

Main board with MCB DB Switch and fuse box

Objectives: At the end of this lesson you will be able to

- state the I E regulations/ B I S recommendations/ NE Code of practice with regard to the main board and distribution fuse box.

Reception and distribution of main supply

There shall be a circuit breaker or a linked switch with fuse in each live conductor of the supply mains at the point of entry.

The neutral wire should not have any break in the form of switch or fuse unit. In the main switch, the neutral conductor should be marked clearly.

The main switchgear shall be located in a place where it is accessible and should be near to the terminating point of the service line.

Main switches and switchboards

Reference BIS 732-1963 and NE code.

All main switches shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply.

Location

Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing rooms or laundries, or in bathrooms, lavatories, toilets, or kitchens.

In the case of switchboards unavoidably fixed in places likely to be exposed to atmospheric weather, the outer casing shall be weatherproof and shall be provided with glands or bushings or adapted to receive screwed conduit, according to the manner in which the cables are run.

Metal-clad switchgears shall preferably be mounted on any of the following types of boards.

Hinged type metal boards

These shall consist of a box made of sheet metal not less than 2 mm thick and shall be provided with a hinged cover to enable the board to swing open for examination of the wiring at the back.

The joints shall be welded. The board shall be securely fixed to the wall by means of rag bolts, plugs, or wooden gutties and shall be provided with a locking arrangement and an earthing stud. All wires passing through the metal board shall be bushed. Alternatively, hinged type metal boards shall be made of sheet covering mounted on channel or angle iron frames.

Such types of boards are particularly suitable for small switchboards for mounting metal-clad switchgears connected to supply at low voltages.

Fixed type metal boards

These shall consist of an angle or channel iron frame fixed on the wall or on the floor and supported on the wall at the top, if necessary. There shall be a clear distance of one metre in front of the switchboard.

Such types of boards are particularly suitable for large switchboards for mounting large number of switchgears or higher capacity metal-clad switchgear or both.

Teak wood boards

For small installations connected to a single phase 240 volts supply, teak wood boards may be used as main boards or sub-boards. These shall be of seasoned teak or other durable wood with solid back impregnated with varnish of approved quality with all joints dovetailed.

Thoroughly protected both inside and outside with good insulating varnish conforming to IS:347-1952 and of not less than 6.5 mm thickness, shall be provided at the back for attachment of incoming and outgoing cables. There shall be a clear distance of not less than 2.5 cm between the teak wood board and the cover,

Recessing of boards

Where so specified, the switchboards shall be recessed in the wall. The front shall be fitted with a hinged panel of teak wood or other suitable materials, such as Bakelite, or with unbreakable glass doors in teak wood frames with locking arrangement, the other surface of the doors being flush with the walls. Ample room shall be provided at the back for connection and at the front between the switchgear mountings.

Arrangement of apparatus

Equipment which is on the front of a switchboard shall be so arranged that inadvertent personal contact with live parts is unlikely during the manipulation of switches, changing of fuses or like operation.

No apparatus shall project beyond any edge of the panel. No fuse body shall be mounted into 2.5 cm of any edge of the panel and no hole other than the holes by means of which the panel is fixed shall be drilled closer than 1.3 cm from any edge of the panel.

In every case in which switches and fuses are fitted on the same pole, these fuses shall be so arranged that the fuses are not live when their respective switches are in the 'off' position.

No fuses other than the fuses in the instrument circuit shall be fixed on the back of or behind a switchboard panel or frame.

Marking of apparatus

Where a board is connected to a voltage higher than 250 volts, all the apparatus mounted on it shall be marked in the following colours to indicate the different poles or phases to which the apparatus or its different terminals may have been connected.

Alternating current

Three phases – red, yellow and blue.

Neutral – black.

Where three-phase, 4-wire wiring is done, the neutral shall be in one colour and the other three wires in another colour.

Where a board has more than one switch, each such switch shall be marked to indicate which section of the installation it controls. The main switch shall be marked as such and where there is more than one main switch in the building, each such switch shall be marked to indicate which section of the installation it controls.

Main and branch distribution boards

The main and branch distribution boards shall be of any type mentioned here.

The main distribution board shall be provided with a switch or circuit-breaker on each pole of each circuit, a fuse on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

Branch distribution boards shall be provided with a fuse on the live conductor of each circuit and the earthed neutral conductor shall be connected to a common link and be capable of being disconnected individually for testing purposes. One spare circuit of the same capacity shall be provided on each branch distribution board. Lights and fans may be wired on a common circuit. Such sub-circuit shall not have more than a total of ten points of lights, fans and socket outlets. The load of such circuit shall be restricted to **800 watts**. If a separate fan circuit is adopted, the number of fans in the circuit shall not exceed ten.

Power sub-circuits

The outlet shall be provided according to the load design for these circuits but in no case shall there be more than two outlets on each circuit. The load on each power sub-circuit should be restricted to **3000 watts**.

Installation of distribution boards

- The distribution fuse-boards shall be located as near as possible to the centre of the load they are intended to control.
- Distribution boards shall be fixed at a height not more than 2 metres from the floor level.
- These shall be fixed on suitable stanchion or wall and shall be accessible for replacement of fuses.

- These shall be of either metal-clad type or all-insulated type. But, if exposed to weather or damp situations, they shall be of weatherproof type and, if installed where exposed to explosive dust, vapour or gas, they shall be of flame proof type.
- Where there are two or more distribution fuse-boards in feeding low voltage circuits and fed from a supply at medium voltage, these distribution boards shall be:
 - fixed not less than 2 m apart; or
 - arranged so that it is not possible to open two at a time, namely, they are interlocked and the metal case is marked 'Danger 415 Volts'; or
 - installed in a room or enclosure accessible to only authorized persons.
- All distribution boards shall be marked 'Lighting' or 'Power' as the case may be and also marked with the voltage and number of phases of the supply. Each shall be provided with a circuit list giving details of each circuit with controls, the current rating and its size of fuse-element.

Wiring of distribution boards

In wiring branch distribution board, the total load of the consuming devices shall be divided, as far as possible evenly between branch circuits.

Cables shall be connected to a terminal only by soldered or welded or crimped lugs using suitable sleeve or lugs or ferrules unless the terminal is of such a form that it is possible to securely clamp them without cutting away cable strands.

Fuses

- a A fuse carrier shall not be fitted with a fuse element of higher rating than that for which the carrier is designed.
- b The current rating of a fuse shall not exceed the current rating of the smallest cable in the circuit protected by the fuse.
- c Every fuse shall have in its own case or cover, or in an adjacent conspicuous position, an indelible indication of its appropriate current rating for the protection of the circuit which it controls.

Selection of size of conductor

The size of conductors of circuits shall be so selected that the drop in voltage from the consumer's terminals in a public supply (or from the bus-bars of the main switchboard controlling the various circuits in a private generation plant) to any point on the installation does not exceed 3 per cent of the voltage at the consumer's terminals.

In each circuit or sub-circuit the fuse shall be selected to match the cable rating to ensure the desired production.

All conductors shall be of copper or aluminium. The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area of not less than 1.00 mm² copper and 1.50 mm² aluminium. The cross-sectional areas of conductors for power wiring shall be not less than 2.5 mm² copper, 4.00 mm² aluminium. The minimum

cross-sectional area of conductors of flexible cords shall be 0.50 mm² copper.

Branch switches

Where the supply is derived from a three-wire or four-wire source and distribution is done on the two wire system, all the branch switches shall be placed in the outer or live conductor of the circuit and no single phase switch or fuse shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit.

Passing through walls and floors

Where conductors pass through walls the conductor shall be carried either in a rigid steel conduit or a rigid non-metallic conduit or in a porcelain tube of such a size which permits easy drawing in. The end of the conduit shall be neatly bushed with porcelain, wood or other suitable material. This steel conduit shall be earthed and securely bushed.

Where a wall tube passes outside a building so as to be exposed to the weather, the outer end shall be bell mouthed and turned downwards and properly bushed on the open end.

Fixing to walls and ceilings

Plugs for ordinary walls or ceilings shall be of well seasoned teak or other suitable hardwood not less than 5 cm long and 2.5 cm square on the inner end and 2 cm square on the outer end. They shall be cemented into walls to within 6.5 cm of the surface, the remainder being finished according to the nature of the surface with plaster.

In the case of new buildings, wherever possible, teak wood plugs shall be fixed in the walls before they are plastered. To achieve neatness, plugging of walls or ceilings may be done by a suitable type of asbestos, metallic or fibre fixing plug.



NE code of practice and IE Rules for mounting energy meter board

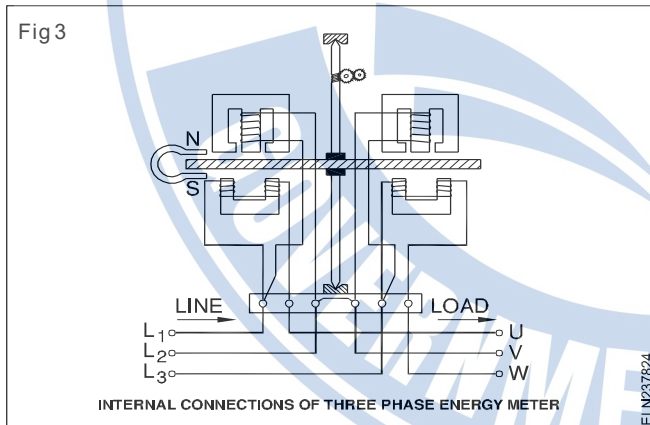
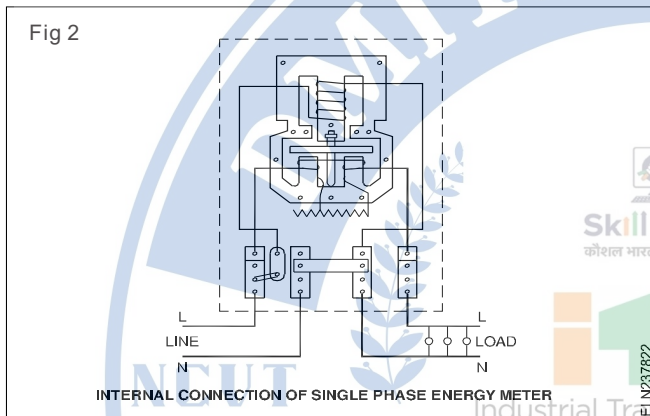
Objectives: At the end of the lesson you shall be able to

- state the BIS recommendations pertaining to the mounting of the energy meters.

The BIS symbols for energy meters are given in Figs 1a and 1b



Internal circuit diagrams of single phase and three phase meters are Fig 2 and 3 respectively.

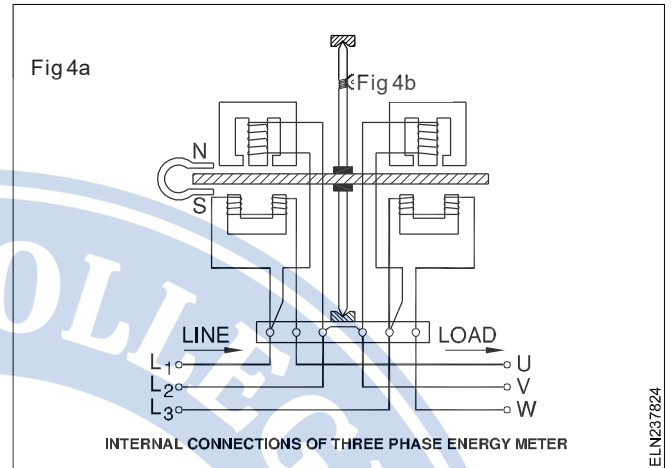


In earlier domestic installations the service mains were brought inside the consumer premises and first connected to the IC cutouts, then to the energy meter and to the consumer main switch (Fig 4a and 4b)

However, to avoid pilferage of electricity, certain electricity boards insist that the service connections should first be connected to the energy meter, then to the IC cutout and then to the consumer main switch. In all the cases the neutral should be directly connected from the outgoing terminals of the energy meter to the consumer main switch. (Fig 4b)

Precautions while installing energy meters

- Energy meters which are tested and approved by the local electricity board authorities only should be used.



- Energy meters should be used in vertical position only.
- Connections for incoming and outgoing supply should be made according to the manufacturer's instructions/ connection diagram which will be available on the inner side of the terminal plate of the energy meters.

NE code of practice and IE rules for energy meter installation

Energy meters shall be installed at such a place which is readily accessible to both the owner of the building and the authorised representatives of the supply authority.

It should be installed at a height where it is convenient to note the meter reading; it should preferably be not installed below 1 m from the ground. The energy meters should either be provided with a protective covering, enclosing them completely, except the glass window through which the readings are noted or should be mounted inside a completely enclosed panel provided with hinged or sliding doors with arrangement for locking it.

Any meter placed upon the consumer's premises shall be of appropriate capacity and shall be deemed to be correct if its limits of error do not exceed 3% above or below absolute accuracy at all loads in excess of one tenth of full loads and up to full load.

No meter shall register at no load.

General instructions : The body of the energy meter should be earthed to the general mass of earth using a proper size of earth continuity conductor depending upon the current capacity of the installation.

For multi-storeyed buildings which consist of a number of offices or commercial centres or flats occupying various areas, the electrical load for each of them is metered separately. In such cases, all the energy meters are located in a meter room which is normally situated on the ground floor.

Estimation of load, cable size, bill of material and cost for a wiring installation

Objectives: At the end of this lesson, you will be able to

- calculate the load(s) and select the number of sub(branch) circuits
- estimate the load in a circuit
- select proper cable size for branch main circuits and the supply system
- estimate and list out the accessories for given wiring installation.

A minimum of two lighting sub-circuits shall be provided in each house so that in case of fault in one sub-circuit, the whole house is not plunged in total darkness.

The load on power circuits should be restricted to 3000 watts having not more than two socket outlets.

Estimation of load requirements

Electrical installation in domestic dwellings is basically designed to cater to light and fan loads and for electrical appliances and gadgets. In estimating the current to be carried by any branch circuit, unless the actual values are known, these shall be calculated based on the following recommended ratings.

Item	Recommended rating (in watts)
Incandescent lamps	60
Ceiling fans	60
Table fans	60
6 A, 3-pin socket-outlet points	100
Fluorescent tube	40
Power socket outlets (16 A)	1000

Example

Estimate the cost of material for wiring PVC channel for an office room having 2 lamps 1 fan one 6A socket outlet.

To estimate the cost of material the electrician has to follow these steps:

Type of wiring to be decided- PVC channel (casing and capping - given).

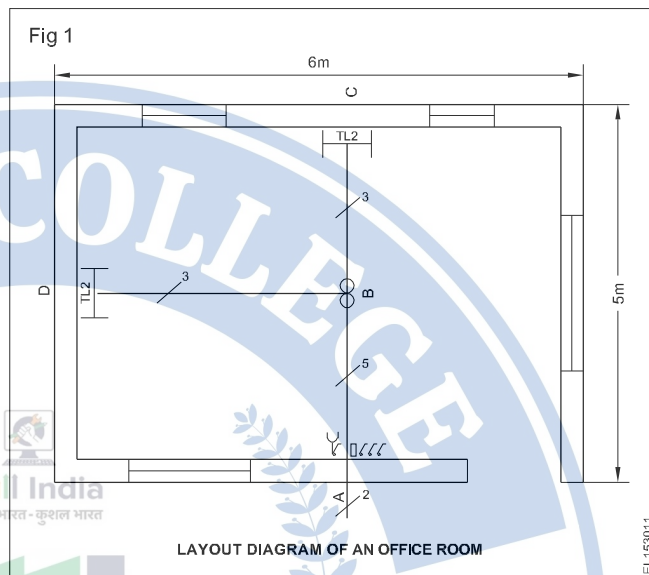
Position of the electrical points/Loads has to be decided as per the requirement.

Layout of the office has to be prepared (Fig 1).

Total load to be calculated, In the given example

- i Tube 2nos x 40 W = 80 W
 - ii Fan 1no x 60 W = 60 W
 - iii 6A socket 1 no = 100 W
- 240 W

circuit/connection diagram for the room has to be developed.



Based on the layout and circuit diagram calculate the length of PVC channel required.

- 1) Length of PVC channel in Roof = 5 + 3 = 8m
- 2) Vertical drops = 0.5 + 0.5 + 2.0 = 3.0m
- Total = 8 + 3.0 = 11.0 m
- 3) Add 10% tolerance = 1.1 m
- 12.1 m

Calculate the length of wire and size of wire based on layout, circuit diagram and load. In the given example, the total load is 240W the current taken by the total load are

$$I = \frac{P}{V \times \cos\theta} = \frac{240}{240 \times 0.8} = 1.25A$$

Hence PVC copper flexible 1sqmm wire is enough to this circuit/room. However since this wiring come in the category of commercial wiring, for safe-side, we can choose 1.5sq mm PVC insulated copper flexible wire.

Assume vertical drop is 0.5 m for tube lights and 2m for switch board then the length of wire required is

From A to B and vertical drop = (2.5 + 2)m x 5 = 22.5 m

From B to C and vertical drop = (2.5 + 0.5) m x 3 = 9m

From B to D
 vertical drop = (3 + 0.5)m x 3 = 10.5m
 total length = 22.5 + 9 + 10.5 = 42m
 add 10% tolerance = 42 + 4.2 = 46 m

The maximum number of wire runs in a PVC channel is 5 hence 19 mm x 10mm PVC channel may be used.

List of electrical accessories required with complete specification has to be prepared. Also calculate the cost of materials as per the present market rate.

SI No	Accessories	Length	unit price	price
1	PVC channel 19 mm x 10mm	12m		
2	1.5 sq mm PVC insulated copper flexible 650V	46 m		
3	Flush type SPT switch 6 A 250 V	4 No		
4	Flush type socket 6 A 250V	1No		
5	Wooden switch board 250mm x 150mm	1No		
6	Tube light fitting complete set 250V 4 feet 40W	2No		
7	Ceiling fan 250V, 1200 mm sweep	1 No		
8	electrcial fan regulator 250V , 60W	1No		
9	Wood screws 15 x 4mm, 25 x 5mm, 30 x 6mm	25 Nos each		
10	PVC insulation tape 19mm width 9m length	1No		
11	Ceiling rose 3 plate 250 V , 6 A	3No		
Total	Cost of the material required			

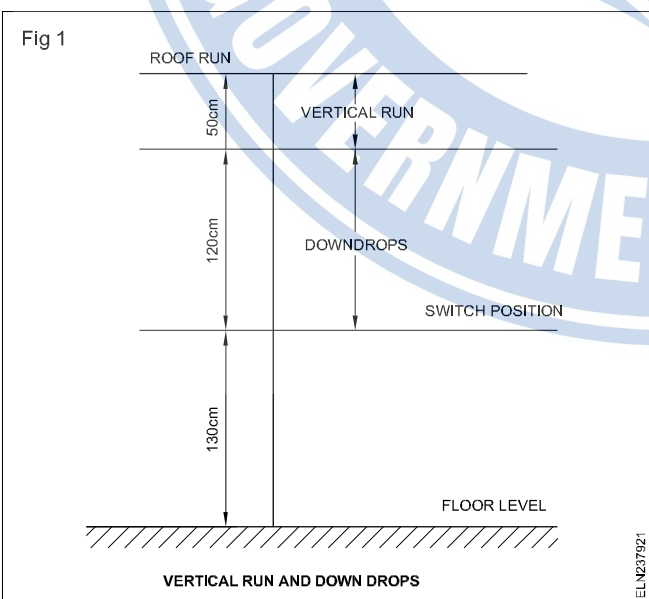
Estimation for 3 phase domestic and commercial wiring

Objectives: At the end of this lesson you shall be able to

- state specific rules related to 3-phase wiring installations
- estimate the wiring by load calculation, load distribution, layout diagram, wiring diagram, selection of cables, selection of conduit, calculation of conduit length, cable length, accessories required and the cost of wiring.

Estimation of wiring

Fig 1 shows the vertical and down drops and switch position measurement from the ground level.



Study the consumer's requirement of light, fan and power points in each room (Fig 2).

Required conduit length has to be calculated as per given method.

NE code recommends the horizontal run of cables should be at a height of 2.5m (250cm) and the height of switches from floor level should be 130cm. The example taken here for the roof height is 3m (300cm) from floor level. In all cases the dimension of the rooms should be available for estimating.

Vertical run : As such all vertical runs can be calculated as under (Refer Fig 4) for L₂ phase.

Length of selected conduit =

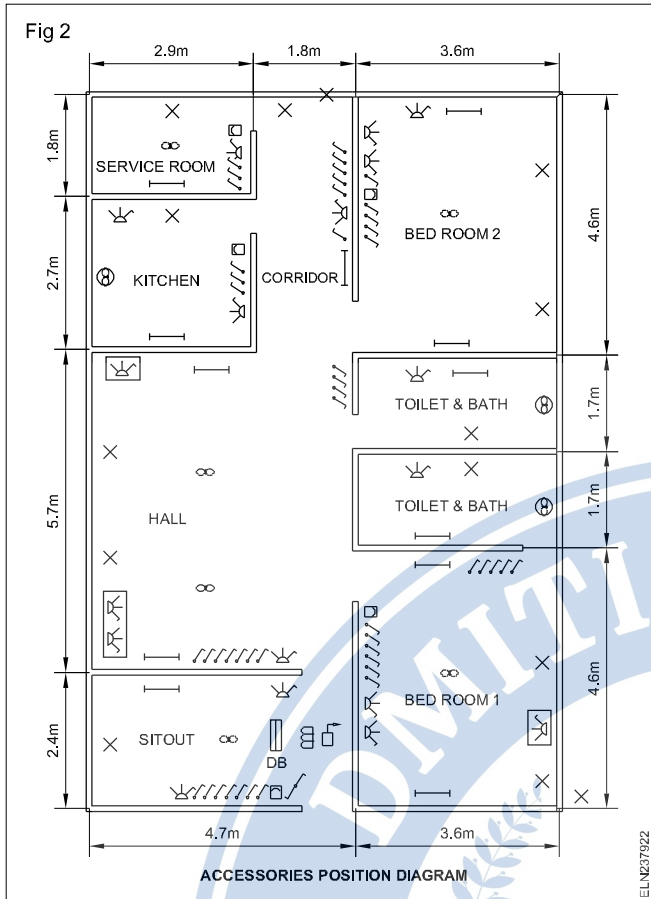
Roof height - (down drop + switch height) x No. of vertical runs

= 3m - (1.20m + 1.30m) x No. of vertical heights

= (3m - 2.5m) x No. of vertical heights

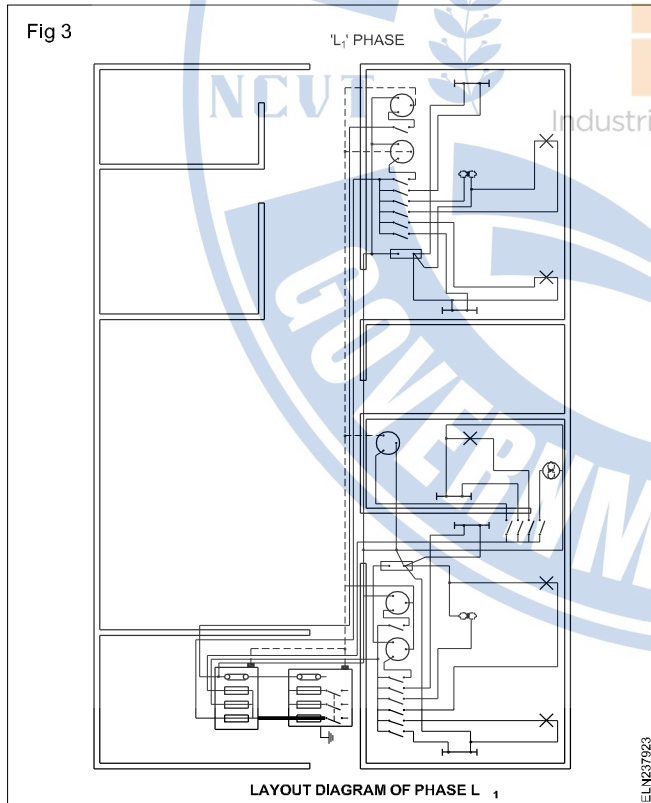
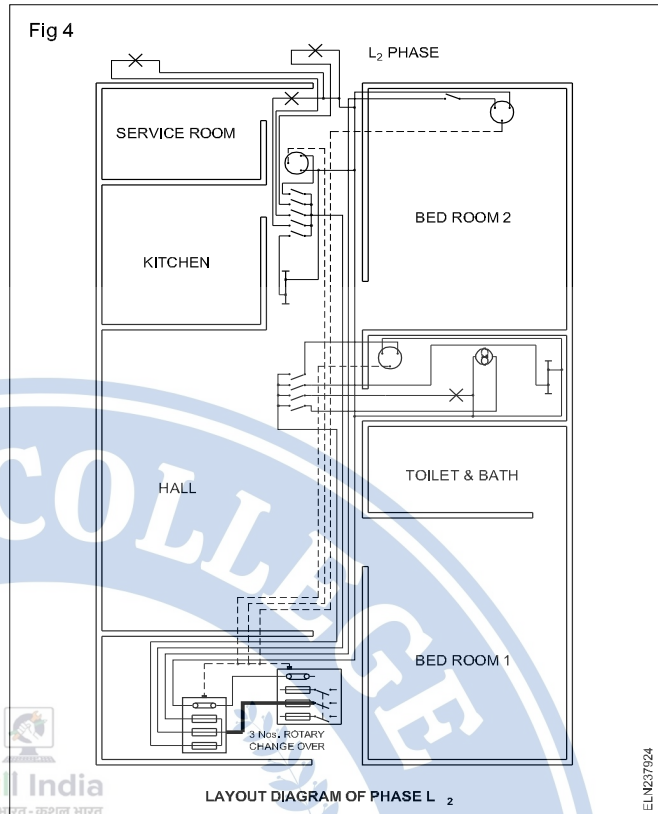
= 0.5m x No. of vertical heights (Eqn. 1)

The value 0.5m will change if there is difference in roof height and height of horizontal run of conduit changes.



$$= (2.5\text{m} - 1.3\text{m}) \times \text{No. of down drops for switches}$$

$$= 1.2\text{m} \times \text{No. of down drops to switches}$$



Length of conduit required for down drops

This could be calculated as under:

Length of selected conduit = Height of conduit in horizontal run - Switch position height x No. of down drops for switches

Length of conduit required for roof runs

This could be calculated as under

Length of selected conduit = Sum of the actual length of roof run taken in each case.

For each size the total requirement is to be calculated.

Length of conduit required for horizontal run

Length of selected conduit = sum of the actual length of horizontal run taken in each case.

Length of conduit required for the distance between main switch and DB is to be calculated. In most of the cases wall is thickness has to be taken into account.

Example : (Refer the layout and wiring diagram with respect to phase L₁) In all cases except for main switch and DB the cable used is 1/1.12 copper cable and maximum number of cable it can accommodate in 19mm conduit is 7 cables. Hence PVC conduit of 19mm is chosen.

1 Length of conduit required for vertical run

Length for vertical run = 0.5m x No. of vertical height

A careful study of layout indicates there are 8 vertical height runs

$$= 0.5\text{m} \times 8 = 4\text{m of 19mm PVC conduit}$$

2 Length of conduit required for down drops

Length of down drops = 1.2m x No. of down drops

A careful study of layout indicates there are 9 down drops = 1.2m x 9 = 10.8m

3 Length of conduit required for roof runs	+ F ₆ to L ₁₅ + F ₆ to L ₁₄	
Length of conduit = 2.35m + 2.35m + 2.35m + 2.35m + 1.45m + 0.9m = 9.75m	= + (3.6m + 1m) ² + (4.7m + 1m) ³	26.3m
4 Length of conduit required for horizontal runs	+ (0.36m + 0.5m) x 5 +	
Length of conduit = 4.7m + 3.6m + 1m + 1m + 1.2m + 4.7m + 2.4m + 1.35m + 1.2m + 2m + 2.35m + 5.7m + 2.9m + 2.9m + 1.35m + 2.7m + 2.5m + 1.45m + 1.8m + 1.45m = 48.25m	(1.2m + 3m + 1.2m) ²	15.1m
5 Length of conduit required for main switch and DB	+ (1.2m + 3m + 1.2m) ²	10.8m
If individual phase line is to be drawn through 19mm PVC conduit will be sufficient on the other hand if all three phase cables to be drawn through single pipe, the requirement to be calculated separately.	+ (1.2m + 4m + 1.2m) ⁵	32.0m
Assuming individual phases will be drawn through individual conduits the 19mm PVC conduit will be sufficient to draw two cables of sizes upto 1/2.8 or 7/1.06 aluminium and copper cables respectively.	+ (0.5m + 2.35m) ²	5.7m
Length of conduit required for the distance between main switch and DB: Length of conduit = wall thickness + allowance for connection = 0.36m + 0.5m + 0.5m = 1.36m	+ (1.2m + 2.35m) ³ + 2.35m x 2	15.35m
Total length of PVC conduit 19mm for wiring phase L ₁ as per layout and wiring diagram	+ (1.2m + m ² + 1.2m) ²	8.8m
= Vertical run + down drops + roof runs + horizontal runs + switch DB	+ (1.2m + 4m + 2m) ⁶	43.2m
= 4m + 10.8m + 9.75m + 48.25m + 1.36m = 74.16 m	+ (0.5m + 2.35m) ²	5.7m
Assuming 10% wastage, the total required length of 19mm PVC conduit will be 73.81m + 7.3m = 81.11m or say 80m	+ (1.2m + 1.5m) ²	5.4m
Calculation of length of cable required for wiring phase L₁: For calculating the length of cable accurately the layout and wiring diagrams should be referred. Selected cable in this case is 1 sq.mm copper cable.	+ (1.2m + 4m + 2m + 1.2m) ²	14.8m
Cable required = For outside runs ((L ₁ + L ₂ + L ₃ + L ₄) down drop + Horizontal run + switch board to outside wall (thickness of wall) + DB to switch board (DD + HR + DD) + Switch board to L ₅ + (DD + HR) + L ₅ to F ₁ (VR + RR) + L ₅ to L ₆ L ₇ (HR + HR) + DB to SB ₂ (DD + HR + DD) + SB ₂ to L ₉ (DD + HR) + L ₉ to F ₂ (VR + RR) + SB ₂ to S ₃ , S ₄ (DD + HR + DD) + L ₉ to L ₁₀ (HR) + L ₁₀ junction to F ₃ (VR + RR) + L ₁₀ junction to L ₁₁ (HR) + S ₃ , S ₄ to S ₅ (DD + HR + DD) + From DB to S ₆ (DD + HR + DD) + From S ₆ to L ₁₂ (DD + HR) + L ₁₂ to F ₅ (HR) + S ₆ to F ₄ (DD + HR + DD) + S ₆ to L ₁₃ (DD + HR) + S ₆ to S ₈ (DD + HR + DD) + S ₆ to S ₇ (DD + HR + DD) + S ₈ to F ₆ (DD + RR)	+ 2m x 4	8.0m
	+ (0.5m + 2.35m) ²	5.7m
	+ (2m + 2.5m) ²	9.0m
	+ (1.2m + 5m + 1.2m) ²	14.8m
	+ (1.2m + 4m + 5.7m + 2.9m + 2m + 1.2m) ²	34.0m
	+ (1.2m + 1.4m + 1.5m) ³	12.3m
	+ (1.5m + 1.35m) ²	5.7m
	+ (1.35m x 3m) + (1.35m x 2m)	6.75m
	+ (1.35m + 1.45m + 1.2m) ²	8.00m
	+ (1.2m + 1.4m + 0.9m + 1.2m) ²	9.4m
	+ (1.2m + 1.45m + 1.2m) ²	7.7m
	+ (1.2m + 1.45m) ³	7.95m
	+ 0.9m x 2m	1.8m
	+ 0.9m x 2m	1.8m
		325.95m
	Add 10%	32.59m
	Say 360m of 1 sq.mm copper	358.54m
	The length of the cable required for power circuit in phase L ₁ . The cable chosen is 4 sq.mm copper cable which can carry 24 amps	
	Total length of cable = (1.2m + 0.36m + 2.4m + 3.6m + 2.4m + 1.2m) ²	
	= 11.16m x 2	
	= 22.32m	
	Add 10% for wastage = 2.2m	
	24.52m	
	Say 25m of 4 sq.mm copper cable is required.	
	In the same way for the circuits in L ₂ and L ₃ phases should be calculated. After the list of accessories for entire wiring is prepared the cost of the accessories could be obtained from any local electrical dealer.	
	Instructor is requested to discuss with the trainees about the mandays required to complete the job alongwith the cost of labour.	
	Total cost of wiring compris of following components.	
	Total cost of wiring = cost of the accessories	
	+ cost of cable	
	+ cost of conduit	
	+ cost of hardware items	
	+ labour cost	

Estimation of cost for workshop wiring

Objectives: At the end of this lesson you shall be able to

- calculate the full load current and size of cables
- estimate the cost for workshop wiring
- tabulate the material required.

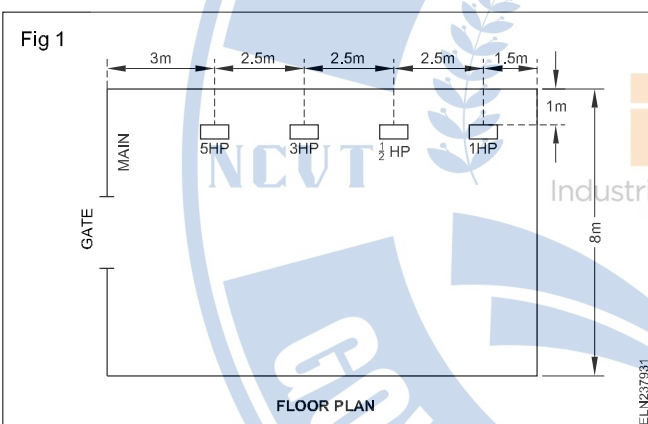
The trainees can be instructed to estimate the cost of materials for the workshop wiring. Some of the guidance are given below for the trainees and instructor reference.

A sample requirement is given below for trainee's reference

- 1 One 5HP, 415V 3 phase motor
- 2 One 3HP, 415V 3 phase motor
- 3 One ½ HP, 240V 1 phase motor
- 4 One 1HP, 415V 3 phase motor

The motors are to be arranged in row (Fig 1).

The main switch, motor switch and starters are to be mounted at a height of not more than 1.5m from the ground level and the height of horizontal run from ground level will be 2.5 m.



Calculation for the size of cable:

Assuming the motor efficiency to be 85% and the power factor to be 0.8 for all the motors and the supply voltage is 400V.

$$\text{FL current of 5HP motor} = \frac{5 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 7.8 \text{ A}$$

$$\text{FL current of 3HP motor} = \frac{3 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 4.68 \text{ A}$$

$$\text{FL current of } \frac{1}{2} \text{ HP motor} = \frac{0.5 \times 735.5}{240 \times 0.85 \times 0.8} = 2.25 \text{ A}$$

$$\text{FL current of 1HP motor} = \frac{1 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 1.56 \text{ A}$$

The main switch and the cable from meter to main switch should be capable of handling starting current of one motor of high rating plus full load current of the all other motors.

$$\text{i.e., } 15.6 + 4.68 + 2.25 + 1.56 = 24.19 \text{ A}$$

Assuming the starting current of each motor will be two times of their full load current Table 1 gives cable size of each motors to be installed for guidance.

Table - 1

Sl. No.	Motor	FL current I_L in Amp	Starting current $I_s = 2I_L$ in Amp	Recommended cable size
1	5HP motor	7.5	15.6	2.0mm ² copper conductor cable (17A) or 2.5mm ² aluminium conductor cable (16A)
2	3HP motor	4.68	9.36	2.0mm ² copper conductor cable (17A)
3	1/2 HP motor	2.25	4.5	1.0mm ² copper conductor cable (11A) minimum recommended cable
4	1HP motor	1.56	3.12	1.0mm ² copper conductor cable (11A) minimum recommended cable

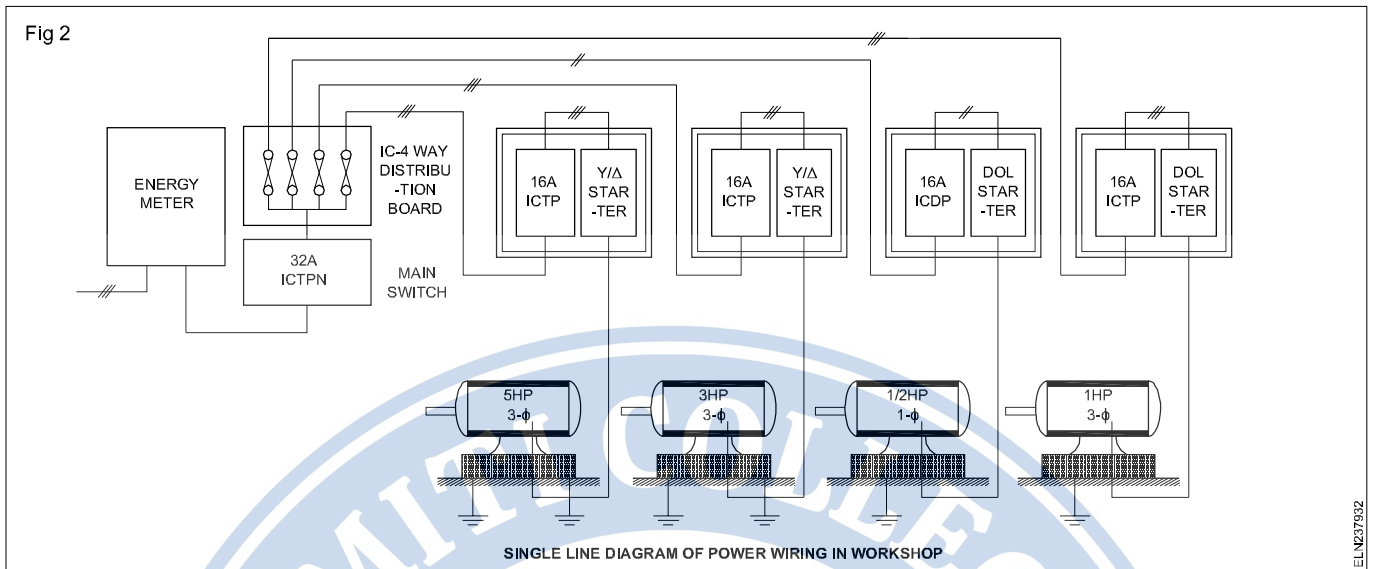
The type and gauge of cable shall be selected by referring the table - 1

Some guidance are given below to select the suitable switches and distribution board for trainees reference.

- A 32A, 415V ICTP switch with fuses can be used as main switch.
- 16A, 415V, ICTP switches with fuses can be used for 5HP, 3HP, & 1HP motors.

- 16A, 240V, ICDP switch with fuses can be used for ½ HP motor.
- 415V, 4 way, 16A per way IC distribution board with neutral link can be used for power distribution.

The single typical line diagram of power wirings (Fig.2)



Calculation for the sizes and length of conduit:

19mm heavy gauge conduit should be used for 3 cable runs and 24.4 mm heavy gauge conduits should be used for 6 cable runs.

- 19 mm heavy gauge conduit

Length from main board to 5HP motor starter = $1+1+3+1 = 6.0m$

Length from main board to 3HP motor starter = $1+1+5.5+1 = 8.5m$

Length from main board to ½ HP motor base = $1+1+8+1+1.5+1.5 = 14.0m$

Length from main board to 1HP motor base = $1+1+10.5+1+1.5+1.5 = 16.5m$

Total = 45.0 m

10% wastages = 4.5m

Total length = 49.5m, say 50.0m

- 25.4 mm heavy gauge conduit.

Length from meter to main switch = 0.75 m

Length from 5HP motor starter to 5HP motor base (1.5 + 1.5) 3.0 m

Length from 3HP motor starter to motor base = 3.0 m

Total = 6.75 m

10% wastage = 0.67 m

Total = 7.42m, Say 8.0m

- 25.4 mm flexible conduit for 5HP & 3 HP motor (0.75+0.75) = 1.5, Say 2.0m

- 19mm flexible conduit for 1/2 HP & 1 HP motor (0.75+0.7) = 1.5, Say 2.0m

Calculation for the length of cables:

2.0mm² copper conductor from main board to 5HP motor terminals = $3(1+1+3+1) + 6(1.5+1.5+0.75) = 40.5m$

15% wastages & end connections = 7.2 m

Total = 47.7m , Say = 48.0m

1.0mm² copper conductor from main board to 1/2 HP motor terminals = $2(1+1+8+1+1.5+1.5+0.75) = 29.5 m$

15% wastages & end connections = 7.76m

Total = 37.26m, Say 38m

Trainees may be instructed to tabulate the list of materials.

Testing a domestic wiring installation - location of faults - Remedies



Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to

- state the type of test to be carried out in wiring installations and explain the procedure of conducting them
- determine the condition of installation and the method of improving the condition.

General requirement of inspection and tests (Ref: B.I.S.732-(Part III) 1982.)

Before a completed installation or an addition to the existing installation is put into service, inspection and testing shall be carried out in accordance with the Indian Electricity Rules, 1956. In the event of defects being found, these shall be rectified as soon as practicable, and the installation re-tested.

Items to be inspected in a lighting circuit

Lighting circuits: The lighting circuits shall be checked for ensuring the following.

- Neutral links are provided in double pole switch-fuses which are used for lighting control, and no fuse is provided in the neutral.
- The plug points in the lighting circuit are all of 3-pin type, the third pin being suitably earthed.
- A separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipment.
- Proper connectors and junction boxes are used wherever joints are to be made in conductors or when cross-over of conductors takes place.
- Clear and permanent identification marks are painted in distribution boards.
- The polarity having been checked, all fuses and single pole switches are connected on the phase conductor only and wiring is correctly connected to the socket-outlets.
- The ends of the conduits enclosing the wiring leads are provided with ebonite or other suitable bushes.
- Proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals.
- The number of wires in a conduit conforms to the provisions of Part II of BIS 732.

Testing of installation: After inspection, the following tests shall be carried out, before an installation or an addition to the existing installation is put into service.

- 1 Continuity or open circuit test
- 2 Polarity test
- 3 Earth and ground test
- 4 Insulation and leakage test:
 - between conductors
 - between conductors and earth.

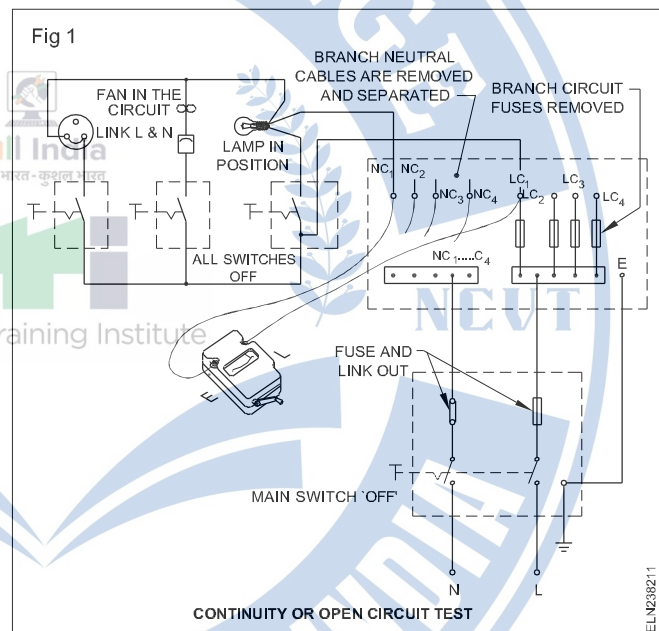
Continuity or open circuit test: This test is carried out to check the continuity of cables in the individual sub-circuits.

Before conducting this test, the main and all the distribution circuit fuses should be removed.

The phase and the neutral of the individual circuits should be identified from the distribution board and segregated.

Place all bulbs in position, connect fans to respective ceiling roses, regulators and switches, short all socket outlets by linking the phase and neutral.

Connect the Megger terminals E and L to the individual circuit phase and neutral (Fig 1) and rotate the Megger.



By switching the switches ON and OFF one by one, the Megger should show zero reading and infinity alternatively. The two-way switches may have to be operated alternatively to ensure the correct test results.

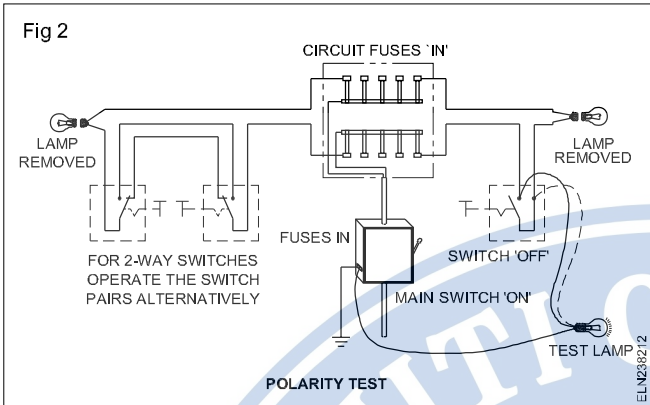
If the Megger shows no continuity in the 'ON' condition of the switch, then the particular circuit is deemed to be open. On the other hand, if the Megger shows continuity in both the 'ON' and 'OFF' positions of the switch, this indicates short in the particular circuit.

Remember to remove all the shorting links at socket points and to connect the phase to the fuse, and neutral to the link, before switching 'ON' the supply.

Polarity test: This test is conducted to check whether switches are connected in phase/live cable or not.

For conducting this test, the lamps are removed from the lamp-holders, the fan regulators are kept in the 'OFF' position and the fuses inserted in the main and distribution boards.

Remove the switch covers and switch 'ON' the supply. Connect one end of the test lamp to the earth continuity conductor and the other end of the test lamp to the switch terminals alternatively (Fig 2).

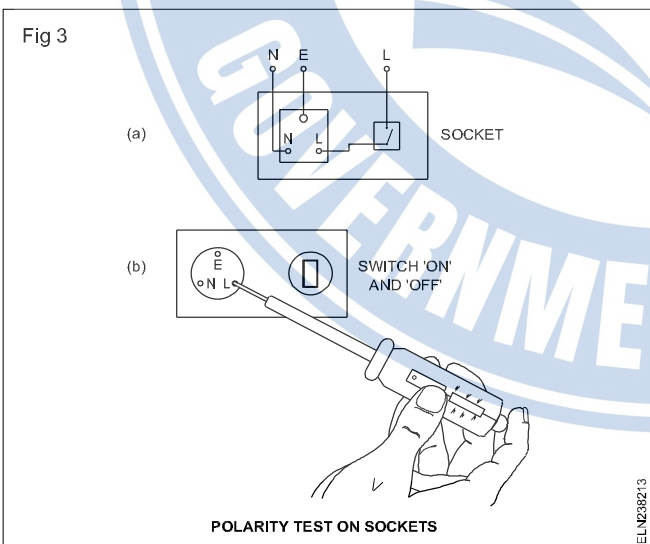


Lighting of the test lamp indicates that the phase or live cable is controlled by the switch.

A further polarity test should be done on the sockets to verify whether

- The phase wire is connected to the right side hole of the socket (Fig 3a).
- The switch controls the phase wire.

For this test, a neon tester could be inserted in the right side hole of the socket as shown in Fig 3b and the control switch is switched 'ON'. Lighting of the neon tester when the switch is 'ON' and no light when the switch is 'OFF' indicate correct polarity. This test is a must, in all old or new wiring installations as a safety measure.



Insulation tests in wiring installation (BIS 732 (Part II) - 1982.)

The following tests shall be done:

Insulation resistance between conductors and earth: For this test, put 'OFF' the main switch and remove the main fuse-carrier. All distribution fuses should be 'IN'; the

lamps should be in their holders and all switches for fans and lights should be in the 'IN' position. Unplug all the appliances from the sockets, and short the phase and neutral of the sockets with a jumper wire.

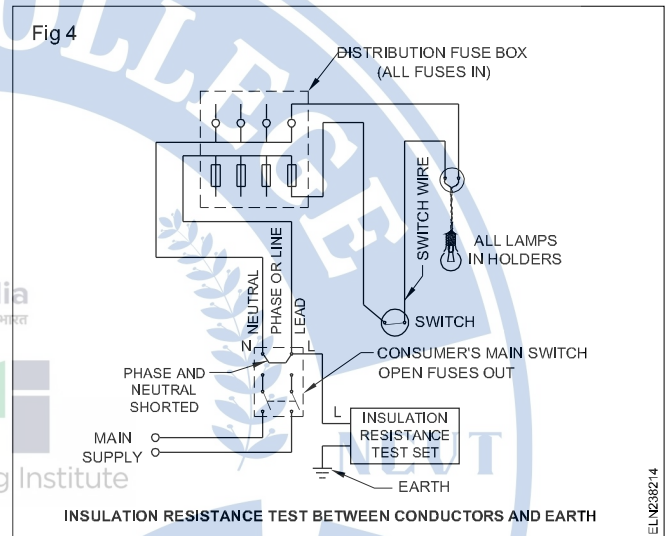
Connect the phase and neutral cables at the outgoing terminals of the main switch together, and connect the lead of the Megger terminal to the shorted cables. (Fig 4) Connect the other lead of the Megger to the earth connection and rotate the Megger at its rated speed.

The reading thus obtained should not be lower than the lowest of the values obtained in these three methods.

Method 1 - Standard value as per B.I.S.

Standard value of insulation resistance

$$= \frac{50}{\text{No. of points in the circuit}} \text{ Mega ohms}$$



where the switch, the lamp-holder and the socket are taken as individual points.

In case, the wiring is done in PVC insulated cables, 50 should be replaced by 12.5.

Method 2 - I.E. rules state that the leakage current in an installation should not exceed 1/5000th part of the full load current of the installation.

Applying this, the value of insulation resistance

$$= \frac{\text{Supply voltage in volts}}{\text{Leakage current}} \text{ ohms}$$

$$= \frac{\text{Supply voltage in volts} \times 5000}{\text{Full load current of the installation}}$$

Where leakage current

$$= \text{Full load current of the installation} \times \frac{1}{5000}$$

Hence the insulation resistance

$$= \frac{\text{Supply voltage in volts} \times 5000 \times 10^{-6}}{\text{Full load current of the installation}} \text{ Megaohms}$$

Method 3 - Thumb rule

The measured insulation resistance of an installation should not be less than one megohm.

Insulation resistance between conductors: For this test, switch off the mains and remove the fuse-carriers.

Remove all lamps from their holders, disconnect all appliances and keep all switches in the ON position.

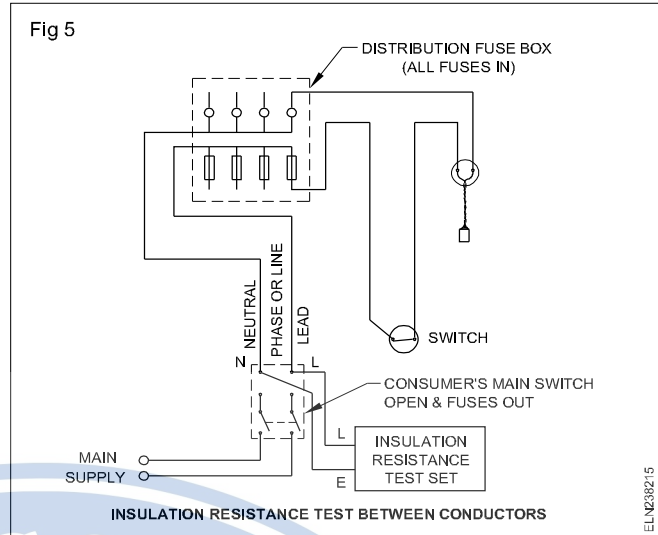
Keep all the distribution fuses in position.

Connect one test prod of the Megger to the phase cable and the other to the neutral (Fig 5).

Rotate the Megger and measure the insulation resistance in megohms.

The reading in megohms should not be less than the lowest of the readings obtained in any one of the three methods, stated under 'Insulation resistance between conductors and earth.'

Inspection, testing and improving the condition of wiring installations



The table given below shows the test results, and the methods to improve the conditions of the wiring installations.

Test Results and Methods for Improving the conditions

S. No.	Test Conducted	Test results	Method of Improvement
1	Continuity or open circuit test	a) Zero reading b) Higher reading in terms of kilohms or megohms	a) Ok. b) Operate each individual switch in the circuit. Where the reading jumps to a higher value, there will be an open circuit, either by fused bulbs or loose connections at the terminals or break in the wire. After identifying the subcircuit, check the continuity of cables in the smaller zones till the defect is detected and rectified. Where 2-way switches are encountered, operate the switches one by one to detect the fault.
2	Polarity test	a) Polarity was found wrong throughout the installation. b) Polarity found wrong in one or two sockets.	a) Switch off the mains. Remove the fuse-carrier. Interchange the output terminals at ICDP switch or at DB. b) See that the phase is connected to the right side terminal of the socket.
4	Insulation test between conductors and earth (or) between the phase and neutral	a) 1 megohm or above b) Less than 1 megohm	a) Ok. Check the value of the insulation resistance by the formula $\text{Megohms} = \frac{50}{\text{No. of outlets}}$ For PVC wired installation replace 50 by 12.5. In case the measured value of insulation resistance is equal to or more than the calculated value, the insulation is OK. b) Otherwise locate the fault by sectionalising the zone and replacing the defective cable with a good one. If, however, the values obtained are not sufficiently high, withdraw all the fuses of the distribution fuse-board and test again. This test will include only that portion of the installation between the main switch and the distribution fuse-board. If the fault does not lie in this section, proceed to the distribution fuse-board, and test each branch circuit in turn till the faulty circuit or circuits are discovered.

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 terminology 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-conductive metal body/parts of an electrical equipment and system to the earth through a low resistance conductor 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 substations.

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.

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.

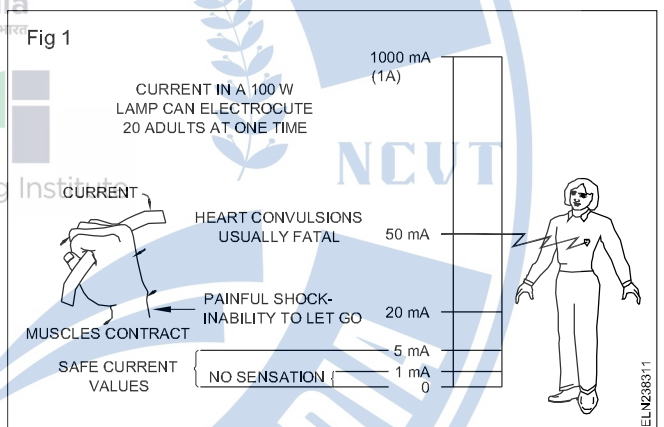
Earth-continuity conductor (ECC): The conductor which connect the non-conductive metal part/body of an electrical system/equipment to the earth electrode is called as earth contained conductor.

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.

Fig 1 shows the magnitude of current and its effect



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

Table 1 shows the body resistance at specified areas of contact.

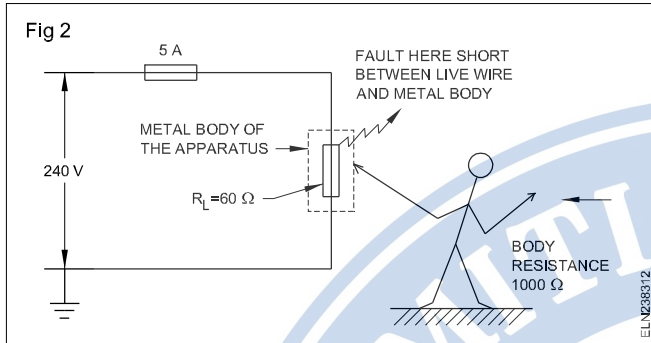
Table 1

Skin condition 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).



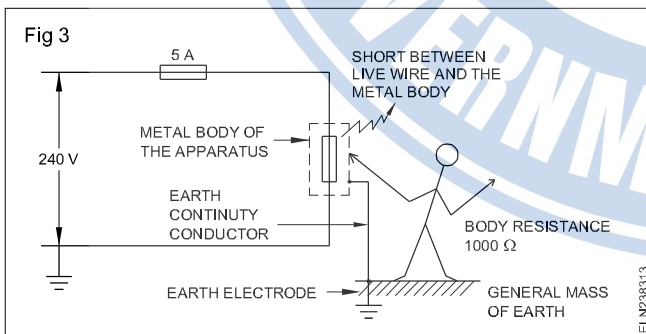
The value of current through the body = $\frac{V}{R_{\text{Body}}}$

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

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.



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

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

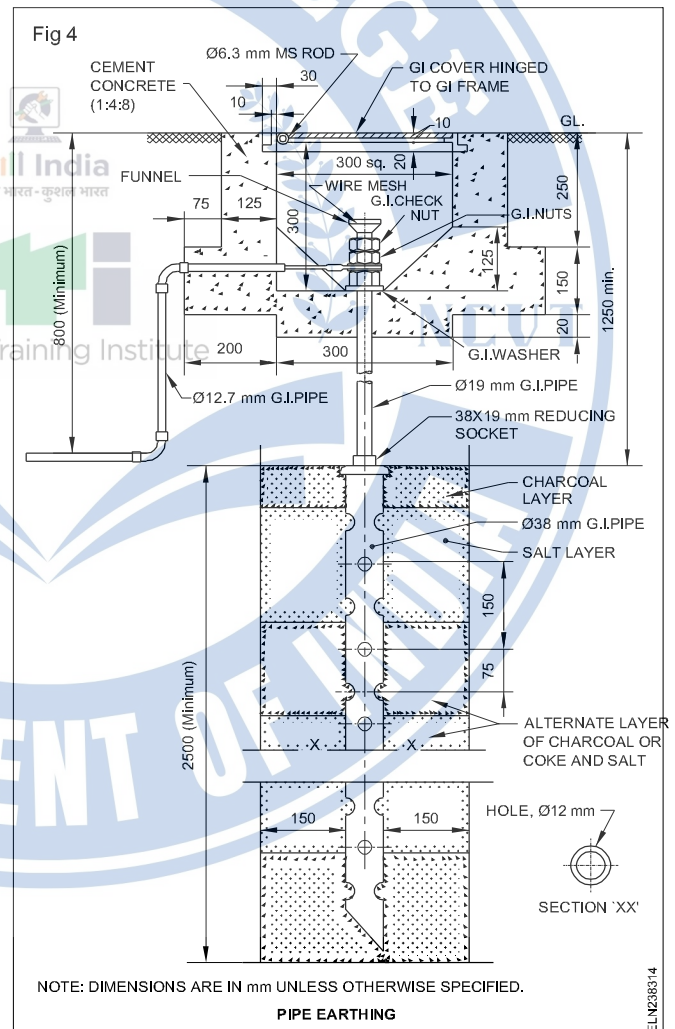
This leakage current is 4.8 times higher than the fuse rating, and, hence, the fuse will blow and disconnect the supply from the mains. The person will not get a shock due to two reasons. Before the fuse operates, the metal body and earth are in the same zero potential, and across the person, there is 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.



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 at least 2.5 m. The length of the electrodes shall be at least 2.5 m, and the inclination not more than 30° from the vertical.

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.

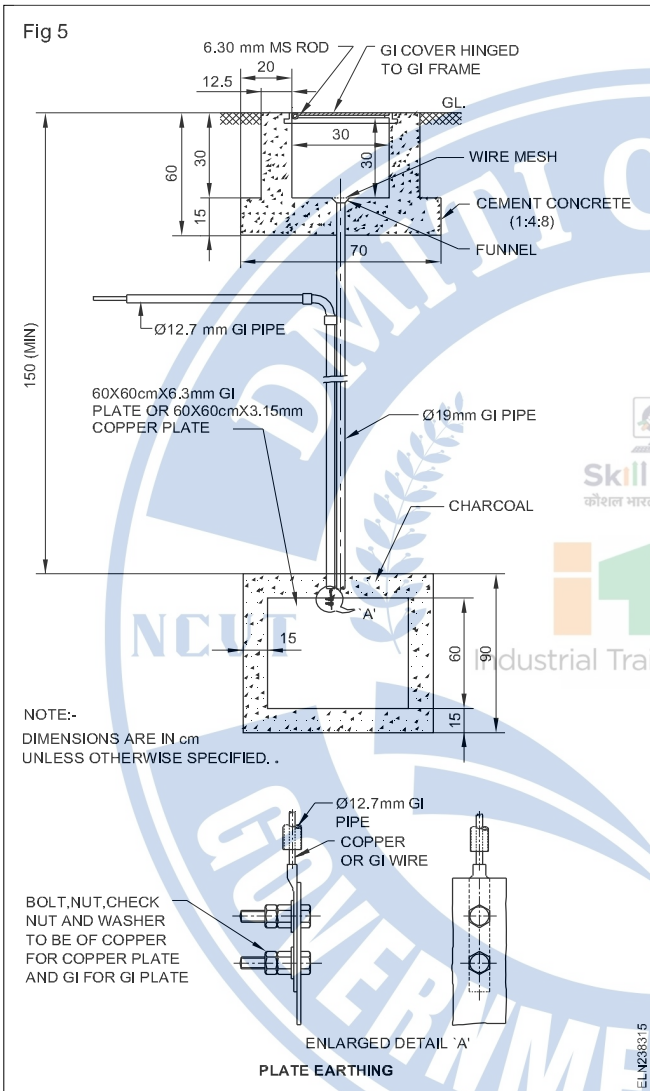


Plate electrodes shall be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground.

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.

Plate electrodes is recommended 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 at least 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 at least 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:

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.
- 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

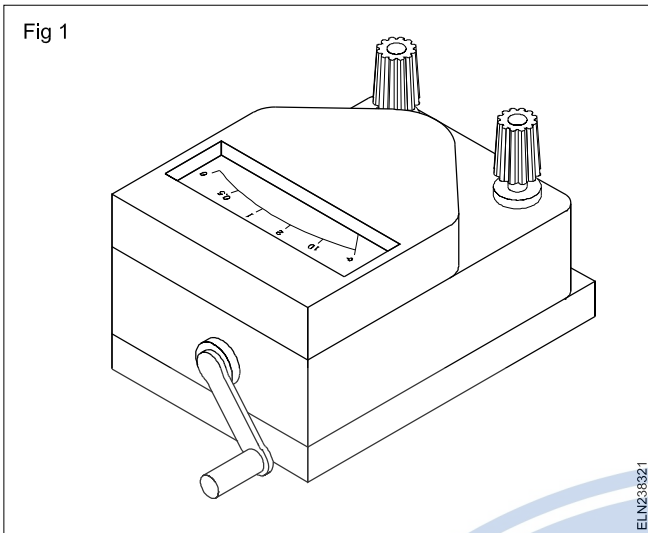
- state the working principle of an insulation tester (Megger)
- explain the construction and working of megger
- state the uses of an insulation tester like insulation test, continuity test etc.
- state the safety precautions to be observed while using an insulation tester.

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

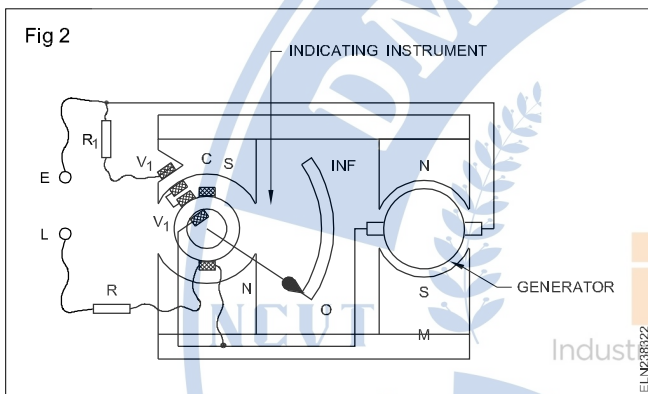
Ordinary ohmmeters and resistance bridges are not generally designed to measure extremely high values of resistance. The instrument designed for this purpose is the megohmmeter. (Fig 1) A megohmmeter is commonly known as MEGGER.



ELN238321

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)



ELN238322

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(M Ω).

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..
- 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 precautions to be followed while selecting a site for the earth electrode
- define earth resistance tester
- explain the principle construction and working of an earth resistance tester
- explain the method of measuring the earth resistance
- state the IE rules pertaining to earthing.

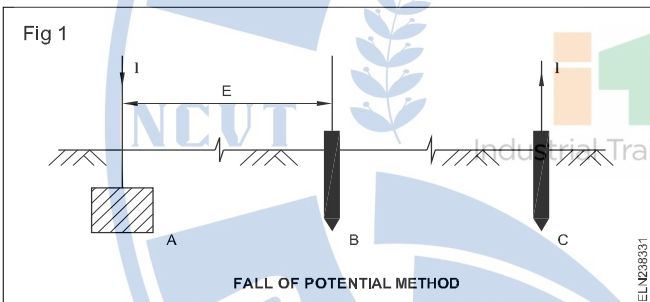
Precautions to be followed while selecting the site for earth electrode: However, even the earth electrode, either rod or plate type, implanted properly in the earth according to the specified recommendations is found to have high resistance resulting in failure of safety. The earth electrode resistance could be kept at a reasonable level.

Necessity of measuring of earth electrode resistance: 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.

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).



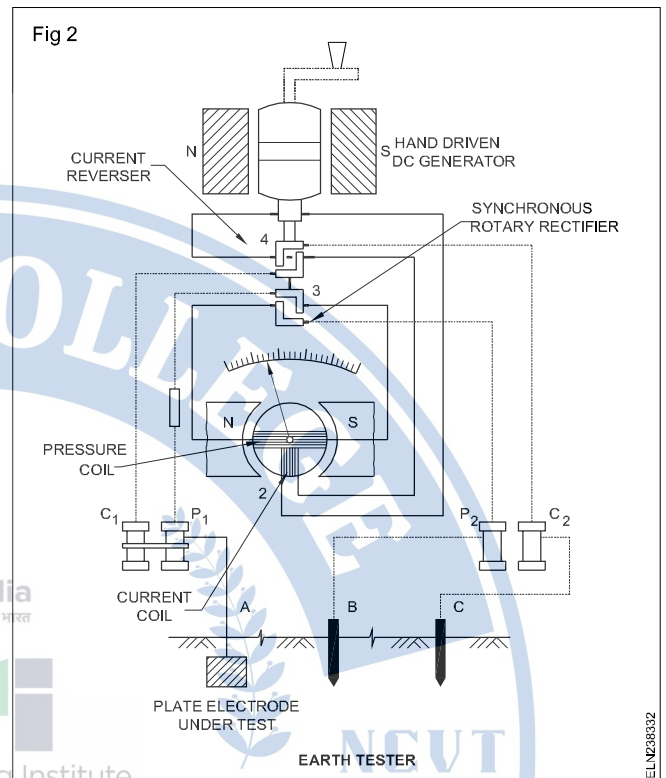
An alternating current of I_{amps} magnitude is passed through the electrode A to the electrode C via the earth and the potential across electrodes A and B is measured.

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.

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 complied 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 transformer.

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 a 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 supply 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 instruments), 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 lesson 1.7.62