Earthing - Types - Terms - Megger - Earth resistance Tester

Objectives: At the end of this lesson you shall be able to
- **explain the reasons for system and equipment earthing**
- **define the terminalogy related to earthing**
- **state and explain the methods of preparing pipe earthing and plate earthing, according to B.I.S. recommendations**
- **explain the procedure for reducing the resistance of earth electrodes to an acceptable value.**

Earthing:

Connecting the non-condutive metal body/parts of an electrical equipment and system to the earth through a low resistance condutor is called as **earthing**.

Earthing of an electrical installation can be brought under two major categories.

- System earthing
- Equipment earthing

System earthing: Earthing associated with current-carrying conductors is normally essential to the security of the system, and is generally known as system earthing.

System earthing is done at generating stations and sub-stations.

The purpose of system earthing is to:

- maintain the ground at zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied
- protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

In most cases such operation involves isolation of the faulty main or plant by circuit breakers or fuses. Earthing may not give protection against faults which are not essentially earth faults.

Equipment earthing: Earthing of non-current carrying metal work and conductor which is essential for the safety of human life, animals and property is generally known as equipment earthing.

Terminology

Trainees can be instructed to refer the international electro technical commission (IEC 60364-5-54) website for the standard safety rules related with earthing installation for the further details.

Dead: Dead' means at or about earth potential and disconnected from any live system.

Earth: A connection to the general mass of earth by means of an earth electrode. An object is said to be `earthed' when it is electrically connected to an earth electrode; and a conductor is said to be `solidly earthed' when it is electrically connected to an earth electrode.

Earth-continuity conductor (ECC): The conductor which connect the non-conductive metal part/body of an electrical system/equipment to the earth electrode is called as earth contained conductor.

Earth electrode: A metal plate, pipe or other conductor electrically connected to the general mass of the earth.

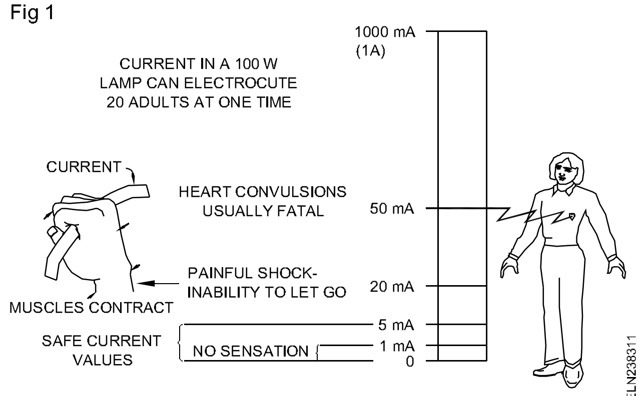
Earth fault: Live portion of an electrical system getting accidentally connected to earth.

Leakage current: A current of relatively small value, which passes through the insulation of conductive parts/ wire.

Step potential: The maximum value of the potential difference possible of being shunted by a human body between two accessible points on the ground separated by the distance of one step, which may be assumed to be one metre.

Touch potential: The maximum value of potential difference between a point on the ground and a point touched by a person.

Fig 1



Reasons for earthing: The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to a person or animal touching the metal part.

An electric shock is dangerous only when the current through the body exceeds beyond a certain milliampere value. In general, any current flow through the body beyond 5 milliamperes is considered dangerous. Fig 1 shows the magnitude of current and its effect.

However, the degree of danger is also dependent on the time during which it flows, and resistance of the body. In human beings, the resistance between hand and hand or between hand and foot can easily be as low as 400 ohms under certain conditions. Table 1 shows the body resistance at specified areas of contact.

Table 1

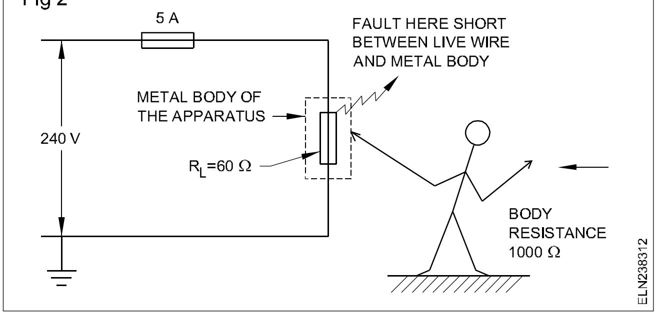
Skin conditon or area	Resistance value
Dry skin	100,000 to 600,000 ohms
Wet skin	1,000 ohms
Internal body-hand	400 to 600 ohms to foot
Ear to ear	about 100 ohms

CASE 1: **Metal body of apparatus when it is not earthed**

Let us consider a 240V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of cable makes the metal body live and the metal body is not earthed.

When a person, whose body resistance is 1000 ohms, comes in contact with the metal body of the apparatus which is at 240V, a leakage current may pass through the body of the person (Fig 2).

Fig 2



The value of current through the body = $\frac{V}{R_{Body}}$

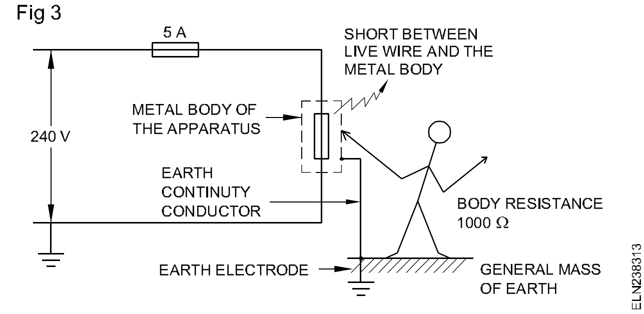
$$= \frac{240}{1000} = 0.24 \text{ amps or 240 milliamps.}$$

This current, as can be judged from Table 1, is highly dangerous, and might prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240V supply and may electrocute any person touching it.

CASE 2: **Metal body of apparatus when earthed.**

In case the metal body of the apparatus is earthed (Fig 3), the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.

Fig 3



Assuming that the sum of the resistace of the main cable, metal body, earth continuity conductor and the general mass of earth is to the tune of 10 ohms

$$\text{the leakage current} = \frac{V}{R_{Total}} = 240/10 = 24 \text{ amps.}$$

This leakage current is 4.8 times higher than the fuse rating, and, hence, the fuse will blow and disconnect the supply from the mains. The person will not get a shock due to two reasons. Before the fuse operates, the metal body and earth are in the same zero potential, and across the person, there is no difference of potential. Within a short (milli-seconds) time the fuse blows to open the defective circuit, provided the earth circuit resistance is sufficiently low.

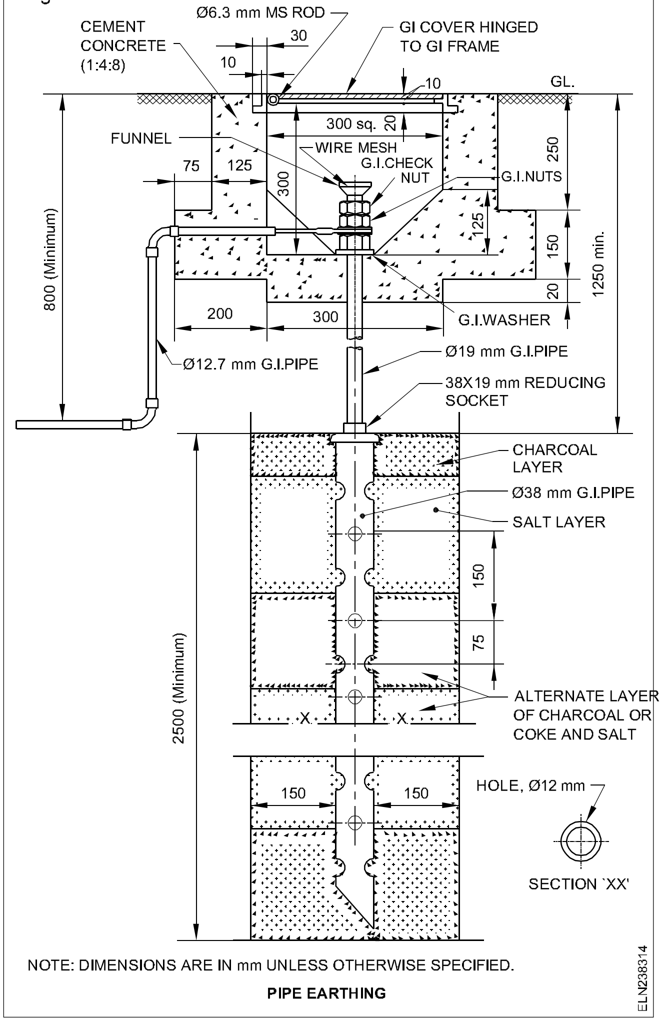
By studying the above two cases, it is clear that a properly earthed metal body eliminates the shock hazards to persons and also avoids fire hazards in the system by blowing the fuse quickly in case of ground faults.

Types of earth electrodes

Rod and pipe electrodes (Fig 4): These electrodes shall be made of metal rod or pipe having a clean surface not covered by paint, enamel or other poorly conducting material.

Rod electrodes of steel or galvanised iron shall be at least 16 mm in diameter, and those of copper shall be at least 12.5 mm in diameter.

Fig 4



PIPE EARTHING

Pipe electrodes shall not be smaller than 38 mm internal diameter, if made of galvanised iron or steel, and 100 mm internal diameter if made of cast iron.

Electrodes shall, as far as practicable, be embedded in earth below the permanent moisture level.

The length of the rod and pipe electrodes shall not be less than 2.5 m.

Except where rock is encountered, pipes and rods shall be driven to a depth of atleast 2.5 m. Where rock is encountered at a depth of less than 2.5 m, the electrodes may be buried, inclined to the vertical. In this case too, the length of the electrodes shall be atleast 2.5 m, and the inclination not more than 30^0 from the vertical.

Deeply driven pipes and rods are, however, effective where the soil resistivity decreases with depth or where a sub-stratum of low resistivity occurs at a depth greater than those to which rods and pipes are normally driven.

Pipes or rods, as far as possible, shall be of one piece.

For deeply driven rods, joints between sections shall be made by means of a screwed coupling,which should not be of a greater diameter than that of the rods which it connects together.

Plate electrodes (Fig 5): Plate electrodes,when made of galvanised iron or steel,shall not be less than 6.3 mm in thickness. Plate electrodes of copper shall be not less than 3.15 mm in thickness. Plate electrodes shall be of a size, at least 60 cm by 60 cm.

Fig 5

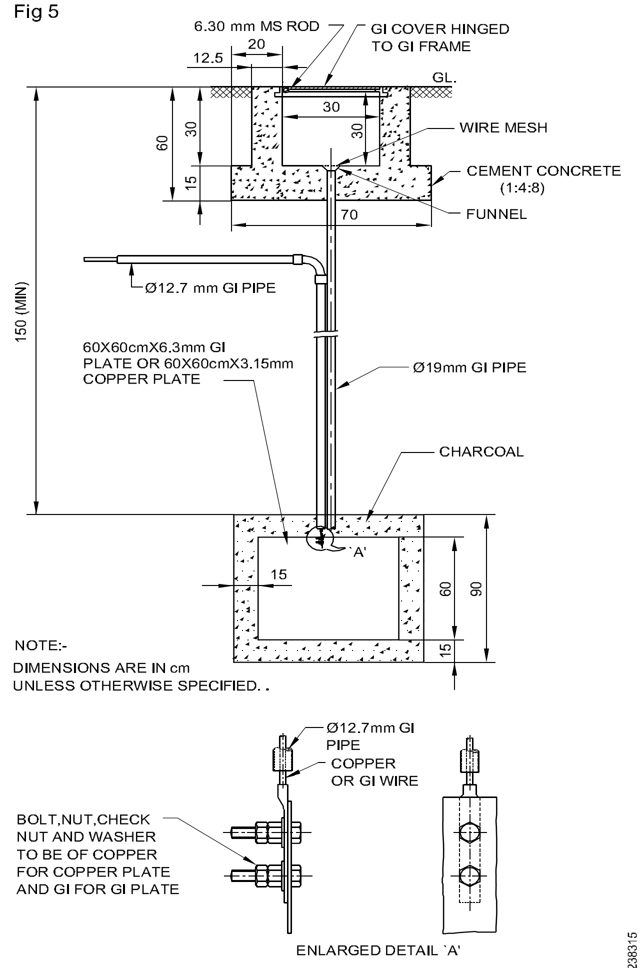


PLATE EARTHING

Plate electrodes shall be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground.

Where the resistance of one plate electrode is higher than the required value, two or more plates shall be used in parallel. In such a case, the two plates shall be separated from each other by not less than 8.0 m.

Plates shall preferably be set vertically.

Use of plate electrodes is recommended only where the current-carrying capacity is the prime consideration; for example, in generating stations and substations.

If necessary, plate electrodes shall have a galvanized iron water pipe buried vertically and adjacent to the electrode. One end of the pipe shall be atleast 5 cm above the surface of the ground, and it need not be more than 10 cm. The internal diameter of the pipe shall be atleast 5 cm and need not be more than 10 cm. The length of pipe, if under the earth's surface, shall be such that it should be able to reach the centre of the plate. In no case, however, shall it be more than the depth of the bottom edge of the plate.

Methods of reducing the resistance of an earth electrode to an acceptable value:

To achieve efficient operation of the protective devices, under fault condition the earth electrode resistance should be lower than an acceptable value which could be calculated from circuit details.

However, the earth electrode resistance is found higher in rocky or sandy areas where moisture is very low.

The following methods are suggested to bring down the earth electrode resistance to an acceptable value.

1 After installing the rod or pipe or plate in earth, the earth pit (the area surrounding the rod / pipe / plate) should be treated with layers of coke and common salt to get a lower value of earth resistance.

2 Pouring water in the earth pit at repeated intervals lowers the earth electrode resistance.

3 Connecting a number of earth electrodes in parallel reduces the earth electrode resistance. (Distance between two adjacent electrodes shall be not less than twice the length of the electrodes.)

4 Soldering the earth connections or using non-ferrous clamps lowers the earth electrode resistance.

5 Avoiding rust in the earth electrode connections lowers the earth electrode resistance.

Insulation resistance tester (Megger)

Objectives: At the end of this lesson you shall be able to
- **define megger**
- **state the working principle of an insulation tester (Megger)**
- **explain the construction and working of megger**
- **state the uses of an insulation tester like insulation test, continuity test etc.**
- **state the safety precautions to be observed while using an insulation tester.**

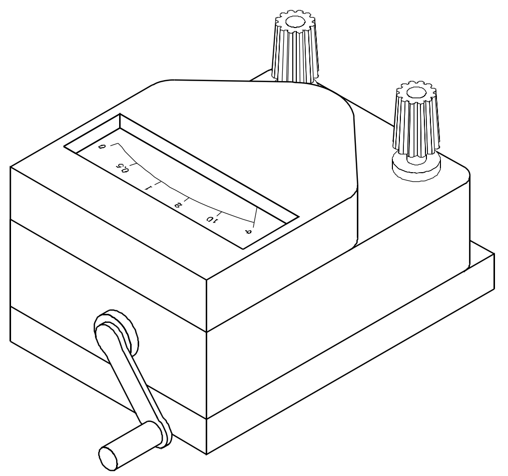
Megger

It is an electrical measuring instrument generally used to measure the insulation resistance of an installation/ equipment etc in terms of Megaohms.

Necessity of megohmmeter

Ordinary ohmmeters and resistance bridges are not generally designed to measure extremely high values of resistance. The instrument designed for this purpose is the megohmmeter. (Fig 1) A megohmmeter is commonly known as MEGGER.

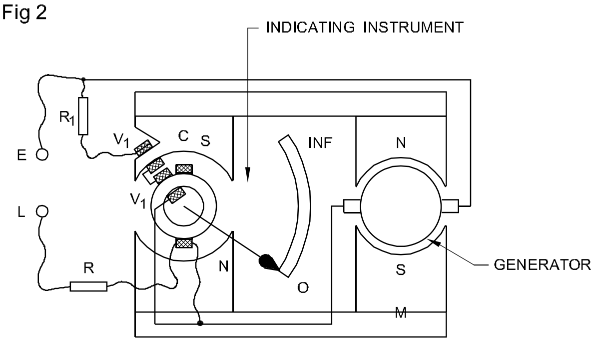
Fig 1



Construction

The megohmmeter consists of (1) a small DC generator, (2) a meter calibrated to measure high resistance, and (3) a cranking system. (Fig 2)

Fig 2



A generator commonly called a magneto is often designed to produce various voltages. The output may be as low as 500 volts or as high as 1 megavolt. The current supplied by the megohmmeter is in the order of 5 to 10 milliamperes. The meter scale is calibrated: kilo-ohms (K Ω) and megohms(MΩ).

Working principle

The permanent magnets supply the flux for both the generator and the metering device. The voltage coils are connected in series across the generator terminals. The current coil is arranged so that it will be in series with the resistance to be measured. The unknown resistance is connected between the terminals L and E.

When the armature of the magnet is rotated, an emf is produced. This causes the current to flow through the current coil and the resistance being measured. The amount of current is determined by the value of the resistance and the output voltage of the generator.

The torque exerted on the meter movement is proportional to the value of current flowing through the current coil.

The current through the current coil, which is under the influence of the permanent magnet, develops a clockwise torque. The flux produced by the voltage coils reacts with the main field flux, and the voltage coils develop a counter-clockwise torque.

For a given armature speed, the current through the voltage coils is constant, and the strength of the current coil varies inversely with the value of resistance being measured. As the voltage coils rotate counter-clockwise, they move away from the iron core and produce less torque.

A point is reached for each value of resistance at which the torques of the current and voltage coils balance, providing an accurate measurement of the resistance. Since the instrument does not have a controlling torque to bring the pointer to zero, when the meter is not in use, the position of the pointer may be anywhere on the scale.

The speed at which the armature rotates does not affect the accuracy of the meter, because the current through both the circuits changes to the same extent for a given change in voltage. However, it is recommended to rotate the handle at the slip speed to obtain steady voltage.

Because megohmmeters are designed to measure very high values of resistance, they are frequently used for insulation tests.

Connection for measurement

When conducting insulation resistance test between line and earth, the terminal 'E' of the insulation tester should be connected to the earth conductor.

Precautions

- A megohmmeter should not be used on a live system.
- The handle of the megohmmeter should be rotated only in a clockwise direction or as specified.
- Do not touch the terminals of a megohmmeter while conducting a test.
- Support the instrument firmly while operating.
- Rotate the handle at slip speed.

Uses of a megohmmeter

- Checking the insulation resistance
- Checking the continuity.

Specification of Megger :

Nowadays electronically operated, Meggers are available, called as push button type for general application and for industrial application motorised megger are also available. Hence a megger is basically specified based on the voltage generated by it .

example: 250 V, 500V, 1KV, 2.5KV, 5KV.

Earth resistance tester

Objectives: At the end of this lesson you shall be able to
- **state the necessity of earthing**
- **state the precautions to be followed while selecting a site for the earth electrode**
- **define earth resistance tester**
- **explain the principle constructon and working of an earth resistance tester**
- **explain the method of measuring the earth resistance**
- **state the IE rules pertaining to earthing.**

Necessity of earthing

Earthing the metal frames/casing of the electrical equipment is done to ensure that the surface of the equipment under faulty conditions does not hold dangerous potential which may lead to shock hazards. However, earthing the electrical equipment needs further consideration as to ensure that the earth electrode resistance is reasonably low to activate the safety devices like earth circuit leakage breaker, fuses and circuit breakers to open the faulty circuit and thereby protect men and material.

Precautions to be followed while selecting the site for earth electrode: However, even the earth electrode, either rod or plate type, implanted properly in the earth according to the specified recommendations is found to have high resistance resulting in failure of safety. This defect is mainly due to the soil and moisture condition. The explanation given below is to guide an electrician to select a proper site for providing an earth electrode so that the earth electrode resistance could be kept at a reasonable level.

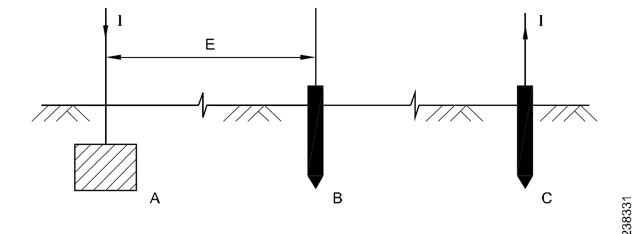
Necessity of measuring of earth electrode resistance: Physically an earth electrode may look alright, but its resistance may be high enough to damage the safety requirement. The only way to ensure the acceptable value of earth electrode resistance is to measure the resistance with the use of an earth resistance tester.

Earth resistance tester: It is an electrical measuring instrument used to measure the resistance between any two points of the earth. It is also called as earth tester. Even varieties of earth testers are available in market, the hand operated earth tester is explained below.

Principle: The earth tester works on the principle of the fall of potential method.

In this method the two auxiliary electrodes B and C are placed at a straight line (Fig 1).

Fig 1



FALL OF POTENTIAL METHOD

An alternating current of I_{amps} magnitude is passed through the electrode A to the electrode C via the earth and the potential across electrodes A and B is measured.

The resistance of electrodes B and C does not influence the measurement result.

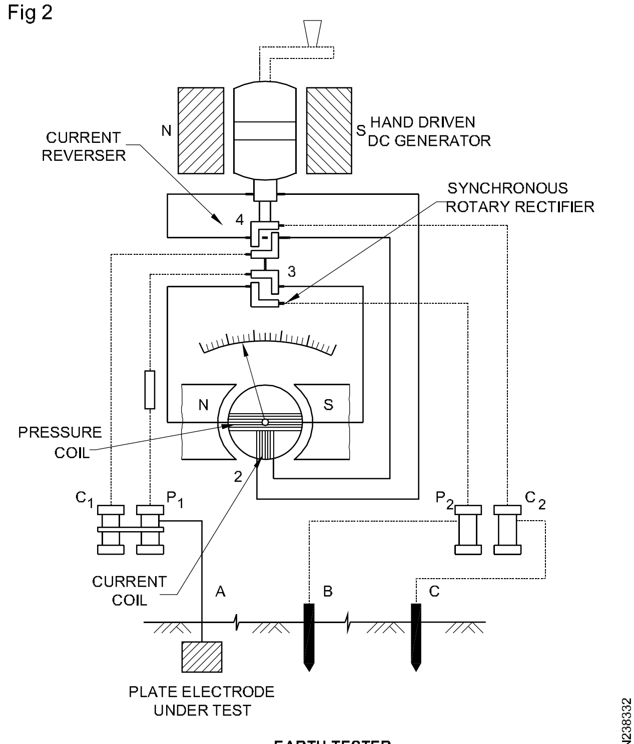
This is achieved by placing the electrode C at a sufficient distance from A so that the resistance areas of A and C are quite independent. A distance of above 15 metres between electrode A and C is regarded as sufficient distance.

Construction and working of earth tester : The earth tester essentially consists of a hand drive generator which supplies the testing current and a direct reading ohmmeter (Fig 2).

The ohmmeter section of this instrument consists of two coils (potential and current coils) kept at 90° to each other and mounted on the same spindle. The pointer is attached to the spindle. The current coil carries a current proportional to the current in the test circuit whereas the potential coil carries a current proportional to the potential across the resistance under test.

Thus the current coil of the instrument acts as an ammeter in the fall of potential method and the pressure coil acts as the voltmeter. Since the deflection of the ohmmeter needle is proportional to the ratio of the current in the two coils, the meter gives resistance readings directly.

Fig 2



EARTH TESTER

When DC is used in electrode resistance measurement the effect of electrolytic emf interferes with the measurement and the reading may go wrong. To avoid this, the supply to the electrodes should be AC.

To facilitate this the DC produced by the the hand generator is changed to AC through a current reverser. After the alternating current passes through the electrodes, the measurement should be done by an ohmmeter which requires DC supply.

To change the alternating voltage drop outside the instrument to direct voltage drop inside, a synchronous rotary rectifier is used (Fig 2)

Sometimes the meter needle vibrates during measurement due to the fact that strong alternating currents of the same frequency as the generated frequency enters the measuring circuit.

In such cases the handle rotating speed of the instrument may be either increased or decreased. In general these instruments are designed such that the readings are not affected by strong currents or by electrolytic emfs.

Method of earth resistance measurement: To measure the earth electrode resistance, the earth electrode is preferably disconnected from the installation. Then two spikes (the current and pressure spikes) are to be driven into the ground at a straight line at a distance of 25 metres and 12.5 metres respectively from the main electrode under test. The pressure and current spikes and the main electrode need to be connected to the instrument (Fig 1)

The earth tester has to be placed horizontally and is rotated at a rated speed (normally 160 r.p.m.). The resistance of the electrode under test is directly read on the calibrated dial. To ensure correct measurement, the spikes are placed at a different position around the electrode under test, keeping the distance the same as in the first reading. The average of these readings is the earth resistance of the electrode.

I.E. Rules pertaining to earthing

Earthing shall generally be carried out in accordance with the requirements of Indian Electricity Rules 1956, as amended from time to time, and the relevant regulations of the electricity supply authority concerned. The following Indian Electricity Rules are particularly applicable to both system and equipment earthing: 32,51,61,62,67,69,88(2) and 90.

Extracts from Indian Electricity Rules, 1956

Rule no. 32: **Identification of earthed and earthed neutral conductors and position of switches and cut-outs therein.**

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be compiled with.

1 An indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such a conductor to be distinguished from any live conductor. Such indication shall be provided:

   a) where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply

   b) where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor at the point where such connection is to be made.

2 No cut-out, link or switch other than a linked-switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two-wire system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:

   a) a link for testing purposes or

   b) a switch for use in controlling a generator or trans former.

Rule no.51: **Provisions applicable to medium, high or extra high voltage installations**

All metal work enclosing, supporting or associated with the installation, other than that designed to serve as ta conductor, shall, if considered necessary by the Inspector, be connected with earth.

Rule no.61: **Connection with earth**

1 The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage between phases or outers normally exceeds 125 volts and of systems at medium voltage.

   a) The neutral conductor of a three-phase four-wire system, and the middle conductor of a two-phase three-wire system shall be earthed by not less than two separate and distinct connections with earth both at the generating station and at the substation. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

   b) In the case of a system comprising electric sypply lines having concentric cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.

   c) The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

   d) In the case of an alternating current system, there shall not be inserted in the connection with earth any impedance (other than that required solely for the operation of switchgear or instrumets), cut-out or circuit-breaker, and the result of a test made to ascertain whether the current (if any) passing through the connection with earth is normal, shall be duly recorded by the supplier.

   e) No person shall make connection with earth by the aid of, nor shall keep it in contact with, any water main not belonging to him except with the consent of the owner thereof and of the inspector.

   f) Alternating current systems which are connected with earth as aforesaid may be electrically interconnected. Provided that each connection with earth is bonded to the metal sheathing and metallic armouring (if any) of the electric supply lines concerned.

2) The frame of every generator, stationary motor, and so far as is practicable, portable motor, and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulation or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.

3) All metal casings or metallic coverings contained or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction-boxes and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that where the supply is at low voltage, this sub-rule shall not apply to isolated wall tubes or to brackets, electroliers, switches, ceiling fans or other fittings (other than portable hand lamps and portable and transportable apparatus) unless provided with earth terminal.

Provided further that where the supply is at low voltage and where the installations are either new or renovated, all plug sockets shall be of the three-pin type and the third pin shall be permanently and efficiently earthed.

4) All earthing systems shall, before electric supply lines or apparatus are energised, be tested for electrical resistance to ensure efficient earthing.

5) All earthing systems belonging to the supplier shall, in addition, be tested for resistance on a dry day during the dry season not less than once every two years.

6) A record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Inspector when required.

Rule no.62: **Systems at medium voltage**

Where a medium voltage supply system is employed, the voltage between earth and any conductor forming part of the same system shall not, under normal conditions, exceed low voltage.

Rule no.67: **Connection with earth**

1) The following provisions shall apply to the connection with earth of three-phase systems for use at high or extra-high voltages:-

In the case of star-connected with earthed neutrals or delta-connected systems with earthed artificial neutral point

a) The neutral point shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station and at the sub-station and may be earthed at any other point, provided that no interference of any description is caused by such earthing;

b) in the event of an appreciable harmonic current flowing in the neutral connections so as to cause interference with communication circuits, the generator or transformer neutral shall be earthed through a suitable impedance.

2) In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be the one to be connected with earth.

3) Where the earthing lead and earth connection are used only in connection with earthing guards erected under high or extra-high voltage overhead lines where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage relays of a type and setting approved by the Inspector, the resistance shall not exceed 25 ohms.

Rule no.69: **Pole type substations**

1) Where platform type construction is used for a pole type substation and sufficient space for a person to stand on the platform is provided, a substantial hand rail shall be built around the said platform, and if the hand rail is of metal, it shall be connected with earth:

Provided that in the case of pole type substation on wooden support and wooden platform the metal hand-rail shall not be connected with earth.

Rule no.88: **Guarding**

1) Every guard-wire shall be connected with earth at each point at which its electrical continuity is broken.

Rule no.90: **Earthing**

1) All metal support of overhead line and metallic fittings attached thereto, shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected ordinarily at four points in every mile or 1.601 km, the spacing between the points being as nearly equidistant as possible. Alternatively, each support and metallic fitting attached thereto shall be efficiently earthed.

2) Each stay-wire shall be similarly earthed unless an insulator has been placed in at a height not less than 10 ft. from the ground.

The details of ELCB and relay are already discussed in the lession 2.2.70.