Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 01, January-2025

Effect of Electrode Depth on the Effectiveness of Earthing and Lightning Protection System.

Ameh B.V., Collins I., Diana O., Simon E.
Electrical MTCE Lead Shell petroleum Development company(SPDC) Nigeria.
Electrical TA, Shell petroleum Development company(SPDC) Nigeria.

***ABSTRACT* - Effective Earthing and Lightning Protection system(ELPS) against over voltage was examined in an oil and gas location in Nigeria in this study. Increase in electrode depth as a method of electrode resistance reduction was evaluated. The electrode depth was investigated in a very high soil resistivity environment, the depth of the buried electrode was increased systematically at each step in order of 6 meters up to 24 meters depth, while burying electrode in the pits, provision for testing over a period of time in the high soil resistivity spots was made. The electrode was tested at each new depth and the resistance value of electrode at each depth was recorded. It was discovered that resistance values of the electrode decreased significantly from the initial value after 48 hours of stability. The electrode resistance values further decreased with further increase in depth. The result of the study showed that increase in electrode depth enhances electrode resistivity as the resistance decreases, The decrease in turn improved the conductivity of electrode. The current dissipation dependency on electrode resistivity was carried out using the measured resistance results at a set voltage. The current (I) against resistivity (R) using Ohm's law V=IR was simulated, the result of the simulation confirmed that increasing the electrode depth decreases electrode resistance from the characteristics plot of the current dependency on electrode resistivity. From the result of the simulation, it was concluded that increasing the depth of electrode decreases the electrode resistivity which in turn increases the electrode conductivity for Earthing and Lightning protection system (ELPS) effectiveness.**
Index Term: Depth, Effect, Electrode, protection, and System.

I. INTRODUCTION

A conscious program designed for periodic earth resistance testing to ascertain the effectiveness of the system is key and cannot be over emphasized. Effectiveness of the earthing and lightning protection system can gradually deteriorate because of continuous and various forms of soil chemical reactions and the reaction of soil salt at various locations. For this reason, checking earth resistance values at the time of installation is not just enough, but conscious effort to always keep the resistance as reasonably low as possible is the ideal long-term remedy for effective earthing and lightning system protection performance. High soil resistivity and other changes have brought about high electrode resistivity in some locations and these changes account for the change of the minimum resistance for effective performance. The changing situation calls for reduction of high electrode resistance to keep the system performance optimally in and out of the season. The purpose of earthing and lightning protection system (ELPS) is to provide a path and equal potential to general mass of the earth.
Seasonal variation in resistivity of soil varies considerably at different times of the year, particularly in locations where there are more extremes of temperature, rainfall, dry spell, and other seasonal variations.

Lightning stroke is a natural occurrence. Lightning strikes are so devastating most of the time. As a natural event that cannot be prevented, it can be redirected to minimize its devastating effect on humans, plants and equipment. Lightning strikes can also result in other dangerous hazards such as fire outbreaks and data loss . In view of these devastating effects, earthing and Lightning protection systems have been categorized as Safety Critical Elements (SCE) in many organizations.

Earthing and lighting protection systems on the other hand is defined as a mechanism that is employed to dispose of the undesirable electrical charge to the general mass of the earth or send back the electrical charge in electrical safety. The transfer of electrical charge may be due to earth faults at low frequency or high frequency noise or transients (e.g., Lightning or switching impulses). To be qualified as an overall earthing protection system, the designed earthing and lightning protection system should be able to manage the currents at all frequencies [4].
Enormous and unpredictable forces are associated with Lightning, therefore, controlling and directing the energy of Lightning to protect humans, buildings, equipment and even in power transmission is a concern of Electrical Engineers. Though effective performance of the earthing and lightning protection system is governed fully by the condition of soil concerned, this is considered as a pathological case if it poses a typical opposition to the realization of high-performance electrical earthing and protection system. Those conditions of concern are soil resistivity, soil stability and other Environmental factors which influence the performance of electrical earthing system,[4].

One of key the purposes of Earthing and Lightning Protection system (ELPS) as posited by [11] in their work is to provide a path to general mass of the earth for the fault current at power frequency of either DC or 50Hz/60Hz AC to generator or transformer even in the event of transient lightning and thunder strike where sub cycle current has risen times in the order of nano seconds to microseconds.

[10] in their work posited that effective Earthing prevents long term overvoltage, minimizes the risk of electric shock hazards, and provides a predetermined path for earth leakage current, which are used to disconnect faulty plant or circuit by operating protective devices.

[5]in their work posited that effective protection methods can combat the effect of considerable losses caused by lightning strikes each year throughout the entire world.

[8] in their results to compare apparent Soil resistivity of two different locations as it affects the grounding systems reveals that the Soil resistivity variation depends on the type of soil and moisture content, they also observed that the Soil resistivity of wet soil is lower than that of dry soil.

Effect of soil treatment on the performance of earth electrode resistance reduction using Biochar was investigated by [9], the result of the investigation showed a significant reduction in earth resistance compared to the case of the untreated soil.

Similar test on the effect of soil treatment on the performance of earth resistance reduction using dead sea water was carried by [5], and the result of the investigation showed a significant reduction of up 70% in earth electrode resistance reduction when compared with an untreated soil as another electrode was added to the single rod which confirms that multiple earth electrode is also a means of earth electrode resistance reduction.

[6] in their studies of concern for corrosive effects with respect to lightning protection systems, posited that Materials used in the construction of a lightning protection grounding system should possess good electrical conductivity, sufficient mechanical strength to withstand electrodynamic stresses and electromagnetic effect of lightning current and demonstrate suitable resistance to corrosion aggressive environment.

Specific useful techniques are applied to decrease high soil resistivity when the resistance to the ground exceeds the required values according to [7] in his work. He also evaluated various methods for reducing the resistance of a grounding electrode. He considered several methods namely, increase in the rod diameter, increase the length of the rod, use of multiple rods and, ttreatment of the soil to reduce its resistivity.

II. SOIL RESISTIVITY

Soil resistivity is the measure of soil resistance to the flow of electricity. The measure of soil resistivity is in ohm-m. Soil resistivity can change dramatically as it varies geographically. One of the key and major influencers of the overall earth resistance is soil resistivity. The proportionality of soil resistivity to earth resistance cannot be over emphasized as earth resistance increases with increase in soil resistivity.

Temperature at a particular depth can affect the resistance of earth. When the temperature is greater than 0 degree Celsius, then its effect on the ground resistivity is negligible; but at 0 degree Celsius the water in the soil starts freezing which increases the Soil resistivity. The resistance of the earth varies from layer to layer. The lower layer of soil with more moisture, has lower resistivity. If the lower layer contains hard and rocky soil, then the resistivity increases with depth.

Material conductivity is the measure of the ease at which an electric charge or heat can flow through a material. A conductor is a material which gives little resistance to the flow of an electric current or thermal energy. Materials are categorized as conductors, semiconductors, and insulators. Conductivity of electrode is one of the prime factors which cannot be neglected when designing a project to reduce the resistance of electrode in an earthing system. Low conductive materials cannot guarantee the effective flow of charge required in the event of thunder and lightning strikes. Though soil conductivity is inversely proportional to soil resistivity, material resistivity is directly proportional to soil resistivity meaning that the impulse ground resistance is equally directly proportional to soil resistivity as shown in figure 1.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 01, January-2025

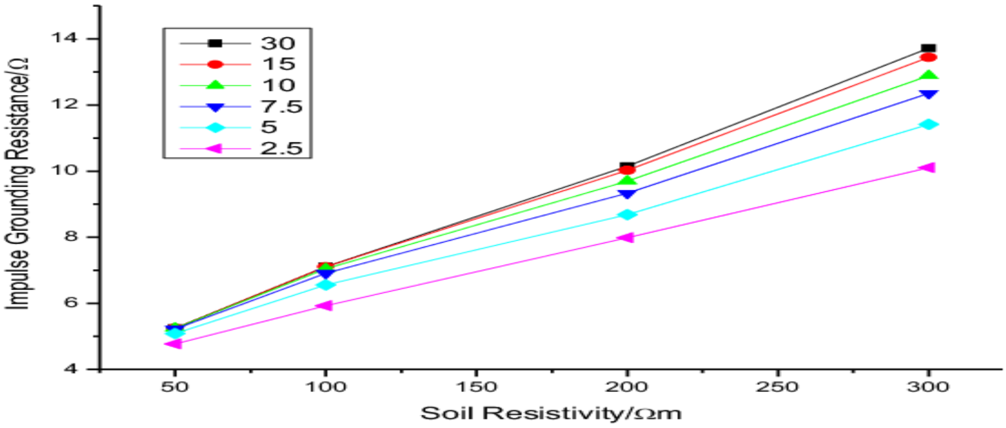

Figure 1; Impulse vs resistivity. (Circuit Globe 2016).

III. FACTORS THAT AFFECT SOIL RESISTIVITY.

A. Moisture Content.

Essential requirement for good soil conductivity moisture content, it varies with seasons and geographically. locating the electrode at a depth at which the moisture content will be present throughout the year so that soil resistivity does not vary too much during annual weather cycle is advisable [3]

[7] Soil resistivity reduction can be achieved by application of the following: Water retention, Chemical salts, Bentonite, Chemical-type of electrodes and ground enhancement materials. It was posited that it is not always easy to reduce the resistance of ground electrode by reducing the resistivity of soil, but reduction of the resistivity of the soil around the electrode can help in achieving the adequate resistance to ground.

B. Effect of Contaminants on Soil Resistivity

Contaminants have a great and adverse effect on soil resistivity. [12] in their work, they evaluated the impact of contaminants on soil resistivity and the result of the evaluation confirmed that contaminants have adverse effect on soil resistivity. Contaminants such as Kerosene and Petrol increase the resistivity of the soil upon addition, while salt (sodium chloride) decreases the resistivity of soil when added to soil but in the long term may initiate corrosion.

Addition of Sodium chloride to the soil reduces resistivity, but the practice is not the proper remedy. [13] in their investigation of whether the act of adding salt to grounding soil is a proper remedy to high soil resistivity; conducted an experiment where different concentration of salt water also known as Sodium chloride (NaCl) solution was poured onto number of segments of soil and the effect was monitored for thirty -six hours. It was observed that NaCl solution addition to soil successfully decreases the value of soil resistance. The effect was temporary, at the end of the monitoring period of an interval of time, the value of resistivity increased back to almost original high resistance value.

C. Soil treatment

Treated soil such as conductive concrete can be utilized for long term performance in high resistivity locations or on rocky grounds. Conductive concrete is considered necessary to improve earth contact resistance around an earth electrode or strip (tape) where applicable. [2] warned that care should be taken to understand how the commercially available materials work during installation to ensure that they remain in contact with the electrode or strip and do not shrink or swell away after drying out.

D. Chemical treatment

The use of ion- producing chemical compounds like sodium chloride, magnesium sulfate (Epsom salt), copper sulfate (blue vitriol), and calcium chloride around the grounding electrodes, decreases the soil resistivity and electrode's resistance to the ground.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 01, January-2025

The most widely used chemical is magnesium sulfate. It is Low-cost, and has strong electrical conductivity, it also has little corrosive effect.

Though ordinary rock salt is cheap. Common salt (sodium chloride) is highly corrosive. This corrosive effect may cause nearby metal objects to deteriorate. Though salt has an excellent conducting ability, its adverse effect of corrosive tendency removes it from the list of preferred chemicals.

Chemical treatment indirectly increases the diameter of electrode by modifying its surrounding soil. Chemical solutions easily permeate into large volumes of porous earth making a large equivalent diameter and this produces quick results. In contrast, when the soil compacts, the chemicals take time to spread, and results are produced more slowly. This method requires caution, as local authorities may prohibit the use of chemicals if they are not considered environmentally friendly [7].

E. Use of Bentonite

Addition of bentonite to the soil reduces soil resistivity and electrode ground resistance. Bentonite is a highly plastic clay of fine-grained formed by volcanic action. It may be used as soil replacement and filter material for electrical grounding in places where soil has high resistivity. Bentonite is chemically hydrated in nature; it is innately stable and retains its properties over time. Bentonite is widely used because of its absorbent and retaining characteristics.

Bentonite absorbs moisture from the surrounding soil and swell up the soil to several times its dry volume. It adheres to the surface of the grounding rods and cables that are laid in trenches there by reducing the contact resistance and increasing their diameter artificially. The resistivity of bentonite depends on water content. The electrical current moves through bentonite with the aid of the water inside the pores.

The performance of Bentonite is highly dependent upon the amount of rainfall, soil moisture, and temperature at the site. In a dry hot climate, the soil dries out and bentonite does not work as desired. It may separate from electrodes thereby increasing the resistance to the ground [7].

Chemical enhancement materials can alter the soil properties such as PH level, soil fertility and soil minerals significantly. [1] in their review of the use of soil enhancement materials for grounding system posited that generally the soil natural materials do not alter the original properties of the soil. Hence, the soil condition can be maintained. They maintained that in high soil resistivity areas such as rocky soil, Bentonite is mostly preferred due to its ability to absorb moisture while maintaining humidity.

F. Chemical Rod

In rocky soil, mountain top, sandy soil and other places where soil resistivity is excessively high, chemical Rods are suitably used for resistance reduction. Chemical rod is in a tubular form filled with mineral salts and bentonite solution which is evenly distributed. It has holes along its length which allows the entry of the mineral solution into soil for soil moisturization. The saline solution seeps out through the hole and soaks into the surrounding soil, continually conditioning a large volume soil around it.

The chemical rod materials available are copper, stainless steel, and hot dipped galvanized iron. The choices of the length are the same as conventional rods; 240cm (8ft), 300cm (10ft). The rod may be installed by drilling holes in the ground, and for rocky soils, manufacturers offer horizontal rods. It is customary to place a grounding enhancement fill around the rod to improve the interface with soil.

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 01, January-2025

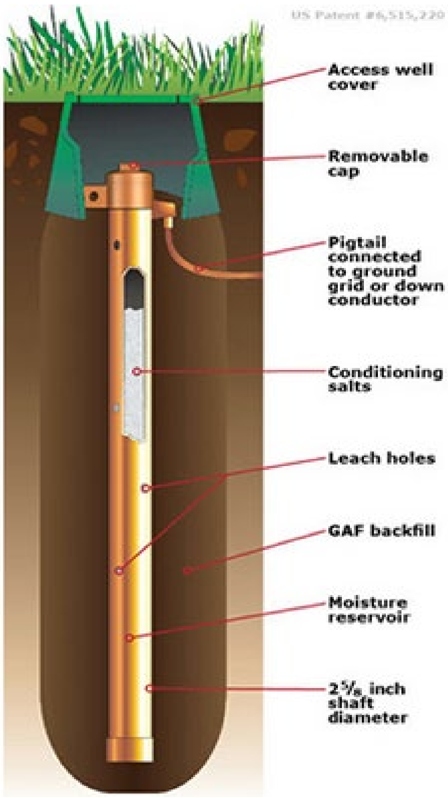

Figure 2: Sample of Chemical Rod (Lorenzo 2020)

G. Ground Enhancement fill

Ground enhancement is another method of soil treatment. The method is achieved by replacing all or part of the soil around an electrode with a low resistivity filler which will facilitate the achievement of low ground resistance. The higher the percentage of earth swapped, the lower the ground resistance. Grounding enhancement fill may have as low as 50Ω-cm (much lower than bentonite). It works in trenches, around ground rod or substation grounding conductors, either dry or slurry.

Ground enhancement fill has the properties of constant resistance, low resistivity, maintain moisture stability, low freezing point, resistance to leaching, non -corrosive, and maintenance free. While all methods of soil treatment are effective, the selection should depend on the site's particular conditions and the ability to carry out proper maintenance when required. [7]

IV. RESULTS AND DISCUSSION

Table 1 shows the field resistance measurement value of six spots from the depth increase of 6 meters in steps, adopting deeper driven method of electrode up to 24meters deep into the soil: using (20ft) galvanized pipe as earth electrode and using Digital Earth Tester DET4TC2 for resistance measurement.

Table 1. Resistance values of tested spots from field measurement

S/N	Electrode. No.	Resistance (Ω)@ 6m	Current (A) @ 6m	Resistance (Ω)@ 12m	Current (A) @ 12m	Resistance (Ω) @ 18m	Current (A) @ 18m	Resistance (Ω)@ 24m	Current (A) @ 24m
1.	E-320-2C	169.2	0.295	70.2	0.71	41.7	1.19	2.4	20.8
2.	E-320-4C	142.8	0.35	78.1	0.64	40.9	1.22	1.66	30.1
3.	E-320-2A	138.8	0.36	69.2	0.72	40.2	1.24	1.34	37.3
4.	E-320-5A	135.9	0.367	77.3	0.64	43.5	1.15	1.52	32.8
5.	E-09	135.6	0.368	68.3	0.73	39.5	1.26	1.25	40
6.	E-320-1A	134.9	0.37	68.0	0.73	36.7	1.36	1.4	35.7

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 01, January-2025

V. DISCUSSION.

The field resistance measurement of six spots was taken at 6m and recorded as base case values. The base case values were all above the maximum set standard values of 10 ohms. The depth of the earth pit was 6 meters deep initially. The depth was increased and resistance at each depth was recorded. Using earth tester DET4TC2, the earth tester Voltage was set at maximum voltage of 50V. After the measurement, the values of current dissipation were determined using ohms law V=IR. as represented in table 1. The current dissipation of each electrode at each depth was determined and recorded and Current dependency on resistivity characteristics plot was obtained using MATLAB SOFTWARE SIMULINK. The results of the plot showed that the lower the electrode resistance, the higher the value of current dissipation to general mass of the earth.

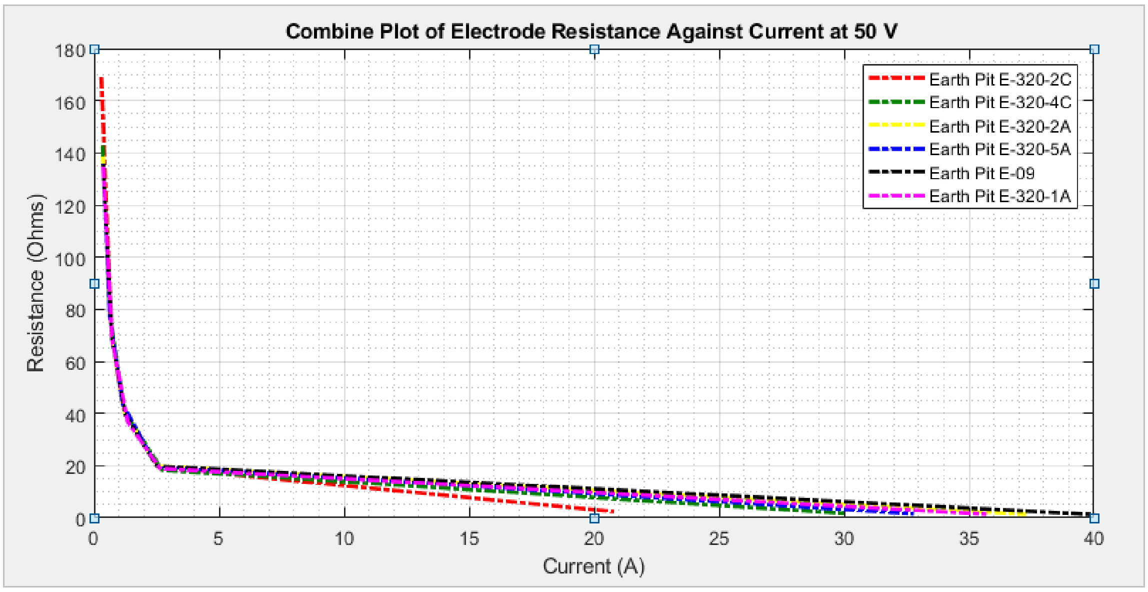

Figure 3: Current vs resistance characteristics plot (Ameh 2022)

VI. CONCLUSION.

The plot of current dependency characteristics showed that the amount of current dissipation into the general depends on the depth of the electrode which produces low resistance. These results also validate the inverse proportionality of Electrode conductivity to Electrode resistivity and direct proportionality of electrode resistivity to soil resistivity. In conclusion, the characteristics plot validates the deeper the earth electrode the lower the electrode resistance.

REFERENCES

[1] Aizat et al. The use of enhancement material in grounding system: a review" Indonesian Journal of Electrical Engineering and Computer Science. Vol. 13, No. 2, pp. 453~460 ISSN: 2502-4752, DOI: 10.11591/ijeecs. v13.i2. pp 453-460.Retrieved from https://www.researchgate.net/publication/330997823
[2] Lorenzo Mari. How to improve Resistance to ground" Technical article. Retrieved from https://eepower.com/technical-articles
[3] Edvard, C. (2015) .Four things Soil resistivity depends on" Technical article. Retrieved from https://electrical-engineering-portal.com. On 27/01/2022
[4] Chun Lim, Gomes, and Ab Kadir Electrical earthing in troubled environment" International Journal of Electrical power and Energy Systems 47:117-128. Retrieved from https://www.researchgate.net/publication/270895623
[5] Yousif, E., and Salim, A., and Alkhawaldeh, S. (2014). An Efficient Method for Earth Resistance Reduction Using the Dead Sea Water. Energy and Power Engineering Journal 6(4), DOI:10.4236/epe.2014.64006. 10 July 2023
[6] Aidin, G., Mohammad, R. M., Shayan, D. and Chandima, (2015). Engineering failure analysis. Pp 434-443, Doi.org/10.1016/j.engfailanal 2015.08.019. 24 0ctober, 2023
[7] Lorenzo, M. (2020). How to improve Resistance to ground. Technical article. Retrieved from https://eepower.com/technical-articles on 25th November 2023
[8] Malanda, S. C., Davidson, I., Buraimoh, E., and Eddie, S. Analysis of soil Resistivity and its impact on grounding system design. A paper presented in IEEE power Africa conference at Cape Town, South Africa. DOI:10.1109/power Africa.2018.8520960. October,2023
[9] Lorenzo Mari. How to improve Resistance to ground" Technical article. Retrieved from https://eepower.com/technical-articles
[10] Rashad, M. K., Aymen, C., Ken, N. Comparison the performance of three earthing system micro-grid protection during grid connected mode. DOI:10.4236/sgre.2011.2304. 2(3). PP.206-215. 5 August 2023

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 01, January-2025

[11] Siow chun Lim, Chandima Gomez and Zainal Kadir. Electrical Earthing in troubled Environment" International Journal of Electrical Power and Energy system. Retrieved from https://www.researchgate.net/publication/270895623

[12] Wilfred, N.I., and Nicholas, U.U. Laboratory Evaluation of the Impact of Contaminants on Soil Resistivity, and the Consequent Effect on Plant's Growth" Journal of environmental protection. DOI:10.4236/jep.2016.712144.7(12), pp.1-9. 11 September,2023.

[13] Kusim, A.S., Abdullah, N.E., Hashim, H, and Beeran, K. S. Effects of salt content on measurement of soil resistivity. A Paper presented at IEEE 7th International Power Engineering and optimization conference (peoco) Langkawi. 3-4 June 2023. Doi:10.1109/peoco.2013.6564528. 22nd July 2013.