BHEL – EMRP MUMBAI	SOIL RESISTIVITY MEASUREMENT METHODOLOGY FOR RAMMAM STAGE III HEP PROJECT (3 X 40 MW)	Doc No.	EM-RMM-14-SR-01
		Rev	01
		Date:	19.04.16

SOIL RESISTIVITY MEASUREMENT METHODOLOGY FOR POWER HOUSE BUILDING, GENERATOR TRANSFORMER YARD, TAIL RACE TUNNEL ,EM BUILDING AT SWITCHYARD, ,B.F. VALVE HOUSE ,SURGE SHAFT AREA, BARRAGE CONTROL BUILDING AND ASSOCIATED AREA AT RAMMAM STAGE III HE PROJECT (3 X 40 MW)

NTPC Document No. 5602-003-H199-PVE-U-003

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CONTENTS

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		NTPC doc no.	5602-003-H199-PVE-U-003
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1. OBJECTIVE:

The objective of this procedure is to explain the method of soil resistivity measurement for the Rammam Stage III HE Project and to ensure its conformance with the relevant standards (IS 3043, Indian electricity rules ANSI/IEEE Standard 80-2000, IEEE Guide for Safety in AC Substation Grounding & CBIP Manual on earthing of AC Power Systems, 2007).

2. INTRODUCTION:

RAMMAM Stage III H.E. Project is run of the river scheme project & it is situated at about 150KM away from Bagdogra/Siliguri district of Darjeeling. Darjeeling town is 50KM away from project site. It comprises of a surface power house of installed capacity 120MW.Three (3) Nos.of Hydro generators with the rated output of 44.44MVA, along with excitation system, Isolated Phase bus ducts & related equipment etc. shall be installed at Power house. Additionally, Three (3) Nos. of Vertical Pelton turbines of rating 40MW with Governing system, Spherical Valve type Main inlet valve shall be installed. It comprises of 11Nos.Single phase oil filled generator Transformers including 2Nos.spare transformers of 11KV/132/√3,17MVA (Three phase Banking rating 51MVA).

3. EQUIPMENTS REQUIRED:

- 4 Pole Digital –Ground resistance tester
- Earthing Rods
- Hammer
- Connecting cables
- Measuring tape
- User's Manuals for meter

4. REFERENCE DOCUMENT

Following document & code latest version in totality or in part shall form the reference document.

ASTM G 57	Field measurement of Soil resistivity using Wenner's four pin method
IS3043	Code of practice for earthing
IEEE-80-2000	Guide for Safety in AC Substation Grounding
IEEE-81-1983	Guide for measuring Earth resistivity

5. CHOICE OF LOCATIONS & ELECTRODES FOR MEASUREMENT

Rammam Stage III HEP is a surface power station. The measurement shall be taken in the following areas:

1. Powerhouse Building (including service bay area & Central Control building)
2. Generator Transformer yard Area (Including 132KV cable trench to switchyard)
3. EM Building at 132KV Switchyard.
4. Tail Race Tunnel.
5. TRT outfall area.
6. BF Valve house & Surge shaft area.
7. Barrage control building & associated areas.

For making resistivity measurements, generally, 25mm diameter holes drilled in the rock to a depth of 1 m and 1.1 m long MS rod of 20mm diameter shall be hammered in the rock. For filling the air-gap between the electrode and rock, a slurry made of powdered rock and water, shall be poured into the holes after placing the electrodes. The electrodes shall be installed at suitable locations. Four (4) such electrodes are used at a time for making resistivity measurements. At any site where electrodes can not be hammered into rock, pneumatic drill is required to make small holes for inserting them into ground by grouting.

6. METHOD OF MEASUREMENT

Resistivity of Soil

Measurements of soil resistivity at the site shall be carried out by the Wenner four-electrode method. The measurements can be made with the Digital Earth Tester. Connections of the meter for measuring earth resistivity are shown in Figure 1.

In this method four electrodes are driven into the earth along a straight line, at equal distances *'a'* meter apart, driven to a depth 'b'. The depth 'b' should be ideally less than 1/20 of spacing 'a'. Current I is passed through the earth via the two outer (Current) electrodes and voltage V is measured between the two inner (potential) electrodes. The meter measures the measured voltage divided by the current (V/I) and gives a value of resistance R.

Apparent soil resistivity values are calculated by using the formula

$\rho=2\pi a R$ .... (1)

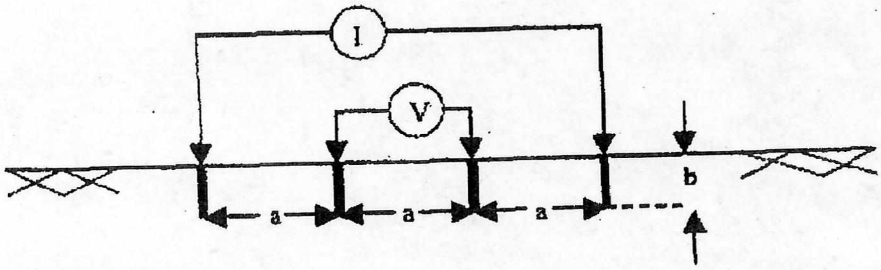

Figure1. Wenner four-electrode method

Where

ρ = apparent resistivity of soil in ohm-m

a = Distance between adjacent electrodes in m

R = ratio of voltage across the inner electrodes to the current circulated between the outer electrodes of Wenner configuration in ohms (read directly by the Digital Earth Tester)

b = depth of electrode in m

if the depth 'b' is not less than 1/20th of spacing 'a', than the general formula is

$$\rho = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}} \quad \text{......} \quad (2)$$

7. FORMAT OF TEST RECORD

S.No.	Electrode spacing "a" m	Radial A			Radial B		
		Measured Resistance "R" (Ω)	Apparent Resistivity "ρ" (Ω-m")	Weighted Average Resistivity "ρ" (Ω-m")	Measured Resistance "R" (Ω)	Apparent Resistivity "ρ" (Ω-m")	Weighted Average Resistivity "ρ" (Ω-m")
1	1						
2	2						
3	3						
4	.....						
5	.....						
6	.....						

8. PROCEDURE FOR MEASURING SOIL RESISTIVITY

For measuring soil resistivity at the site, measurements of resistivity are made along a number of radials at different locations. There ought to be a minimum of two radials at one location. Spacing between the electrodes (probe) should be varied from the smallest value of about 0.5 m to large values, by changing the spacing of electrode from an initial small value of 0.5m up to a distance of 20m (Typical interval of 0.5m, 1.0m, 2.0m, 3.0m, 5.0m, 10m, 15m, 20m etc.) depending on the extent of the earth electrode and condition on the ground. If resistivity variation is large, at least five progressively increasing probe spacing are necessary to get good estimate of deeper layer parameters. The soil along the radials should be free from buried conductive pipes etc. and it should not be recently filled and therefore not yet compacted. For convenience, one probe may be kept near the location of earth tester and the other three moved as required. Test wires should be insulated and should not have joints in between. These should be firmly connected to terminals of earth

Resistance meter and test electrodes. Test electrodes should be clean and free from rust. Hammering of electrodes should not result in loosening of connection between electrode and its test lead and there by an increase of contact resistance between test lead and electrode. Accuracy of earth resistance meter should be checked before and after the measurements. Resistivity value should be calculated after each observation so that if there is an abrupt variation in measured resistivity, measurement for that probe spacing should be repeated after altering the probe location.

9. INTERPRETATION OF MEASUREMENT

ρ is called apparent measured resistivity, represents true resistivity of the soil at the site of measurement only if the soil formation is homogenous and isotropic in (having same properties in all directions) nature. Usually, resistivity variation is not very pronounced in lateral direction and is gradual. Resistivity is more likely to vary along depth of soil below surface. The soil may consist of two or more layers of different resistivities. In that case ρ is a measure of weighted average of true resistivities of different layers. The effective depth of current penetration below earth surface is dependent on distance between current electrodes. ρ is a measure of resistivity up to a depth equal to one third of the distance between current electrodes i.e., depth equal to distance 'a' meters. As magnitude of 'a' is increased from a small value to larger values, the measured resistivity reflects the effect of soil at greater depth. This is the reason that a layered model can be used to reflect the variation in measured resistivity along the depth below earth surface as 'a' is varied. From the soil resistivity measurements, the data becomes available in the form of table I.

If any soil resistivity for electrode spacing is found to be too high or too low, as compared to resistivity for the next smaller and next larger electrode spacing along that radial, it may be ignored when determining the soil model.

The most commonly used soil resistivity models are the uniform soil model and the two-layer soil model (as per clause 13.4 of IEEE-80).In case of non-uniform soil resistivity, two layer model shall be adopted for computation of earth resistivity.

1. Uniform Soil Assumption

The approximate soil resistivity may be obtained by taking an arithmetic average of the measured apparent resistivity data as shown in eq. (3).

$$\rho = \frac{\rho 1 + \rho 2 + \rho 3 \ldots\ldots\ldots\ldots \rho n}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where

$\rho_1 + \rho_2 + \rho_3 + \ldots\ldots\ldots\ldots\ldots + \rho n$ = measured apparent resistivity data obtained at different Spacing in the wenner method

n = total no of measurements

2. Nonuniform Soil Assumption

For no uniform soil the approximate soil resistivity may be obtained by

(i) Two-layer soil model (general):

A two-layer soil model can be represented by an upper layer soil of a finite depth above a lower layer of infinite depth. The abrupt change in resistivity at the boundaries of each soil layer can be described by means of a reflection factor. The reflection factor, K, is defined by eq. (4).

$$K = (\rho_2 - \rho_1)/(\rho_1 + \rho_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where

ρ_1 is the upper layer soil resistivity, in Ω-m

ρ_2 is the lower layer soil resistivity, in Ω -m

(ii) Two-layer soil model by graphical method

A two layer soil model can be approximated by using graphical method described in Sunde. In Sunde's method, the graph (figure 2) used to approximate a two layer soil model, is based on Wenner four-pin test data.

Parameters ρ_1 and ρ_2 are obtained by resistivity measurement. Only h (depth of upper layer) is obtained by Sunde's graphical method, as follows:

a. Plot a graph of apparent resistivity ρ on Y-axis vs. probe spacing on X-axis.
b. Estimate ρ_1 and ρ_2 from the graph plotted in step (a). ρ corresponding to smaller spacing is ρ_1 and for a larger spacing is ρ_2.
c. Determine ρ_2 / ρ_1 and select a curve on the Sunde graph as shown in figure 2, which matches closely and draw a new curve on the graph.
d. Select the value on the Y-axis of p / p_i within the sloped region of the appropriate ρ_2 / ρ_1 curve of figure 2.
e. Read the corresponding value of a/h on the X-axis.
f. Compute p by multiplying the selected value ρ / ρ_1 within step (d) by ρ_1.
g. Read the corresponding probe spacing from the apparent resistivity graph plotted in step (a).
h. Compute h, the depth of the upper layer, using the appropriate probe separation.

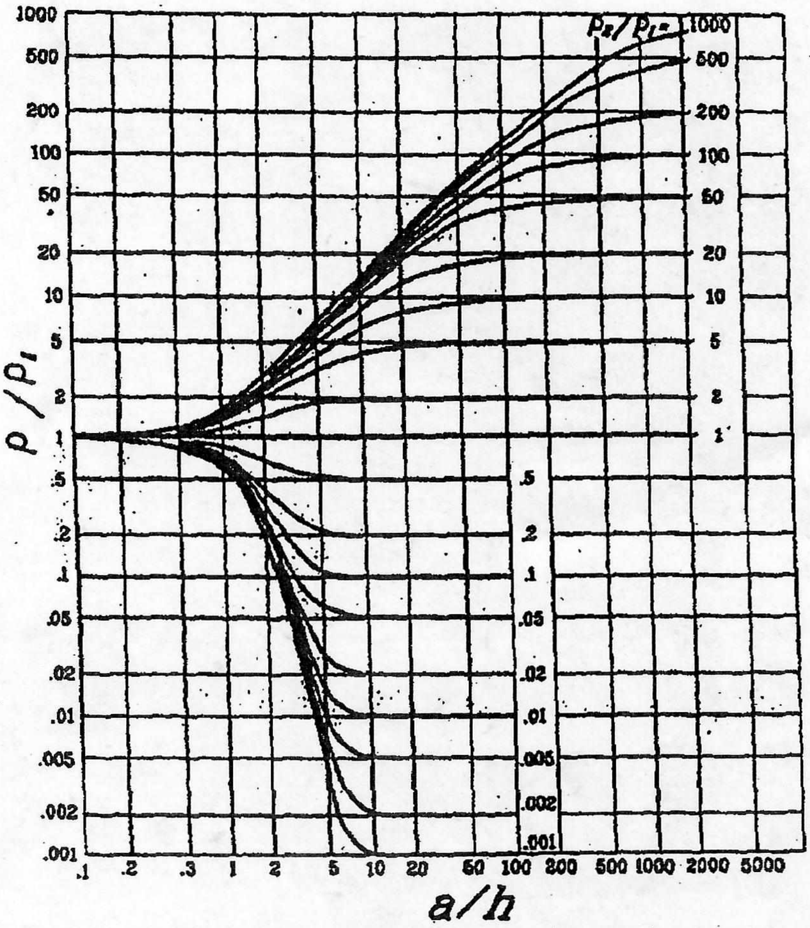

Figure2. Sunde's Graphical Method

10. CONCLUSION

Though it may be possible to obtain the most accurate representation of the actual variations of soil resistivity at the site; it may not be technically feasible to model all the variations.

Use of uniform soil model for the site where the apparent soil resistivity changes significantly with the probe spacing may lead to pessimistic or optimistic designs. It is necessary that a layered model may be adopted when uniform model does not fit the measured values