BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE Affiliated to SCTE & VT)

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LECTURE NOTES
ON
ELECTRICAL INSTALLATION AND ESTIMATING

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DEPARTMENT OF ELECTRICAL ENGINEERING

BIET, MOHADA, BERHAMPUR

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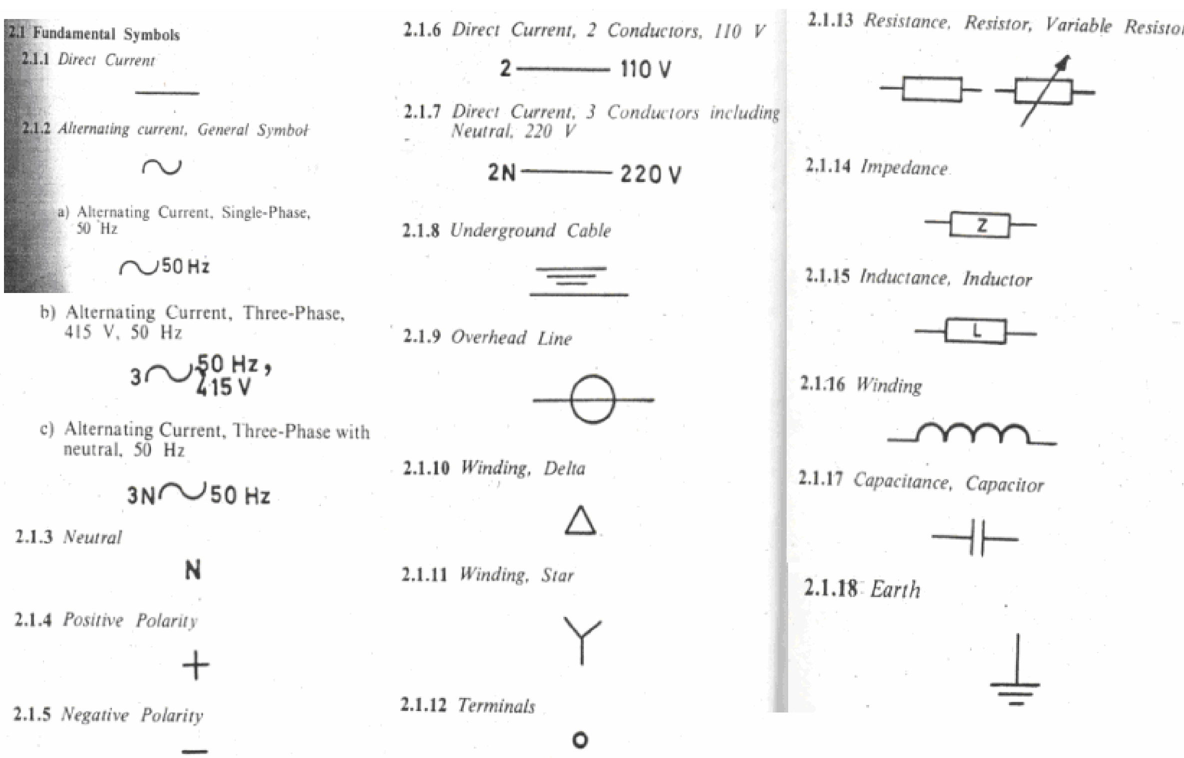
ELECTRICAL ESTIMATION AND COASTING

1. Introduction

Before any electrical project is initiated, it is essential to list out the materials required and compute the cost involved for completion of that work. Thus estimation consists of two parts; (a) preparing list of various items involved and (b) calculating the cost of materials and labour cost involved for executing the work. The quantity and specification of various materials required for installation work written in a tabular form is called schedule of materials.

2. Graphical symbols for diagram

In engineering drawing it is common practice to employ graphical symbols to represent various components. In order to get the same meaning to every one who reads the drawing, symbols are standardized by Bureau of Indian Standards (BIS). As far as possible these symbols are agreed with the convention adopted by the International Electro Technical Commission. An important criterion in the selection of symbol is that, as far as possible, they should be self explanatory and easy to draw. IS 2032 gives a list of standard symbols.



2.1.19 *Fault*

2.2 Equipment

2.2.1 *Flexible Conductor*

2.2.2 *Generator*

AC generator

DC generator

2.2.3 *Motor*

2.2.4 *Synchronous Motor*

2.2.5 *Mechanically Coupled Machines*

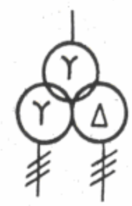
2.2.6 *Induction Motor, Three-Phase, Squirrel Cage*

Induction Motor with Wound Rotor

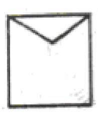
2.2.7 *Transformers with Two Separate Windings*

2.2.8 *Auto-Transformer*

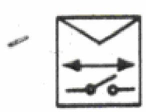
2.2.9 *3-Phase Transformer with Three Separate Windings—Star—Star—Delta*



2.2.10 *Starter*

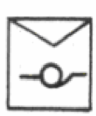


2.2.11 *Direct-on-Line Starter for Reversing Motor*

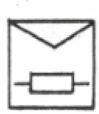


2.2.12 *Star-Delta Starter*

2.2.13 *Auto-Transformer Starter*



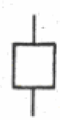
2.2.14 *Rheostatic Starter*



2.2.15 *Switch*

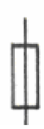
2.2.16 *Contactor*

2.2.17 *Circuit-Breaker*



2.2.18 *Isolator*

2.2.19 *Fuse*

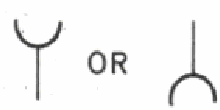


2.2.20 *Signal Lamp*

2.2.21 *Link*

2.2.22 *Distribution Board, Cubicle Box, Main Fuse Board with Switches*

2.2.23 *Socket Outlet, 5A,*



Socket Outlet, 15A

2.2.24 *Plug*

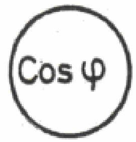
2.2.25 *Voltmeter*

2.2.26 *Ammeter*

2.2.27 *Wattmeter*

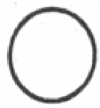
2.2.28 *Varmeter*

2.2.29 *Power Factor Meter*

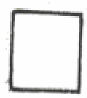


2.2.30 *Ohmmeter*

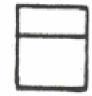
2.2.31 *Indicating Instrument* (general symbol)



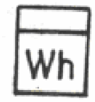
2.2.32 *Recording Instrument* (general symbol)



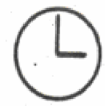
2.2.33 *Integrating Meter*



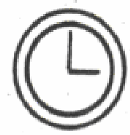
2.2.34 *Watthour Meter*



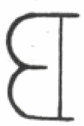
2.2.35 *Clock*



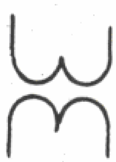
2.2.36 *Master Clock*



2.2.37 *Current Transformer*



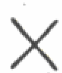
2.2.38 *Voltage Transformer*



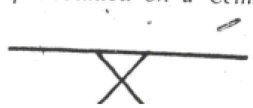
2.2.39 *Wiring on the Surface*

2.2.40 *Wiring in Conduit*

2.2.41 *Lamp*

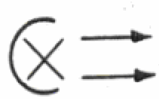


2.2.42 *Lamp Mounted on a Ceiling*



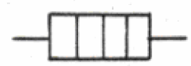
2.2.43 *Emergency Lamp*

2.2.44 *Spot Light*

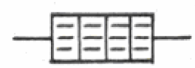


2.2.45 *Flood Light*

2.2.46 *Heater*



2.2.47 *Storage Type Water Heaters*



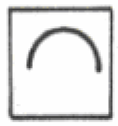
2.2.48 *Bell*

2.2.49 *Buzzer*

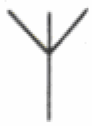
2.2.50 *Ceiling Fan*

2.2.51 *Exhaust Fan*

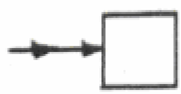
2.2.52 *Fan Regulator*



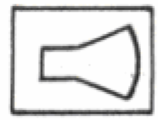
2.2.53 *Aerial*



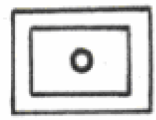
2.2.54 *Radio Receiving Set*



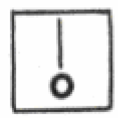
2.2.55 *Television Receiving Set*



2.2.56 *Manually Operated Fire Alarm*



2.2.57 *Automatic Fire Detector Switch*



3. Standard values of voltages

For the sake of completeness, all the standard values of voltages given in IS: 585 – 1962.

- Single phase, two wire system – The standard voltage shall be 240 V
- Three phase system -
  - 415 V, 3.3 kV, 6.6 kV, 11 kV, 22 kV, 33 kV, 66 kV, 110 kV, 132 kV, 220 kV and 400 kV.
- The standard dc voltage shall be 220 / 440 V

4. Voltage limits for AC system

The voltage at any point of the system under normal conditions shall not depart from the declared voltage by more than the values given below;

- 6% in the case of low (250V or less) or medium (251 to 650 V) voltage
- 6% in the higher side or 9% on the lower side in case of High voltage (651 V to 33 kV)

- 12.5% in case of Extra High voltage (above 33 kV)

5. Distance from Electric Lines

No building shall be allowed to be erected or re- erected, or any additions or alterations made to the existing building unless the following minimum clearances are provided from the over head electric supply lines.

		Vertical (m)	Horizontal (m)
(a) Low & medium Voltage lines		2.5	1.2
(b) High voltage lines	Up to and including 11 kV	3.7	1.2
	Above 11 kV up to and including 33 kV	3.7	2.0
(c) Extra high voltage lines		3.7	2.0

Note:- For extra high voltage lines apart from the minimum clearance indicated, a vertical and horizontal clearance of 3.0 m from every additional 33 kV or part thereof shall be provided.

6. Wiring Installations

A major portion of the fixed installation design in a building relates to wiring installation. The essential design and constructional requirements for electrical wiring installations are as follows.

(6.1) Fittings and Accessories

- A ceiling rose or any other attachment shall not be used on a circuit, the voltage of which normally exceeds 250 V.
- Each 15 A socket outlet provided in building for the use of domestic appliances such as AC, water cooler etc.
- Each socket outlet shall be controlled by a switch which shall preferably be located immediately adjacent thereto or combined therewith.
- Ordinary socket outlet may be fixed at any convenient place at a height above 20 cm from the floor level. In a situation where the socket outlet is accessible to children, socket outlet which automatically gets screened by the withdrawal of plug is preferable.
- In an earthed system of supply, a socket outlet with plug shall be three pin types with third terminal connected to earth.
- All lamps unless otherwise required and suitably protected, shall be hung at a height of not less than 2.5 m above floor level.

- Unless otherwise specified, the clearance between the bottom most point of the ceiling fan and the floor shall be not less than 2.4 m. the minimum clearance between the ceiling and the plane of the blade shall be not less than 30 cm.

(6.2) Reception and Distribution of Main Supply

- There shall be circuit breaker or a linked switch with fuse on each live conductor of the supply mains at the point of entry. The main switch shall be easily accessible and shall be situated near to the termination of service line.

- Branch distribution board shall be provided with a fuse or a miniature circuit breaker (MCB) or both of adequate rating / setting.

- Light and fans may be wired on a common circuit. Such sub-circuit shall not have more than a total of 10 points of light, fan and 5 A socket outlets. The load of such circuit shall be restricted to 800 Watts. Power sub-circuit shall be designed according to the load but in no case shall there be more than two 15 A outlets on each sub-circuit.

- The load on any low voltage sub circuit shall not exceed 3000 Watts. In case of new installation, all circuits and sub-circuits shall be designed by making a provision of 20% increase in load due to any future modification.

- The distribution fuse board shall be located as near as possible to the centre of the load. These shall be fixed in suitable stanchion or wall and shall not be more than 2 m from the floor level.

- All conductors shall be of copper or aluminium. Conductor for final sub-circuit of fan and light wiring shall have a nominal cross sectional area not less than 1 Sq. mm copper and 1.5 Sq. mm aluminium. The cross sectional area for power wiring shall be not less than 2.5 Sq. mm copper, 4 Sq. mm aluminium. The minimum cross sectional area of conductors of flexible cord shall be 0.5 Sq. mm copper.

(6.3) Conduit wiring

- Rigid non-metallic conduits are used for surface, recessed and concealed conduit wiring. Conductors of ac supply and dc supply shall be bunched in separate conduits. The numbers of insulated cables that may be drawn into the conduit are given in table.

Maximum permissible number of 1.1 kV grade single core cables that may be drawn into rigid non metallic conduits

Size of cable		Size of conduit (mm)					
Normal cross sectional area (Sq. mm)	Number and diameter (in mm) of wires	16	20	25	32	40	50
		Number of cables, maximum					
1	1/1.12	5	7	13	20	-	-
1.5	1/1.40	4	6	10	14	-	-
2.5	3/1.06	3	5	10	14	-	-
4	7/0.85	2	3	6	10	14	-
6	7/1.40	-	2	5	9	11	-
10	7/1.40	-	-	4	7	9	-
16	7/1.70	-	-	2	4	5	12
25	7/2.24	-	-	-	2	2	6
35	7/2.50	-	-	-	-	2	5
50	19/1.80	-	-	-	-	2	3

Conduit shall be fixed by saddles secured to suitable wood plugs or other plugs with screws at an interval of not more than 60 cm. whenever necessary, bends or diversions may be achieved by bending the conduits or by employing normal bends, inspection bends, inspection boxes, elbows or similar fittings.

7. Earthing

Earthing or grounding means connecting all parts of the apparatus (other than live part) to the general mass of earth by wire of negligible resistance. This ensures that all parts of the equipment other than live part shall be at earth potential (ie, zero potential) so that the operator shall be at earth potential at all the time, thus will avoid shock to the operator. The neutral of the supply system is also solidly earthed to ensure its potential equal to zero.

Earthing shall generally be carried out in accordance with the requirement of Indian Electricity Rule 1956, particularly IE Rules 32, 51, 61, 62, 67, 69, 88(2) and 90.

- All medium voltage equipment shall be earthed two separate and distinct connections with earth through an earth electrode. In the case of high and extra high voltage the neutral point shall be earthed by not less than two separate and distinct connections.

- Each earth system shall be so devised that the testing of individual earth electrode is possible. It is recommended that the value of any earth system resistance shall not be more than 5 Ω, unless otherwise specified.

- Under ordinary conditions of soil, use of copper, iron or mild steel electrodes is recommended. In direct current system, however due to corrosive action, it is recommended to use only copper electrode. Use similar materials for earth electrode and earth conductors to avoid corrosion.

(7.1) Design data on earth electrode

Standard earth electrodes are;

(a) Road and pipe electrodes, (b) Strip or conductor electrodes, (c) Plate electrodes, and (d) Cable sheaths.

Measurement	Type of Electrodes				
	Rod	Pipe	Strip	Round conductor	Plate
Diameter(not less than)	16 mm (Steel or GI) 12.5 mm (copper)	38 mm (Steel or GI) 100 mm (Cast Iron)			
Length/ Depth of burial (not less than)	2.5 m (ideal 3 to 3.5 m)	2.5 m	0.5 m	1.5 m	1.5 m
Size	-	-	25 x 1.60 mm (copper) 25 x 4 (Steel or GI)	3.0 Sq. mm (copper) 6 Sq. mm (Steel or GI)	60 x 60 cm
Thickness	-	-	-	-	6.30 mm (copper) 3.15 mm (Steel or GI)

(7.2) Design of earth electrode

Earth resistivity, $\rho = 2\pi SR\ \Omega\text{-m}$, where S = distance between successive electrode in m, R = earth megger reading in Ω

Permissible current density for 3 sec;

Copper = 118 A/mm^2 Aluminium = 73 A/mm^2 Steel (GI) = 46 A/mm^2

Current density permissible at an earth electrode, $I_d = \frac{7.75 \times 10^{-3}}{\sqrt{\rho t}}$ A/m^2

where, t = duration of fault current (3 sec)

Electrode resistance:

(a) For pipe or rod electrode

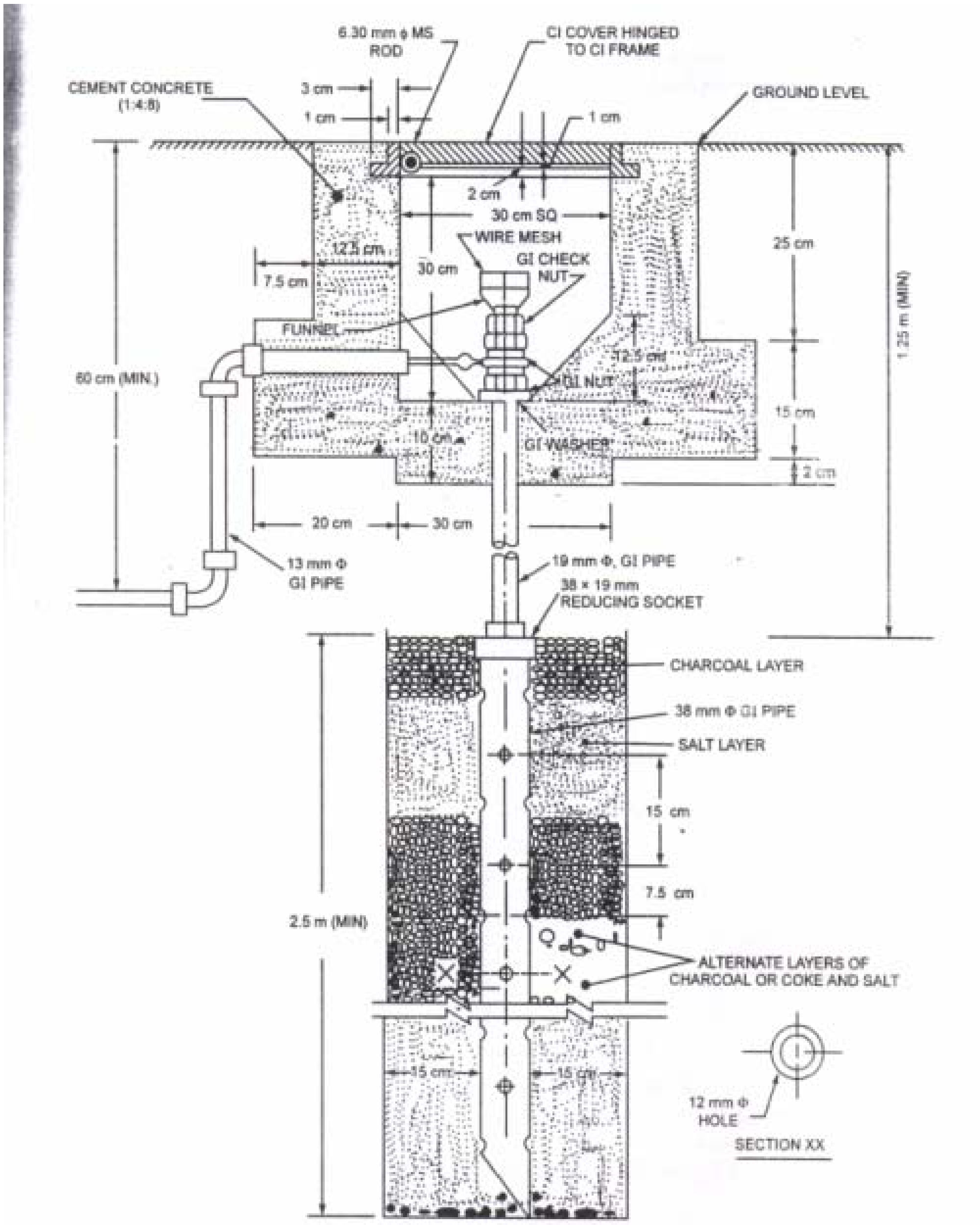
$R = \frac{100\rho}{2\pi l} \log_e \frac{4l}{d}\,\Omega$, where, d= dia of rod and l = length of rod/ pipe in cm

(b) For strip or round conductor

$R = \frac{100\rho}{2\pi l} \log_e \frac{2l^2}{wt}\,\Omega$, where, w= depth of burial of strip electrode in cm and t = width of strip or twice the dia of circular conductor in cm.

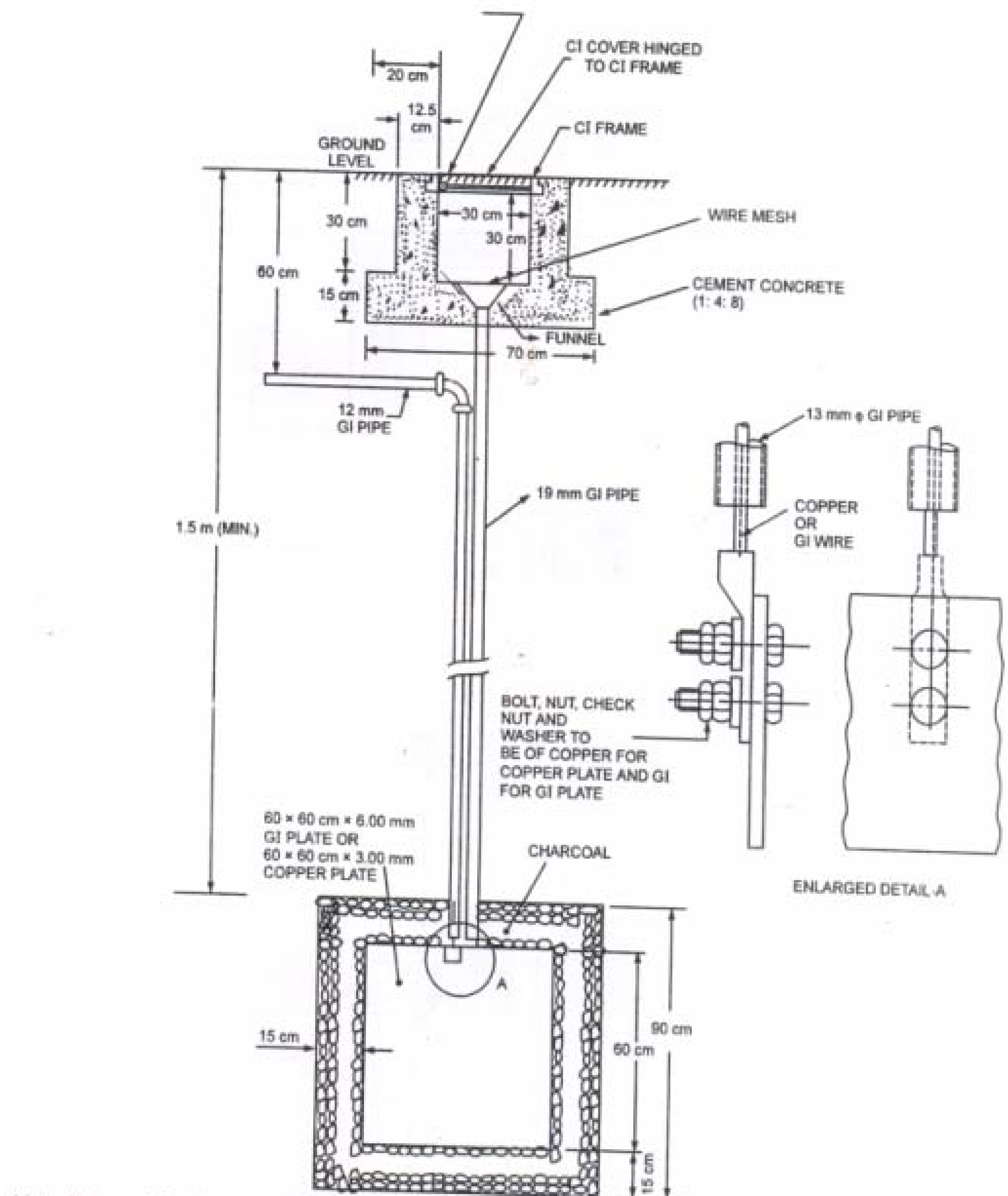
(c) For plate electrode

$R = \frac{\rho}{4}\sqrt{\frac{\pi}{A}}\,\Omega$, where, A= area of both sides of plate in m^2



Note-Three or four buckets of water to be poured into sump every few days to keep the soil surrounding the earth pipe permanently moist.

A Typical Illustration of Pipe Earth Electrode



Note-Three or four buckets of water to be poured into sump every few days to keep the soil surrounding the earth pipe permanently moist.

A Typical Illustration of Plate Earth Electrode

(7.2) Specification

- The earth rod shall be situated at a distance not less than 1.5 m from the building whose installation being earthed
- The size of the continuity conductor shall be 2.9 mm^2 (14 SWG) or half of the installation conductor size.
- The permissible value of earth resistance is,
  - Large Power Station - 0.5 Ω
  - Major Power Station - 1 Ω

- Small Substation - 2 Ω
- In all other cases - 5 Ω
- Earth continuity resistance - 1 Ω (between earth plate and any earth conductor)

(7.3) Fault Level Calculations

$$\text{pu impedance} = \frac{z\,(\Omega)\ \text{x Base MVA}}{\text{Base kV}^2}$$

Inductance of line for eqvt. spacing = $(2\log_e \frac{d}{r} + 0.5) \times 10^{-7}$ H/m, where d = spacing between conductors and r = radius of conductor

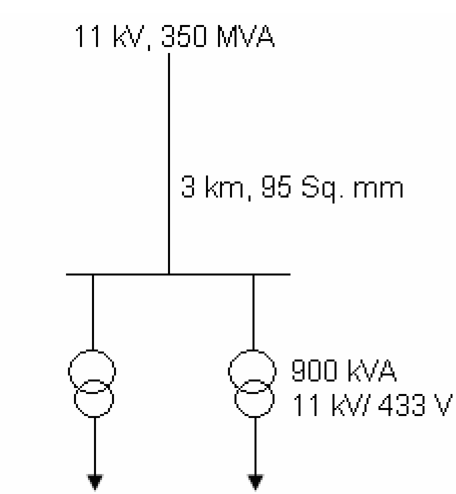
$$\%\ \text{line impedance} = \left(\frac{\text{line impedance}\,(\Omega)\ \text{x Base MVA}}{\text{Base kV}^2}\right) \text{x } 100$$

$$\%\ \text{impedance at new Base MVA} = \frac{(\%\ \text{impedance})_{old}\ \text{x}\ (\text{Base MVA})_{new}}{(\text{BaseMVA})_{old}}$$

$$\text{Short circuit MVA (power fed into the fault)} = \frac{\text{Base MVA}}{\text{Total \% impedance up to the point}} \text{ x } 100$$

$$\text{System \% impedance} = \frac{\text{Base MVA}}{\text{Short Circuit MVA}} \text{ x } 100$$

Eg:- Supply voltage – 11 kV, fault level at 11 kV side at substation – 350 MVA, length of 11 kV feeder from substation to factory – 3 km, 11 kV conductor size – 95 Sq. mm, spacing of conductor – 1 m, resistance of line – 0.5 Ω/ km. Rating of transformer at factory – 900 kVA, 11 kV/433 V, % impedance – 6 Ω (2 Nos in parallel). Soil resistivity, ρ = 200 Ω-m



Take base values: 100 MVA, 11 kV

$$\% \text{ Source impedance} = \frac{\text{Base MVA}}{\text{Short Circuit MVA}} \times 100$$

$$= \frac{100}{350} \times 100$$

$$= 28.57\ \%$$

$$11 \text{ kV cond. radius} = \sqrt{\frac{95}{\pi}} = 5.5 \text{ mm}$$

Spacing between cond. = 1000mm

$$\text{Inductance of line for eqvt. spacing} = (2 \log_e \frac{d}{r} + 0.5) \times 10^{-7} \text{ H/m}$$

$$= \left(2 \log_e\left(\frac{1000}{5.5}\right) + 0.5\right) \times 10^{-7} \times 3000$$

$$= 0.0033 \text{ H}$$

$X_L = 2\pi F L = 1.03\ \Omega$

$R = 0.5 \times 3 = 1.5\ \Omega$

$$Z_L = \sqrt{x_L^2 + R^2} = 1.82\ \Omega$$

$$\% \text{ line impedance} = \left(\frac{\text{line impedance } (\Omega) \times \text{Base MVA}}{\text{Base kV}^2}\right) \times 100$$

$$= \frac{1.82 \times 100}{11^2} \times 100 = 150.4\%$$

Total % impedance up to factory = 150.4 + 28.5 = 178.97%

S/C MVA at 11 kV side at factory = (100 x 100)/ 178.97 = 55.87%

Considering the future expansion (say new substation) in the source side , S/C MVA is taken as 250 MVA.

[Note: unless otherwise specified, a minimum fault level at 11 kV shall be taken as 250 MVA]

$$\text{Fault level at 11kV side} = \frac{250 \times 10^3}{\sqrt{3} \times 11} = 13.122 \text{ kA}$$

$$\% \text{ impedance corresponding to 250 MVA fault level} = \frac{100 \times 100}{250} = 40\%$$

% impedance of transformer at new base MVA (ie,100 MVA) = $\frac{6 \text{ x } 100}{0.9}$ = 666.67%

since two transformers are in parallel the effective impedance = $\frac{666.67}{2}$ = 333.33%

Total % impedance up to 433 V bus = 40 + 333.33 = 373.33%

S/C MVA at 433 kV bus $\frac{100}{373.33}$ x 100 = 26.78 MVA

Corresponding fault current = $\frac{26.78 \text{ x } 10^3}{\sqrt{3} \text{ x } 433}$ = 35.71 kA

Earthing design:

Current density of copper – 118 A/mm^2 (for 3 sec)

Size of conuctor at 11 kV side = $\frac{13.122 \text{ x } 10^3}{118}$ = 111.2 mm^2

Nearest standard size = 25 x 6 mm cu strip

Size of conductor at MV side = $\frac{35.71 \text{ x } 10^3}{118}$ = 302.32 mm^2

Nearest standard size = 63 x 6 mm cu strip

Permissible current density at electrode = $\frac{7.57 \text{ x } 10^3}{\sqrt{\rho\, t}} = \frac{7570}{\sqrt{200 \text{ x } 3}}$ = 309 A/ m^2

Plate electrode of 1.2 x 1.2 x 0.012m is used for earthing

Total area of both sides of plate electrode = 1.2 x 1.2 x 2 = 2.88 m^2

Area required to dissipate fault at 11 kV side = $\frac{13.122 \text{ x } 10^3}{309}$ = 42.46 m^2

Number of plate required = $\frac{42.46}{2.88}$ = 14.74

Therefore 15 plate electrodes are to be provided.

8. Domestic Electric Installations and Estimates

Domestic dwellings/ Residential buildings include any buildings in which sleeping accommodation is provided for normal residential purpose with cooking and dining facilities.

(8.1) Estimation of load requirements

- The electrical installation in this area mainly consists of lights, fans, electrical appliances and other gadgets. In estimating the current to be carried, following ratings are recommended.

Item	Recommended Rating
Incandescent lamps	60 W
Ceiling Fan and Table Fan	60 W
5 A, 3 pin socket outlet	100 W
Fluorescent tubes:	
Power socket outlet (15 A) For Geyser For AC	1000 W 2000 W 3000 W

(8.2) Number of points in branch circuit

Recommended numbers of points for dwelling units are as follows

Sl No.	Description	Area of the main dwelling unit in m^2				
		35	45	55	85	140
1	Light point	7	8	10	12	17
2	Ceiling fans	2 points – 2 fans	3-2	4-3	5-4	7-5
3	5 A socket outlet	2	3	4	5	7
4	15 A socket outlet	-	1	2	3	4
5	Call - bell	-	-	1	1	1

(8.3) Number of socket outlets

Recommended schedule of socket outlets for various sub-units are as follows

Description	Number of socket outlets	
	5 A	15 A
Bed room	2 to 3	1
Living room	2 to 3	2
Kitchen	1	2
Dining room	2	1
Garage	1	1
For refrigerator	-	1
For air conditioner	-	1
Verandah	1 per 10 m^2	1
Bathroom	1	1

(8.4) Recommended levels of illumination

Location	Illumination Level
Entrance Hallways	100
Living room	300
Dining room	150
Bed room General Dress table, bed heads	 300 200
Games or recreation room	100
Table games	300
Kitchen	200
Kitchen sink	300
Laundry	200
Bath room	100
Bath room mirror	300
Sewing	700
workshop	200
stairs	100
Garage	70
Study	300

(8.5) Domestic wiring

- Balancing of circuit in 3 phase installation shall be planned before hand. It is recommended that all socket outlets in a room are connected to one phase.
- Power sub-circuits shall be kept separate and distinct from light and fan sub-circuit. All wiring shall be on the distribution system with main and branch distribution boards convenient physical and electrical load centers.
- It is recommended to provide at least two lighting sub-circuits in each house. Separate lighting circuits be utilized for all external lightings of steps, walkways, porch, car park terrace etc. with two way switch control.
- Whatever the load to be fed is more than 1 kW, it shall be controlled by an isolator switch or MCB
- Switch boards shall not be erected above gas stove or sink or within 2.5 m of any washing unit in the washing room.
- A switch board shall not be installed at height less than 1.25 m from floor level, unless the front of the switch board is completely enclosed by a door.

- Energy meters shall be installed at a height where it is convenient to note the meter reading; it should preferably not be installed at a height not less than 1 m from the ground.

(8.6) Sequence to be followed in carrying out the estimate

1. Wiring layout: Prepare building plan on a suitable scale and mark electrical points, switch boards, main board, meter board, distribution board etc. on the plan using specified symbols. The path of wiring showing connection to each point is marked by a little thick line.

2. Calculation of total connected load: The total connected load and hence the total current is calculated for deciding the cable size, rating of main switch board and distribution board.

3. Selection of Main Switch: Once the connected load is calculated, the main switch can be conveniently selected from the available standard switch list.

(3.1) List of standard Iron Clad main switches for domestic purpose:

a) DPIC (Double Pole Iron Clad) main switch: 5,15 or 30 A, 250V or DPMCB (Double Pole Miniature Circuit Breaker): 5, 10, 16, 32 and 63 A, 250 V

b) TPIC (Triple Pole Iron Clad) main switch: 30, 60, 100, 200 A, 500 V or TPMCB (Triple Pole Miniature Circuit Breaker): 16, 32 and 63 A, 500 V, beyond this TPMCCB (Triple Pole Molded Case Circuit Breaker): 100, 200, 300 and 500 A, 660 V

c) TPN main switch: 30, 60, 100, 200, 300 A, 500 V or TPNMCB: 16, 32, 63A, 500 V, beyond this TPNMCCB: 100, 200, 300, 500 A, 660 V.

4. Selection of Main Distribution Board: The Main Distribution Board is a fuse box or MCB box where different sub-circuits are terminated. Numbers of sub-circuits are decided based on the total connected load or total number of points.

5. Assumptions: the conditions which are not specified in the question may be assumed conveniently. Eg:- location of main switch board, switch boards, height of building(if not specified)

6. Calculation of length of conduit: To avoid duplicity in calculating the length of conduit pipe, this may be calculated in three stages. (a) The conduit installed from switch board up to horizontal run (HR) including from main switch or DB to HR. (b) The conduit on walls running parallel to the floor ie, the HR below ceiling. (c) The conduit installed between HR and ceiling, along ceiling and ceiling to last point on HR.

The total length of conduit is calculated by adding the length of conduit obtained from the three stages and including 10% wastage.

7. Calculation of length of phase wire and neutral wire: The phase wire and neutral wire is calculated sub-circuit wise. Once it is calculated, wastage of 15% is included.

8. Calculation of length of earth wire: The earth wire is run along the conduit. The calculations are carried out in length but it is converted in to weight while preparing material table.

9. Preparing Material Table: The material table should be prepared with complete specification of each item.

(8.7) Current rating of copper conductor single core cables

Size of conductors		Two cables dc or Single phase ac		Three or four cables balanced three phase ac	
Normal area (mm^2)	No. and dia. of wire (mm)	Current rating (A)	Approx. length of run for one volt drop (m)	Current rating (A)	Approx. length of run for one volt drop (m)
1	1/1.12	5	2.9	3	2.8
1.5	3/0.737	10	3	10	3.7
2.5	3/1.06	15	3.4	13	4.3
4	7/.737	20	3.7	15	4.8
6	7/1.06	28	4.0	25	5.2
8	7/1.12	36	4.9	32	6.1
10	7/1.40	43	5.5	39	7.0

(8.8) Selection, rating and installation of equipments on the main switch board

Eg 1:- There are 4 light/ power sub-circuits in an installation of a house wiring. One of them is a sub-circuit for 15 a socket. Draw the single line diagram showing cutout, meter, main switch, main distribution board and other equipment. Make your own assumptions for number of electrical points in each sub-circuit and find out the rating of main switch and distribution board.

ANS:

Load in sub-circuit No. 1

Light point = 2 x 60 = 120 W

Fan point = 2 x 60 = 120 W

5 A socket = 4 x 100 = 400 W

Total connected load = 640 W

Load in sub-circuit No. 2

Light point = 5 x 60 = 300 W

Fan point = 2 x 60 = 120 W

5 A socket = 2 x 100 = 200 W

Total connected load = 620 W

Load in sub-circuit No. 3

Light point = 2 x 60 = 120 W

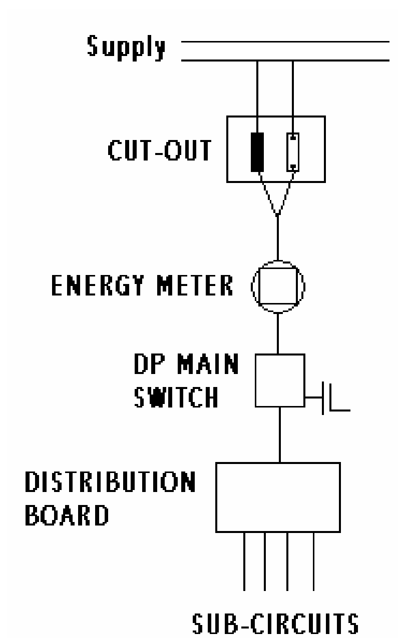
Fan point = 3 x 60 = 180 W

5 A socket = 3 x 100 = 300 W

Total connected load = 600 W

Load in sub-circuit No. 4

Sub-circuit for 15 A socket outlet at 1000 A



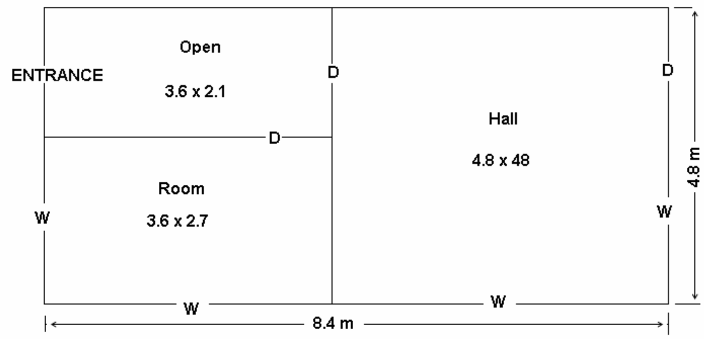
Total connected load on all four sub-circuits in the house

= 640 + 620 + 600 + 1000 = 2860 W

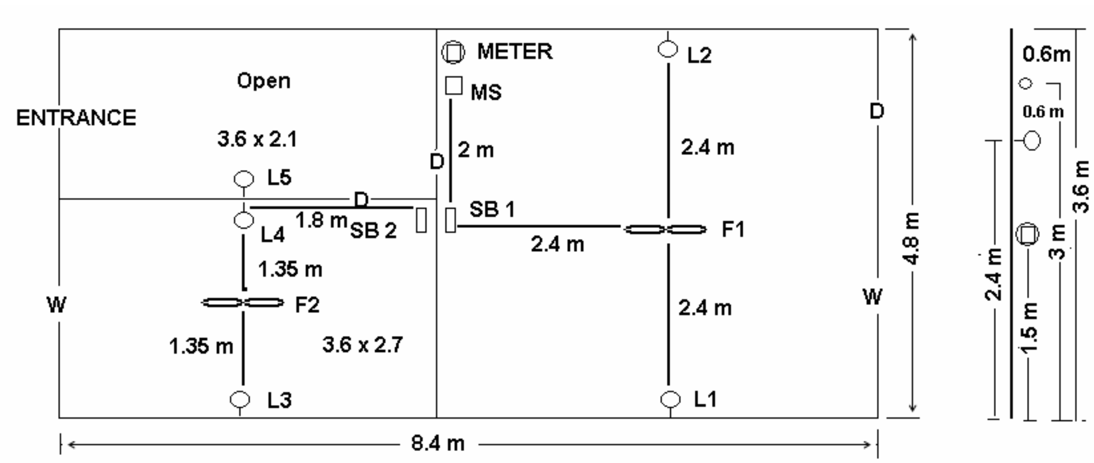
Total load in Amp = 2860 / 230 = 12.43 A

If all points are put on 12.43 A have to be carried. Considering future requirements, an iron clad main switch of 30 A, 250 V is suggested.

Eg 2:- Draw the wiring layout and estimate the quantity of materials required. Assume the height of ceiling as 3.6 m and one plug point is to be provided in each room.



Ans: 1. Wiring layout



Assumption:

a Height of MB from the floor = 1.5 m

b) Height of HR from the floor = 3 m

c) Height of SB from the floor = 1.5 m

d) Thickness of wall = 0.25 m

e) Height of bracket from floor = 2.4 m

2. Calculation of total connected load

Light points	= 5 x 60	=	300 W
Fan points	= 2 x 60	=	120 W
5 A socket	= 2 x 100	=	200 W
Total connected load		=	620 W

Load in Amps = 620 / 230 = 2.69 A

Here there are only 9 points; hence no distribution board is required.

As the total connected load is 2.69 A if all the points are switched on simultaneously. It is suggested to use DPIC main switch of 15 A, 250 V grade is used.

(2.1) Selection of wire: PVC insulated copper wire of 1.5 Sq. mm is used for sub-circuit wiring and PVC insulated copper wire of 1 Sq. mm is used for light/ fan/ 5 A socket points.

3. Calculation of length of 25 mm dia. conduit pipe:

From MB to HR = 1.5 m

From SB1 to HR = 1.5 m

From SB2 to HR = 1.5 m

From HR to L1, L2 & F1 = 0.6 + 2.4 + 2.4 + 1.2 + 2.4 + 1.2 = 10.2 m

From MB to SB1(HR) = 2 m

From HR to SB 2 = 1.5 + 0.25 = 1.75 m

From HR to L4, L5, F2 & L3 = 0.6+ 0.6 + 1.35 + 1.35 + 0.6 +0.25 = 4.75 m

From HR between Sb2 and L4 = 1.8 m

Total = 25 m

10% wastage = 2.5 m

= 27.5 m

say 28 m

4. Calculation of PVC insulated copper wire:

a) Circuit wire (1.5 Sq. mm)

From MB to SB1 = (1.5 + 2 + 1.5) x 2 = 10 m

From MB to SB2 = (1.5 + 2 + 1.5 +0.25) x 2 = 10.5 m

Total = 20.5 m

Wastage 15% = 3.075m

= 23.575 m

Say 24 m

b) Light/ fan/ 5 A socket points wire (1 Sq. mm)

Phase wire:

From SB1 to F1, L1 & L2= (1.5 + 0.6 +2.4) x 3 + (2.4 +0.6)x 2

= 19.5 m

From SB2 to F2, L3, L4 & L5 = (1.5 +1.8) x 4 + 0.6 + 0.25 + (1.35 +0.6) x 2 +(1.35 +0.6)

= 19.675 m

Total = 39.175 m

Neutral wire:

From SB1 to F1, L1 & L2= 1.5 + 0.6 +2.4 + (2.4 +0.6)x 2
= 8.1 m

From SB2 to F2, L3, L4 & L5 = 1.5 +1.8 + 0.6 + 0.25 +1.2 +1.35+1.35+0.6 = 8.65 m

Total = 16.75 m

Total 1 Sq. mm wire = 16.75 + 15 % wastage = 19.2625

Say, 20 m

c) Earth wire (14 SWG)

From MB to SB1 = (1.5 + 2 + 1.5) = 5 m

From MB to SB2 = (1.5 + 2 + 1.5 +0.25) = 5.25 m

Total = 10.25 m

Total 14 SWG bare cu wire + Wastage 15% = 11.78m

say, 12 m

5. Material Table:

Sl No.	Description	Quantity
1	15 A, 250 V,DPIC switch	1 No.
2	25 mm PVC conduit	28 m
3	PVC bend, Tee	15 Nos
4	Saddle clips	75 Nos
5	1 Sq. mm ,PVC insulated copper wire	20 m
6	1.5 Sq. mm ,PVC insulated copper wire	24 m
7	5 A piano switch	9 Nos
8	Ceiling rose	2 Nos
9	Angle bracket	5 nos
10	5 A, socket	2 Nos
11	Teak wood box, 25 x 20 cm for SB1 & SB2	2 Nos
12	Teak wood box, 25 x 15 cm	1 No
13	Teak wood Batten 7 x 7 cm	5 Nos
14	Wooden screws	300 nos
15	14 SWG bare cu wire	12 m
16	Earthing set(pipe earth)	1 Set
17	Cement, sand etc.	Lump sum

9. Power distribution in an industry

The power distribution in an industry has different levels

- Main Switch Board (MSB) level
- Sub Switch Board (SSB) level
- Distribution Board (DB) level

DB is the last element before the loads. But large loads are directly connected to SSB or MSB.

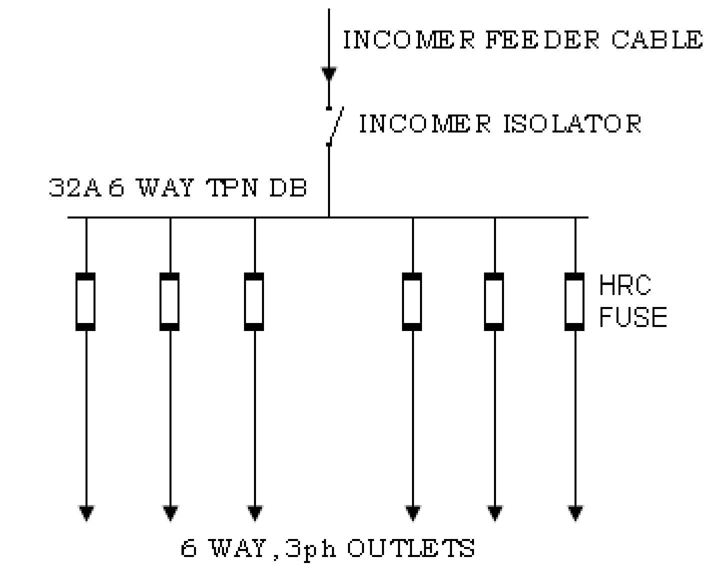
DB / DFB (Distribution Fuse Board) / FDB (Fuse Distribution Board)

✓ Usually even numbers of ways are used in DBs (2, 4, 6, 8, 10 and 12). As per IS the maximum number of ways is limited to 12.
Eg:- 12 way 3 ph DB = 4 x 12 = 48 cable connection including neutral.

✓ Usual current rating of DB s are : 16A, 32A and 63A

✓ 63A, 12 way DB s are not common. Since maximum input current = 63 x 12 = 700A, which is not possible to handle by a DB. Hence 63A DB is 2 ways or 4 ways.

- ✓ Motor loads up to 20 hp are fed from DB s of various rating.
- ✓ All DBs have isolator or SFU as incomer switch. But in some case this is avoided if the switch board supplying to the DB is within 3m from the DB



- ✓ In a designed system 20% spare outlets are kept for future expansion. ie, in each DB, 1 or 2 outlets shall be kept as spares.

<u>Selection of rating of incomer isolator/SFU and incomer feeder size</u>

In any system, all the connected loads will not be put on simultaneously. This reduces the maximum demand from simply computing by adding all connected loads. The maximum demand is expressed through a factor called 'Diversity Factor,

$$\text{Diversity Factor (DF)} = \frac{\text{Sum of connected load}}{\text{Simultaneous max. demand(MD)}}$$

>1

- ✓ From the requirement data, the details of connected load on each DB are known to us. For spare outlets, an average of other outlets can be assumed.
- ✓ If the DF is known, we can find the maximum current requirement of the DB to feed all loads including spares. Instead of furnishing the DF, a usual practice is specifying MD. A commonly accepted and safe value of DF is 1.5. this value can be assumed for each DB
- ✓ If motor loads are connected, for selection of isolator / SFU, the starting

current has to be taken in to account rather than continuous current.

Eg:- 5 hp - 5Nos and 10 hp - 2Nos motors are connected to a DB

Total connected load = 45hp

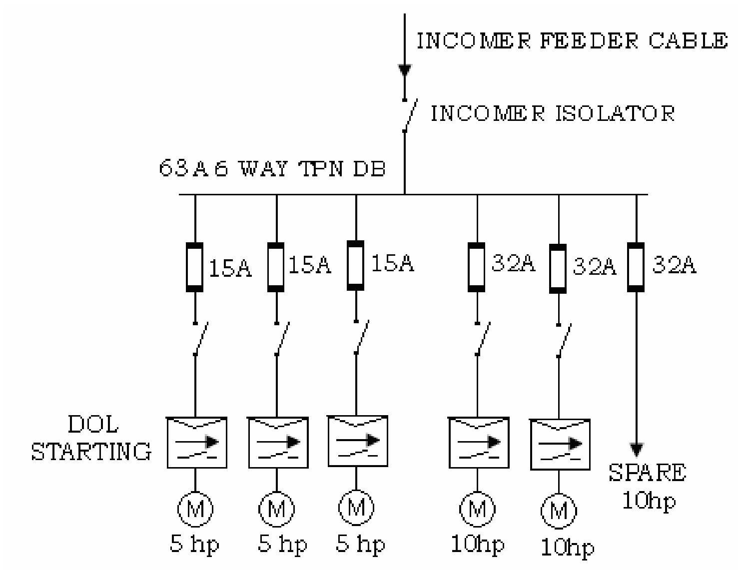
$$MD = \frac{45}{1.5} = 30\,hp$$

Corresponding maximum current is 30 x 1.4 = 42 A. This current is the continuous maximum current

✓ When motors are started we have to account the starting inrush current of large motor in the down stream. Starting current of DOL starting motor is 2.5 times the rated current and for assisted starting (star delta), it is 1.5 times the rated current.

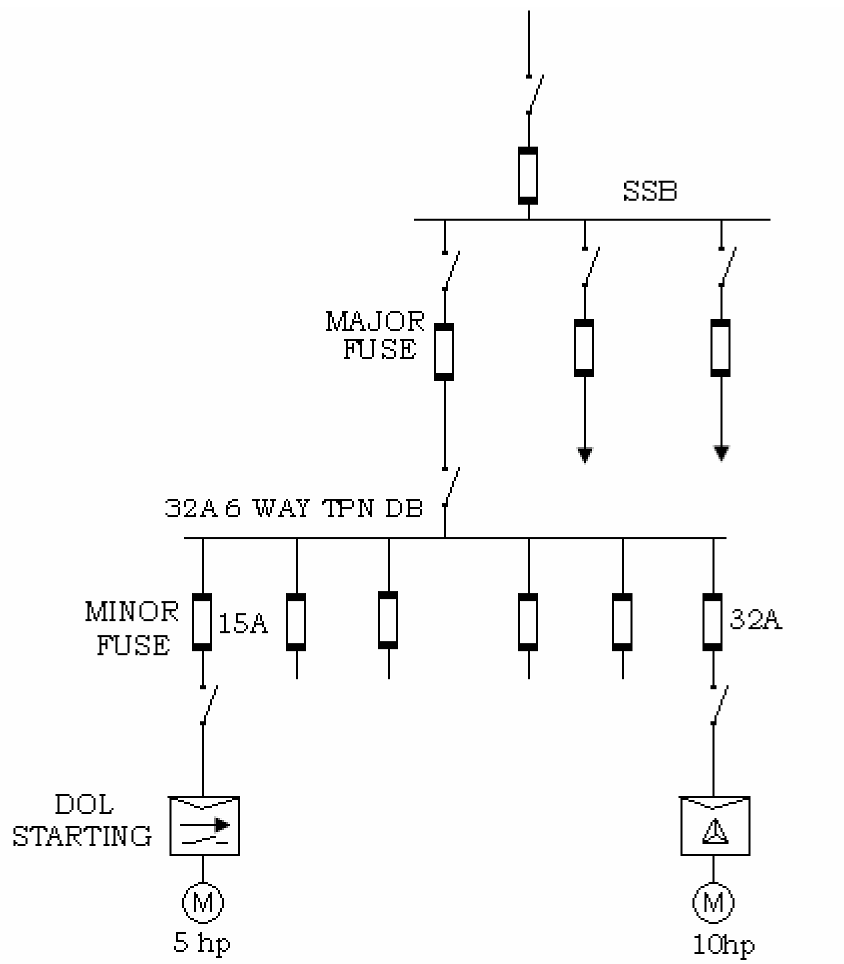
So the MD calculation in the above case is as follows:

- One 10 hp (one higher rating) kept aside
- Now only MD of 20 hp is existing
- Its maximum current = 20 x 1.4 = 28 A
- For one 10 hp alone, maximum current = 2.5 x (10 x 1.4) = 35 A
- Therefore MD of the DB = 28 + 35 = 63 A
- ie, incoming feeder, isolator/SFU of the DB can be rated to 63 A



Grading or Discrimination between Feeder Fuse and DB Fuse

The feeder to a DB will be fed from an SSB or MSB. This feeder will be protected by the HRC fuse in the SSB or MSB. It is necessary that the feeder protective fuse should not blow off before the motor protective fuse in the DB. This is achieved by proper grading between the fuses. The fuse of SSB/MSB is denoted as major fuse and that of DB is termed as minor fuse. For achieving grading the ratio between major and minor fuses shall be 2:1 or more



- ✓ Feeder cable is selected by considering the 20% excess of the MD of DB. Also major fuse rating should match with the cable selection.
- ✓ If the cable length exceeds 75 to 100mtr, the voltage drop condition should be taken in to account. The voltage drop in the feeder should not be more than 3% in the maximum demand condition.

Eg 1:- 50 hp, 415 V, 3 ph Induction motor use PVCAPVC 150 m cable.

Ans: $I_L = (50 \times 753.5)/(\sqrt{3} \times 415 \times 0.8 \times 0.85) = 76$ A

50 Sq. mm, 4 core cable is selected

Its voltage drop/Amp/mtr = 1.3 mV

% volage drop = $(1.3 \times 10^{-3} \times 76 \times 150 \times 100)/415$

= 3.57 % - exceeds the limit

Next higher size cable is 70 Sq. mm

Its voltage drop/Amp/mtr = 0.93 mV

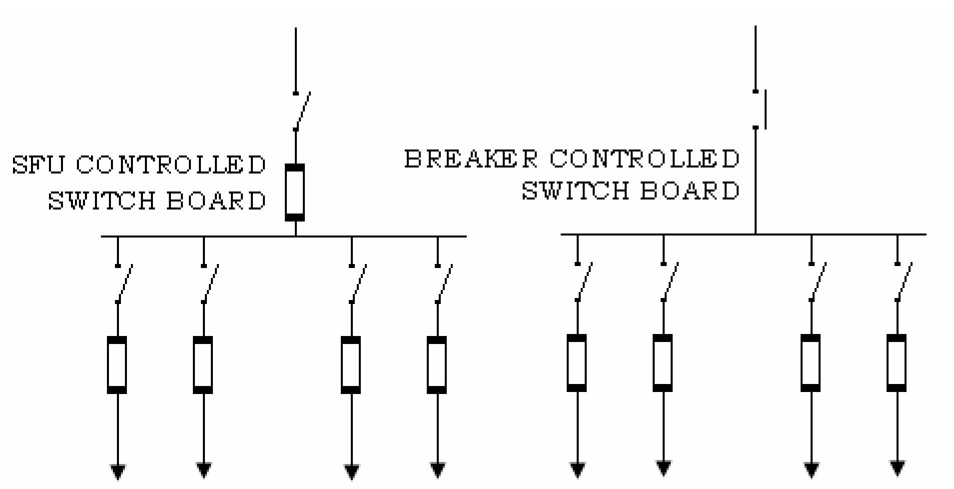
% volage drop = $(0.93 \times 10^{-3} \times 76 \times 150 \times 100)/415$

= 2.55 % - within limit

Therefore 70 Sq. mm AYFY (PVCAPVC), 4 core cable is selected.

Design of incomer SFU, Cable size and Bus bar rating for SSBs and MSBs

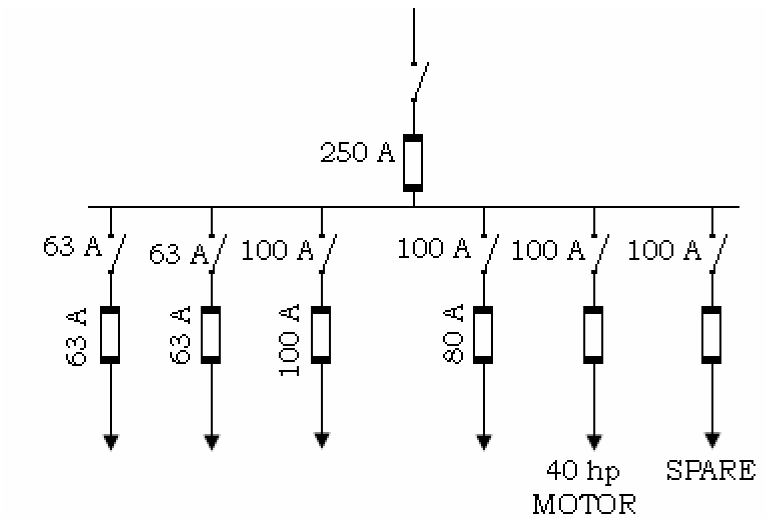
Switch boards in general are power distribution centers with SFUs/MCCBs/ACBs/OCBs for controlling outlets and incomer. Unlike DBs, switch boards are specified by its total current carrying capacity or incomer current rating. Where as in DBs current rating of the outlet is the specified rating. Standard switch board ratings are 100 A, 200 A, 400 A, 800 A, 1200 A, 1600 A, 2000 A, 2500 A and 3200 A. If the incomer supply is controlled with an SFU, the switch board is called switch fuse controlled board and if the incomer is ACB/ OCB controlled, it is called breaker controlled board.



- ✓ A switch board having three sections
  - Outlet control gears
  - Bus chamber
  - Incomer control gear

The outlet switch, fuse and cable rating are decided by the load that has to be handled through that feeder. If the number of loads is more, SSB is required, which is installed almost at the load centers. In smaller set up SSB may not be necessary and MSB will be the only switch board.

Consider the setup:-



- For 63 A and 100 A respective rating of switch and fuse are available.
- For 80 A, 100 A switch with 80 A fuse may be used, since 80 A switch is not available.
- For 40 hp motor with star-delta starter
  - Starting current = 40 x 1.4 x 1.5 = 84 A

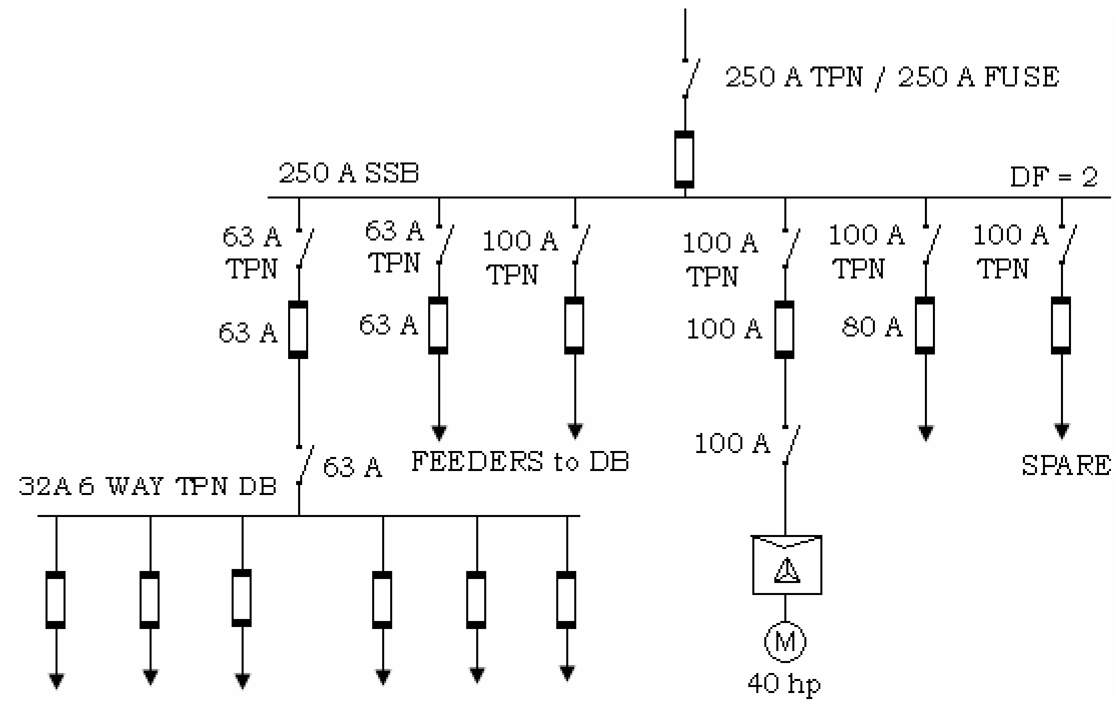
    Therefore 100 A switch and fuse are used

- Spare is taken as 100 A
- Total out going fuse rating = 63 x 2 + 100 x 3 + 80 = 506 A
- DF of 2 is assumed
- The MD will be = (506/2) = 253 A
- Taking 20 % extra, the maximum current requirement = 303.6 A

  say, 300 A

  Hence the incomer switch and fuse shall have a rating of 300 A is used. If 300A switch is not available, 400A switch with 300A fuse can be used. The incomer cable is also rated for 300A.

- But in this case, instead of 56A (40 x 1.4) continuous current of 40 hp motor, we have taken 84 A and fuse of 100A. Considering all these, a practical and most economical selection is 250A incomer.
- Since the incomer fuse is 250A, any fuse on the outlet greater than 125A will grade with 250A. Here maximum fuse rating is 100A and grading is automatically satisfied.



✓ Next step is finding Bus bar size.

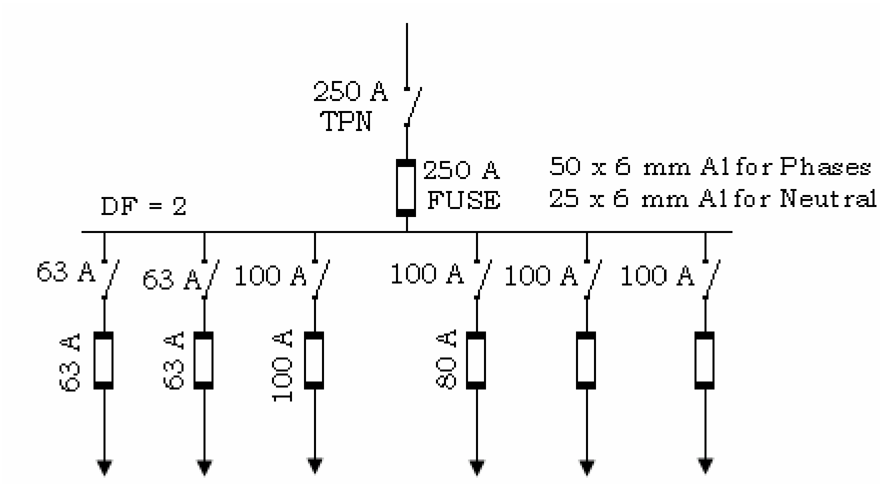
- Bus bar materials are:
    - Aluminum or Aluminium alloy – working current density, 0.8 A/ Sq.mm
    - Copper – working current density, 1.2 A/ Sq.mm
    - For the above set up:-
        - 250/0.8 = 312.5 Sq. mm
        - For neutral bus bar, half the size of phase bus bar size is sufficient.
        - ie, 40 x 8 mm or 50 x 6 mm Al bus bar may be

used for phases and 20 x 8 mm or 25 x 6 mm for neutral.

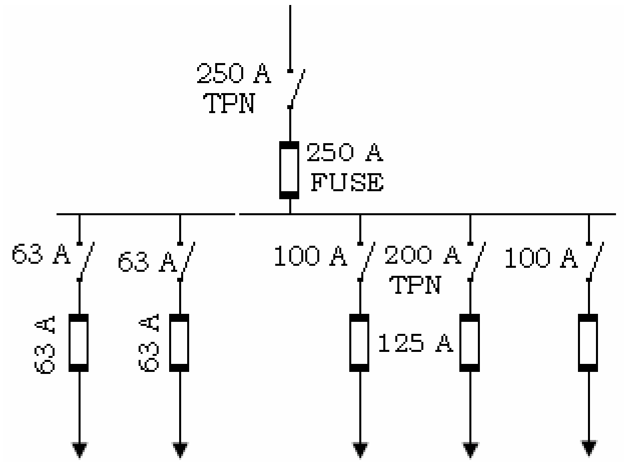
Or

- 31 x 6 mm Cu bus bar may be used for phases and 31 x 3 mm for neutral.

- For small switch boards the distance between the bus supports will be 50 cms.



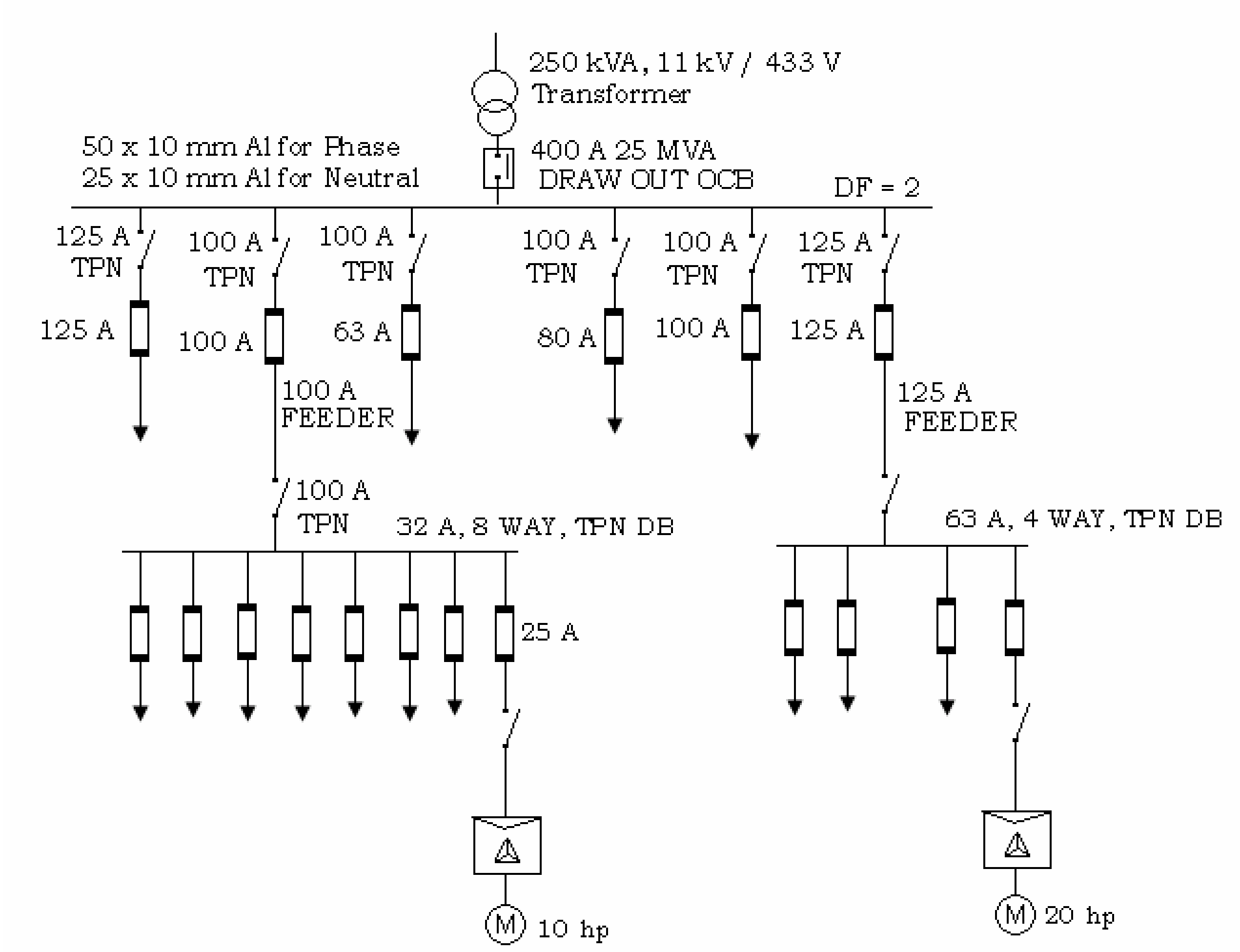
- If DF is not given, we can assume, DF as 2 for all switch boards.
- The term ampacity is some times used to denote the maximum current rating of the feeders. If DF is not clearly known, the total ampacity of outlet feeders shall not be more than two times the ampacity of the incomer feeder.
- The feeder cables need to be selected for the fuse used in the SFU.
    - Eg:- when we want 125A feeder, the fuse and cable corresponding to 125A. But the switch may be 200A, since above 100A, only 200A switch is available.
- Standard switch ratings are: 32A, 63A, 100A, 200A, 250A, 400A, 630A AND 800A. Some manufactures makes 125A and 320A also.



- ✓ In the above diagram, the incomer switch and fuse are rated for 250A. One of the outlet switches is rated to 200A. But the scheme is correct. Though the switch is rated to 200A, the fuse is only 125A, which will grade with the incomer 250A.
- ✓ There is no lower limit for the outlet of fuses, except those are imposed by practical consideration of mounting. ie, it may not be possible to mount a 5A fuse in a 32A switch. But there is lower limit for outlet switch rating.
- ✓ **When the incomer of a switch board is controlled with an SFU**
    - **Maximum outlet <u>fuse rating</u> is $\frac{1}{2}$ of incomer fuse rating. There is no upper limit for switch rating except that is imposed by economic consideration.**
    - **Minimum outlet <u>switch rating</u> is $\frac{1}{10}$ to $\frac{1}{12}$ of incomer fuse rating. There is no lower limit for fuse rating other than availability and mounting possibility.**

- ✓ **When the incomer of a switch board is controlled with a Breaker, the maximum current rating of outlet fuse should not be more than $\frac{1}{3}$ of incomer rating (setting of CB) and minimum outlet switch rating shall not be less than $\frac{1}{5}$ of the breaker rating.**

- CBs are available in the ranges of 400A, 800A, 1200A, 1600A, 2400A, 3200A and 3600A



10. Substations

On the basis of design substations may be classified in to

(a) Outdoor type

i. Pole mounted (single stout pole/ H-type/ 4-pole structure employed for transformers of 25 kVA, 100 kVA and above 100 kVA)

ii. Foundation mounted (For transformers above 250 kVA and voltage of 33 kV and above)

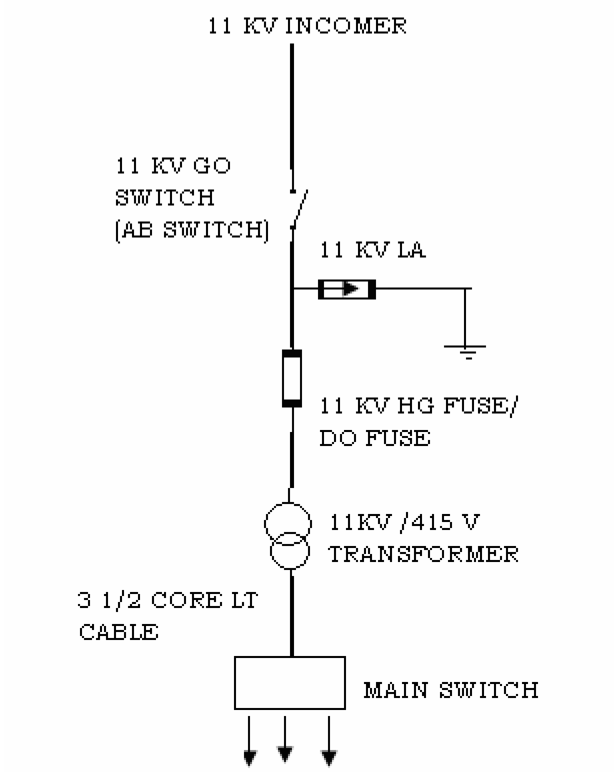
(b) Indoor type (In this the substation apparatus are installed within the building)

(10.1) Outdoor substation

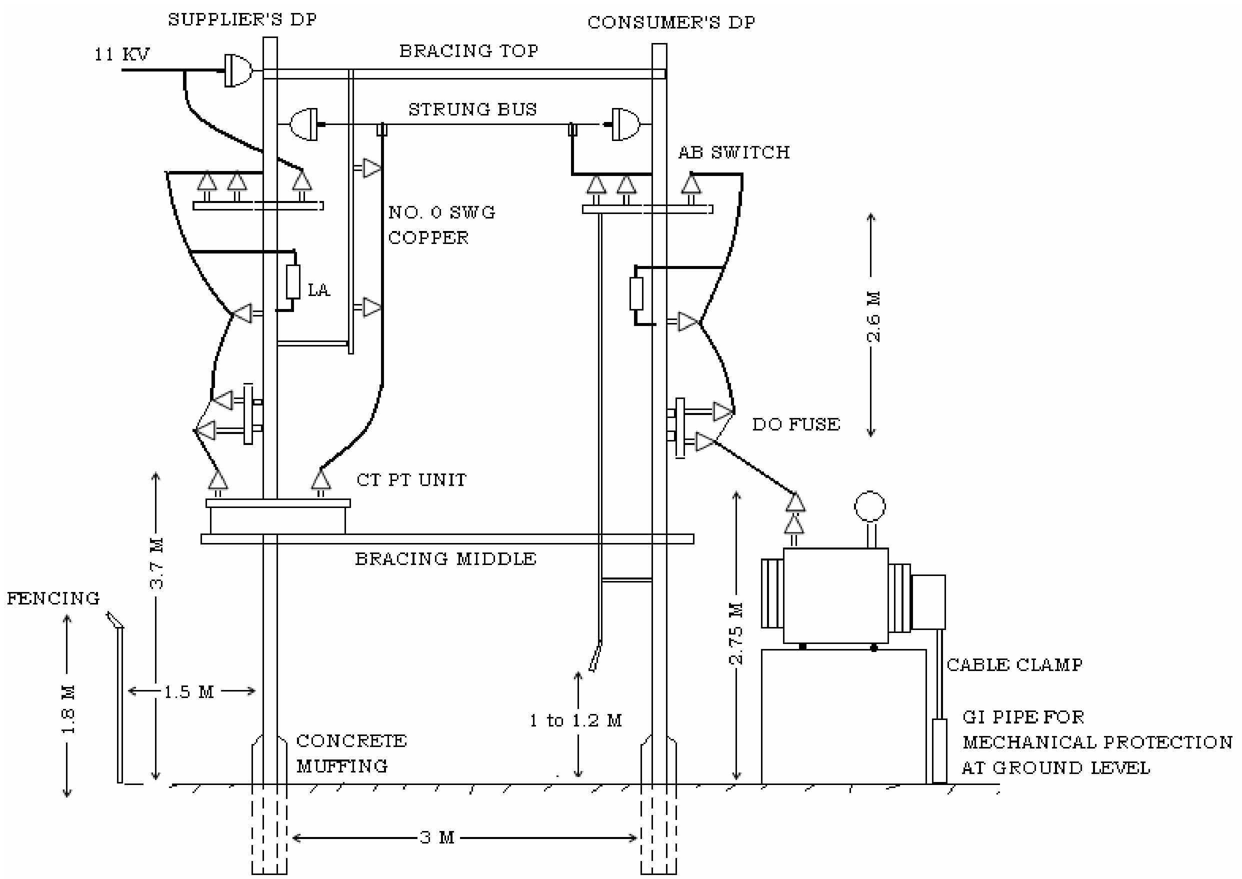
When transformers are installed out door, certain clearances must be maintained.

- Clearance between supplier's and consumer's structure should not be less than 3 meters. This is for maintaining the minimum sectional clearance of 206 m at 11 kV.

- Supplier's and consumer's structure shall be braced together when the clearance between them is 5 m or less.
- The ground clearance of the live parts of CTPT unit shall not be less than 3.7 m.
- Phase to phase clearance at the AB switch shall be 915 mm
- Phase to earth clearance at the AB switch shall be 610 mm. It is the clearance between the operating rode of the AB switch and the jumpers of 11 kV down conductors
- The supported length of 11 kV jumpers shall be limited to 1.5 m for standard conductors and 2.44 m for solid conductors (No. 2 or No. 0 SWG copper).
- Where there is a cable end box with open terminations, the clearance of the live pars to ground shall not be less than 305 m
- The ground clearance of ht parts, usually 11 kV at the transformer bushings shall not be less than 2.75 m.
- The ground clearance of AB switch handle shall be between 1 and 1.2 m



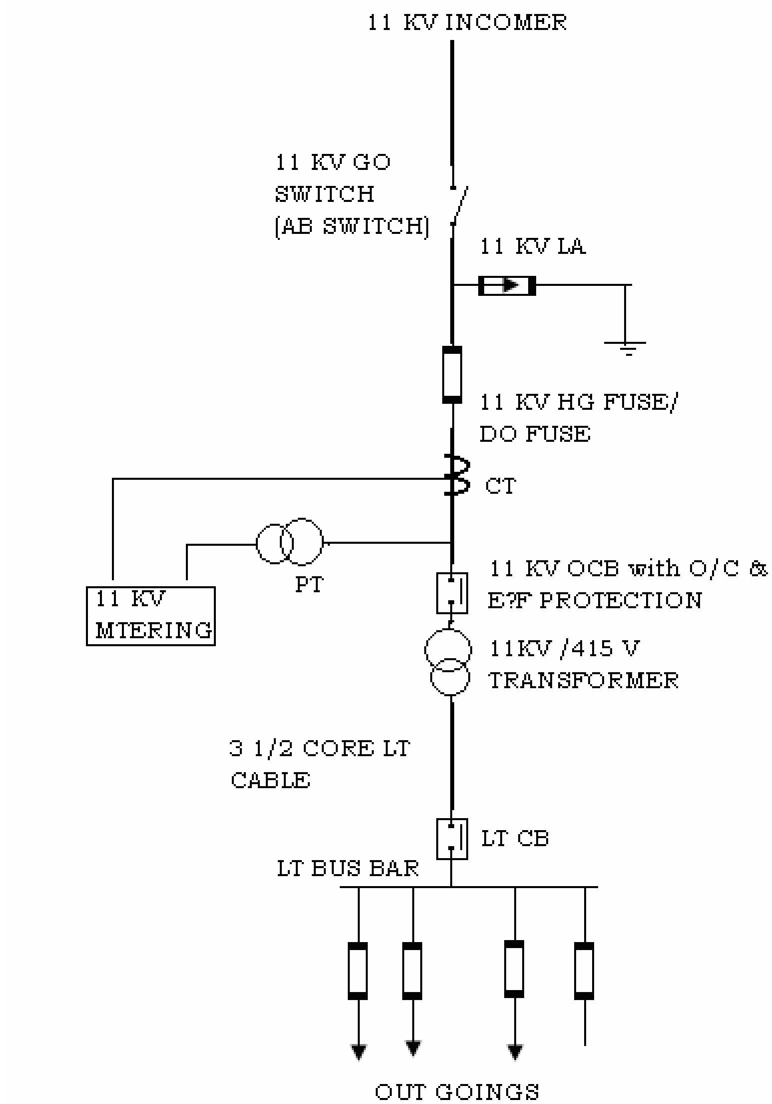
SINGLE LINE DIAGRAM OF 11 KV OUTDOOR SS



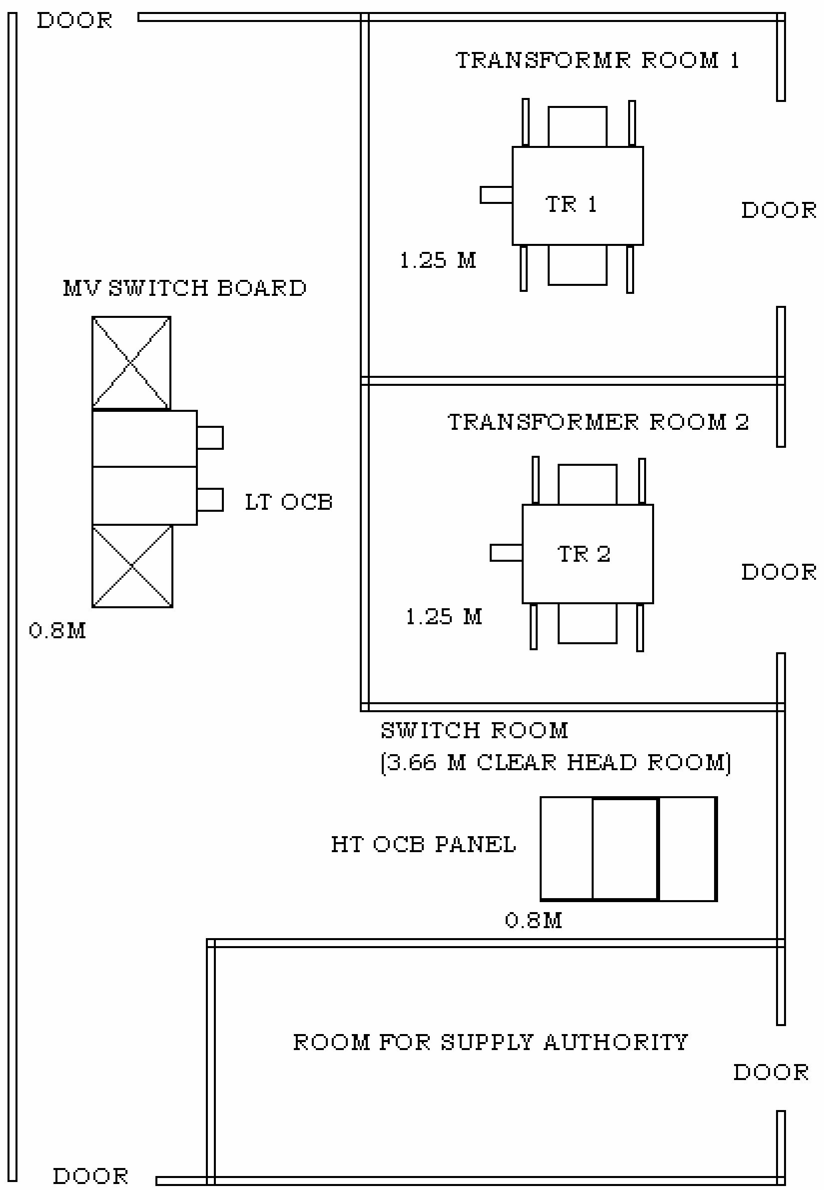
(10.2) Indoor Substation

Indoor substation of 11 kV/415 V are usually installed at industrial areas and other load areas like multistoried buildings, telephone exchange etc. Substation building is constructed for installing transformer, HT and LT panel etc. Room size should be sufficient, so as to give adequate clearance between wall and various equipments. Suitable ventilation for entry of fresh air at the bottom of transformer room and exit of hot air at top on opposite sides are necessary. The installation of transformer should that the cable boxes are on the sides and not facing the door.

The OH line terminates on a DP structure outside the indoor substation. All protection accessories such as AB switch, LA and DO fuse are installed in the DP structure. CT PT unit is installed for connecting metering device. Supply to HT side of transformer is brought through UG cable. Both sides of the transformer are protected by suitable capacity CB. Adequate fire fitting equipment shall be provided at easily accessible positions. Danger notice board should be provided on the HV and MV equipments.



Key diagram of a 11 kV/415 V indoor substation



Layout of indoor substation