

SUBSTATION EARTHING

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Agenda

- Introduction
- Concepts
- Electric Shock
- Objectives of Earthing
- Classification of Earthing
- Basic Design
- General Considerations
- Earth Potential Rise (E.P.R)
- Case studies
- References

INTRODUCTION

Introduction

- IMPORTANCE OF EARTHING,EARTH CONDUCTION,VOLTAGE GRADIENTS
- ELECTRIC SHOCK,TOUCH AND STEP POTENTIALS
- SOIL RESISTIVITY,CONDUCTION
- FAULT LEVELS AND MAX. EARTH FAULT CURRENT,
- DESIGN AND LAYING OF EARTHMAT,
- DESIGN OF EARTHMAT UNDER DIFFICULT CONDITIONS,
- EARTH POTENTIAL RISE (E.P.R) AND INTERFERENCE WITH TELECOMMUNICATION CIRCUITS.

Importance of Earthing, in Power System

50 % Failure of equipments attributed to Earthing.

40,000 Lightning storms/day or

100 Lightning storms/second

98 % of the faults in the system are due to SLG Faults

1.5 % of the faults are due to Line to Line Faults

0.5 % of the faults are due to 3 Phase Faults

Importance of Earthing, in Power System

- **PLAY A FUNDAMENTAL ROLE IN PREVENTING OVER VOLTAGE AND CURRENT CONDITIONS**
- **IMPARTS ON SHORT AND LONG TERM LIFE OF ELECTRICAL EQUIPMENTS**
- **AT THE LOW COST OF IMPLEMENTATION THERE IS NO MEASURE THAT IS MORE COST EFFECTIVE**
- ***EARHING IS THE ONE COMMON DENOMINATOR WHICH CONTROL OVER VOLTAGES AND CURRENTS DURING ABNORMAL CONDITIONS***

POPULAR (MIS) CONCEPTS ABOUT EARTHING

- EARTH IS A GOOD CONDUCTOR
- GROUND POTENTIAL IS ALWAYS ZERO
- PROTO TYPE EARTHING DESIGN IS SUFFICIENT
- EARTHING IS JUST BURYING CONDUCTOR
- EARTHING IS ONLY FOR ACHIEVING LOW RESISTANCE VALUE
- USE OF COPPER FOR EARTHING WILL GIVE LOW RESISTANCE

REASONS WHY EARTHING PROBLEMS ARE COMPLEX

- EARTH IS A POOR CONDUCTOR
- NON HOMOGENEOUS
- CONDUCTORS BURIED IN SOIL HAVE COMPLICATED SHAPE
- ACTIVE ONLY DURING FAULT CONDITIONS
- MOST OF THE ANALYSIS OF EARTHING IS BY EMPIRICAL FORMULAE

WHAT IS EARTHING ?

Earthing means an electrical connection to the general mass of earth to provide safe passage to fault current to enable to operate protective devices and provide safety to personnel and Equipments.

OBJECTIVES OF EARTHING :-

- Avoid potential rise of parts of equipments other than the live parts.
- Safe passage to earth for the fault current.
- Suppress dangerous potential gradients on the earth surface.
- To retain system voltages within permissible limits under fault conditions.
- To facilitate using of Graded insulation in power transformers

ELECTRIC SHOCK

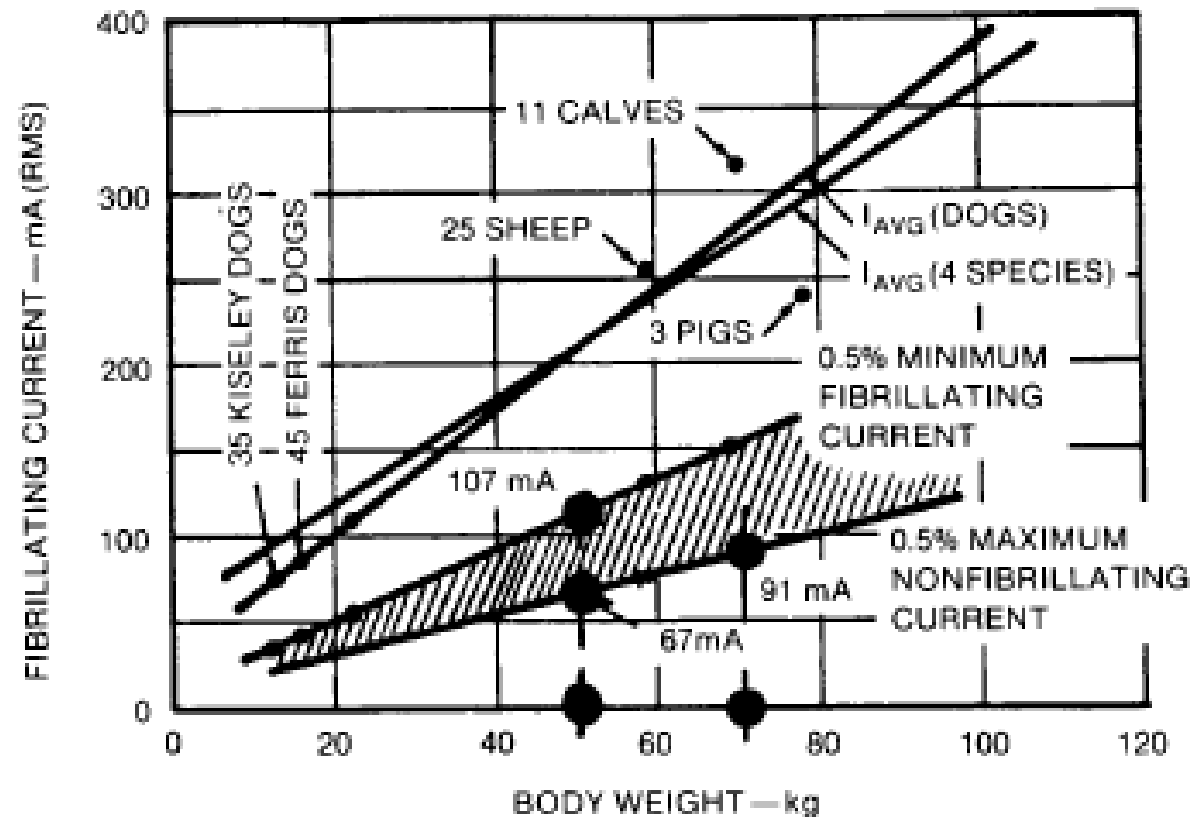
ELECTRIC SHOCK

The effect of electric current passing through vital organs of the body depends on:-

- *magnitude,*
- *duration and*
- *frequency of current.*

The most dangerous consequence is a heart condition known as ventricular fibrillation, which results in stoppage of blood circulation.

Fibrillation current verses Body weight for various Animals based on a three second shock



VALUE OF CONSTANT k FOR
EFFECTIVE RMS VALUES OF
 I_B ($k = I_B \sqrt{t_s}$):

$$k_{70} = 0.091 \sqrt{3} = 0.157$$

$$k_{50} = 0.067 \sqrt{3} = 0.116$$

$$k_{50} = 0.107 \sqrt{3} = 0.185$$

FIBRILLATION

ELECTRIC SHOCK

ELECTRIC SHOCK IS DUE TO ENERGY
ABSORBED BY BODY

$$(IB)^2 t = S_B$$

Where

IB = magnitude of current through the body in amps

t = duration of the current exposure in seconds

S_B = Empirical constant related to the shock energy
absorbed by a certain percent of a given population



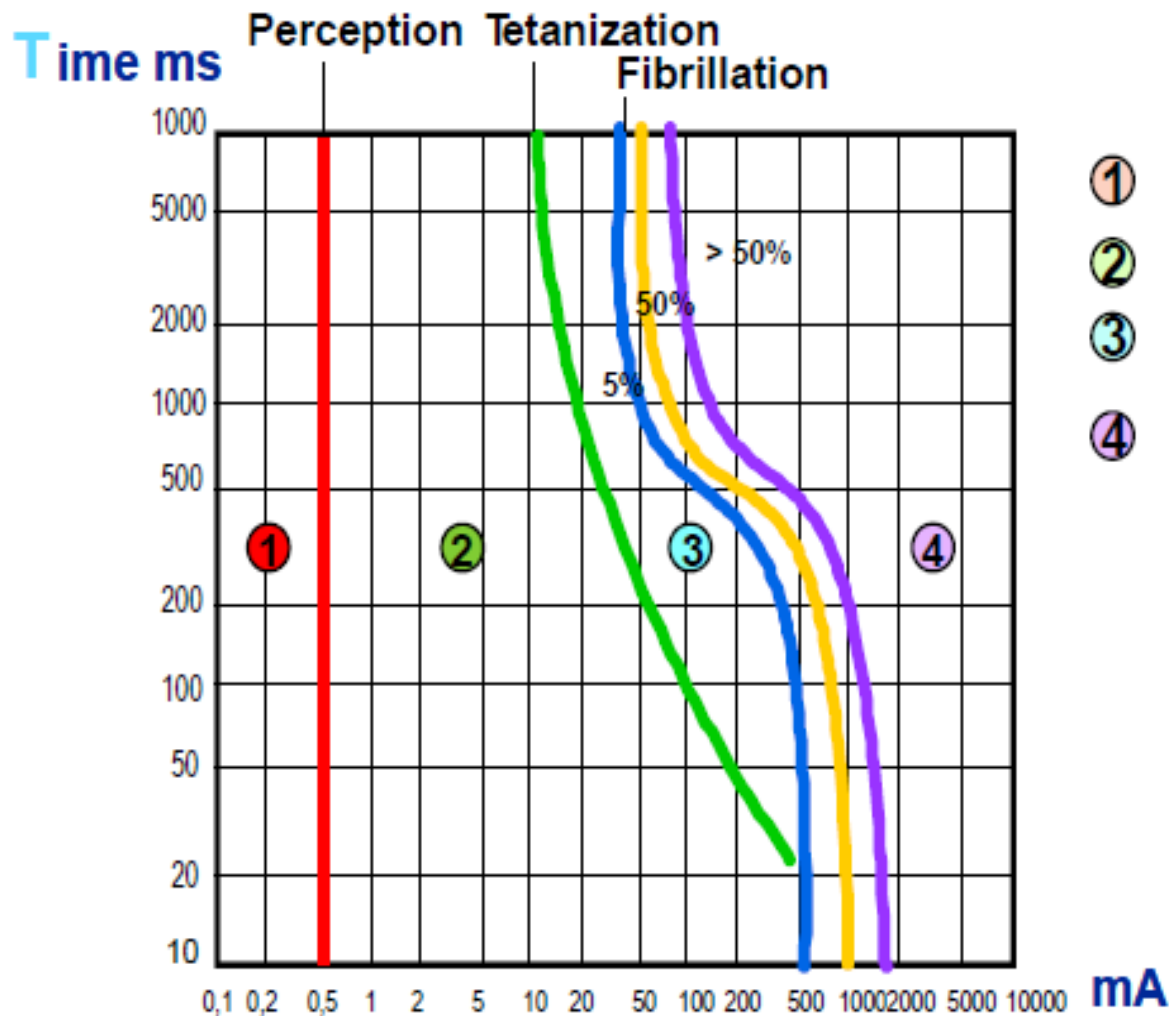
ELECTRIC SHOCK

Effect of magnitude of current

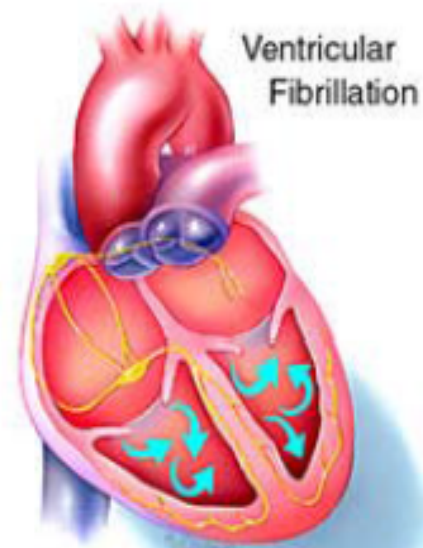
- The *threshold of perception* is a current of 1 m.A.
- Currents in the range of 1-6 m.A are known as '*let go current*' because these currents, though unpleasant, do not impair the ability of a person, holding an energized object to release it.
- Currents in the 9-25 mA range may be painful and impair the ability to release energized object.
- Still higher currents make breathing difficult.
- If the current is less than about 60 mA, the effects are not permanent and disappear when current is interrupted.
- Currents higher than 60 mA may lead to *ventricular fibrillation*, injury and death.

Physiological effects

► IEC describes as follow the current effects:



- ① No reaction
- ② No harmful physiological effect
- ③ Reversible pathological effects
- ④ Fibrillation risk greater than 50%



Effects Of Current on Human Body

Milliamperes						
Alternating current						
Direct current		60 hertz		10,000 hertz		
men	women	men	women	men	women	
1. Slight sensation on hand	1	0.6	0.4	0.3	7	5
2. Perception threshold	5.2	3.5	1.1	0.7	12	8
3. Shock - not painful, and muscular control not lost	9	6	1.8	1.2	17	11
4. Painful shock - painful, but muscular control not lost	62	41	9	6	55	37
5. Painful shock - let-go threshold	76	51	16	10.5	75	50
6. Painful and severe shock muscular contractions, breathing difficult	90	60	23	15	94	63
7. Possible ventricular fibrillation effect:						
a. 0.003 second shock	1300	1300	1000	1000	1100	1100
b. 3 second shock	500	500	100	100	500	500
c. Short shock	--	--	#	#	--	--
d. High-voltage surges	*27	*27	*13.5	*13.5	--	--
8. Ventricular fibrillation - certain death	Multiply values above for 3 second shock by 2-3/4. To be lethal, short shocks must occur during susceptible phase of heart cycles.					

= $K / \text{square root of } T$

K = 116 for a 110 pound (50 kg) man

K = 157 for a 150 pound man

K = 165 for a 165 pound man

* Energy in watt-seconds or joules

T = time, in seconds

ELECTRIC SHOCK

Effect of frequency

The tolerable currents mentioned above are for

50 - 60 Hz. It has been found that human body can tolerate about 5 times, at high frequencies

(3000 – 10000 Hz).than the direct current.

ELECTRIC SHOCK

Effect of duration of current

The magnitude of 50 HZ tolerable current is related to duration. According to tests reported by Dalziel, 99.5% of persons of 50 Kg weight can withstand the current given by equation.

$$I_B = 0.116 / \sqrt{t}$$

Where I_B is the rms value of body current in amperes and 't' is the time in seconds. If the weight of body is 70 Kg., the equation for tolerable current is

$$I_B = 0.157 / \sqrt{t}$$

These equations are valid for $0.03 < t < 3$ seconds.

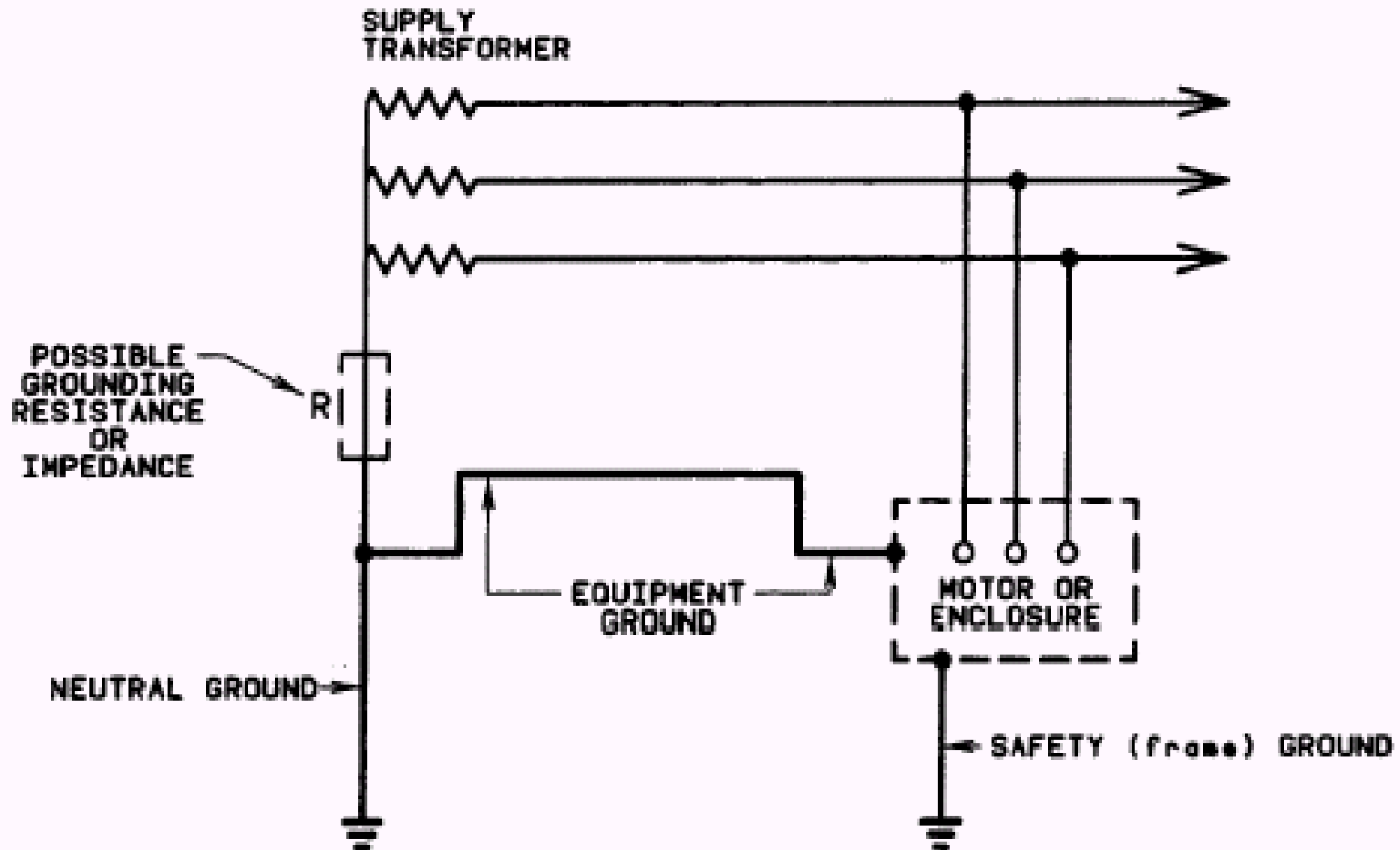
Objectives of Earthing

- For safety of equipments
- Safety of Operating personnel
- Safety of telecommunication equipments

TYPES OF EARTHING

- Neutral Earthing : deals with the earthing of system neutral to ensure system security and protection.
- Equipment Earthing : deals with earthing of non-current carrying parts of equipment to ensure safety to personnel and protection against lightning.

Types of Grounding



Neutral Earthing

1. Solidly Earthed

- Here neutral is directly connected to earth electrode/mat

2. Resistance/Impedance Earthing

- Here a resistance or an impedance, in general a potential transformer or a single phase distribution transformer is connected between the neutral and the earth electrode/mat.
- This is generally applicable to Synchronous generator earthing.

Disadvantages of solidly grounded systems

- High fault currents interfere with communication circuit.
- Danger to personnel in the vicinity of fault is high.
- Heavy fault currents may cause considerable damage to equipments.

BASIC DESIGN

EARTHING OF H.V. SUB-STATIONS

➤ *Soil Resistivity* :

Wenner's four electrode method of measurement.

➤ *Earth Fault Current* :

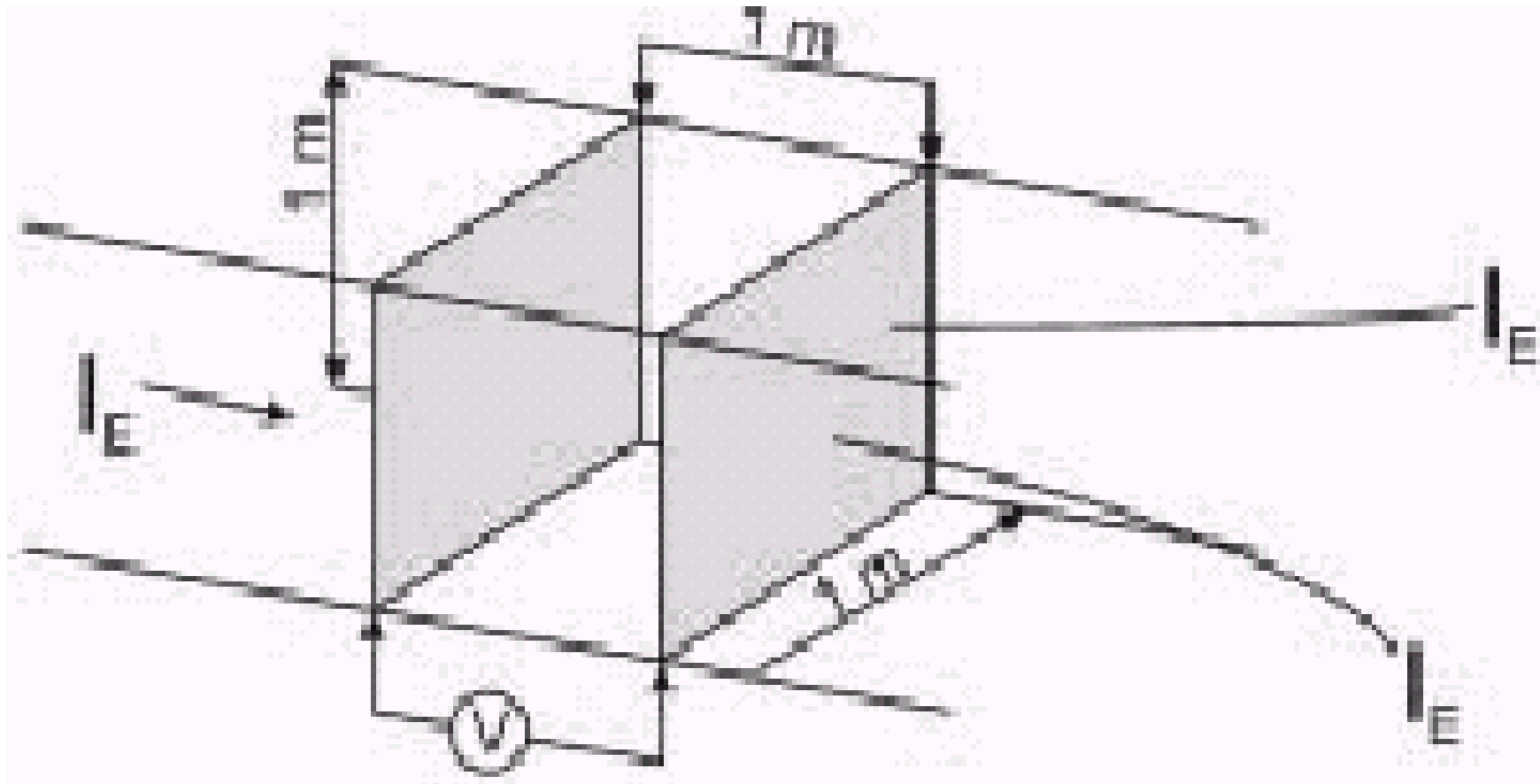
Determine the max. fault current for the location.

➤ *Safe Body Current* :

- ❖ Effect of magnitude.
- ❖ Effect of duration.
- ❖ Effect of frequency.

Objectives of Soil Resistivity Measurements:

The first is to determine the type of earth connection required to provide the objective resistance to earth. The second is to define any geological limitations that might be present, such as a rock layer, that would restrict installation of the grounding system.



Earth Resistivity (Specific Earth Resistance)

Is the resistance measured between two opposite Faces, of one metre cube of earth. The Earth Resistivity Is expressed in Ohm-metre.

BASIC SOIL RESISTIVITY MEASUREMENT

Introduction:

The depth to which the average soil resistivity is desired determines the distance (A) between the test electrodes. This distance will typically be the length of the ground electrode to be installed plus the depth below the earth's surface to which it will be driven. A measurement should be taken with test electrode spacing of one-half, one, two and four times the length of the proposed ground electrode. This will identify the presence of large deviations in the soil resistivity. Place four test electrodes along a base line in relation to the proposed vertical ground electrode location.

Soil Resistivity Measurements are commonly made with a test instrument that uses the four-terminal fall of potential method.

The test instrument has four terminals that are connected to four electrodes arranged at equal distances along a straight line. Internally the instrument contains a current circuit and a voltage circuit. The current source can be a hand driven a.c. generator or a voltage reversing vibrator that causes a current to flow between the two outer electrodes. A potential is measured between the inner electrodes.

The voltage and current circuits are coupled within the test set to provide a reading in ohms.

The Theory for This Measurement was developed by Dr. Frank Wenner of the U.S. Bureau of Standards in 1915 and published in Report No. 258, Bulletin of Bureau of Standards, Vol. 12, No. 3, October 11, 1915, "A Method of Measuring Earth Resistivity." Dr. Wenner established that, if the test electrode depth is small compared to the distance between the electrodes, the following equation applies to determine the average soil resistivity to a depth equal to the distance between the electrodes:

$$\rho = 2\pi AR = 6.28AR$$

Where: ρ = Average soil resistivity to depth equal to A, in ohm-centimeters
 π = 3.1416
A = Distance between electrodes, in centimeters
R = Test instrument resistance reading, in ohms

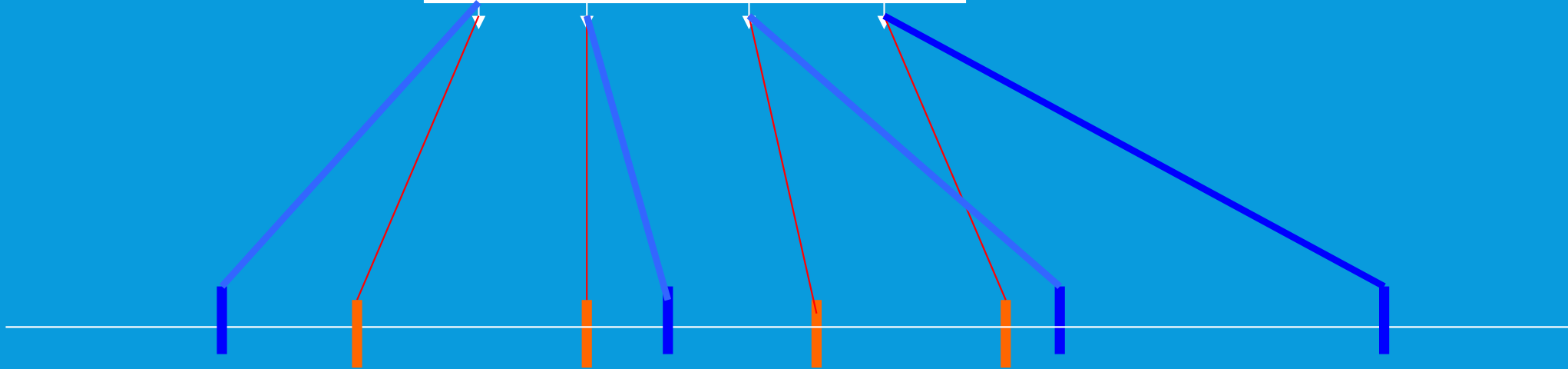
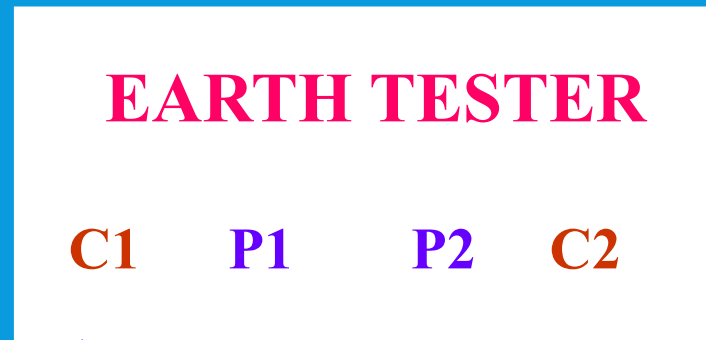
Note: Divide ohm-centimeters by 100 to convert to ohm-meters.

$$\rho_a = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}}$$

Where:

- ρ_a = Apparent resistivity of the soil in Ω -m
- R = Measured resistance in ohms
- a = Distance between adjacent electrodes in meters
- b = Depth of the electrodes in meters

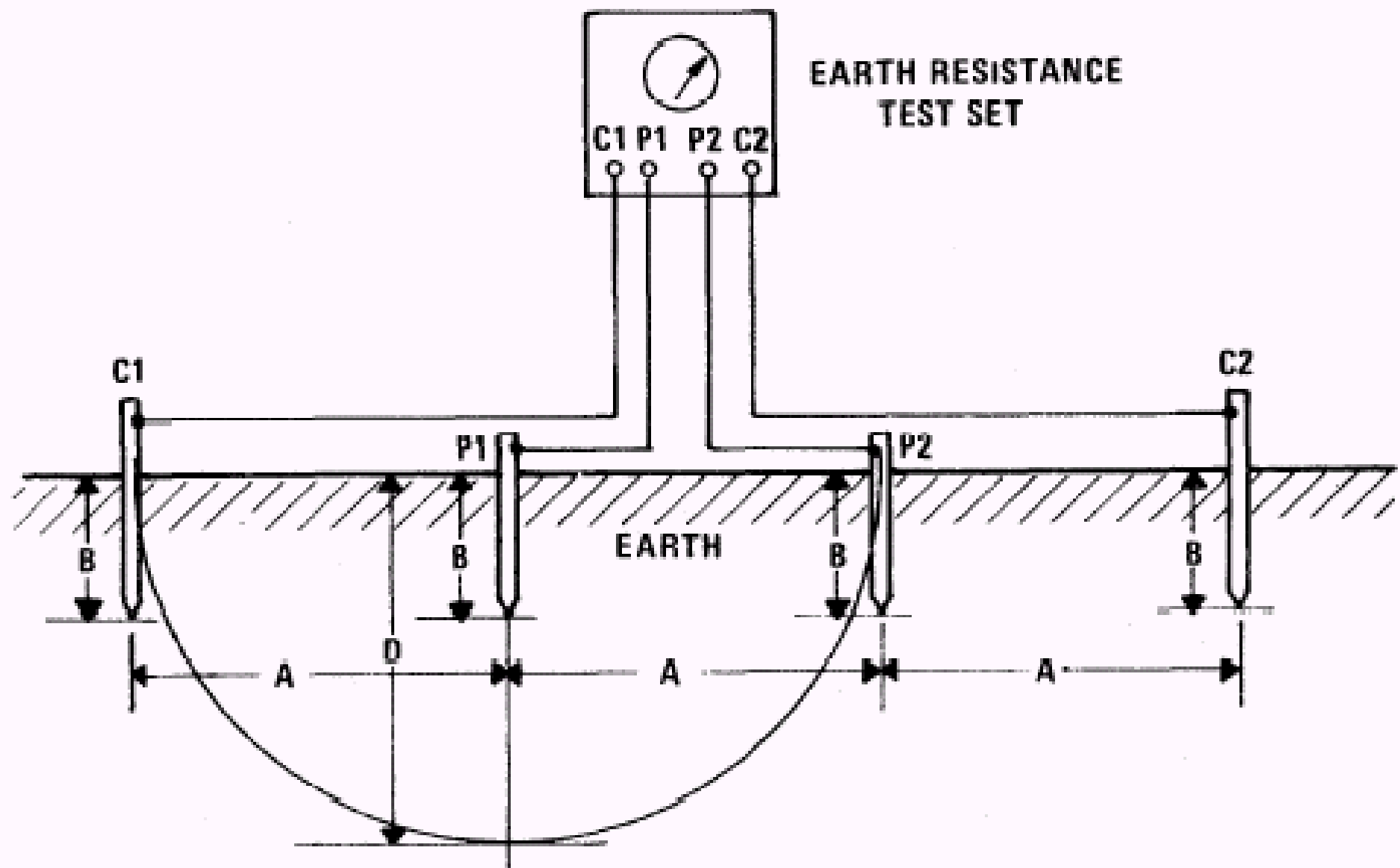
MEASUREMENT OF SOIL RESISTIVITY



C1 , C2 CURRENT TERMINALS

P1, P2 POTENTIAL TERMINALS

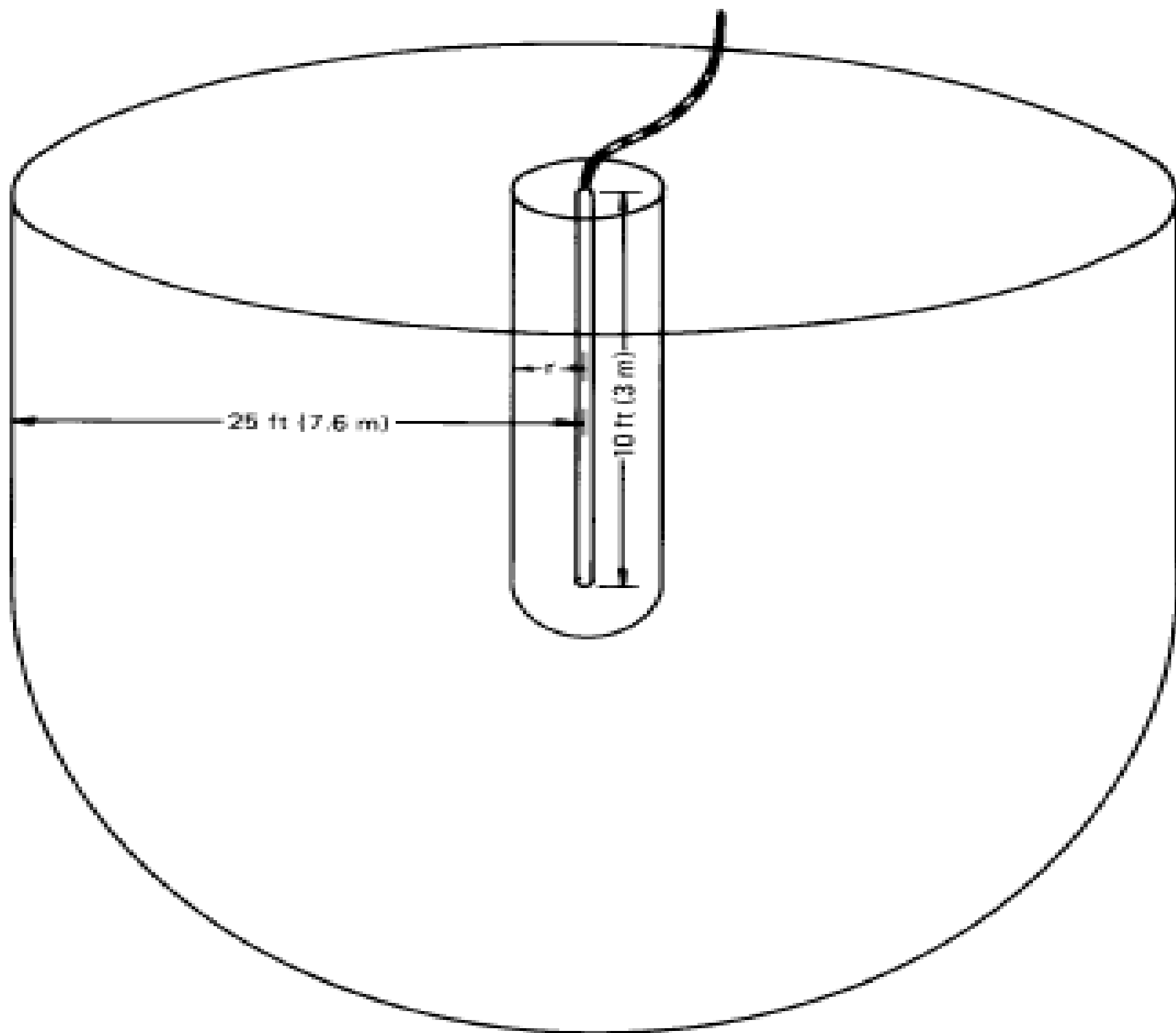
Measurement Of Earth Resistance



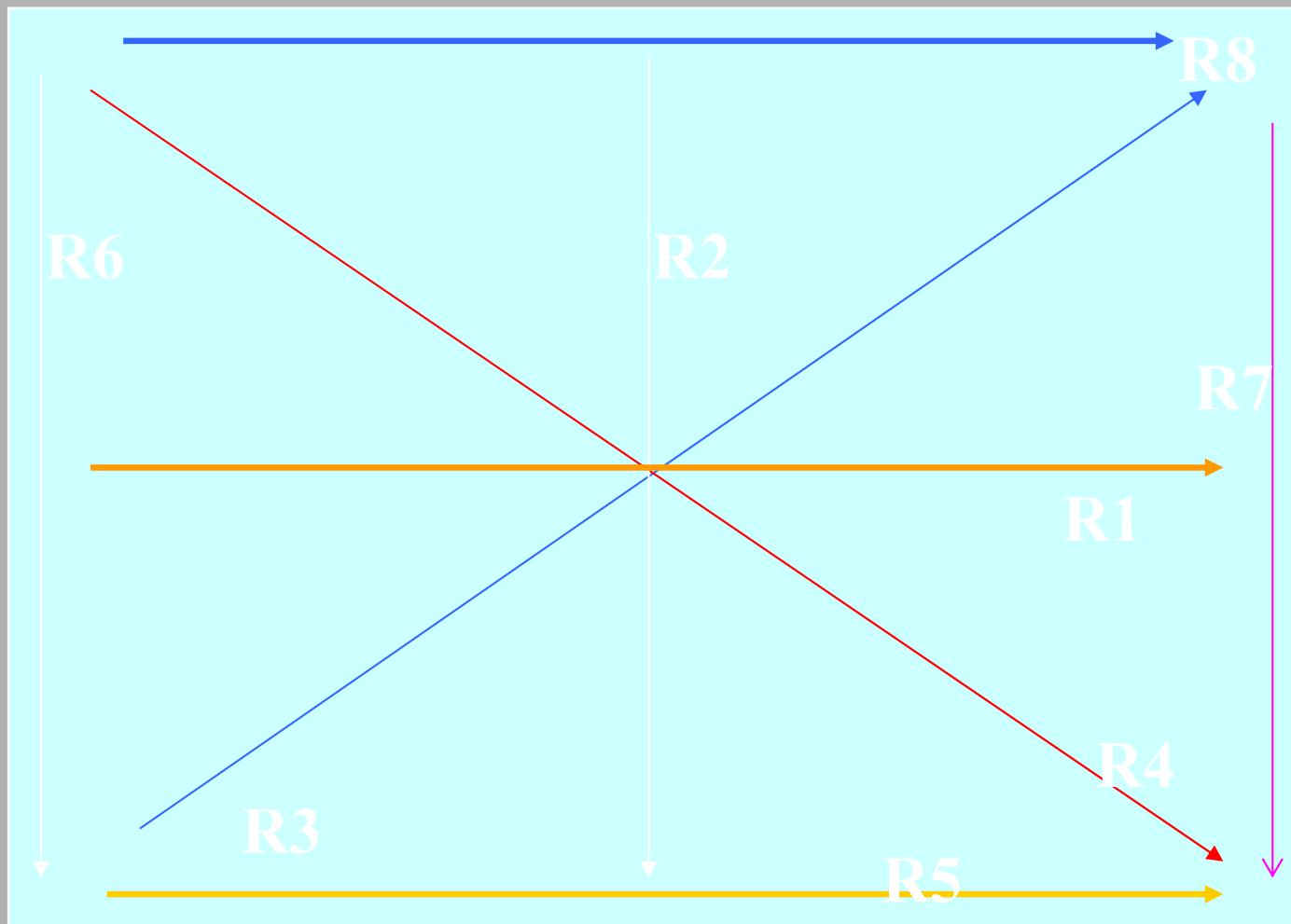
A = ELECTRODE SPACING

B = DEPTH OF PENETRATION $< A/20$

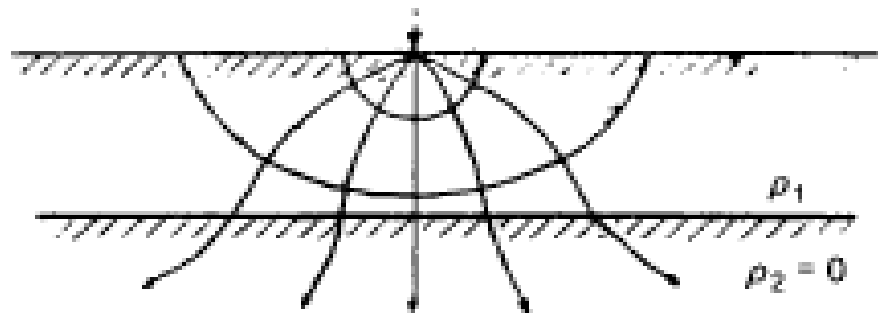
D = DEPTH AT WHICH RESISTIVITY IS DETERMINED = A



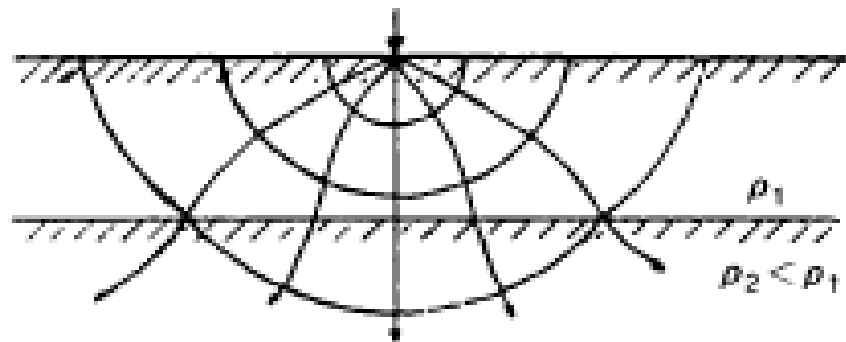
MEASUREMENT OF SOIL RESISTIVITY



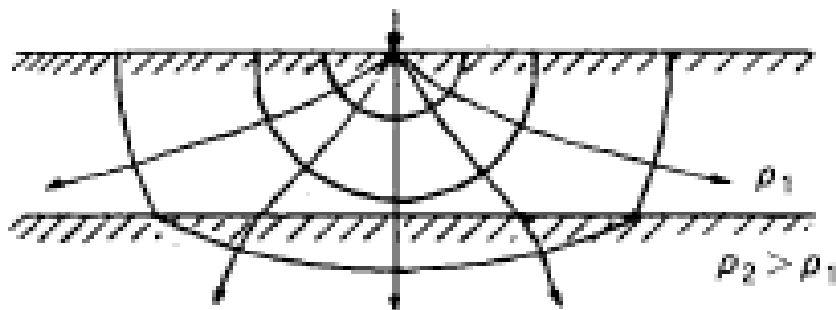
EARTH CONDUCTION



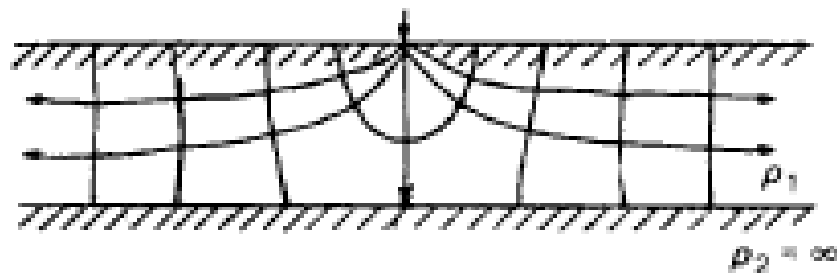
CASE-1 LOWER LAYER WITH ZERO RESISTIVITY



CASE-2 UPPER LAYER HIGH RESISTIVITY THAN LOWER LAYERS



CASE-3 UPPER LAYER RESISTIVITY LESS THAN LOWER LAYERS



CASE-4 LOWER LAYER WITH INFINITE RESISTIVITY

MEASUREMENT OF SOIL RESISTIVITY

METHODOLOGY ADOPTED

- MEASUREMENTS ARE MADE ALONG A NO OF RADIALS AT DIFFERENT LOCATIONS IN THE STATION SUCH THAT THE WHOLE AREA IN WHICH EARTHING ELECTRODES / MAT IS LAID IS COVERED
- SPACING BETWEEN THE PROBES WHICH ARE HAMMERED INTO THE SOIL BE VARIED RADIALLY FOR TAKING DIFFERENT READINGS
- TYPICALLY IF THE STATION IS 100 TO 150 MTRS THE SOIL RESISTIVITY READINGS MAY BE TAKEN FOR A PROBE SPACINGS OF 1 , 2, 5, 10 , 15, 25 AND 50 MTRS
- A FEW DROPS OF WATER WATER MAY BE POURED IN THE NEIGHBOURHOOD OF PROBES TO GET GOOD CONDUCTIVE CONNECTION BETWEEN PROBE AND THE SOIL SURROUND IT.

THE BURIED METALLIC PIPES IN THE NEIGHBOURHOOD AND RECENTLY FILLED UP SOIL WILL AFFECT THE SOIL RESISTIVITY READINGS

MEASUREMENT OF SOIL RESISTIVITY

TWO COMMONLY USED SOIL MODELS ARE
UNIFORM SOIL AND TWO LAYER SOIL MODEL

AS MAGNITUDE OF SPACING B/W PROBES IS INCREASED FROM
SMALL VALUE TO HIGHER VALUE THE MEASURED SOIL RESISTIVITY
REFLECTS THE EFFECT OF SOIL AT DIFFERENT DEPTHS

UNIFORM MODEL IS CHOSEN IF THE MEASURED SOIL RESISTIVITY
VALUES VARY WITHIN 30 % OF AVERAGE VALUE

CASE-1 RESISTIVITY OF UPPER LAYER MORE THAN LOWER LAYERS

$R_g (\text{Uniform layer value}) < R_g \text{ obtained}$

$(E_{\text{touch}} \& E_{\text{step}}) (\text{Uniform layer value}) < (E_{\text{touch}} \& E_{\text{step}}) \text{ obtained}$

CASE-2 RESISTIVITY OF UPPER LAYER LESS THAN LOWER LAYERS

$R_g (\text{Uniform layer value}) > R_g \text{ obtained}$

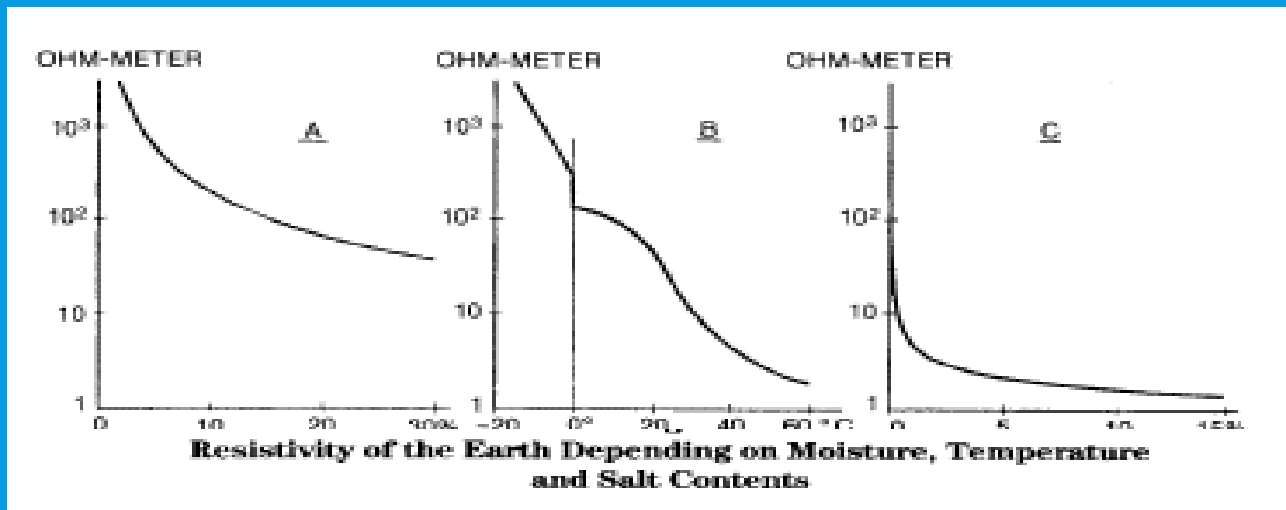
$(E_{\text{touch}} \& E_{\text{step}}) (\text{Uniform layer value}) > (E_{\text{touch}} \& E_{\text{step}}) \text{ obtained}$

MEASUREMENT OF SOIL RESISTIVITY

FACTORS DETERMINING SOIL RESISTIVITY

- MOISTURE
- DISSOLVED SALTS
- TEMPERATURE
- GRAIN SIZE AND DISTRIBUTION
- SEASONAL VARIATION
- CURRENT MAGNITUDE

VARIATIONS IN RESISTIVITY DUE TO MOISTURE, TEMPERATURE, SALT

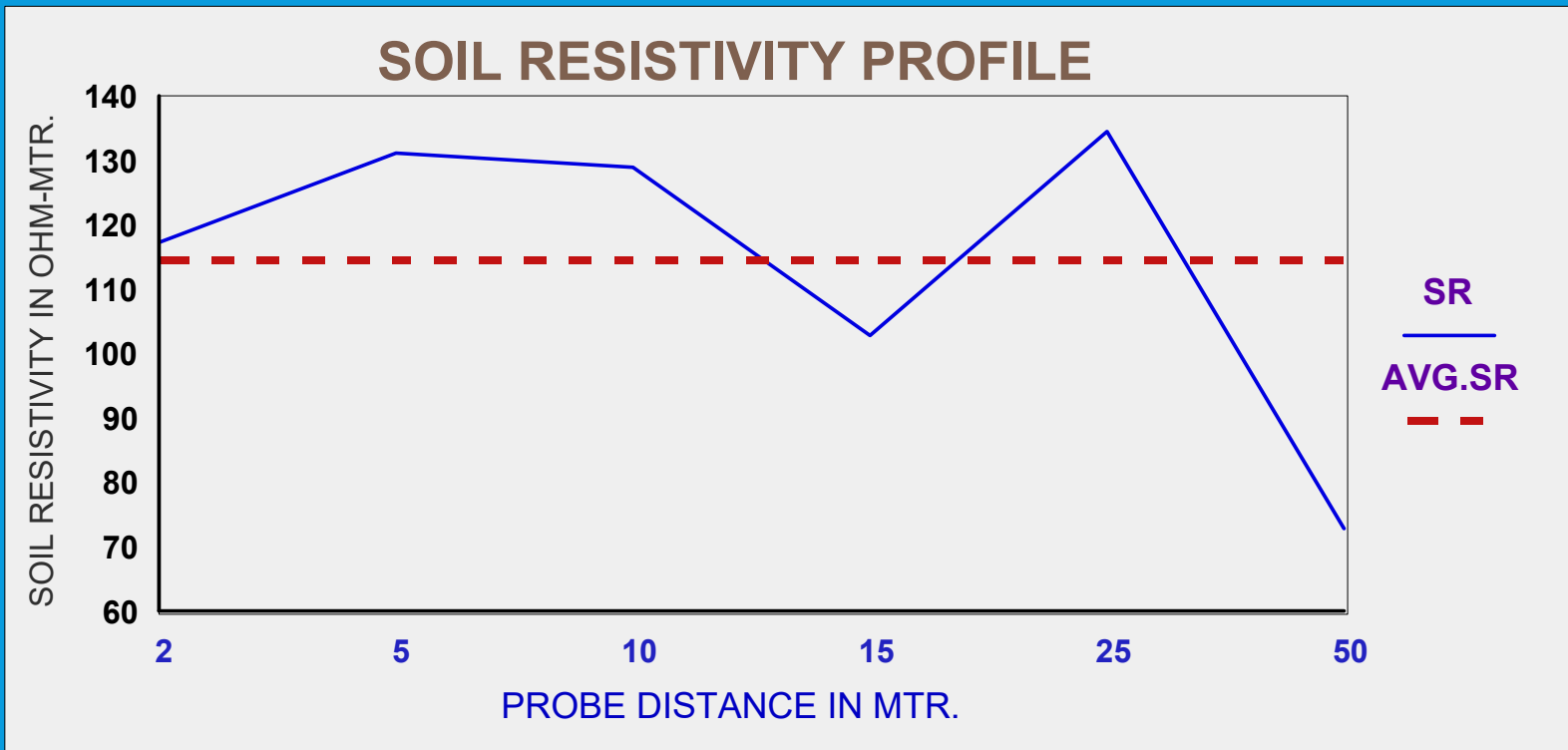


SEASONAL VARIATIONS

To account for the seasonal variations , the average Soil resistivity is multiplied by the factor as shown below, which is termed as the apparent resistivity.

Season of measurement Multiplication factor

Summer	1.0
Winter	1.15
Rainy	1.3



SOIL RESISTIVITY DATA : <--MEASURED EARTH RESISTANCE IN OHM-->

PROBE DISTANCE IN MTR.	R1	R2	R3	R4	R5	R6	R7	R8	AVG. SR
2	8.30	9.19	9.93	9.92	9.34	9.34	9.34	9.34	117.31
5	5.31	3.23	4.12	4.10	4.19	4.19	4.19	4.19	131.63
10	1.67	3.18	1.61	1.76	2.06	2.06	2.06	2.06	129.12
15	0.95	0.96	0.90	1.10	1.20	1.25	1.20	1.18	102.97
25	0.85	0.88	0.90	0.85	0.79	0.92	0.78	0.88	134.50
50	0.25	0.20	0.19	0.25	0.22	0.25	0.25	0.25	73.04

AVERAGE SOIL RESISTIVITY
S.R. FOR DESIGN AFTER CORRECTION FACTOR FOR WEATHER

115 OHM-MTR
103 OHM-MTR

MEASUREMENT OF SOIL RESISTIVITY

ACCURACY OF EARTH TESTERS

POWER FREQUENCY AS WELL AS HARMONIC LEAKAGE CURRENTS NORMALLY FLOW IN THE EARTH DUE TO:-

- NEUTRAL CONNECTIONS OF THE POWER TRANSFORMERS
- INTENTIONAL USE OF EARTH AS A CONDUCTOR
- UNBALANCED OPERATION OF POWER SYSTEM
- CAPACITIVE COUPLING BETWEEN EARTH AND DIFFERENT COMPONENTS OF POWER SYSTEM

SUCH CURRENTS WILL PRODUCE EXTRANEIOUS VOLTAGE BETWEEN THE PROBES CONNECTED TO “ P1” AND “ P2 “

EARTH TESTERS SHOULD BE ABLE TO DISTINGUISH BETWEEN THE EXTRANEIOUS VOLTAGE THUS APPEARING BETWEEN P1 & P2 AND DUE TO CURRENT INJECTED INTO THE EARTH BY EARTH TESTER

FAULT LEVELS FOR 2011 CONDITIONS IN KPTCL GRID

NAME OF THE STATION	VOLTAGE	3PH.	SLG
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MUNDGOD	33	30	21
MAHALINGAPUR	33	724	651

ANTHARASANTHE	66	153	104
B-STATION	66	6051	5219

ANAVATTI	110	418	290
HUBLI	110	4239	3698

KOLLEGAL	220	2353	1767
NELAMANGALA	220	13824	14400

TALAGUPPA	400	7635	6402
BIDADI	400	18967	19202

DESIGN OF EARTHMAT FOR HV STATIONS

As the earthing system has to carry the earth currents, the maximum earth fault current likely to flow in the system which is generally S.L.G fault is considered for designing the earthing. A good earthing system for H.V. station can be designed using an earthmat which is formed by a grid of horizontally buried conductors which serves to dissipate the earth fault currents to earth, also as an equipotential bonding conductor system, along with the required number of vertical earth electrodes which are connected to the points of earthing of various equipments and structures and also interconnected with the horizontal earthmat.

SOIL RESISTIVITY

Before designing earthmat, it is necessary to determine the soil resistivity of the area in which H.V. sub-station is to be located. The resistivity of the earth varies considerably from 10 to 10,000 Ω mtr. depending upon the types of soil.

Further, the resistivity may also vary at different depth depending upon the type of soil, moisture content and temperature etc., at various depths which affects the flow of current due to the fact that the earth fault current is likely to take its path through various layers.

Typical values of resistivity for various types of soils are as follows :-

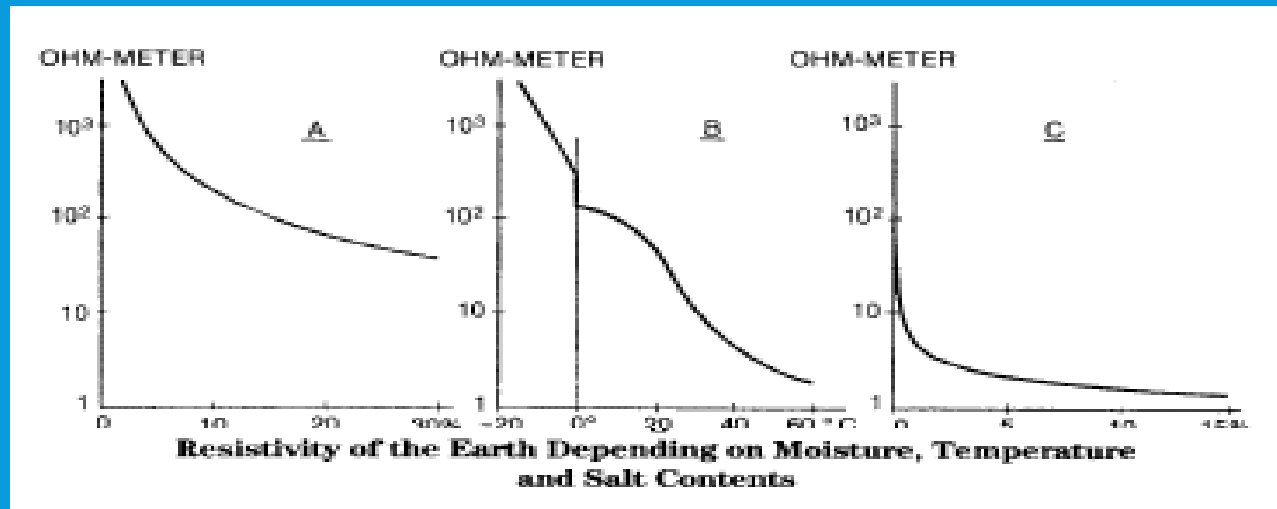
1 Red loamy soil	40-200 Ω -m
2 Red sandy soil	200-2000 Ω -m
3 Laterite soil	300-2600 Ω -m
4 Shallow black soil	20-100 Ω -m
5 Medium black soil	50-300 Ω -m
6 Deep black soil	50-250 Ω -m
7 Mixed red & black soil	50-250 Ω -m
8 Coastal alluvium	300-1300 Ω -m
9 Laterite gravelly	200-1000 Ω -m

SEASONAL VARIATIONS-RESISTIVITY

To account for the seasonal variations , the average Soil resistivity is multiplied by the factor as shown below, which is termed as the apparent resistivity.

<u>Season of measurement</u>	<u>Multiplication factor</u>
Summer	1.0
Winter	1.15
Rainy	1.3

VARIATIONS IN RESISTIVITY DUE TO MOISTURE, TEMPERATURE, SALT



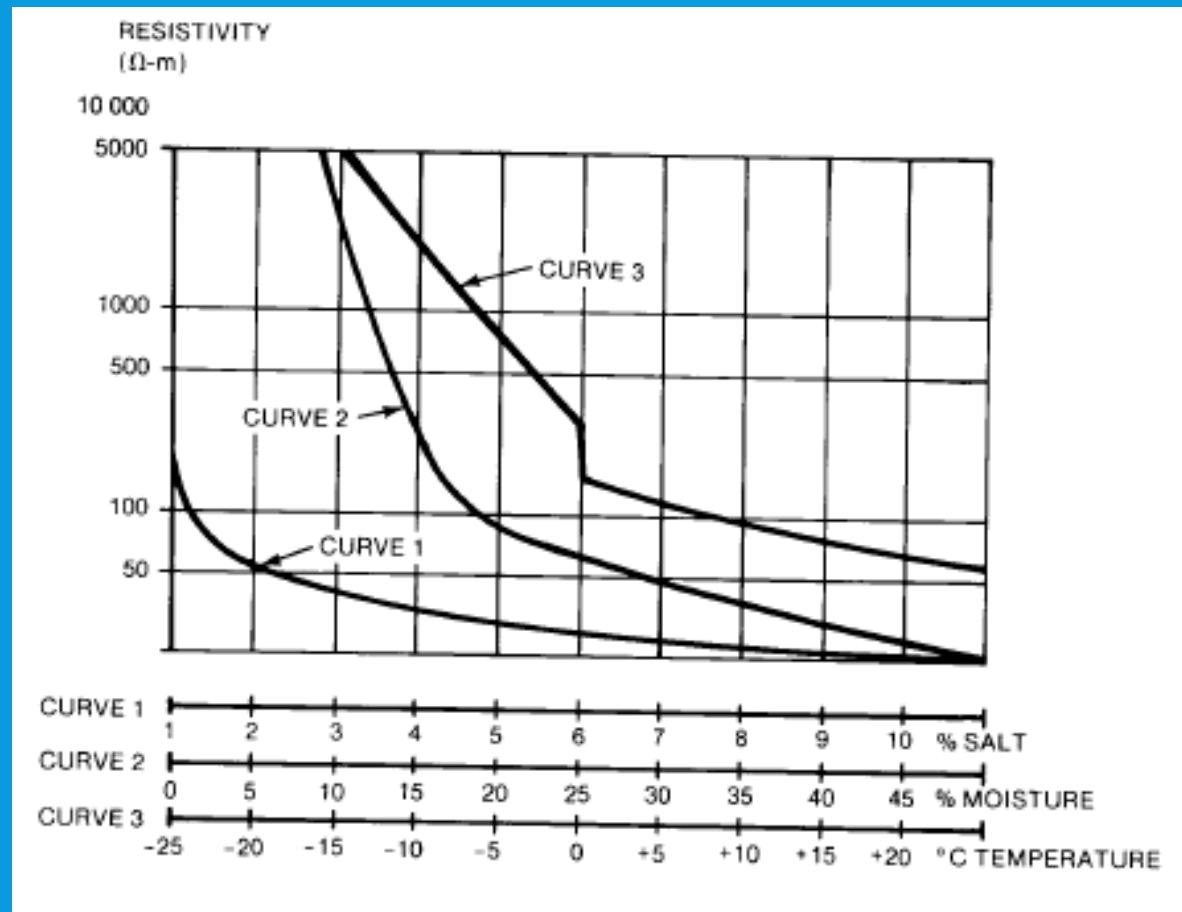
SEASONAL VARIATIONS

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Effect of Salt Moisture and Temperature on Soil Resistivity



Choice of materials and size of earthmat conductor

Cross-section of the M.S. conductor in Sq mm is given by the formula.

$$= I_f * 12.5 * \sqrt{t_c} \text{ Sq mm. for welded joints}$$

$$= I_f * 15.8 * \sqrt{t_c} \text{ Sq. mm. for bolted joints.}$$

Where I_f = Fault current in K.Amps.

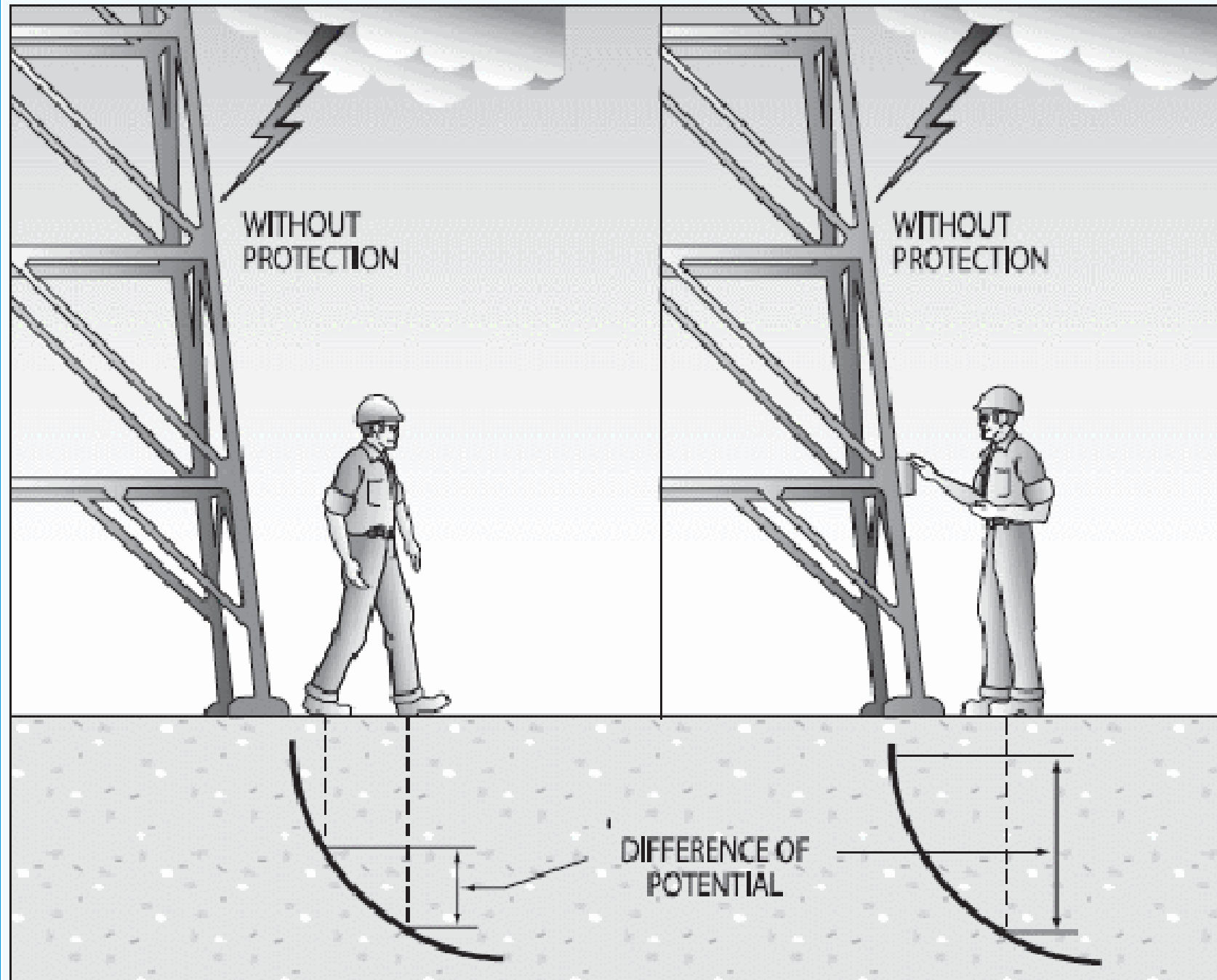
t_c = fault clearing time in seconds.

Suitable correction shall be made to this cross sectional area by providing an allowance for corrosion as below:

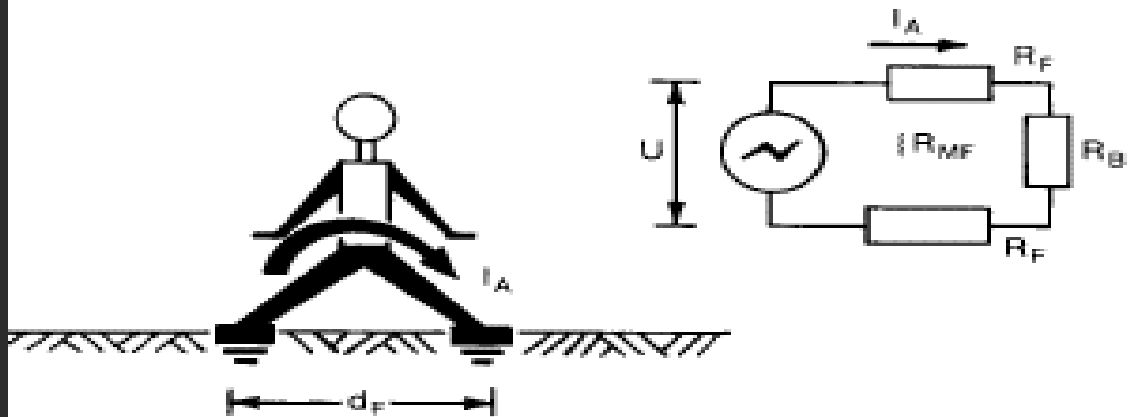
- a) If $\rho > 100 \Omega \text{ mtr}$: no corrosion allowance be made.
- b) If $\rho > 25 < 100 \Omega \text{ mtr}$: an allowance of 15% is to be made.
- c) If $\rho < 25 \Omega \text{ mtr}$: an allowance of 30% is to be made.

STEP POTENTIAL

TOUCH POTENTIAL

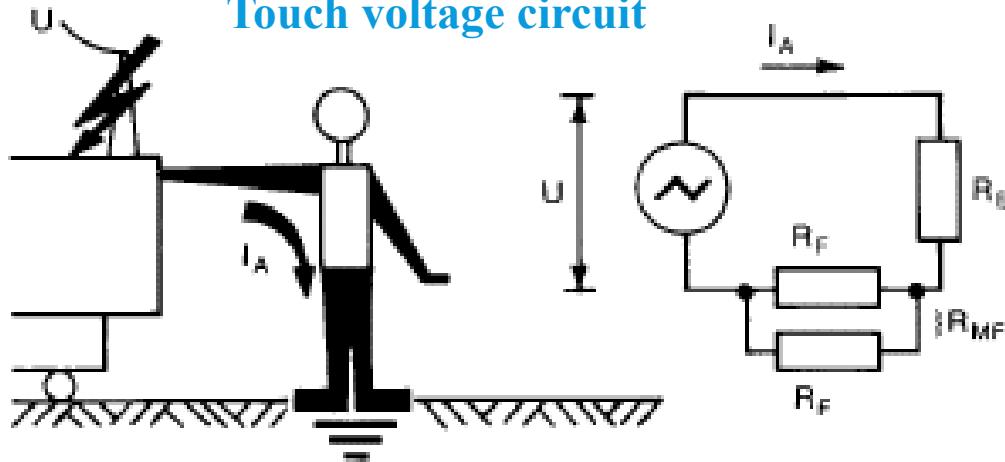


Step Voltage Circuit



Step potential: The potential difference shunted by a human body between two accessible points on the ground separated by a distance of one pace assumed to be equal to one meter

Touch voltage circuit



Touch potential:- The potential difference between a point on the ground and a point on an object likely to carry fault current (e.g., frame of equipment) which can be touched by a person

Tolerable values of Touch and Step Potential

$$E_{\text{touch}} = [1000 + 1.5 C_s \rho_s] (0.116 / \sqrt{t_s}) \text{ Volts.}$$

$$E_{\text{step}} = [1000 + 6 C_s \rho_s] (0.116 / \sqrt{t_s}) \text{ Volts.}$$

Where t_s = Fault duration in secs.

ρ_s = Surface layer resistivity in Ω mtr.

= 3000 Ω mtr. for crushed stone layer.

$$C_s = 1 - a [(1 - \rho/\rho_s) / (2 h_s + a)]$$

$C_s = 1$ when no protective surface layer or crushed stone is used.

Where $a = 0.106 \text{ mt}$

h_s = Height of surface layer i.e., thickness of the crushed

stone layer which is normally 0.1 mt.

Step Voltage (E_s)

Step voltages within a grid system designed for safe mesh voltages will be well within tolerable limits.

This is because step voltages are usually smaller than touch voltages, and both feet are in series rather than parallel. Also, the body can tolerate higher currents through a foot-to-foot path since the current does not pass close to the heart. The step voltage has to be less than the tolerable step voltage for the ground system to be safe.

The step voltage values are obtained as a product of the geometrical factor K_s , the corrective factor K_i , the soil resistivity (r), and the average current per unit of buried length of grounding system conductor (IG/LS):

$$A_{mm^2} = I \frac{1}{\sqrt{\left(\frac{TCAP \cdot 10^{-4}}{t_c \alpha_r \rho_r}\right) \ln\left(\frac{K_o + T_m}{K_o + T_a}\right)}}$$

I	is the rms current in kA
A_{mm^2}	is the conductor cross section in mm ²
T_m	is the maximum allowable temperature in °C
T_a	is the ambient temperature in °C
T_r	is the reference temperature for material constants in °C
α_o	is the thermal coefficient of resistivity at 0 °C in 1/°C
α_r	is the thermal coefficient of resistivity at reference temperature T_r in 1/°C
ρ_r	is the resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_o	$1/\alpha_o$ or $(1/\alpha_r) - T_r$ in °C
t_c	is the duration of current in s
$TCAP$	is the thermal capacity per unit volume

Table 1 — Material constants

Description	Material conductivity (%)	α_r factor at 20 °C (1/°C)	K_o at 0 °C (0 °C)	Fusing^a temperature T_m (°C)	ρ_r 20 °C ($\mu\Omega\cdot\text{cm}$)	TCAP thermal capacity [J/(cm³·°C)]
Copper, annealed soft-drawn	100.0	0.003 93	234	1083	1.72	3.42
Copper, commercial hard-drawn	97.0	0.003 81	242	1084	1.78	3.42
Copper-clad steel wire	40.0	0.003 78	245	1084	4.40	3.85
Copper-clad steel wire	30.0	0.003 78	245	1084	5.86	3.85
Copper-clad steel rod ^b	20.0	0.003 78	245	1084	8.62	3.85
Aluminum, EC grade	61.0	0.004 03	228	657	2.86	2.56
Aluminum, 5005 alloy	53.5	0.003 53	263	652	3.22	2.60
Aluminum, 6201 alloy	52.5	0.003 47	268	654	3.28	2.60
Aluminum-clad steel wire	20.3	0.003 60	258	657	8.48	3.58
Steel, 1020	10.8	0.001 60	605	1510	15.90	3.28
Stainless-clad steel rod ^c	9.8	0.001 60	605	1400	17.50	4.44
Zinc-coated steel rod	8.6	0.003 20	293	419	20.10	3.93
Stainless steel, 304	2.4	0.001 30	749	1400	72.00	4.03

^aFrom ASTM standards.

^bCopper-clad steel rods based on 0.254 mm (0.010 in) copper thickness.

^cStainless-clad steel rod based on 0.508 mm (0.020 in) No. 304 stainless steel thickness over No. 1020 steel core.

$$E_s = \frac{\rho \cdot K_s \cdot K_i \cdot I_G}{L_S}$$

Where:

- ρ = Soil resistivity, Ω -m
- K_s = Spacing factor for step voltage, simplified method
- K_i = Correction factor for grid geometry, simplified method
- I_G = Maximum grid current that flows between ground grid and surrounding earth (including dc offset) in amperes
- L_S = Effective buried conductor length in meters

$$L_S = 0.75 \cdot L_C + 0.85 \cdot L_R$$

Where:

- L_C = Total length of grid conductor in meters
- L_R = Total length of ground rods in meters

The maximum step voltage is assumed to occur over a distance of 1 meter, beginning at and extending outside the perimeter conductor at the angle bisecting the most extreme corner of the grid. For the usual burial depth of $0.25 \text{ m} < h < 2.5 \text{ m}$, K_s is expressed by Equation 9-36:

Equation 9-36

$$K_s = \frac{1}{\pi} \left[\frac{1}{2 \cdot h} + \frac{1}{D + h} + \frac{1}{D} (1 - 0.5^{n-2}) \right]$$

Where:

- D = Spacing between parallel conductors in meters
- h = Depth of ground grid conductors in meters
- n = Geometric factor composed of factors n_a , n_b , n_c , and n_d

cases, the touch voltage at the corner of the grid may exceed the corner mesh voltage.

In a substation that utilizes a grid as part of the grounding system, it is theoretically possible to design and install the grid in such a way that the mesh voltage can be kept within desired limits.

The mesh voltage values are obtained as a product of the geometrical factor K_m , a corrective factor K_i that accounts for some of the error introduced by the assumptions made in deriving K_m , the soil resistivity (r), and the average current per unit of effective buried length of the grounding system conductor (I_G/LM):

$$E_m = \frac{\rho \cdot K_m \cdot K_i \cdot I_G}{L_M}$$

Where:

- ρ = Soil resistivity, Ω -m
- K_m = Spacing factor for mesh voltage, simplified method
- K_i = Correction factor for grid geometry, simplified method
- I_G = Maximum grid current that flows between ground grid and surrounding earth (including dc offset) in amperes
- L_M = Effective length of $L_C + L_R$ for mesh voltage in meters
- L_C = Total length of grid conductor in meters
- L_R = Total length of ground rods in meters

$$K_m = \frac{1}{2 \cdot \pi} \cdot \left[\ln \left[\frac{D^2}{16 \cdot h \cdot d} + \frac{(D + 2 \cdot h)^2}{8 \cdot D \cdot d} - \frac{h}{4 \cdot d} \right] + \frac{K_{ii}}{K_h} \cdot \ln \left[\frac{8}{\pi(2 \cdot n - 1)} \right] \right]$$

Where:

- D = Spacing between parallel conductors in meters
- d = Diameter of grid conductors in meters
- h = Depth of ground grid conductors in meters
- n = Geometric factor composed of factors n_a , n_b , n_c and n_d
- K_h = Corrective weighting factor that emphasizes the effects of grid depth, simplified method
- K_{ii} = Corrective weighting factor that adjusts for the effects of inner conductors on the corner mesh, simplified method

Ground Potential Rise (GPR)

In all the above situations for step, touch, and transferred voltage, the actual voltage potential encountered by the person involved is related to the ground potential rise of the grounding system above remote earth.

This fact stresses the importance of keeping that value as low as possible. Ground potential rise is the maximum electrical potential that a substation grounding grid may attain relative to a distant grounding point assumed to be at the potential of remote earth. This voltage, GPR, is equal to the maximum grid current times the grid resistance:

$$R_g = \rho \left[\frac{1}{L_T} + \frac{1}{\sqrt{20A}} \left(1 + \frac{1}{1 + h\sqrt{20/A}} \right) \right]$$

Where:

h = Depth of the grid in meters

A = Area occupied by the ground grid in m^2 (calculated in Section 9.4)

L_T = Total buried length of conductors in meters

ρ = Soil resistivity in Ω -m (calculated in Section 9.3.2 , $\rho_{a(av1)}$)

DESIGN POTENTIALS SHOULD BE LESS THAN TOLERABLE LIMITS

DESIGN STEP AND TOUCH POTENTIALS DEPENDS ON:-

- MAX. FAULT CURRENT
- AVG. & SURFACE SOIL RESISTIVITY
- TOTAL LENGTH OF BURIED CONDUCTOR-WHICH
INTURN DESIDES THE SPACING B/W PARALLEL
EARTHMAT CONDUCTORS
- DEPTH OF BURIAL OF EARTHMAT
- NO. AND LENGTH OF VERTICAL ELECTRODES

The potential differences caused by the current injected in the ground by a HVDC-electrode can cause corrosion of e.g. pipelines and operational problems in transformer stations.

Also, hazardous electric fields can arise in the vicinity of HVDC-electrodes. High potentials and strong fields from electrodes are, in principle, related to high-resistivity rock in the ground.

The presence of such potentially problematic rock volumes is not routinely checked before the construction of an electrode site. However, geophysical methods are available that can estimate the electrical properties of the bedrock down to considerable depths.

Such surveys, in combination with geological knowledge and modeling can be used to predict the environmental impact of an electrode

High-voltage DC current (HVDC) is an efficient method for power transmission. Most land schemes operate in bipolar operation mode with no return current, but the systems are also designed to operate in monopolar operations that require electrodes where significant amounts of current is injected into the ground.

In a high-resistivity environment, the injected current will create large potentials and hence electric fields in the vicinity of the electrode. The strong electric fields can create safety problems close to the electrode for humans, grazing cattle etc.

The effect of the electrode can also be noted at quite large distances as electric potential differences of more moderate magnitude. These potential differences can give rise to corrosion of pipe-lines and other installations and also interfere with e.g. transformer stations.

Two types of possible problems can be identified due to an electrode.

Firstly, there might be near-source problems related to hazardous electric fields in the immediate vicinity of the electrode. Areas where the electric field reaches levels of tens of Volts per meters might put humans and animals in danger.

Secondly, there might be far-distance problems related to fairly moderate field strengths. Electric fields of the order of a few Volts per km can in some cases create corrosion problems.

The amount of corrosion is however also a function of the design and orientation of the object in question. Constructions oriented parallel to the current flow in the ground will be most affected.

The most common choice of geophysical method for very deep investigations is magneto-tellurics. Naturally occurring electromagnetic fields are measured.

The sources to such fields are particle radiation from the sun captured in the ionosphere and distant thunder storms. It can be shown that the magnetic and electric fields from such sources become horizontal and perpendicular to each other over a layered earth at a sufficient distance from the source.

Also, the ratio of the electric to the magnetic field strength is directly related to the resistivity of the ground.

It is not always possible to perform geo-electric measurements everywhere and with the desired resolution and depth of investigation.

It is therefore also important to be able to use auxiliary information to support the modelling.

The geometry of a geological unit might be determined from other types of geophysical data like magnetometry or gravity surveys. Geological mapping and modelling will also assist in reducing ambiguities in the geophysical models.

POTENTIAL DISTRIBUTION FOR A GROUND MAT WITH VARIOUS MESH SIZES

(GROUND MAT POTENTIAL = 100 PERCENT)

36

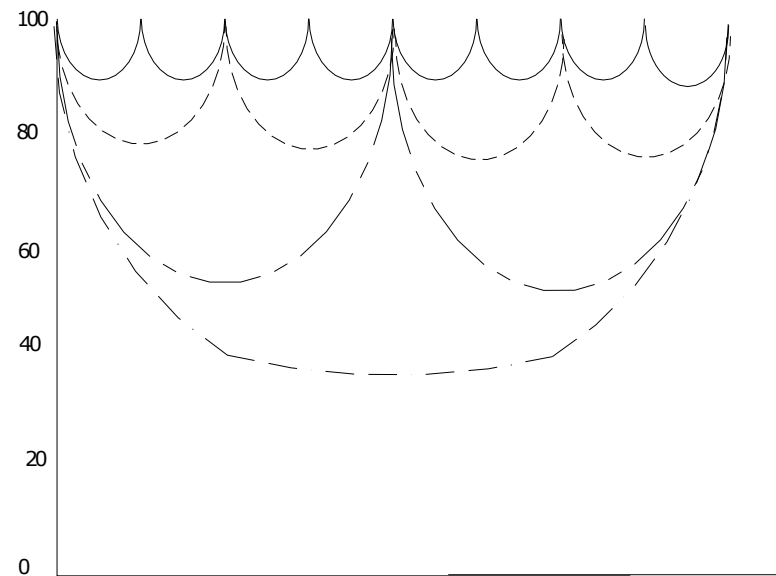
55	55
55	55

70	70	70	70
70	70	70	70
70	70	70	70
70	70	70	70

80	83	85	86	86	85	83	80
83	87	88	88	88	88	87	83
85	88	88	89	89	88	88	85
86	88	89	89	89	89	88	86
86	88	89	89	89	89	88	86
85	88	88	89	89	88	88	85
83	87	88	88	88	88	87	83
80	83	85	86	86	85	83	80

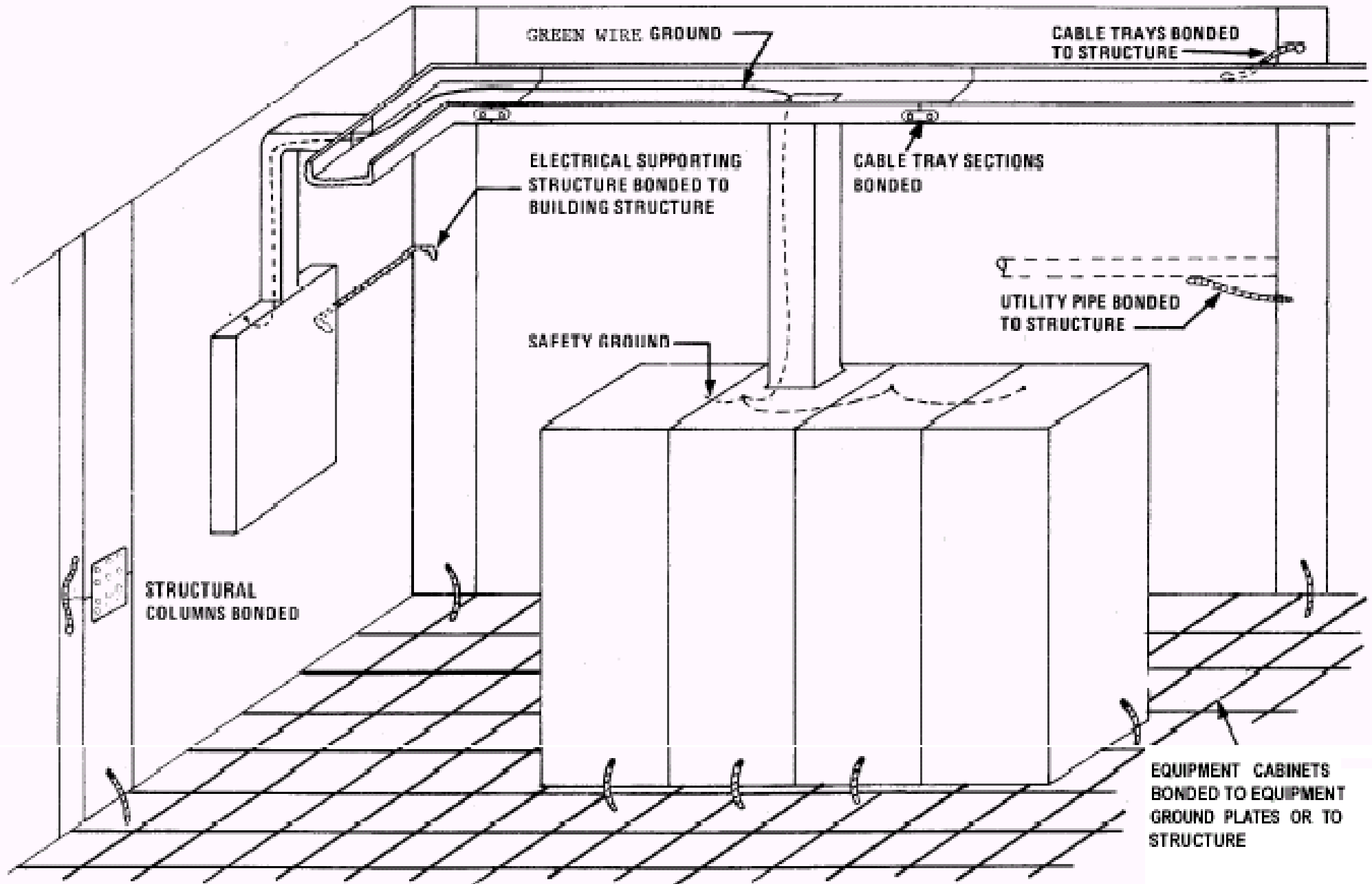
80	83	85	84	65
85	87	87	86	
85	87	88	87	
84	86	87	86	
59				57

80	84	85	84	65
85	87	88	87	
85	88	89	88	
84	87	88	87	
59				57



GENERAL CONSIDERATIONS

Elements Of Earthing



General Considerations

- Guide lines for laying Earthmat
- Earthing of Power Cables
- Providing crushed rock surface layer
- Separation between CI Pipe Electrodes
- Precautions
- Enhancing Sub-Station Earthing
- Maintenance Of Earthing System
- Test Configuration for earthing
- Earthing in difficult situations

GUIDE LINES FOR LAYING EARTHMAT

- Earth Connections.
- Power Transformer Neutral.
- Lightning Arrestor and Mast Earthing.
- Switchgear & Control Room Earthing.
- Non – current carrying metal parts.

POWER CABLES

- Earthing of Three Core Cable Sheath.
- Earthing of Single Core Cable Sheath.
- Clearance between Power and Control Cables.

EARTHING OF

- Out going 11 KV feeders within the Sub-station area.
- Out going 11 KV feeders outside the Sub-station area.
- Sub-station fencing.

PROVIDING CRUSHED ROCK SURFACE LAYER

- Controls step and touch voltages.
- Avoids weed growth.
- Retains moisture in the soil.
- Avoids movement of reptiles in the yard.

SEPARATION BETWEEN CI PIPE ELECTRODES

- Minimum distance between two electrodes - twice the length.
- The lead connecting the equipment to the earthmat should have least length.
- Ensure that the CI Pipe is uncoated.

GENERAL

- Labeling of Electrodes.
- Earthing of Control Panel.
- Earthing of Switchgear Panel.
- Auxiliary Transformer – Neutral Earth.

PRECAUTIONS

- **Labeling of electrodes.**
- **Earthing of Control Panel.**
- **Earthing of Switchgear Panel.**
- **Auxiliary Transformer – Neutral Earth.**

Enhancing Sub- Station Earthing

- SIZE CONDUCTORS FOR ANTICIPATED FAULTS
- SELECT THE RIGHT CONDUCTOR
- PAY ATTENTION TO EARTH ROD LENGTH,NUMBER,PLACEMENT AND SPACING
- PREPARE THE SOIL
- ELIMINATE STEP AND TOUCH POTENTIAL
- EARTH THE FENCE
- EARTH ALL SWITCH HANDLES
- EARTH ALL SURGE ARRESTORS
- EARTH ALL CABLE TRAYS

Maintenance of Earthing System

- KEEP TOP PORTION OF ELECTRODES FOR INSPECTION
- CHECK FOR ARCING FAULTS
- PERIODICAL INTEGRITY CHECK OF EARTHING
- ARREST WEED GROWTH
- REPLACE ALL DETERIORATED ELECTRODES AND EARTH CONNECTION
- AUXILLARY SUPPLY TO THE STATION FROM DEDICATED TRANSFORMER ONLY
- DO NOT RUN METALLIC WATER PIPE OUTSIDE STATION
- SWITCH GEAR AND CONTROL PANEL SHOULD BE MADE VERMIN FREE

EVALUATION OF GRID RESISTANCE AND G.P.R

A Minimum value of the Sub-Station grounding resistance in uniform soil can be estimated by

$$R_g = \frac{\rho}{4} \sqrt{\frac{\pi}{A}}$$

Eq-1

where

R = station ground resistance in Ω

ρ = average earth resistivity in $\Omega\text{-m}$

A = the area occupied by the ground grid in m^2

Upper value of the Sub-Station grounding resistance in uniform soil can be estimated by

$$R_g = \frac{\rho}{4} \sqrt{\frac{\pi}{A}} + \frac{\rho}{L}$$

Eq-2 Where “L” is the total buried length of conductor in mtr.

For grid depths between 0.25 to 2.5 mtr. Is given by incorporating correction factor for grid depth

$$R_g = \rho \left[\frac{1}{L} + \frac{1}{\sqrt{20A}} \left(1 + \frac{1}{1 + h \sqrt{20/A}} \right) \right]$$

Eq-3

Where “h” is the depth of Grid in mtr.

Ground potential rise: (GPR) = $I_g * R_g$ Volts

Earthing in difficult situations

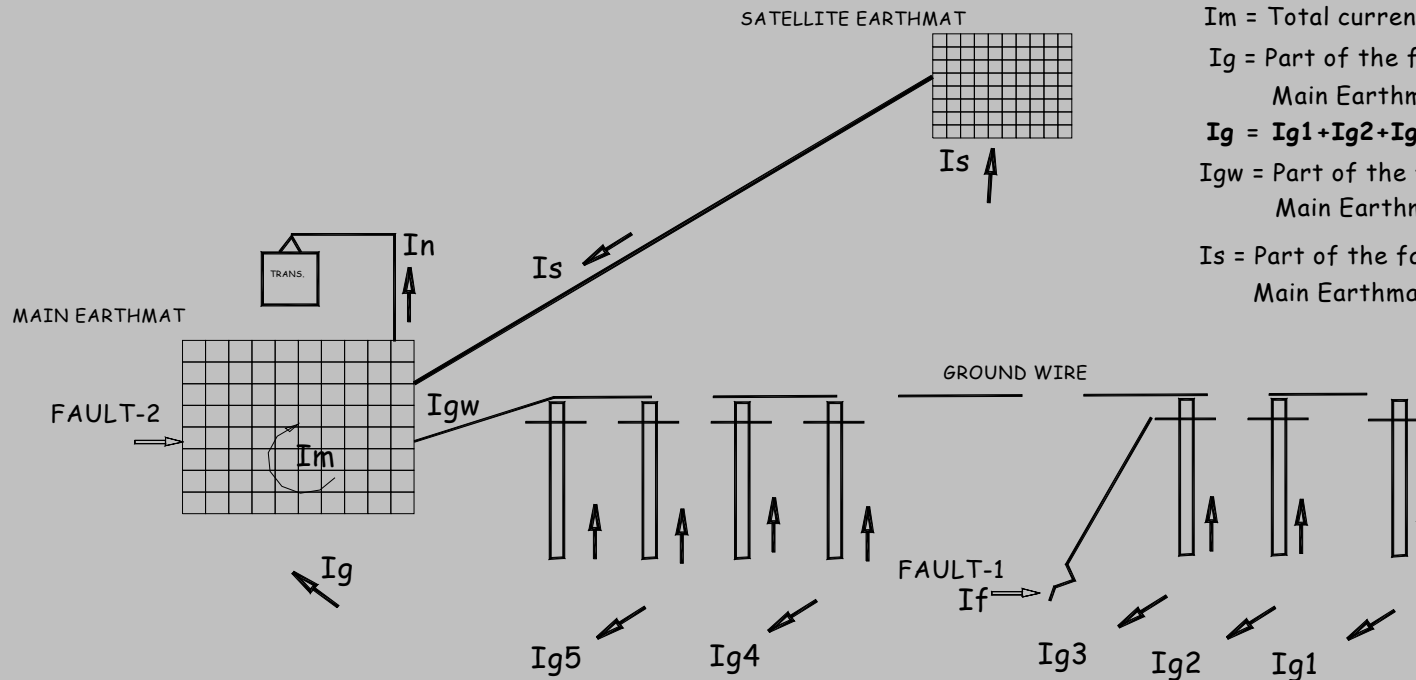
The earthing resistance can be improved by any one or more of the following methods.

1. Increase the area of the earth mat.
2. Provide deep earth electrodes.
3. Provide auxiliary earth mat in a nearby place where the resistivity is low and connect it to the main earth mat.
4. Treating the earthmat and the electrode with suitable chemicals.

Depending upon the situation any one or more of the above methods can be used to reduce the earth resistance.

SATELLITE EARTHMAT

EARTH POTENTIAL RISE (E.P.R)



I_f = Fault current I_n = Neutral current

$I_f = I_n$

I_m = Total current flowing in the Earthmat

I_g = Part of the fault current Entering the Main Earthmat through the Earth.

$I_g = I_{g1} + I_{g2} + I_{g3} + \dots + I_{gn}$

I_{gw} = Part of the fault current Entering the Main Earthmat through the Overhead Ground wire.

I_s = Part of the fault current Entering the Main Earthmat through the Satellite Earthmat.

$$I_n = I_m = I_f = I_g + I_{gw} + I_s$$

$$I_g = I_{g1} + I_{g2} + I_{g3} + \dots + I_{gn}$$

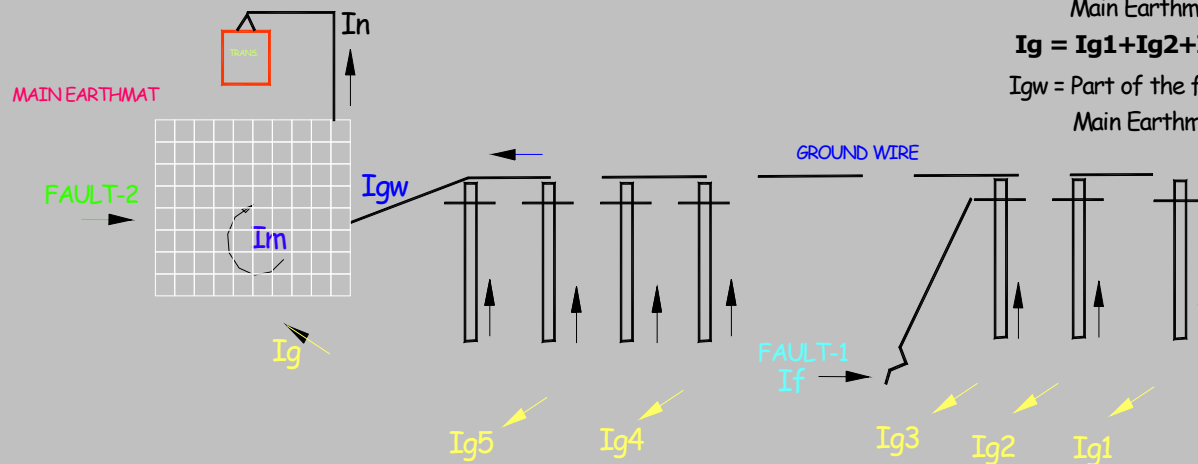
ONLY THE CURRENT I_g CONTRIBUTES TO THE E.P.R AND
NOT THE TOTAL CURRENT FLOWING IN THE EARTHMAT (I_m) OR NEUTRAL (I_n)

➤ The diversion of fault current through the main earth mat.

➤ Selection of site and interconnection.

EARTH POTENTIAL RISE

EARTH POTENTIAL RISE (E.P.R)



I_f = Fault current I_n = Neutral current

$I_f = I_n$

I_m = Total current flowing in the Earthmat

I_g = Part of the fault current Entering the Main Earthmat through the Earth.

$I_g = I_{g1} + I_{g2} + I_{g3} + \dots + I_{gn}$

I_{gw} = Part of the fault current Entering the Main Earthmat through the Overhead Ground wire.

$$I_n = I_m = I_f = I_g + I_{gw} + I_s$$

$$I_g = I_{g1} + I_{g2} + I_{g3} + \dots + I_{gn}$$

ONLY THE CURRENT I_g CONTRIBUTES TO THE E.P.R AND

NOT THE TOTAL CURRENT FLOWING IN THE EARTHMAT (I_m) OR NEUTRAL (I_n)

CASE-1 Fault outside the substation

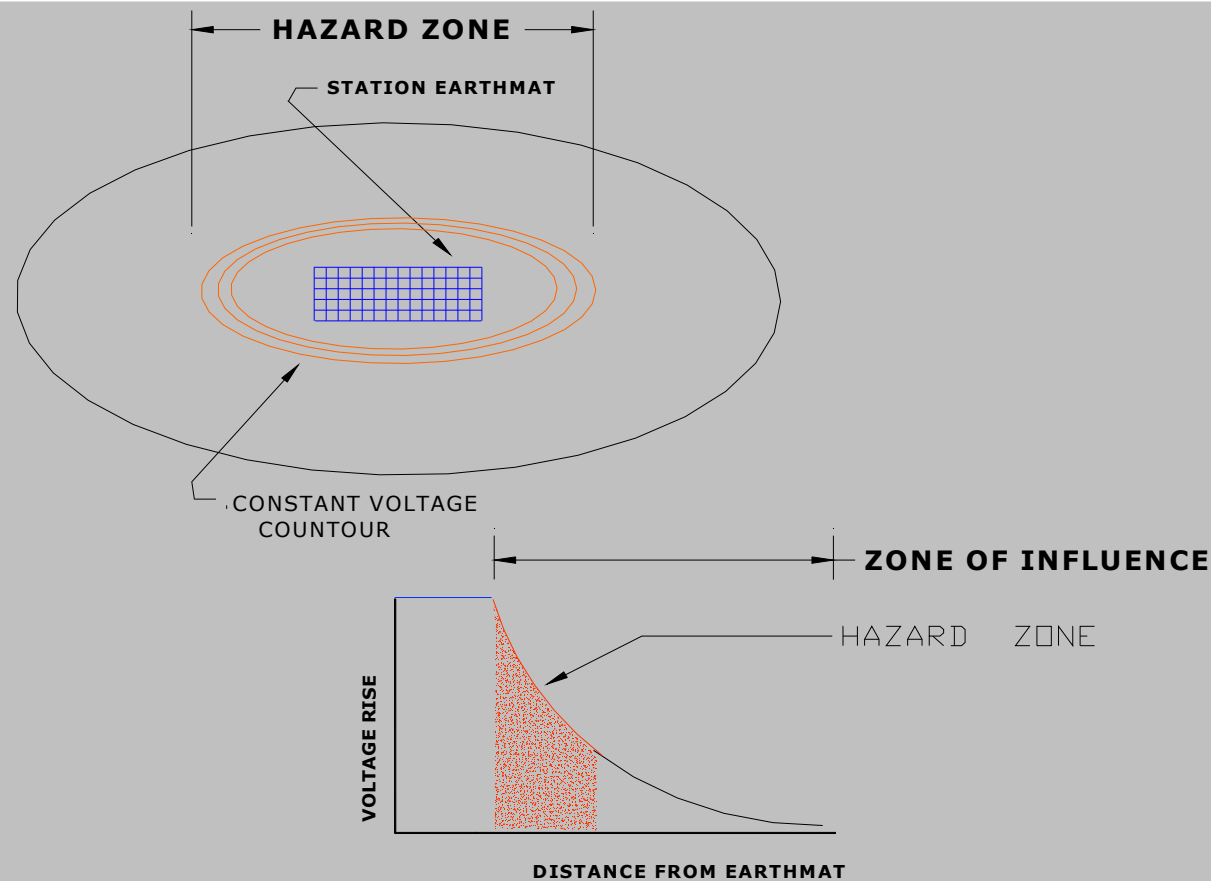
E.P.R of Earthmat w.r.t remote point is directly proportional to I_g

CASE-2 Fault within the sub-station

$$I_g = I_{gw} = 0$$

$I_n = I_m$ and E.P.R is Zero w.r.t remote point

- Path of the Earth fault current
- Earth Potential Rise (E.P.R)
- In Solid Earthing systems large fault current flows from the fault point to the neutral via earth

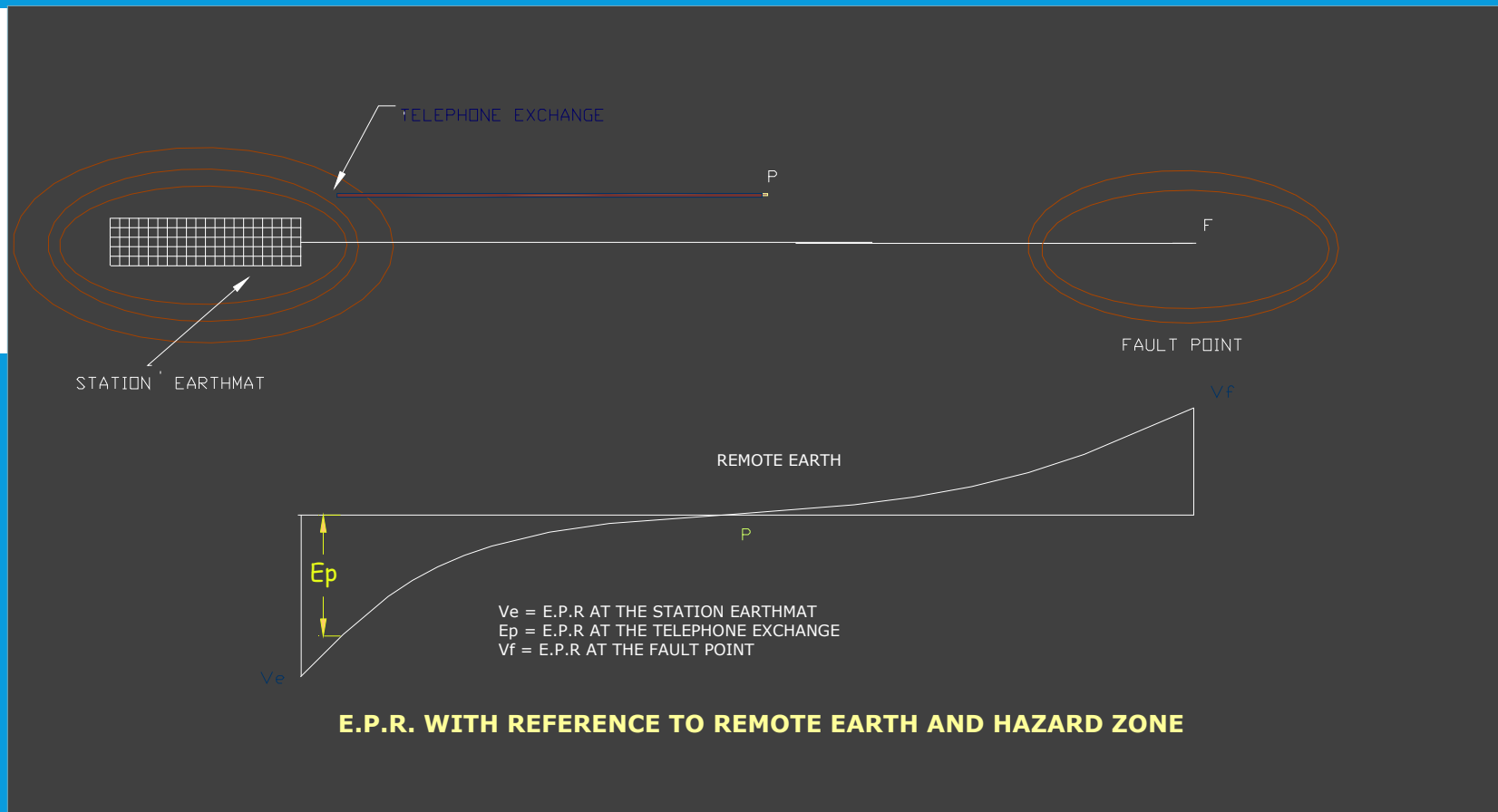


E.P.R. HAZARD ZONE AND INFLUENCE

- **Magnitude and Zone of Influence of E.P.R.**
- **Factors affecting Voltage gradients**
- **An Earth mat designed to limit Voltage gradients**

Limits of E.P.R in our country :-

Telephone Exchange / Terminal apparatus	 430 Volts.
Tecommunication Lines	650 Volts



RNE

The ill-effects of E.P.R. reported in our system are :

Burning of Telephone cards and Mother boards at Tel.Exchange,

Charred out Tag blocks and cables at Pillar boxes ,

Melting of telephone Sets,modems and service main at consumer premises,

Frequent failure of telephone cables,

EPR Limits (As per PTCC Manual)

Sl no	Type of Telecom plant	Type of Power System	
		High Reliability lines	Other lines
1	Terminal apparatus, joints, cabinets, pillars, manholes, pits, poles	650V	430v
2	Telephone Exchanges	430V	430V
3	Cables		
	a) Metal sheathed b) Plastic insulated and plastic sheathed	650V 7kV	430V 7kV

Minimum separation for Telecom cables in the soil

Earth Resistivity in Ohm Metres	Power network system with		Location
	Isolated Neutral or Arc separation coil	Directly earthed neutral	
<50m	2	5	Urban
	5	10	Rural
50 - 500	5	10	Urban
	10	20	Rural
500 - 5000	10	50	Urban
	20	100	Rural
75000	10	50	Urban
	20	100-200*	Rural
* 200 metres in areas with extremely severe soil resistivity around 10000 ohm metres			

(Source PTCC Manual 1995 edition)

Measurement of EPR Zone

Theoretical formula for EPR Zone

$$X = \frac{\rho I}{2\pi E_x} \quad \text{Metres}$$

ρ = Soil Resistivity in ohm metres

I = Fault current in Amperes

E_x = EPR Voltage

Applicable for
single electrode earthing

$$E_x = \frac{E_{\max} \times D}{d + D} = \frac{IR \times D}{d + D}$$

E_x = The potential at radial distance 'd' from the perimeter of earthmat

I = Maximum fault current through the earthmat in Ampere

D = Half the diagonal distance of the mat in metres

d = Distance in metres from the perimeter of earthmat

Applicable for large earthmats

Case Studies

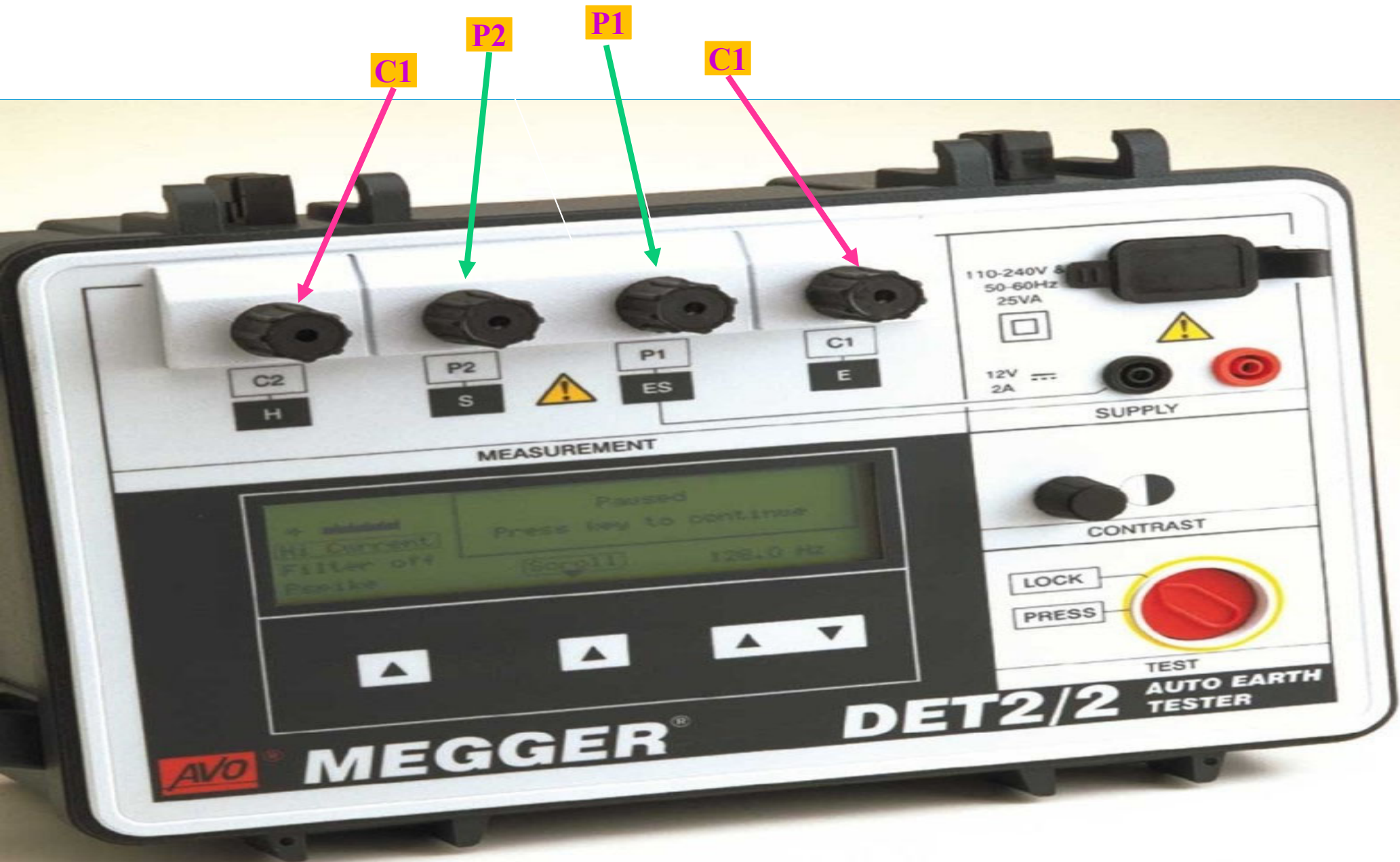
1. Interference with telecommunication lines at HSR Layout Bangalore
2. Control of EPR At Yesloor
3. Soil Resistivity measurement at Shivasamudram
4. Deep bore electrodes at Jayadeva (220 KV station)
5. Shivasamudram generating station earthing

References

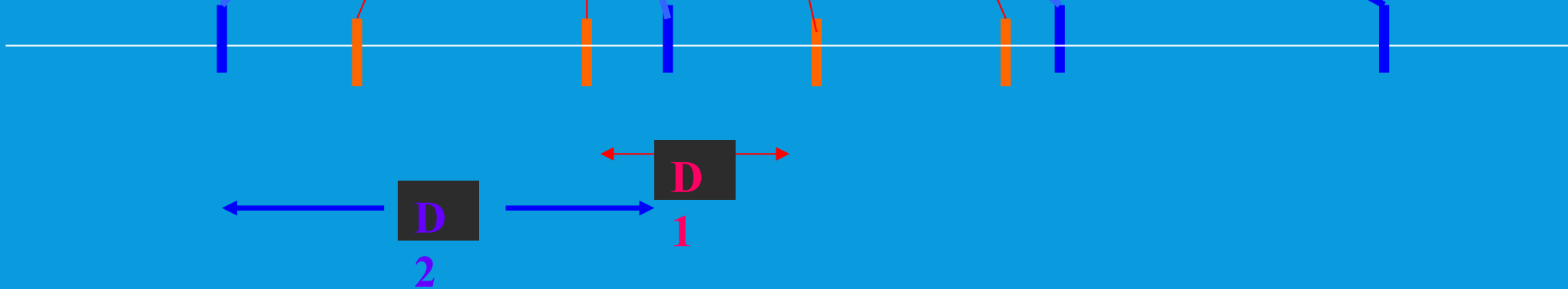
1. IEEE guide for AC Substation Grounding (IEEE 80)
2. IEEE guide for Measuring earth Resistivity, Ground impedance, and earth surface potentials for a ground system(IEEE 81)
3. IEE recommended practice for grounding industrial and commercial power systems (IEEE 142)
4. IEEE Guide for generating station grounding(IEEE 665)
5. Indian standard specifications (3043 Earthing)

EARTHING INTEGRITY CHECK

EARTH TESTER



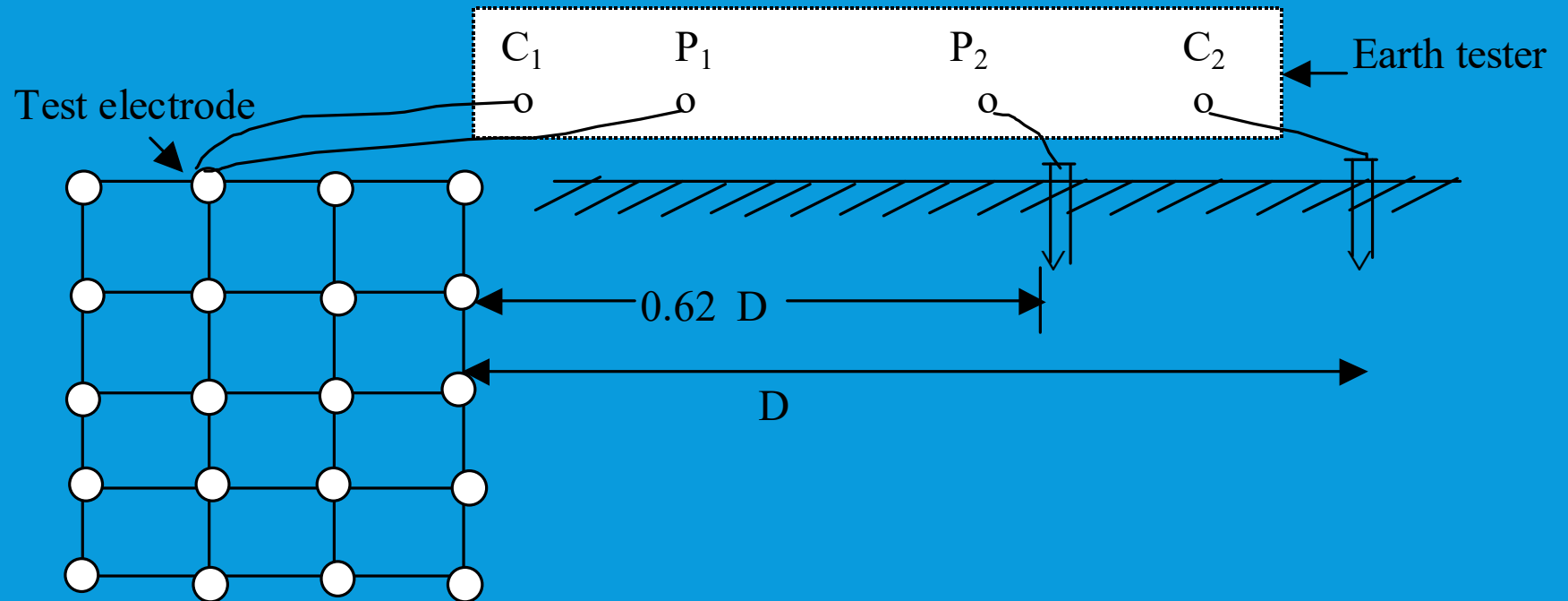
MEASUREMENT OF SOIL RESISTIVITY



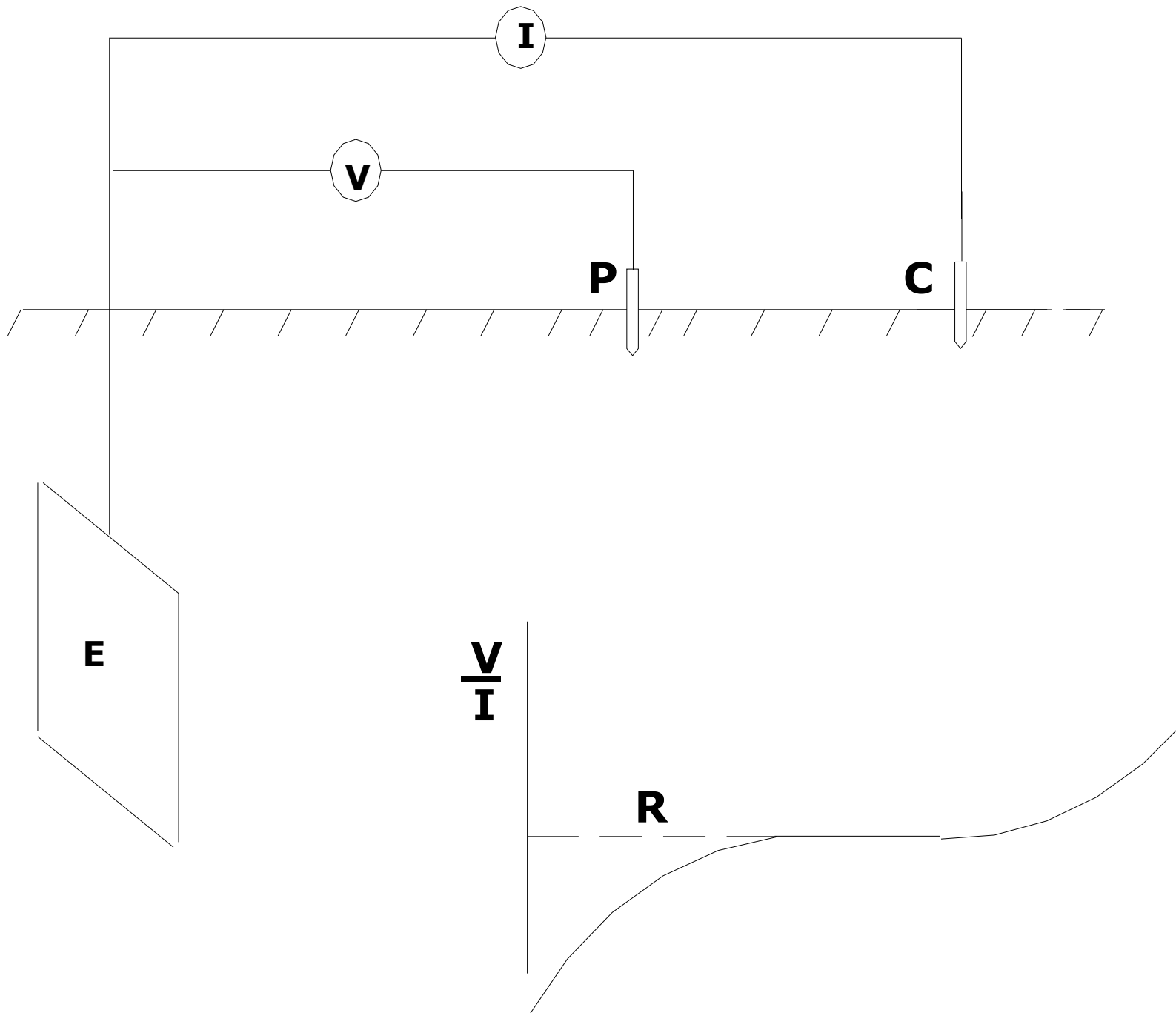
C1, C2 CURRENT TERMINALS

P1, P2 POTENTIAL TERMINALS

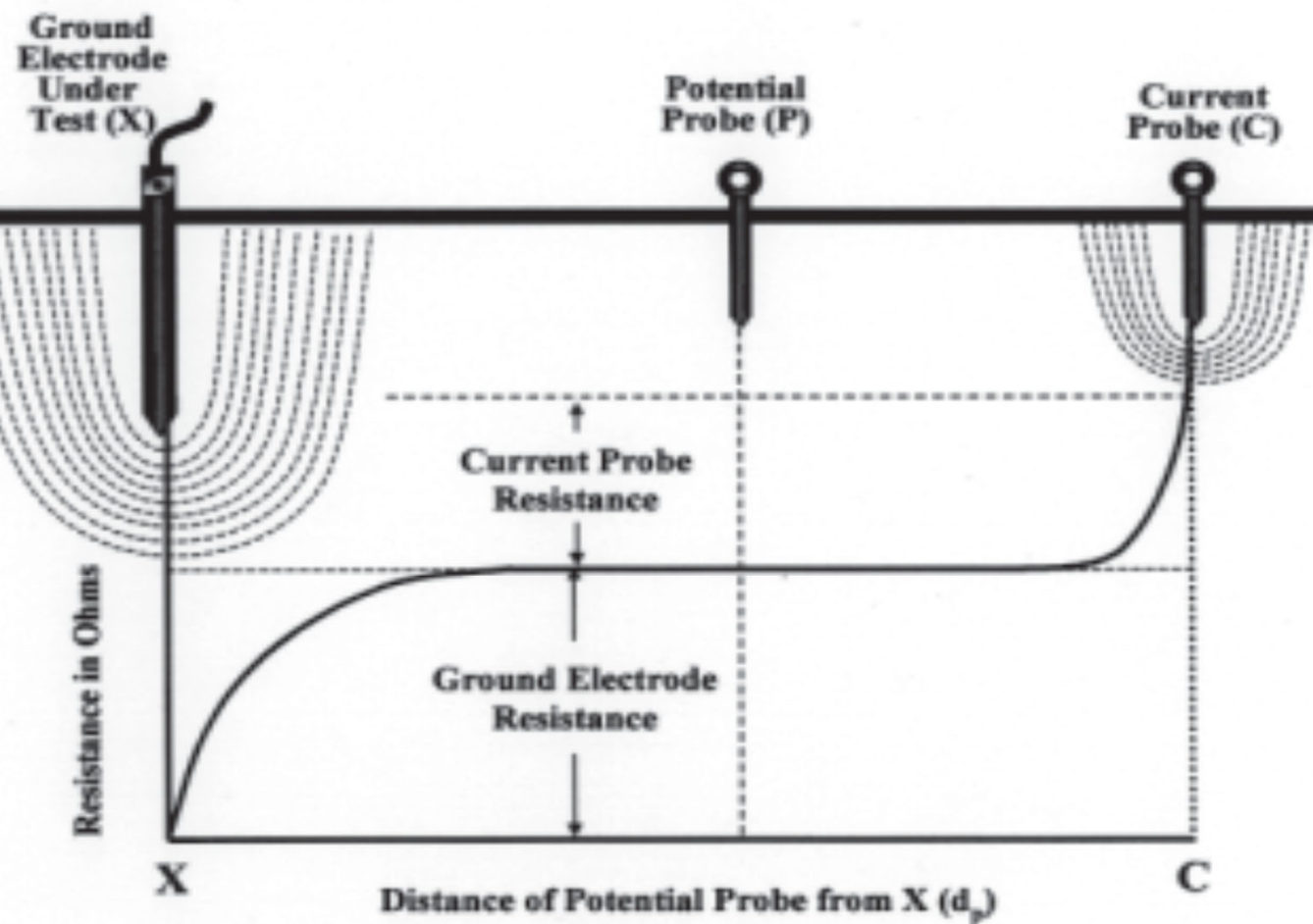
TEST CONFIGURATION FOR SUB-STATIONS:



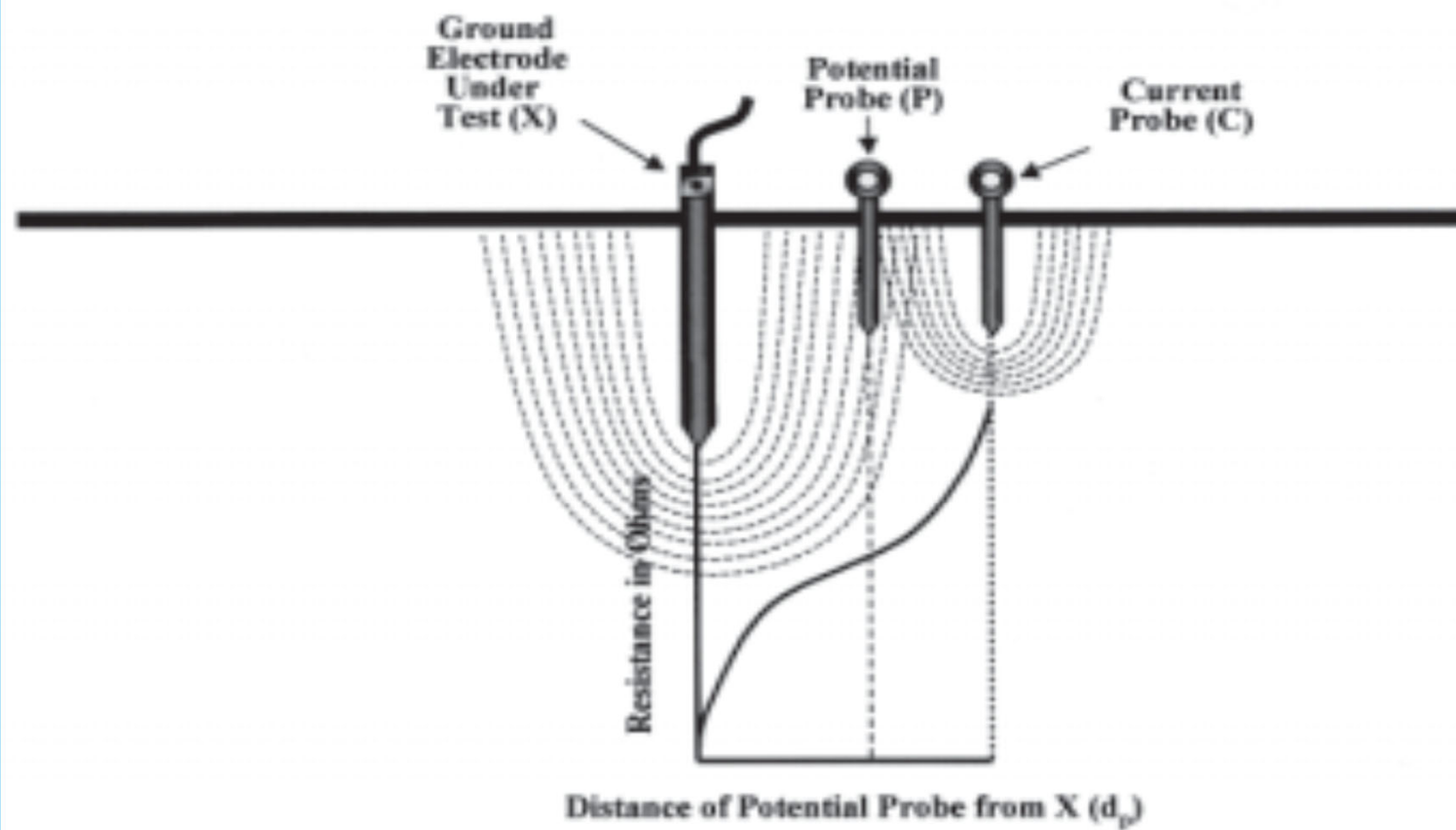
MEASUREMENT OF EARTH RESISTANCE R

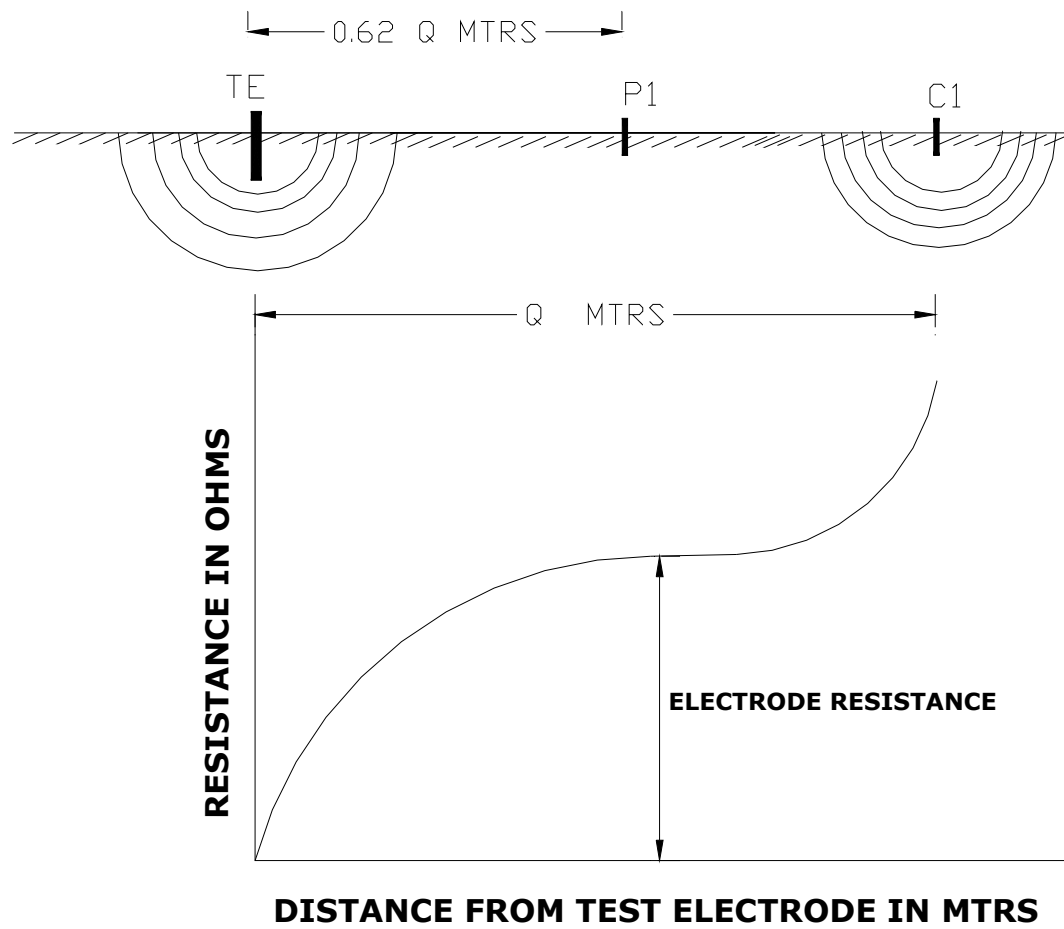


Acceptable Test Set-Up

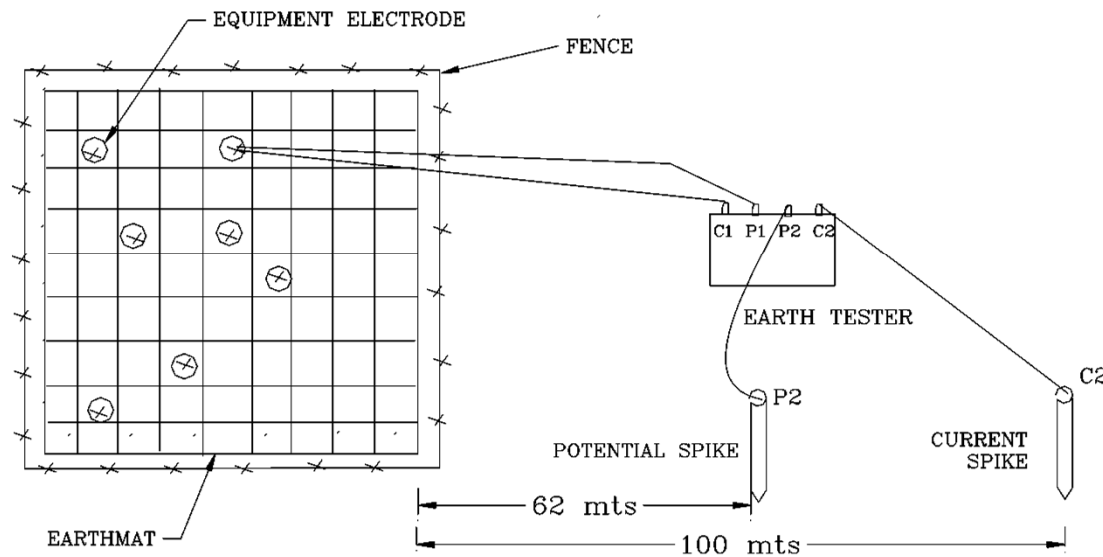


Insufficient Probe Spacing





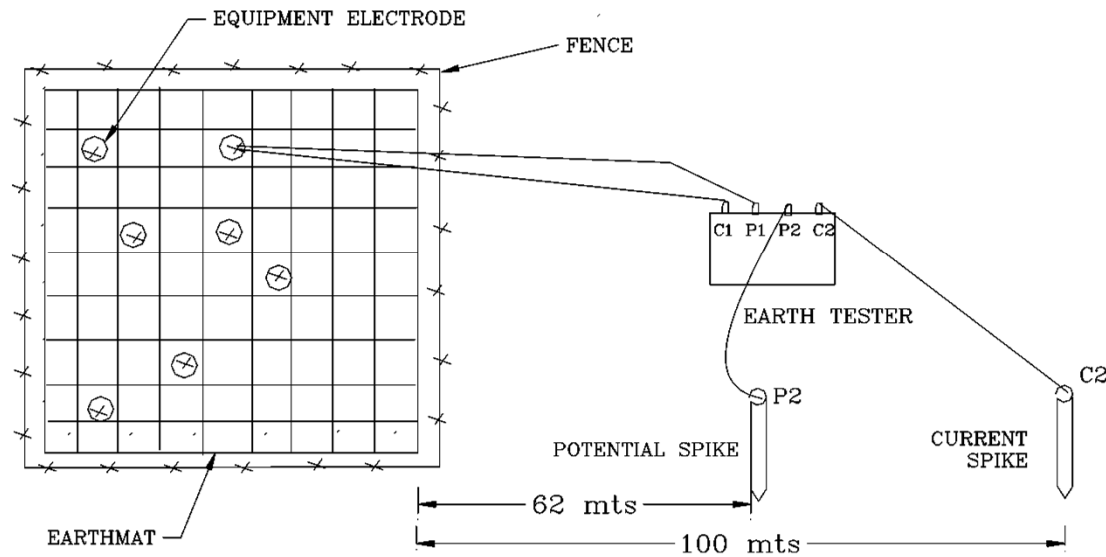
MEASUREMENT OF EQUIPMENT EARTH RESISTANCE—INTEGRITY CHECK.



An earth connection integrity check can be made with the help of earth tester.

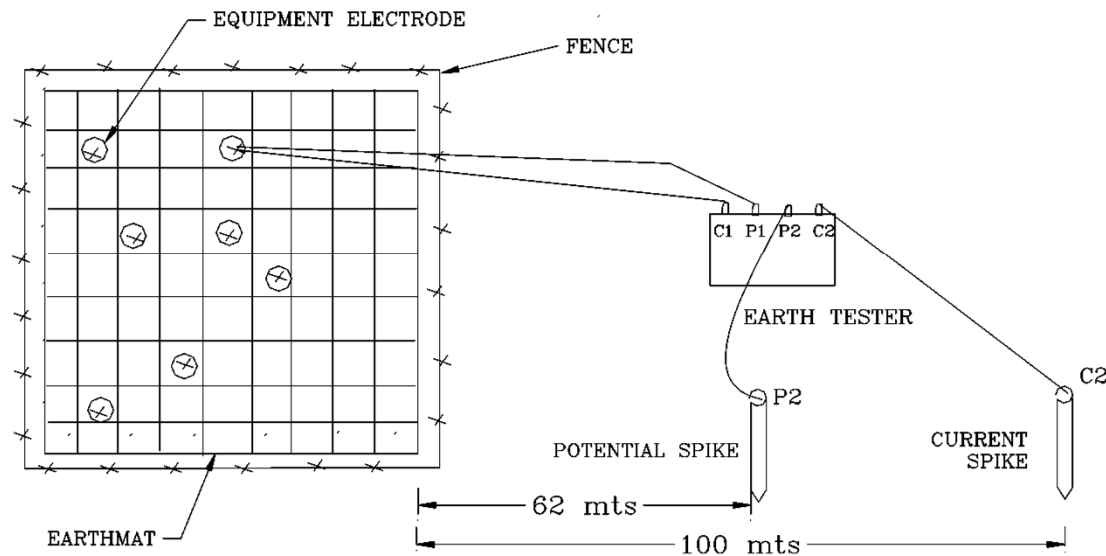
The equipment earth connection to the Sub-Station Earthmat play on important role in protecting the equipment from damage and for proper operation of protective relays

MEASUREMENT OF EQUIPMENT EARTH RESISTANCE-INTEGRITY CHECK.



1. C2- current spike shall be driven at 100mtr from the edge o the Earthmat.
2. P2 - potential spike shall be driven at 62 mts from the edge of the Earthmat.
3. Two separate leads form C1 & P1 terminals of earth tester shall be connected to the equipment earth connection and resistance measured.

MEASUREMENT OF EQUIPMENT EARTH RESISTANCE-INTegrity CHECK.



Then move C1 & P1, lead to other equipments earth connections and record the resistance. Repeat till all earth connections are measured. If all the readings are in agreement within small percentage variation, then, the integrity of earth connections is good.

- If some earth connections show higher values and is not in agreement, then, the integrity of earth connection is in doubt.
- The earth connection at the equipment/ electrode/ Earthmat shall be checked for electrical soundness and attended to whenever higher values of resistance is recorded during integrity check.
- Precautions to be taken up while making integrity checkup

THE SALIENT POINTS TO BE OBSERVED WITH REFERENCE TO OLDER DESIGNS OF EARTHING SYSTEM AND THE NEW DESIGN

Old earthing System	New earthing System
Copper conductors/Strips for Earth mat, Copper/bunched GI wires for equipment earthing, and GI pipes electrodes for individual equipments are suggested.	MS flats for Earth mat, G I flats for equipment earthing and CI pipes electrodes for individual equipment are suggested
Bolt & nut connections at the electrodes should be free from rust and must be tight and electrically sound. Lugs for end termination should be inspected for melting of lead (crimping of lugs is better)	Welding connections at the electrodes should be sound with welding on all four sides and the welded portion shall be applied with 2 coats of thick ACB paint duly removing deposited weld, flux and burr's.
The earthing leads shall be inspected for any rusting/broken condition and replaced wherever required.	The flats provided generally remain intact for its life period, unless otherwise physically damaged, or under extreme Soil/Weather conditions.

THE SALIENT POINTS TO BE OBSERVED WITH REFERENCE TO OLDER DESIGNS OF EARTHING SYSTEM AND THE NEW DESIGN

Old earthing System	New earthing System
GI pipe electrodes might have rusted at the reducing collar or the main G I pipe itself may be totally rusted.	The CI pipes generally do not rust. Welded portion of the split clamp shall be checked for its soundness.
There may be number of joints in the earth wire leads. Avoid joints and as far as possible use a through lead.	As far as possible use continuous MS/GI flats. Avoid joints. If joints are inevitable use lap joints, so that the overlap length is equal to a minimum of the flats width. The overlap portion shall be welded on all four sides by continuous welding and apply ACB paint

MAINTENANCE OF EARTHING SYSTEM

- KEEP TOP PORTION OF ELECTRODES FOR INSPECTION
- CHECK FOR ARCING FAULTS
- PERIODICAL INTEGRITY CHECK OF EARTHING
- ARREST WEED GROWTH
- REPLACE ALL DETERIORATED ELECTRODES AND EARTH CONNECTION
- AUXILLARY SUPPLY TO THE STATION FROM DEDICATED TRANSFORMER ONLY
- DO NOT RUN METALLIC WATER PIPE OUTSIDE STATION
- SWITCH GEAR AND CONTROL PANEL SHOULD BE MADE VERMIN FREE

GUIDE LINES FOR IMPROVING
EARTHING OF EXISTING STATIONS

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

PROVIDING NEW ELECTRODES

If G.I. Pipes provided to the following are deteriorated, C.I. Pipe Electrodes of size 100 mm ID, 13mm thick, 2.75mtrs. long are to be provided as mentioned below:-

Transformer Neutral	1 For each Neutral
LA's	1 For each Phase
11 KV Switch Gear Panel	2 Nos On Either side
Control Room Panel	2 Nos On Either side
11 KV DP's	1 for each feeder DP's

These C I pipe electrodes are to be interlinked by using M.S. Flat and connected to the earthmat by welding.

GUIDE LINES FOR IMPROVING EARTHING **OF EXISTING STATIONS**

If G.I. Pipes provided to the following are deteriorated, C.I. Pipe Electrodes of size 100 mm ID, 13mm thick, 2.75mtrs. long are to be provided as mentioned below:-

- | | |
|----------------------------|------------------------|
| 1. Transformer Neutral | 1 For each Neutral |
| 2. LA's | 1 For each Phase |
| 3. 11 KV Switch Gear Panel | 2 Nos On Either side |
| 4. Control Room Panel | 2 Nos On Either side |
| 5. 11 KV DP's | 1 for each feeder DP's |

For Transformer Neutral 50 x 6 mm GI Flat shall be used from the neutral bushing to the electrode and from the electrode to the earthmat. All connections shall be made by proper welding.

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

If G.I. Pipes provided to the following are deteriorated, C.I. Pipe Electrodes of size 100 mm ID, 13mm thick, 2.75mtrs. long are to be provided as mentioned below:-

- | | |
|----------------------------|----------------------|
| 1. Transformer Neutral | 1 For each Neutral |
| 2. LA's | 1 For each Phase |
| 3. 11 KV Switch Gear Panel | 2 Nos On Either side |
| 4. Control Room Panel | 2 Nos On Either side |

Each Phase of the L.A.'s should be connected to the individual electrodes provided for that purpose. The electrodes in turn shall be connected to the earthmat by welding using GI Flat. Additional CI pipe electrodes are to be provided in case individual electrodes are not provided for each phase or existing G.I. Pipe electrodes are deteriorated

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

SWITCH GEAR PANEL

Panels) suitable holes shall be made in each panel and cable sheath be connected using G.I. Bolts and Nuts. The free ends of the G.I. Flat shall be linked to the earthmat through two independent cast iron pipe electrodes

CONTROL PANEL

A separate earth bus of Galvanised Steel Flat shall be run in the duct of the control room and earth points provided in the control/annunciator panel and battery charger shall be connected to this bus. The control panel earth bus shall be connected to the two cast iron pipe electrodes provided around the control room.

Switch gear and control panel cable entry shall be made vermin proof

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

D.P.STRUCTURE

A separate G.I.Flat shall run from the top cross arm of the D.P's where strain insulators are provided for stringing of over head line and welded. The welding shall also be done at other cross arms provided for fixing G.O.S. and Pot Head and to the existing ground pipe. The cable sheath shall be connected to the supporting cross arm by G.I. Bolts and Nuts.

If the 11 KV Feeder D.P. Structures are situated out side the station yard only interconnections between electrodes are made but *shall not be* connected to earthmat

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

NON CURRENT CARRYING METAL PARTS

- **Transformer Body,**
 - **P.Ts, C.Ts Body,**
 - **Circuit Breaker Body,**
 - **Out door Structure and**
 - **Isolator Structure**

are deteriorated then these equipment are to be directly connected to the earthmat using Galvanised Steel Flats with 2 distinct connection running in opposite direction.

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

DETERIORATED EARTH CONDUCTOR

Additional G.I. Flat earth conductor shall be provided if the existing earth conductor is deteriorated & connections to the electrode/earthmat shall be made by proper welding.

Replace rusted M.S. bolts & nuts by G.I. bolt & nuts(provide copper lugs & brass bolt & nuts for copper earth conductors).

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

AUXILLARY TRANSFORMER

The station must have a dedicated Auxiliary Transformer installed within the station yard with its neutral firmly connected to the station earthmat through an independent electrode.

For no reason the power supply from the station auxiliary transformer should be extended beyond the station yard.

MAINTENANCE OF GROUND PITS AND LABELLING OF ELECTRODES

All the ground pits shall be cleaned at least 30 cms below the ground to avoid corrosion of pipes, Bolt & Nuts in earth pits & also for enabling inspection of earth electrodes and periodical testing of electrodes.

All electrodes should be labelled for proper identification.

GUIDE LINES FOR IMPROVING EARTHING OF EXISTING STATIONS

IMPORTANT POINTS

The distance between any two CI pipe electrodes should not be less than twice the length of the CI Pipe electrode

While working on grounding either at equipments or at the electrode the respective equipments shall be on line clear for safety.

The CI pipe electrode for lightning arrester and power Transformer neutral shall be as near as practicable to the respective equipment.

The lightning arrester earth connection should not be run over the ground surface.

They should be buried at the mat depth and connected to the earthmat at the nearest point.

CORRODED EARTH ELECTRODE



REJUVENATED EARTH PIT



1. C2- current spike shall be driven at 100mtr from the edge of the Earthmat.
2. P2 - potential spike shall be driven at 62 mts from the edge of the Earthmat.
3. Two separate leads form C1 & P1 terminals of earth tester shall be connected to the equipment earth connection and resistance measured.
4. Then move C1 & P1, lead to other equipments earth connections and record the resistance. Repeat till all earth connections are measured.
5. If all the readings are in agreement within small percentage variation, then, the integrity of earth connections is good.

If some earth connections show higher values and is not in agreement, then, the integrity of earth connection is in doubt.

The earth connection at the equipment/electrode/Earthmat shall be checked for electrical soundness and attended to whenever higher values of resistance is recorded during integrity check.

Thank You

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