International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

Development of An Earthing Grid System for A Transmission Station

Olaiya Olayinka.O[1], Onalaja Olabisi.O[2]
[1]*Department of Computer Engineering, Federal Polytechnic, Ilaro, Ogun State, Nigeria*
[2]*Department of Computer Science, Gateway Polytechnic, Saapade, Ogun State, Nigeria*

Abstract
A very essential limitation in acquiring a good resistance measurement for the earth electrode is through the soil resistivity. It is very important to carry out soil resistivity for the purpose of designing the earthing layout grid in Soil resistivity is a veritable tool for the design and development of an earthing system for any environment that is electrically inclined. Electrical earthing design eddying protection depends on exact resolution of the vertical soil resistivity sequence. This study is based on the development of a typical earthing grid model in a sedimentary area of Portharcourt transmission station through the use of the wenner four-pin method measuring techniques described in detail in IEEE STD 1981-1983.Earthing systems has an important role in electrical systems regarding safety in the environment against the danger of electric shocks, protection and adequate operation of equipment during the incidence of faults. The study is objected at delineating the various soil layers that underlain the area in order to determine their average resistivity value and in accordance with IEEE grounding design guideline and norms. The results of the soil earthing carried out in the area shows that the average resistivity of the soil ranges from 409 Ohm-m to 424 Ohm-m across the two distinctive traverses which consist of the six(6) diagnosed soil resistivity stations. However, a resistivity of 203 Ohm was diagnosed within the vicinity of the transmission station with a depth of 3.2m and this is proposed to be used for the purpose of the grounding earthing design.
Keywords: IEEE, Earthing, Resistivity, Soil, Portharcout, Wenner four pin Method.

1.0 Introduction

One of the striking requirements for assuring safety on any industrial electrical is to provide an earth electrode for the power station or plant. The people living within the vicinity are in danger if there is no earth/ground electrode, and thus electrical installations and other property may be ruined. In order to guide against this unforeseen circumstances, soil resistivity data is the key factor in designing a grounding system for a specific performance objective. The soil variation in resistivity across the vertical soil sequence account for a significant role in determining a suitable location for grounding system. In other to have safety and lower the tendency of damage to equipment, the earthing of an electricity supply network requires its network plant and customer electrical equipment to be connected to the earth.

All soils conduct electrical current, with some soils having good electrical conductivity, while the majorities have poor electrical conductivity. The resistivity of soils varies widely throughout the world and changes dramatically even within small areas. Soil resistivity is mainly influenced by the type of soil (Clay, Sand, and Shale etc), moisture content, the amount of electrolytes (Minerals and dissolved salts) and finally temperature in temperate and Polar Regions. When designing a grounding system for a specific performance objective, it is necessary to accurately measure the soil resistivity of the site where the ground is to be installed. To delineate the various layers that underlain the area to determine their average resistivity value in accordance with the IEEE 80 grounding design guideline, soil resistivity through the wenner four pin method is important. To ascertain from the resistivity values the ability of the subsurface to act as an earthing medium, which can prevent safety hazard for both equipments

DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

and personnel and to recommend an appropriate depth for the earthing electrode are the fundamental objectives of this study.

The term earthing and grounding are used interchangeably to denote a way of connecting the equipment with the earth materials. Though the apparent resistivity estimation using the conventional Wenner four electrode measurements, it is relatively simple, useful, recognized way of assessing the earthing grounding resistivity. It is not a method explicitly directed at multilayer soil structures. The resulting data still shows lack of accuracy for two-layer soil model. The designing of grounding system depends on the soil resistivity model chosen for the substation soil i.e. uniform, two layers or multilayer soil model. It is essential to ascertain the soil resistivity value at the initial stage of the planning as it gives an overview of the amount of electrode is likely to be required for the earthing purpose.

Soil resistivity changes in time and space and varies in vertical sequence and as well as horizontal nature. It varies in areas to areas and within the same environment. It increases during the dry season whereas it decreases during rainy season. Unde, M.G. and Kushare, B.E.,2013 stated that substation grounding grid designed in one season which is safe, may become unsafe in another season. According to Cummins, 2002, the power system grounding is very essential especially despite a vast majority of faults is on the ground or are as a results of the effect of thunderstorm or lighting. Accurate soil model can be obtained by using proper method of measurement of resistivity of soil. Dawalibi *et al*, 1994 uses computer techniques to develop two-layer soil methods based on field measurements. As the earthing resistance virtually relied on the resistivity of the soil in respective of the earthing configuration, there is a proportional relationship between the two parameters. A high soil resistivity invariably is a diagnostic feature of a high earthing resistance. The exact soil prototype can be obtained by using appropriate method of measurement of resistivity of soil. Earthing denotes applying a wire conductor to have a contact with an earth electrode to the metal chassis earths which might accidentally come into contact with the electric current due to an insulation fault on an electrical device. In this respect, there will be no danger for people because the fault current will have drained into the earth. If there is no earthing, any person involved will go through an electric current which may kill them, depending on its pedigree.

The soil resistivity measurements are very important for the following reasons. It enables location choosing, earthing electrodes types and earth networks prior building them, state the electrical requirements of the earth electrodes and configuration, enhanced the assembly costs for the earth electrodes and connectivity, because of this the soil resistivity measurements are used for a more robust power distribution sub-stations or transmission station where it is essential to choose the best positions for the earth electrodes. The earthing structure is also very essential for lightning protection of the electrical power substation. In order to have a low resistance flow in a soil profile to inject current into the earth, it is desirable that all electrical structures, appliances should be earthed because mistakes in any electrical structures can be abated.

Wenner dated back to 1915 practical performed field resistivity measurement and confirmed that the field soil resistivity test measurements are often acquired using the four-pin method. In 1982, Blattner make a comparism of the four-pin method and inferred that the wenner four-pin method is the most simplest to carry out and the driven rod methods are more costly and time consuming to perform. In 1990, Gustafson *et al* concentrated on the seasonal changes in distribution of the system grounding and their effect on neutral-to-earth voltage.

Lim, S. C. and Al-Shawesh, Y, 2019 proposed a systematic step-by-step approach for the design of reliable and effective earthing systems for low-voltage installations.

Furthermore, surface electrical resistivity measurement is based on the guiding philosophy that the spreading of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivity and distribution of the surrounding soils and rocks.

DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

The study is objected at examining the soil profile that are present within the vicinity of Eleme Transmission Station using the widely known wenner four pin method according to the IEEE 80 grounding design guideline, to derived from the resistivity values the ability of the subsurface to act as an earthing grid, to guide against hazard for station structures, people and also to give a exact depth for the earthing electrode within the vicinity of the transmission station.

2.0 Fundamentals of Earth Grid Design

The major goal should be that the exact shock and step voltages should not be more than the tolerable values in designing any earthing system for a transmission station or a substation (IEEE Std, 80-2000).Earth potential rise also called the Ground potential rise (GPR) denotes the highest voltage that the earthing system may attain in reference to a faraway point taken to be at the potential of earth (Richard. P. Keil, 2003). Touch energy or voltage consist the potential difference which exist between earth potential rise on a structure and the surface latent at the point where someone is immobile while touching the structure. Step voltage is the surface latent difference existing between the feet of someone motionless on the surface. (Richard. P. Keil, 2003). The basic facts obligated in laying out an efficient earthing system are area coverage of the grid, resistivity of soil layers, grid fault clearing time and the highest grid current. In overall, the design procedure of an efficient earthing structure consist of resistivity data acquisition of the soil profile and its scientific interpretation, calculation of allowable touch and step voltages, calculation of highest grid current, Insitu earth grid layout and Safety assessment of the layout earthing structure to make sure potentials are within the normal standard. This paper is centered on strict compliance with the guideline as contained in the IEEE 1981-1983. A larger grid area is a function of a lower grid resistance which can be developed and designed.

3.0 Materials and Method

The materials used for this study includes Digital Earth Resistance/Ground resistivity Tester using the PASI 16GL equipment, four stainless steel probes, four insulated wire conductors, measuring tape and hammer to drive in probes. A total of six (6) soil resistivity measurements were carried out along the transmission station in Eleme; Portharcourt. The methodology used is the measurement of the soil resistance using the Wenner four-pin method (Figure 1).This is one of the measuring techniques fully described in IEEE STD 1981-1983. This method is the most famous owing to the fact that (a) The method acquire the soil resistivity data for deeper layers without driving the test pins to those layers (b) No heavy equipment is needed to carry out the test(c) The results are not in overall affected by the resistance of the test pin or the holes created in driving the test pins into the soil. Four distinctive probes are inserted into the earth in a straight line, at the same distances '**a**' apart to a depth '**b**'. The voltage between the two inner (potential) electrodes is then measured and divided by the current between the two outer (current) electrodes to give a value of resistance; R. Then, the apparent resistivity value is estimated using the relationship in equation 1 below:

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

ρ_a is the apparent resistivity of the soil measured in ohm-m , R is the resistance measured ohms (Ω) displayed by the equipment on the screen, a is the distance between adjacent electrodes in m, b is the depth of the electrode measured in meters. **'b'** is always very small compared to **'a'** and is therefore counted as negligible .In essence equation 1 can be minimized to

$$\rho_a = 2\pi aR$$

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

4.0 Results and Interpretation

The soil resistivity data has been acquired by using Wenner four Pin probe method at a transmission station in Eleme, Porthatrcourt and the results are presented in Table 1 and Table 2 respectively. The apparent soil resistivities against the probe spacing curve are shown in Figure 2 and 3 respectively. For the uniform soil model analysis, the average soil resistivity **=156.12 Ω m**.Based on this resistivity, and the grid resistance the conclusion on the eathing depth at the station was envisaged according to the IEEE std 81 -1983 standard guideline for earthing grid design.

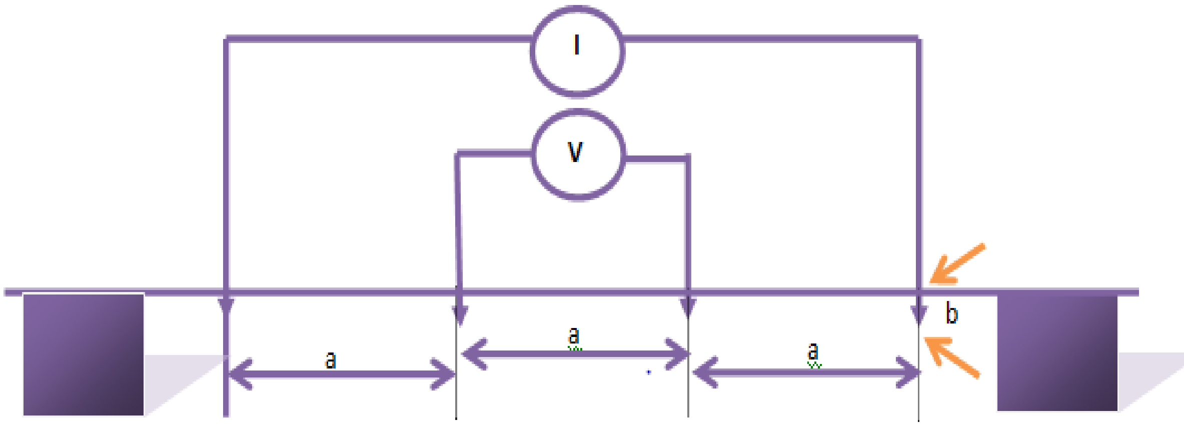

Figure 1:The Wenner Four-Pin Set Up

Table 1: Soil resistance and resistivity Data at ERT 1, 2 and 3 using Wenner four-Pin Method

PROBE SPACING "a" in meters	TR 1 Resistance (Ohms)	TR 2 Resistance (Ohms)	TR 3 Resistance (Ohms)	TR 1 Apparent Resistivity (Ohm-m)	TR 2 Apparent Resistivity (Ohm-m)	TR 3 Apparent Resistivity (Ohm-m)
1	58.9	21.3	27.2	370	134	171
1.5	37.1	15.1	19.8	350	142	187
2	28.8	8.4	16.0	362	106	201
2.5	26.9	7.1	17.4	423	112	274
3	28.5	5.0	14.6	538	94	275
4	28.0	3.1	14.6	704	78	367
5	24.9	2.8	9.6	783	88	302
6	19.6	2.8	10.6	739	106	400
8	12.6	3.2	8.0	634	161	402
10	9.4	3.4	9.4	591	214	591
12	8.6	3.1	8.6	649	234	649
15	8.6	4.5	6.4	811	424	603
20	7.2	4.2	5.0	905	528	628
25	5.6	4.7	5.5	880	738	872
30		4.2	6.2		792	1169

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

Table 2: Soil resistance and resistivity Data at ERT 3, 4 and 5 using Wenner four-Pin Method

PROBE SPACING “a” in meters	TR 4 Resistance (Ohms)	TR 5 Resistance (Ohms)	TR 6 Resistance (Ohms)	TR 4 Apparent Resistivity (Ohm-m)	TR 5 Apparent Resistivity (Ohm-m)	TR 6 Apparent Resistivity (Ohm-m)
1	40.6	39.6	87.0	255	249	547
1.5	17.3	27.6	41.6	163	260	392
2	11.4	16.5	34.2	143	207	430
2.5	9.9	13.5	28.6	156	212	450
3	10.1	9.1	20.5	191	172	387
4	9.5	7.2	17.0	239	181	427
5	9.0	6.0	10.4	283	189	327
6	8.7	7.1	2.6	328	268	98
8	8.2	7.9	2.2	412	397	111
10	6.2	7.2	2.1	390	453	132
12	6.2	4.3	2.4	468	324	181
15	4.5	6.4	3.6	424	603	339
20	4.3	5.7	7.5	540	716	943
25	3.4	6.3	8.6	534	990	1351
30	2.7	3.5	7.3	509	660	1377

Table 3: Average Soil Resistivity along Traverse 1 to Traverse 2

PROBE SPACING “a” in meters	**AVERAGE SOIL RESISTIVITY (Ohm-m)**	
	Traverse 1	**Traverse 2**
1	225	350
1.5	226	272
2	223	260
2.5	270	273
3	302	250
4	383	282
5	391	266
6	415	231
8	399	307
10	465	325
12	511	324
15	613	455
20	687	733
25	830	958
30		849

DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

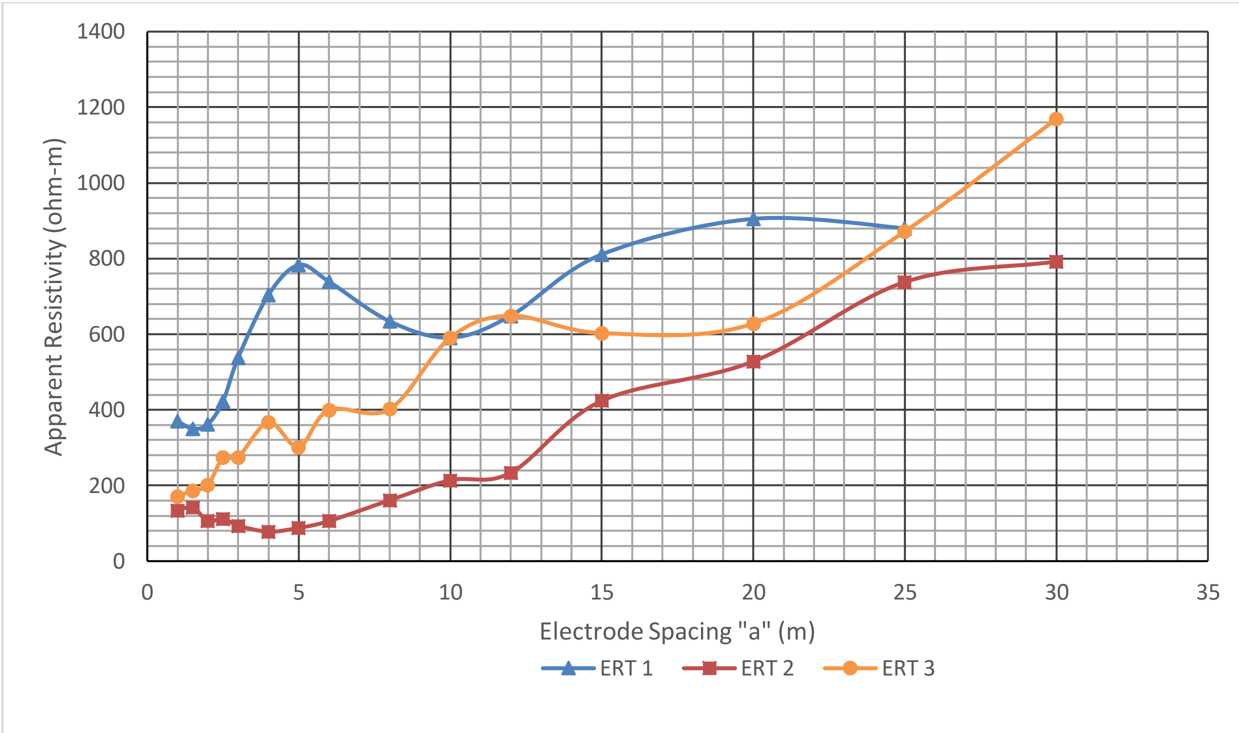

Figure 1: Apparent Resistivity Plot against electrode spacing plot for ERT 1,2 and 3

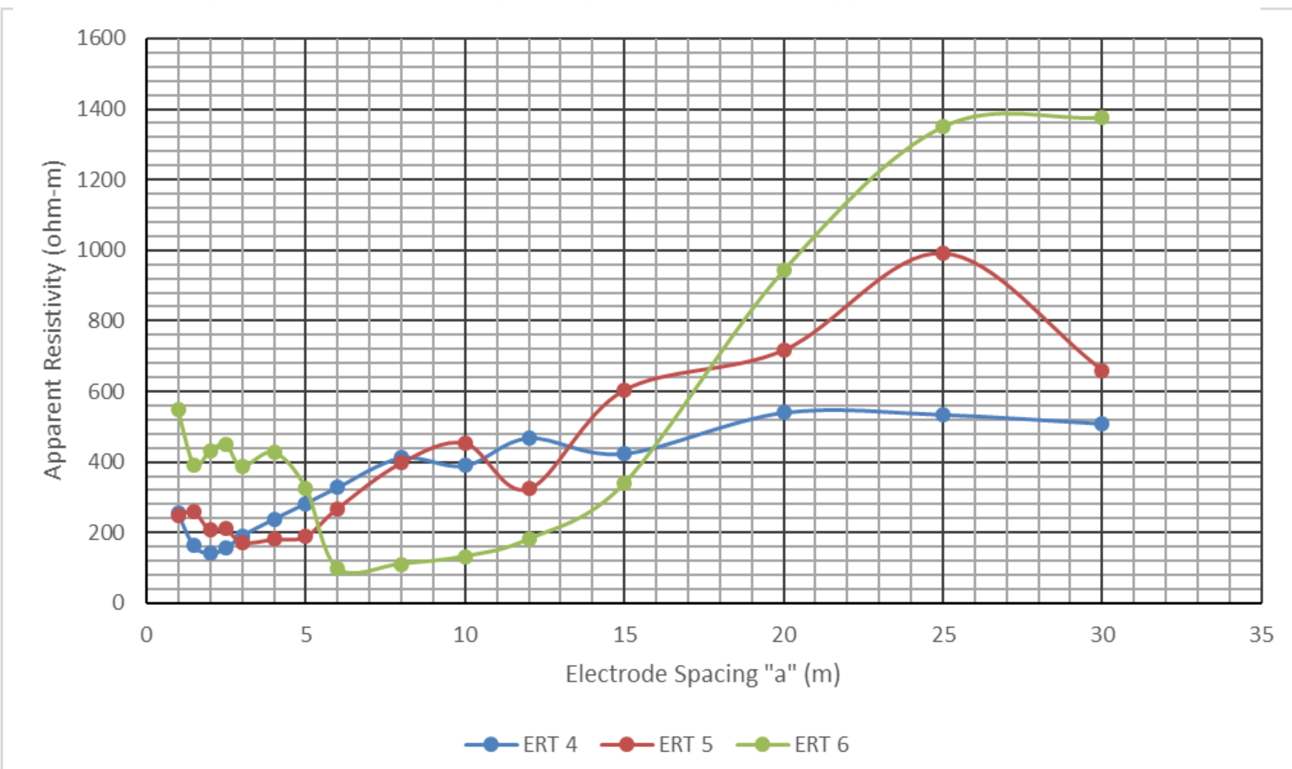

Figure 2: Apparent Resistivity against Electrode Spacing Plot for ERT 4, 5 and 6

DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

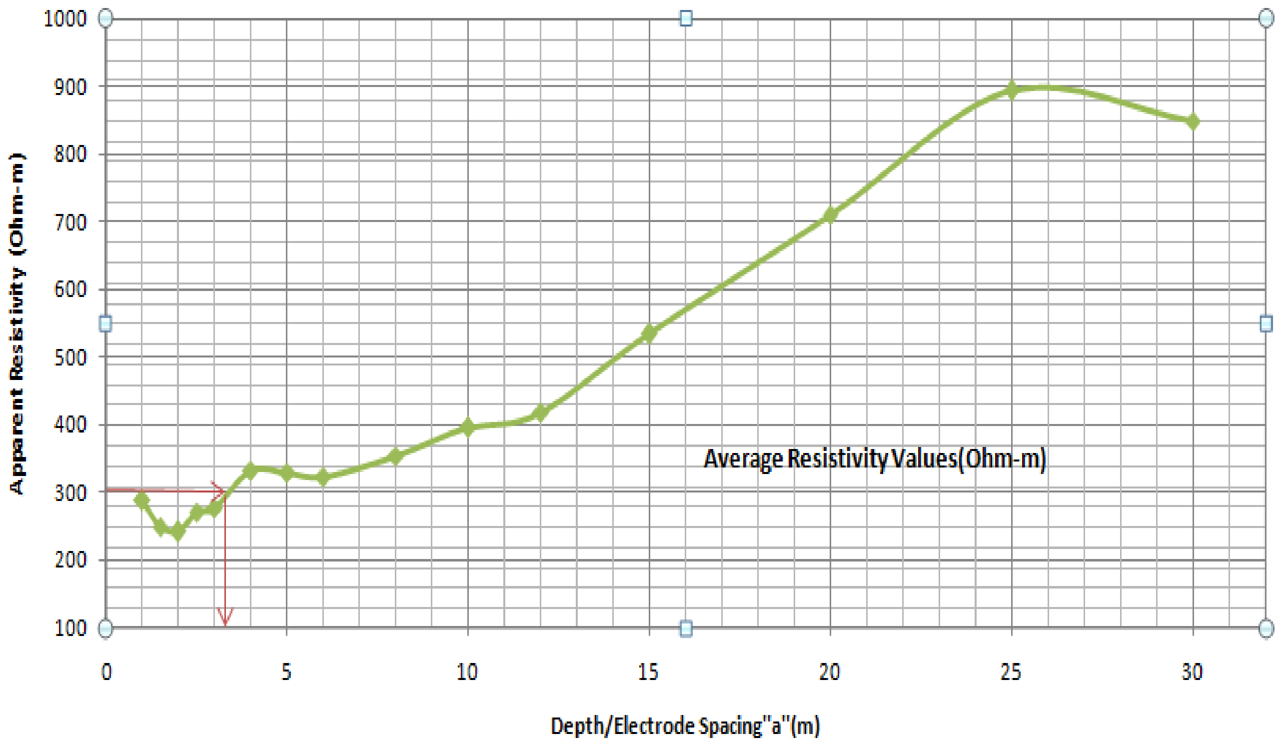

Figure 3: Average Apparent Resistivity plot against the Depth/Electrode Separation of the study area.

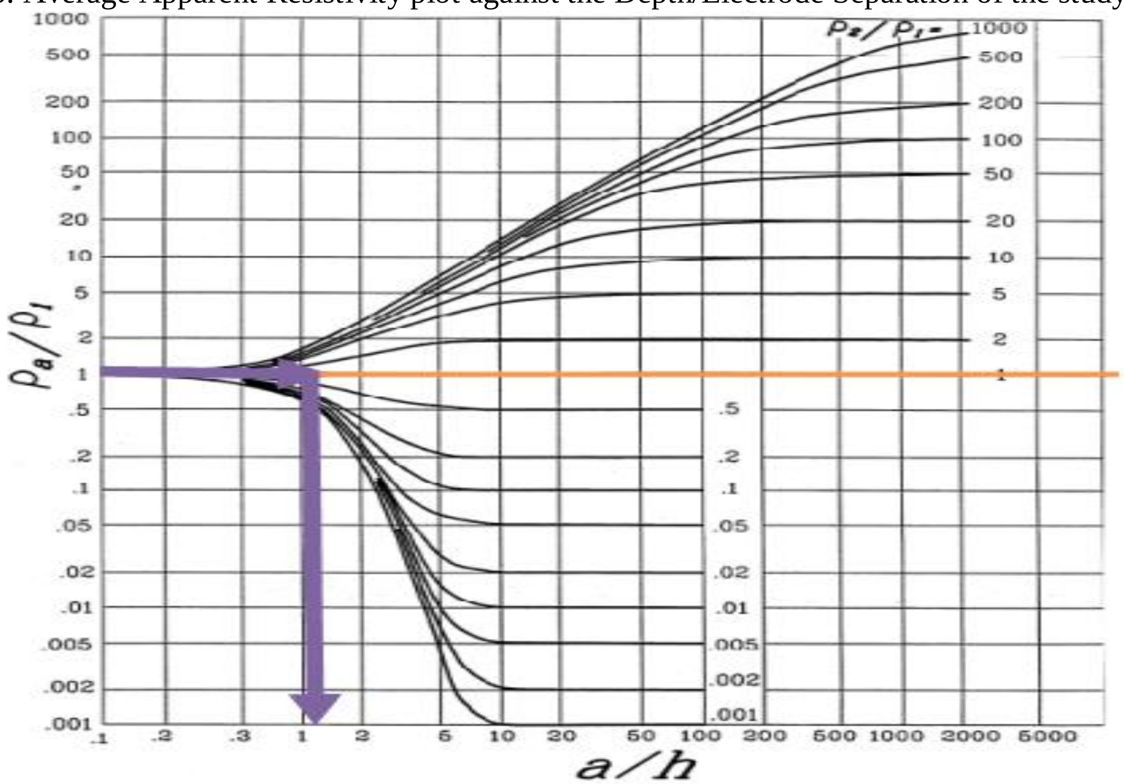

Figure 4: A typical Sunde Curve

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

4.1 Guideline for estimating the Resistivity and Depth of earthing soil

It is a known fact that resistivity changes with depth taken into consideration a non-uniform soil and this variations are witnessed from the average resistivity measurement depicting point of intersection from which inferences about the soil layer into two or more layers can be drawned.In 1968,Sunde ,E.D developed a two-Layer soil model called the Sunde graph and the assumptions from the Sunde's analysis holds for the exact soil situation and the span of resistivity changes established within the territory of the transmission station. The guideline described below gives a vivid way of estimating or calculating the resistivity and depth for earthing grid design.

Guideline 1

Figure 3 exactly shows the average apparent resistivity plot against the Depth/Electrode Separation of the study area and Table 3 concisely shows the average soil resistivity along traverse 1 to traverse 2.The following values of resistivity and depth were arrived at. P_1= 225 Ohm-m for 1m spacing, P_2= 302 Ohm-m for 3.6m spacing at the point of inflection.Dividing ρ_{2}/ρ_{1} = 1.3. This value is called the resistivity coefficient ratio

Guideline 2

The curve was estimated as shown in the green line with the above ratio refer to the Sunde curve as shown in Figure 4 above

Guideline 3

The y-axis value ρ_{a}/ρ_{1} was taken within the sloped area of the estimated ρ_{2}/ρ_{1} curve ratio as seen in Figure 2 and this yielded the value 0.9

Guideline 4

The value for ρ_a was estimated as ρ_a =0.9 ρ_1, thus ρ_a= **203 Ohm-m.**

Guideline 5

The value of "a" (probe distance/depth) was arrived at which corresponds to the 203 Ohm-m on the average resistivity graph of Figure 3 and this yielded 0.9m

Guideline 6

From the Sunde graph as seen in Figure 4 above, the value on the x-axis gives the value a/h= 1.0 hence h= 3.2 m

5.0 Conclusion

A highly designed earthing system is very essential to guide against shock or electrical killing to a person, lowering of electromagnetic disturbance and overall network of supply system. For the guideline and standard to be followed in safety measures, any electrical damages in any supply system are cannot be avoided. In this respect, all the electrical gadget or electrical system should be earthed to have a lower resistance flow for distribution of fault current in to the earth. It is very glaring that value of earth resistance is directly proportional to the property of the soil and earthing electrode. The amount of the earth resistance can be lowered drastically through the use of a very good conducting property earthing electrode and a good soil preparation. Based on the two layer soil modeling of the resistivity investigation carried out at transmission station along port-harcourt, It was concluded that the average resistivity value at the study area varies between 409 ohm-m to 424 Ohm-m. However, a resistivity of 203 Ohm was diagnosed within the vicinity of the transmission station with a depth of 3.2m as the specification for the transmission station earthing grid in the vicinity of the station. Six (6) distinctive soil resistivity measurements were made in the study area. The curve of soil resistivity against probe spacing vividly shows distinct layers and its correspondent depth. However, use of multilayer soil model, provides all the information of soil resistivity and its depth for each layer.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

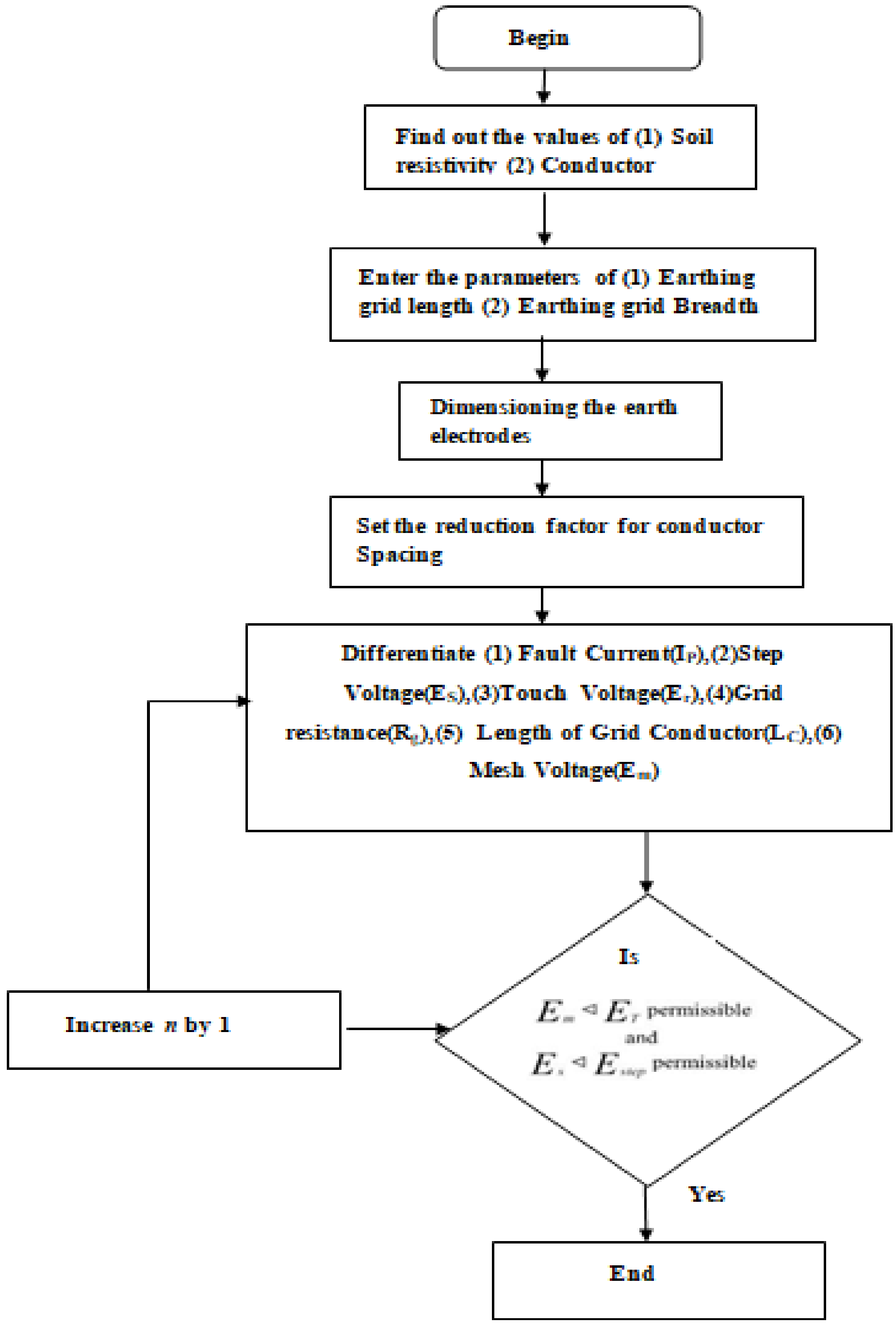

Figure 5:A typical algorithm for the development of eartthing and designing of grounding system for a Power station(Arjunsingh *et al.*, 2012; Ubeku and Odiase, 2009)

DOI:10.46647/ijetms.2022.v06i05.135 ISSN: 2581-4621

The result table shows that layer soil model suitable for a given soil resistivity data. The study area falls within Niger Delta. The area is underlain by sediments groups as Benin Formation , Agbada Formation and Akata Formation ,which conformably overlain the basement.

According to the IEEE Green Book 1992, the ground electrode resistance of large electrical substation for commercial and industrial should be in the range of 2 ohm-m to 5 ohm-m. The resistivity value obtained in the study area is higher than these suggested values. The earth conductivity values of the study area need to be improved in order to meet the required standard values and increase its absorption power and its richness with charge carrying ions. Ground conductivity enhancement materials like graphite, ionic salt and bentonite could be used to provide a conductive medium between the earth rod surface and contact soils. Enough artificial conductive materials should be used within the earthing rod and the contact soil to reduce the layer resistivity to the standard range of 2 ohm-m to 5 ohm-m.

However, based on the resistance and the resistivity values of the study area, an eathing grid is envisaged to be coordinated to the depth of 3.2 m in each of the grounding station even though the resistivity evaluated for the study area are much higher than that of the IEEE regulation and standard. It was also concluded that only the earth/ground electrode is not adequate to assuring absolute safety but persistence and prompt inspections can assure that the electrical installation is operating perfectly.

References

Arjunsingh A. Mehta, S. N. Singh, and M. K. Singhal(2012), Earthing System Design for Small Hydropower (SHP) Station – A Review. IACSIT International Journal of Engineering and Technology, Vol. 4, No. 3, June edition

Blatner, C.J., (1982), Study of Driven Ground Rods and Four Point pin soil Resistivity Tests, IEEE Transactions on Power Apparatus and Systems, Vol. PAP 101, No.8, pp. 2837-2850

Cummins, K.L. (2002), "Lighting information for use in power systems analysis": how much more do we need to know? Panel Paper, IEEE PES transmission and distribution Conference and Exhibition

Dawalibi F. P., and Mukhedkar, D (1974), Ground electrode resistance measurements in non-uniform soils, IEEE Transactions on Power Apparatus and Systems, vol. PAS-93, no.1, pp. 109–116.

Gustafson, R.J., Pursley, R. and Albertson V.D.,(1990), seasonal Grounding Variations on Distribution Systems, IEEE Transactions on Power Delivery, Vol. 5, No.2.

IEEE std 81-1983," IEEE guide for Measuring earth Resistivity, Ground impedance, and earth surface potentials for a ground system" IEEE Guide for safety in AC substation grounding, IEEE standard 80-2000

Lim, S.C., Al-Shawesh, Y(2019), A Systematic Method for the Design of Earthing System for Low-voltage Installations, Journal of Recent Technology and Engineering (IJRTE), vol.8, October, pp. 12 – 15. ISSN: 2277-3878

Richard. P. Keil, "Electric Power Substation Engineering – Substation Grounding," 2nd Ed., Boca Raton, FL., CRC Press, 2003, pp. 11-1 – 11-17

Sunde, E. D 1968: Earth conduction effects in transmission systems, New York: McMillan

U. Ubeku and F. Odiase, "Substation Earthing Grid Safety Analysis," (2009). International Journal of Electrical and Power Engineering, vol 3, Issue 5, pp. 262-267.

Unde, M.G. and Kushare, B.E.(2013), Impact of seasonal variation of soil resistivity on safety of substation grounding system, in Proc. IET Conference,173-181