrodes of similar mass.

**iii) Strip Electrodes:**

These consist of copper strips, not smaller than 25 m.m. and 1.6 m.m. in cross section of bare copper conductor not less the 3 $(m.m.)^2$ in section. They are buried in horizontal trenches, not less than 2.5 m. deep. The length shall be such as to give required earth resistance. Fig (3.10).

Fig (3.10) Strip Electrode

**Earth Continuity Conductor**:

The wire running between the Distribution Board and various Plugs and appliances is known as Earth Continuity Conductor.

### Lightning Protection System

Copper lightning protection systems may be superior to other metals in both corrosion and maintenance factors. **NFPA 780** (Standard for the Installation of Lightning Protection Systems) should be considered as a minimum design standard. Fig (3.11).

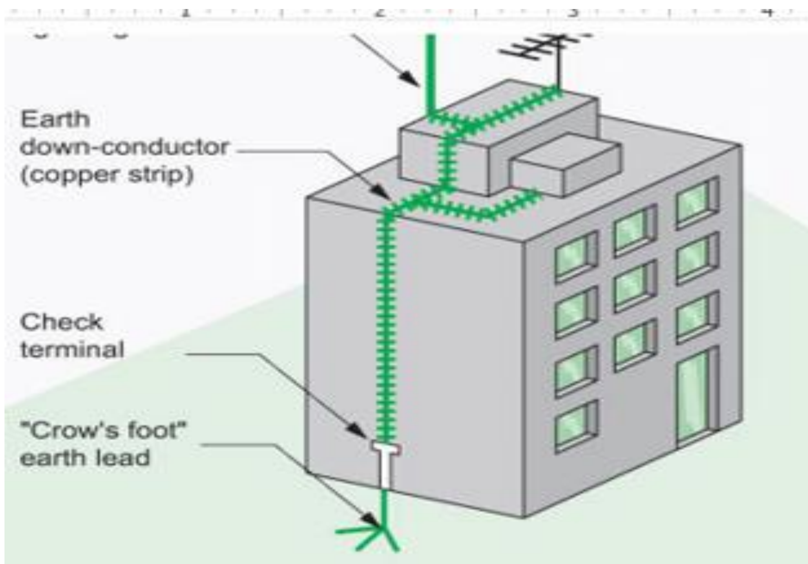



Fig (3.11) Lightning Protection System

According to Consult manufacturers' guidelines, generally, a surge protection device should not be installed downstream from an uninterruptible power supply (UPS).

## Earth Resistance Test

Earth resistivity is usually measured using Wenner method, which involves the use of four temporary **earth** spikes. The spikes do not need to be moved as part of the testing procedure however – their location and spacing is determined by the depth at which it is required to determine the earth resistivity. Fig (3.12)

## (1) Four Point Method (Wenner Method):

- This most commonly method used for measuring soil resistivity

### Required Equipment:

- Earth Tester (4 Terminal). * 4 No's of Electrodes (Spike).
- 4 No's of Insulated Wires. * Hammer. * Measuring Tap

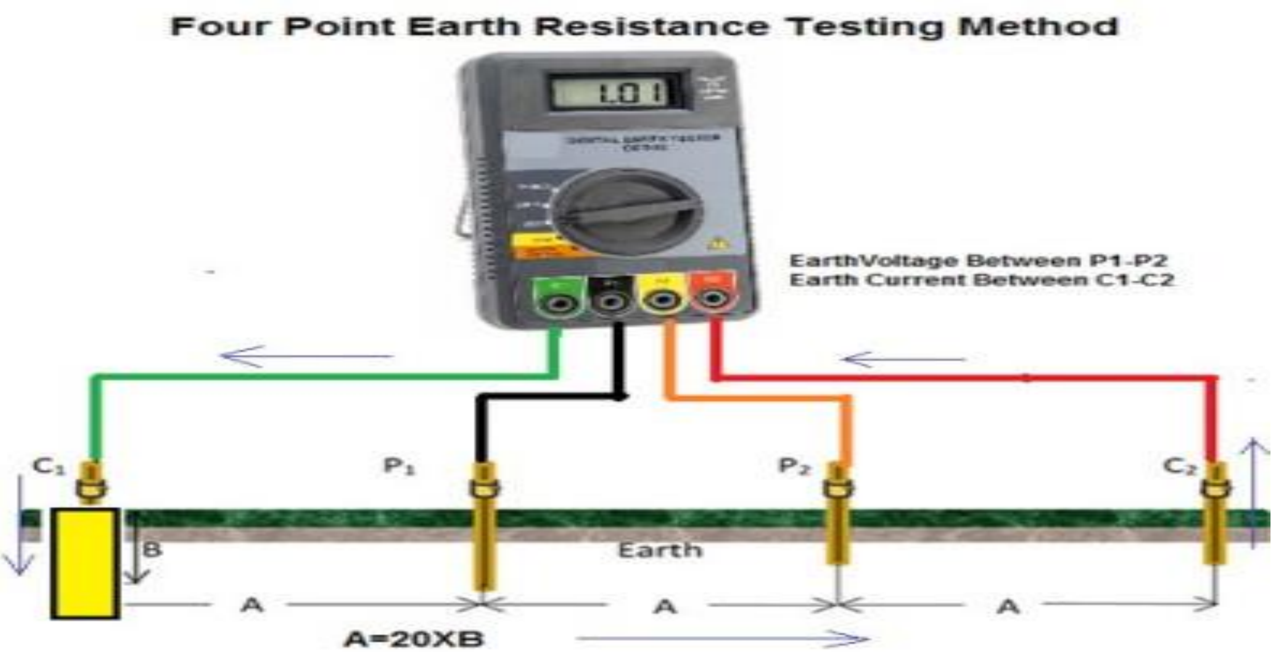



Fig (3.12) **Four Point Method (Wenner Method)**

**Earth Leakage Circuit Breaker System (**or ELCB)

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 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**

**principle working** is quite simple. One terminal of relay coil is connected to the equipment metal body which needed protected against **earth leakage** and other terminal is connected to earth directly. Fig(3 .13)

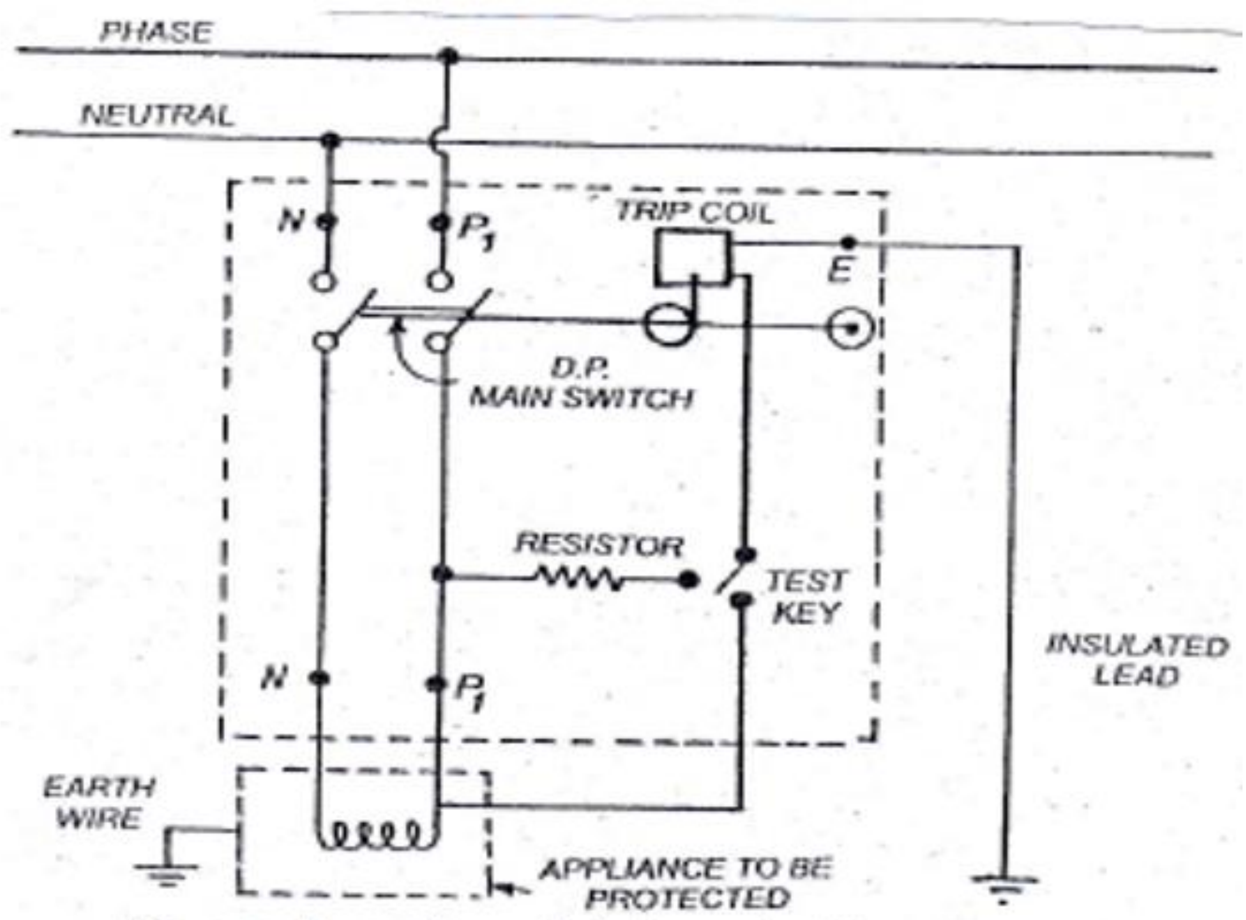



**Fig (3 .13) Single Phase Earth Leakage Circuit Breaker System**

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 of equipment.