Earthing DESIGN

Guest Lecture on Earthing Design at ACCET, Karaikudi on 29-08-2017

By

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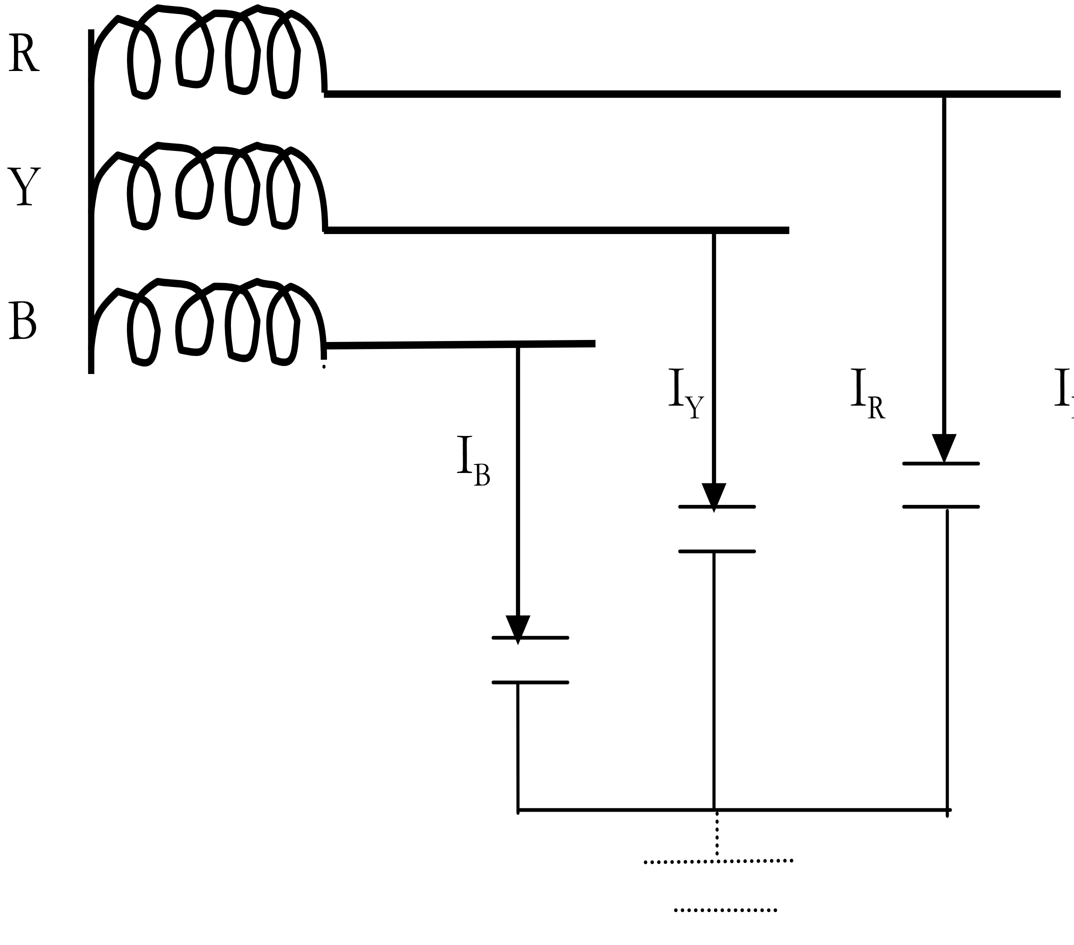
Unearthed system



$$\vec{I}_R + \vec{I}_Y + \vec{I}_B = 0$$

Figure-4: Circulating current in an unearthed system

Unearthed system

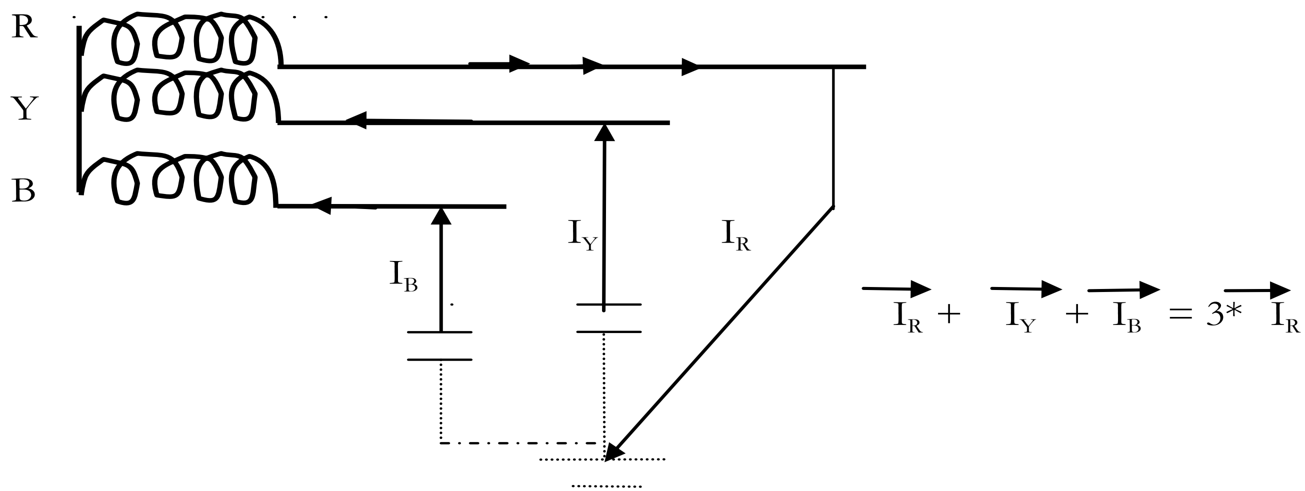


Figure-5: Circulating current when one of the phases is faulted to the earth.

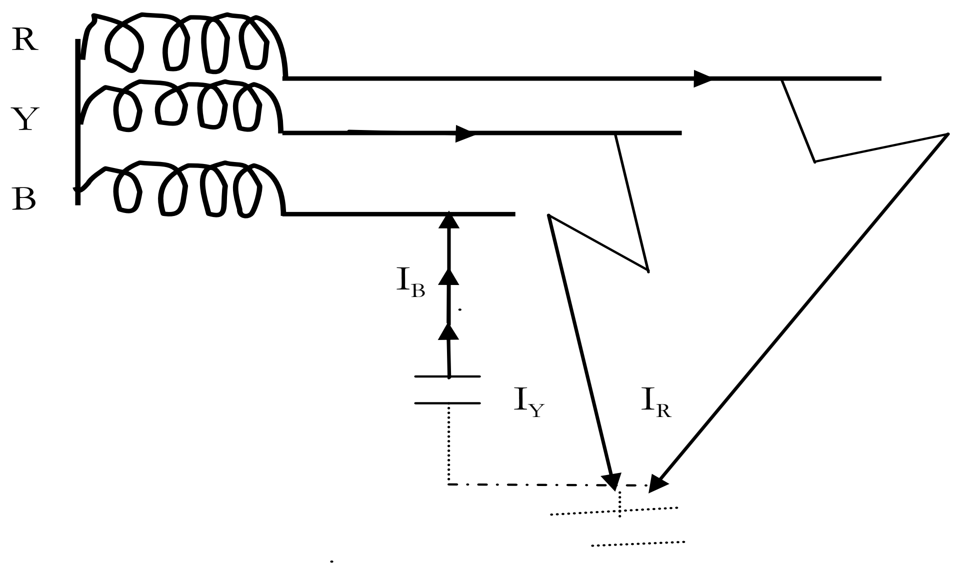


Figure-6 The second earth fault creates a short circuit between the faulty phases.

CEA Regulation

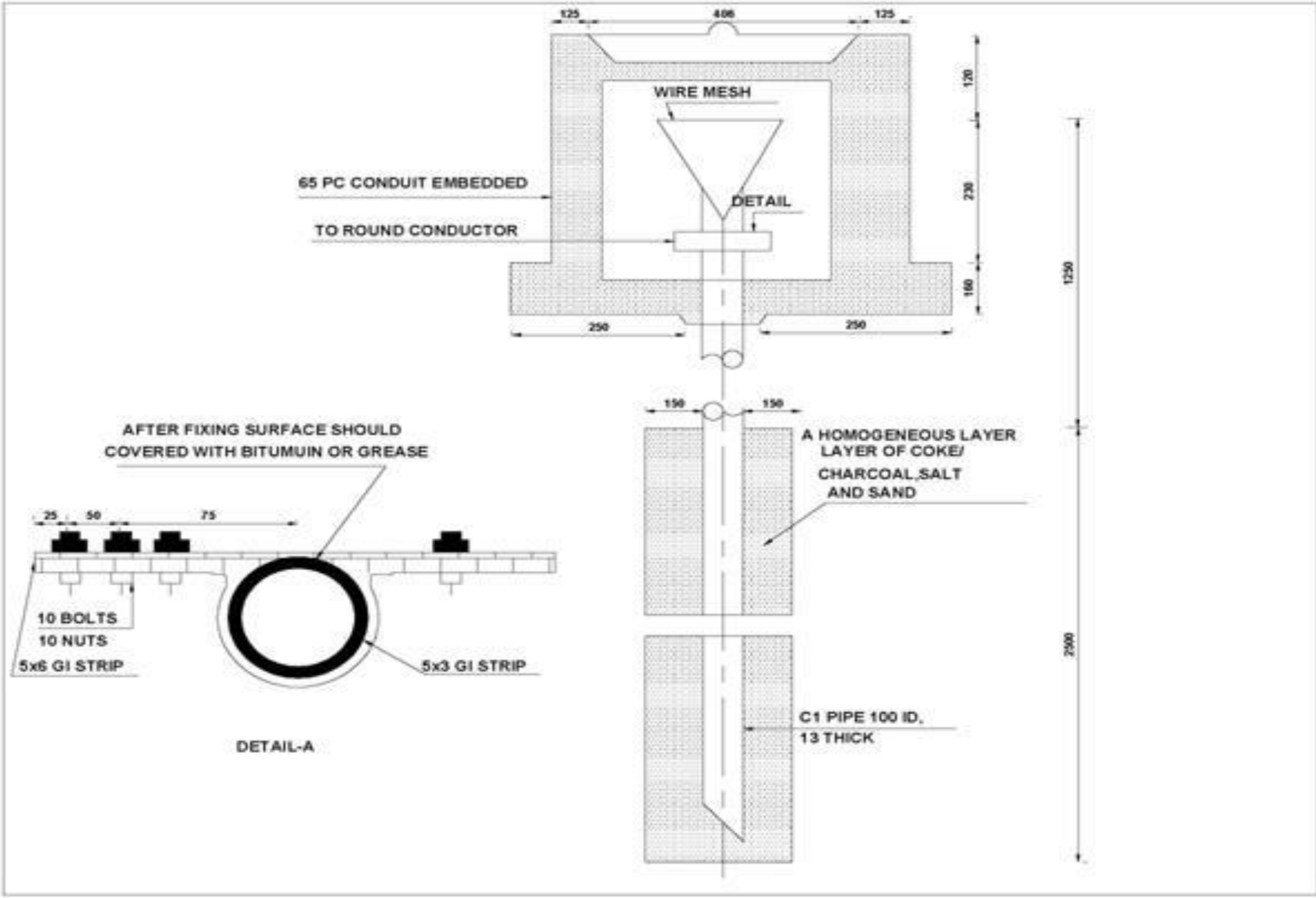
48. Connection with earth for apparatus exceeding 650V: -

(1) All non-current carrying metal parts associated with an installation of voltage exceeding 650 V shall be effectively earthed to a grounding system or mat which shall,-

(ii) limit the ground potential rise to tolerable values so as to prevent danger due to transfer of potential through ground, earth wires, cable sheath, fences, pipe lines, etc.;

(iii) maintain the resistance of the earth connection to such a value as to make operation of the protective device effective;

Typical pipe earth electrode



Typical Earthing Scheme

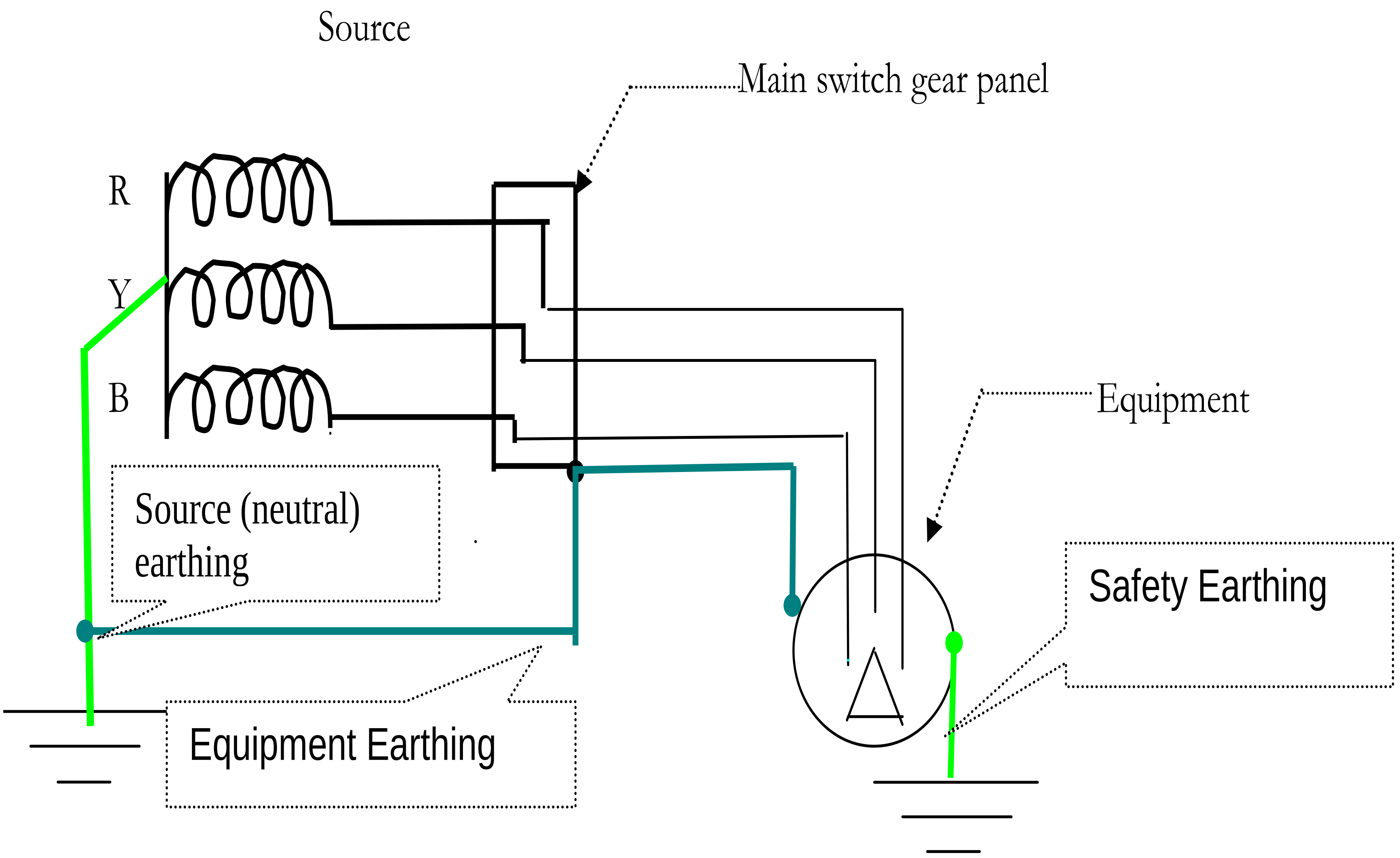


Figure-7: Standard way of earthing

Purpose of earthing

- **Limit the step and touch voltages on the accessible equipment and surfaces both during normal operation and during transients to safe levels.**

- **Earthing provides a low impedance earth fault return path in order to ensure proper clearing of faults thereby limiting hazardous voltage and restriking which in turn reduces the risk of fires and personnel injuries**

- **Minimise electrical noise interference in control and instrumentation systems**

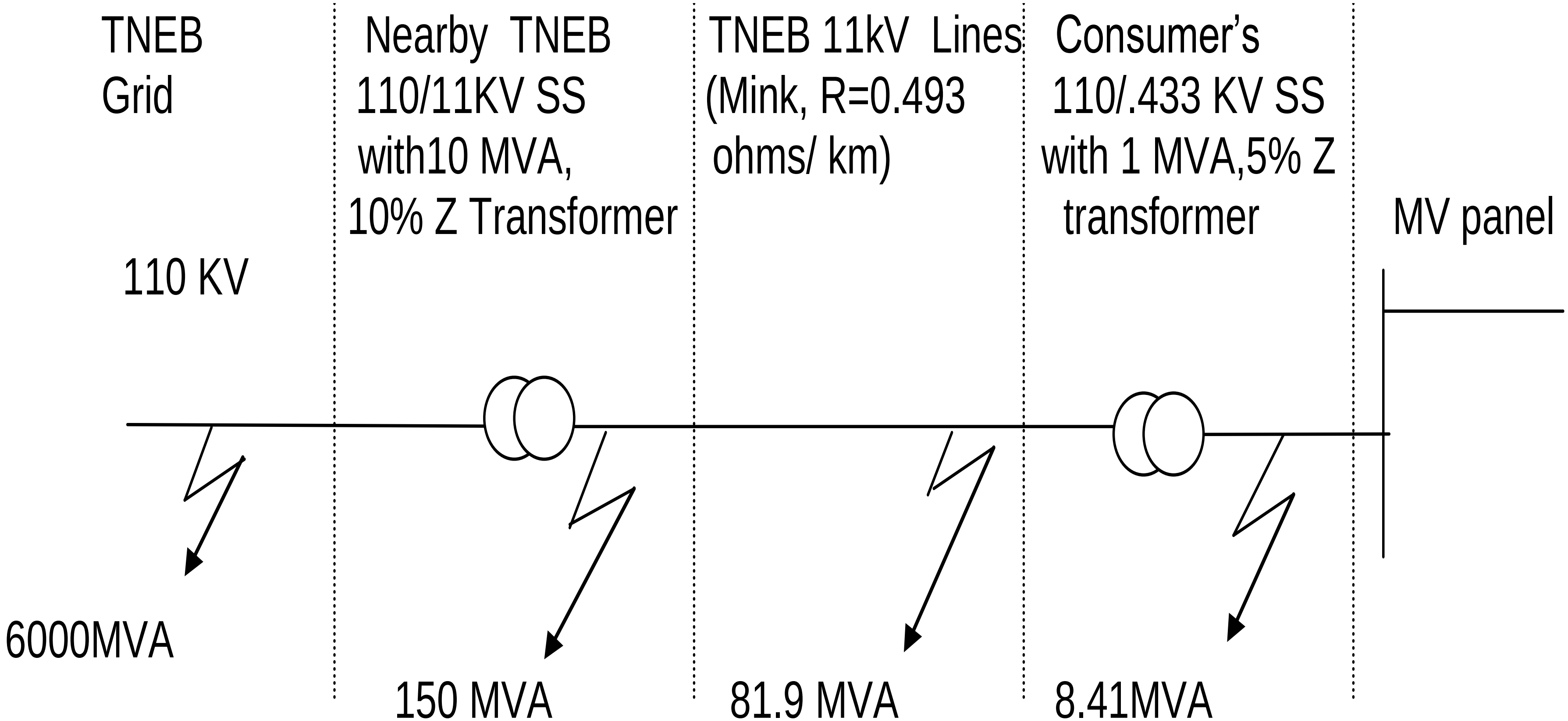
- **Minimise the effect of lightning strikes on personnel , equipment and structures and arcing grounds.**

- **Earthing serves the primary functions of referencing the AC systems.**

Important factors relating to the principles of earthing and to arrive at a design

- Fault level
- Current transformers, Relays & Protective gears
- Safe let-through current (Permissible touch voltage) and duration of fault clearance
- Effective earth resistance value required for limiting the touch voltage
- Soil resistivity
- Configuration of various types of earth electrodes
- Adequacy for the size of earth flats to withstand the fault level
- Adequacy for the size of earth flats to meet the current loading effect
- Design calculations to cover the above factors

Fault level at different location



Model Fault current calculation

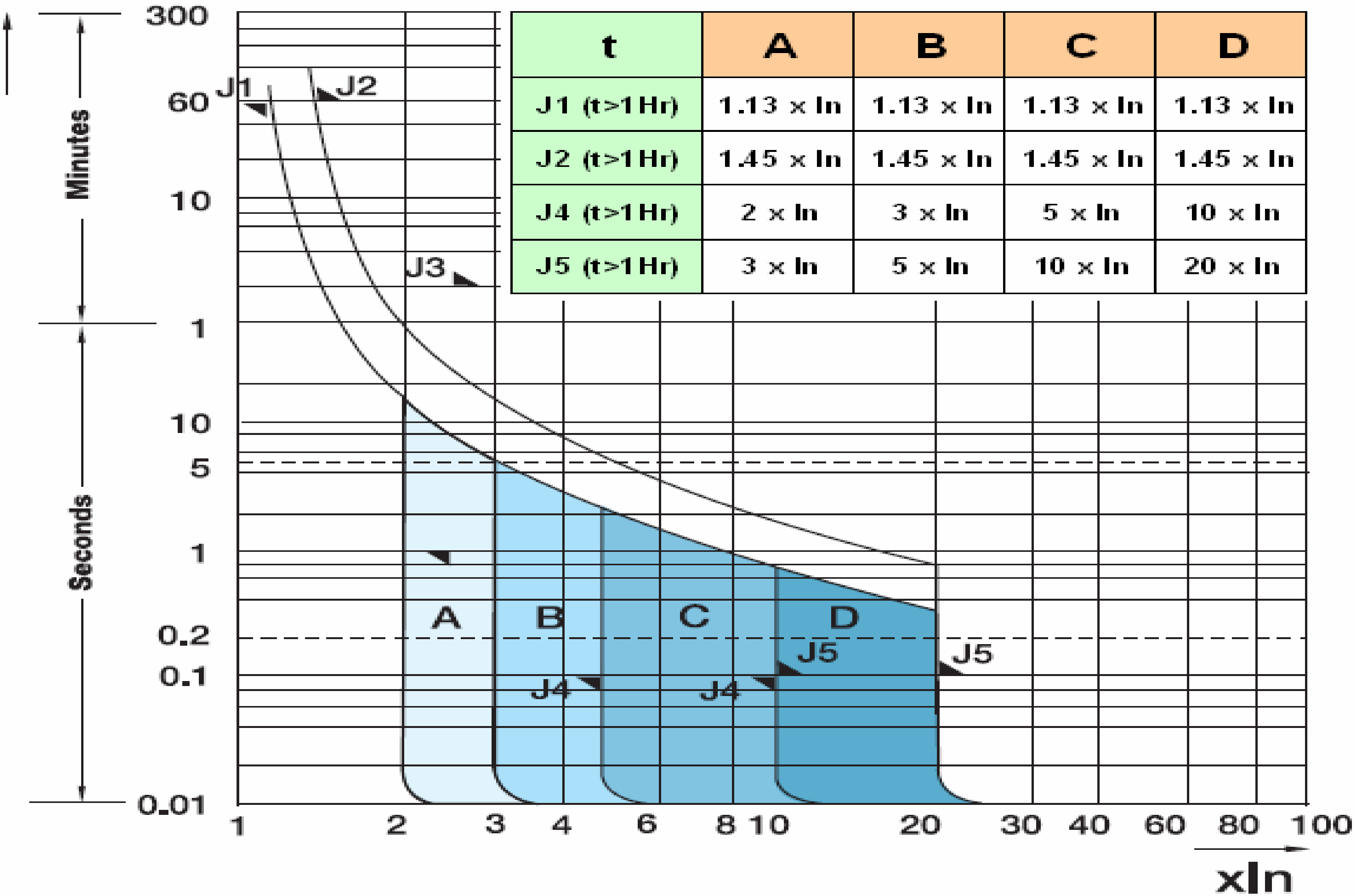
- Fault MVA = $(kV)^2$ / Impedance

- Source (utility) impedance = $(kV)^2$ / Fault MVA

- Impedance of the (utility) transformer = %Z x $(kV)^2$ / (100 * MVA)

- Impedance converted to the secondary side of transformer = Z1 $(kV2^2/kV1^2)$

Tripping Characteristic – Time Current Curve of MCB



t	A	B	C	D
J1 (t>1 Hr)	1.13 x In	1.13 x In	1.13 x In	1.13 x In
J2 (t>1 Hr)	1.45 x In	1.45 x In	1.45 x In	1.45 x In
J4 (t>1 Hr)	2 x In	3 x In	5 x In	10 x In
J5 (t>1 Hr)	3 x In	5 x In	10 x In	20 x In

It should always be ensured that the (I^2 t) let through energy of the protective gear is matched and is always less than that of the protected circuit's permissible let through energy.

Safe let-through current and Touch potential

- A person can withstand without ventricular fibrillation, the passage of a current in magnitude and duration determined by the formula: $I_b = 0.116/\sqrt{t}$;

  where Ib is the fibrillating current in Amps ,

  ‘t’ is the duration of current flow in seconds.

  Based on this expression and normal body resistance, the safe touch potential is expressed as: E_{TOUCH}(in volts) = $I_b * 1000$.

Tolerable touch voltage

I_b in milli Amps or E_{touch} in volts	259	164	116	82	67
t in seconds	0.2	0.5	1	2	3

Current Transformers

- E.g.: 5P15,200/1A, 30 VA CT means that:
- 5 is the accuracy class, 15 is the accuracy limit factor (ALF),200/1 is the CT ratio and 30 is the burden.
- (ALF): when the primary current is 15 times the rated value (ie., 15x200 = 3000A) the CT can still feed the burden of 30 ohms and the composite error will not exceed 5%.

Selection of CTs

- It is governed by the sensitivity (minimum earth fault setting) and highest instantaneous setting in % of primary current rating.
- Neutral CT of lower rating independent of CT for overload protection is feasible.
- 800/5,5P20 CT will be required for a fault level of <16kA
- This will yield a response for just 320A primary fault current at 40% setting.
- Lower the primary current selection higher the permissible earth resistance value for a same touch voltage

SOIL RESISTIVITY -TYPICAL VALUES

p = 2*22/7*s*R Ohm-Metre

(s) distance between successive earth spikes in metres	(R) Resistance in Ohms(as measured by the instrument)	(p) Soil Resistivity in Ohm-Metres	Effect of corrosion on the range of soil resist	
5	0.5	15.715	Soil resistivity in Ohm-metre	Effect of corrosion
5	1	31.43		
5	2	62.86		
5	3	94.29	upto 25	Severely corrosive
5	4	125.72	upto 50	Moderately corrosive
5	5	157.15	upto 100	Mildly corrosive
5	7	220.01	above 101	Very mildly corrosive

Note:1) The depth of earth spike into the earth should not exceed10 to 15 cm during the test and it should be less than 1/20 th of spacing between the earth spikes.

Note:2) More than 15% moisture does not improve earth resistance value

Note:3) More than 5% salt does not improve earth resistance value

Note:4) The use of coke as an infill aggravates corrosion esp. where soil resistivity is <25 Ohm

Pipe electrodes

- Resistance of Pipe or Rod Electrode

  R = 100 x p x [Ln(4L/d)] Ohms

- More than 3 m length of pipe does not yield improvement in earth resistance value unless the substrata posses a very low resistivity down to 6-9 m depth

Resistance of Pipe or Rod Electrodes

TYPICAL VALUES			
(p) SOIL RESISTIVITY IN OHM-M	(L)LENGTH OF PIPE OR ROD IN CM	(d) DIAMETER OF PIPE IN CM	(R)RESISTANCE OF EARTH ELECTRODE IN OHMS
10	300	3.8	2.522646045
15	300	3.8	3.783969067
20	300	3.8	5.045292089
25	300	3.8	6.306615112
30	300	3.8	7.567938134
40	300	3.8	10.09058418
50	300	3.8	12.61323022
60	300	3.8	15.13587627
75	300	3.8	18.91984534
100	300	3.8	25.22646045
500	300	3.8	126.1323022
1000	300	3.8	252.2646045

Note:1) More than 3 m length of pipe does not yield improvement in earth resistance value unless the substrata posses a very low resistivity down to 6-9 m depth .

Note:2) Electrode material does not affect earth resistance value,but care should be taken for the environment and corrosion

Note 3)Soil treatment can achieve further reduction of combined value of earth resistance value. But the seasonal variation off sets such an improved value. Hence these factors are not taken into account on the side of safety.

Note 4)Concrete encased earthing methods for a deep sand strata, bentonite treatment for bed rock soil and building re-bars utilized for the earthing system greatly reduces the effective earth resistance values.

Strip electrodes

$$R = \frac{100*p* Ln(2*L^2/w*t) \text{ Ohms}}{2*22/7*L}$$

where

(R) is the resistance of earth electrode in ohms,

(L)length of strip or rod in cm,

(w) depth of burial of electrode in cm,

(t)width(for strip) or twice the dia (for conductors) in cm ,

(ρ) soil resistivity in ohm-m.

Resistance of Strip Electrodes

TYPICAL VALUES					
(p) SOIL RESISTIVITY IN OHM-M	(L)LENGTH OF STRIP OR ROD IN CM	(w)Depth of burial of electrode in CM	(t)Width(for strip) or twice the dia (for conductors) IN CM	(R)RESISTANCE OF EARTH ELECTRODE IN OHMS	Where
10	1000	50	6	1.4013394	(R) is the resistance of earth electrode in ohms
15	1000	50	6	2.1020091	
20	1000	50	6	2.8026788	(L) Length of strip or rod In cm
25	1000	50	6	3.5033486	(w) Depth of burial of electrode in cm
30	1000	50	6	4.2040183	
40	1000	50	6	5.6053577	(t) Width
50	500	50	6	11.807038	ρ = soil resistivity in ohm-m
60	1000	50	6	8.4080365	
75	1000	50	6	10.510046	
100	1000	75	6	13.368076	
100	500	50	6	23.614076	
100	1500	50	6	10.202686	
100	2000	50	6	8.1098751	
100	3000	50	6	5.8367952	
100	1000	50	6	14.013394	

Size of earth flats

- **S = $\frac{\text{I*Sq Root (t)}}{\text{K}}$ Sq.mm Where t<=3seconds**

- Apply constants for: increase in future fault level due to plant and system modifications CP = 1.25 and decrement factor Cd = 1.3 if the fault clearing time is less than 0.2s or 1 if the fault clearing time is equal to or more than 0.2 s

i.e. If x 1.25 x 1.3 (or 1.0)

- Corrosion factor for various types of soil

Table-6	Values of k factor for calculting the area of cross section of various type of earthing conductors for a fault clearing time of 3 seconds

A. Bare conductor with no risk of fire or danger to any other touching or surrounding material

Initial temperature	Final temperature	Copper	Aluminium	Steel
40	395	118		
40	325		73	
40	500			46

B. Insulated protective conductors not incorporated in cables or Bare conductors touching other insulating cables

Initial temperature	Final temperature	Copper	Aluminium	Steel	
40	160	79	52	28	PVC
40	220	92	61	33	Butyl rubber
40	250	98	65	36	XLPE/EPR

C. Protective conductor as a core in multicore cables

Initial temperature	Final temperature	Copper	Aluminium	
70	160	66	44	PVC
85	220	77	51	Butyl rubber
90	250	83	54	XLPE/EPR

D. Protective bare conductors in hazardous areas where there is risk of fire from petroleum bound oil or other surrounding material

Initial temperature	Final temperature	Copper	Aluminium	Steel
40	150	76	50	27
40	200	88	58	32

Typical Size of Earth Flats

Typical values

Fault current flowing through the protective device in Amps	(t) Operating time of the disconnecting device in seconds	(k) Constant for various type of materials used as earthing conductors (for 1 to 3 sec operating time)		Area of cross-section of the earth conductor in Sq.mm
		copper(for 3 sec)	steel (for 3 sec)	For copper
2500	3	118	46	36.695992
7000	3	118	46	102.74878
10000	3	118	46	146.78397
15000	3	118	46	220.17595
20000	3	118	46	293.56793
21350	3	118	46	313.38377
35000	3	118	46	513.74388
50000	3	118	46	733.91983

Note: Mechanical considerations
1.a) Minimum size of 16Sqmm copper (if protected) or 25Sqmm Cu. with thickness not less than 2mm (if unprotected) is required.b) If the earthing conductor is forming one of the cable cores along with the phase conductors, the minimum size shall be 2.5Sqmm copper or 4 Sqmm aluminum up to phase conductor size of 2.5Sqmm, for size above 2.5Sqmm and up to 35Sqmm, the size of earthing conductors shall be not less than that of the phase conductor.
2. Apply constants for: increase in future fault level due to plant and system modifications CP = 1.25 , and CF = 0.5 for grid division factor.
3. Corrosion factor for various types of soil in the case of steel conductor is:
a) 30% allowance for severely corrosive soil;
b) 15% for moderately and mildly corrosive soil;
c) no allowance for very mildly corrosive soil.
4. The ‘K’ factor has to be modified in special cases according to IEEE 665.

Spread Sheet to design an earthing system or simulation

IEC 60364 Part 7-710: Requirements for special installations or locations – Medical locations

- group 0 where no applied parts are intended to be used where no applied parts are intended to be used
- Group 1 where applied parts are intended to be used – externally; – invasively to any part of the body
- Group 2 medical location where applied parts are intended to be used in applications such as intracardiac procedures, operating theatres and vital treatment where discontinuity (failure) of the supply can cause danger to life
- The TN-C system is not allowed in medical locations and medical buildings downstream of the main distribution board
- Protection against direct contact
  - Protection by obstacles is not permitted.
  - Protection by placing out of reach is not permitted.
  - Only protection by insulation of live parts or protection by barriers or enclosures are permitted.

EQUIPMENT USED FOR MEASUREMENT OF SOIL RESISTIVITY:

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