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Comparison, Similarities, Differences, Merits and Demrits of Methods of Effective Electrode Resistance Reduction

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Abstract:- The power associated with Lightning are enormous and unpredictable, controlling and directing the Lightning energy to protect humans, buildings and equipment is a thing of concern to Electrical Engineers. Earthing and Lightning protection system is a life wire of any Electrical safety.There is no convincing evidence that lightning can be prevented, so, one must design a facility byresponding appropriately to make lightning strikes harmless.Lightning protection system is a system put in a place for protection against overvoltage.In this study, diverse factors that affect earth electrode resistance for effective performance was investigated. Based on the investigation, different methods of earth electrode resistance reduction were compared. In comparison, factors that differentiate various methods was ascertained, and some of the methods were found to have common factors that canreduce resistance when applied while others have different resistance reduction factors all together.Merits and demerits of the different methods were identified, and the identification of those merits and demerits suggest the method that is ideal in an environment for effective performance as conclusion.The study concluded that no method overshadows another method as different methods suits different environment where it is most preferred and effective.

Keywords:- *Comparison, Similarities, Differences, Merits, Demerits, Methods.*

I. INTRODUCTION

One of the most important aspects of electrical distribution is the designing of electrical earthing with lightning protection systems in electrical distribution system. This aspect is sometimes misunderstood and subsequently not effectively managed during the installation. There are several reasons for designing and installingEarthing and Lightning protection systems (ELPS). These reasons range from equipment protection, Loss of important data to the most important loss of human lives and properties. Considering these reasons, other factors that aid the effective performance of Earthing and Lightning protection system come into play as those important reasons are of essence.Again, during the design care must be taken of the location, nature of the soil, seasonal variation, and the temperature of where the system so designed will be situated. In view of the above reasons, the maximum standard Electrode resistance required to operate the designed Earthing and lightning protection system effectively in the environment where the system is situatedbecomes a major factor. Failure to consider this all-inclusive principal factor may results in high electrode resistance which may spell doom for the system or render system ineffective in its performance during the operation of the system . Complete information about the soil resistivity, seasonal variation, temperature variation and the method of reduction of electrode resistance in the event of high resistance will to some extent guarantee the effectiveness of the system's operation.

II. FACTORS THAT AFFECT ELECTRODE RESISTANCE

A. Effect of Electrode Material

Material conductivity is the degree of the simplicity at which an electric charge or heat is transferred through a material. A conductor is a material which gives little resistance to the flow of an electric or thermal energy. Conductivity of electrode is one of the prime factors which cannot be over emphasized when designing a project to reduce the resistance of electrode in an earthing system. Low conductive materials cannot guarantee the effective flow of charge needed in the event of thunder and lightning strike.Material conductivity shows how well a material will allows electrical charge to travel through. [4], Thermal limits is the maximum power or currentthat transmission line can accommodate. The amount of heat individual part can sustain limits the amount of power that can be transmitted. Usually, the flow of current through the transmission line(I^2R), or real power losses in the form of heat leads to increase in temperature which may then stretch the conductor to sag point.

Metals are solidcrystalline structures with ions thatfillthe translational equivalent position in the crystal lattice. Thermal energy transferis of two effects namely:

- The migration of free electron
- Lattice vibrational waves (phonon)

Thermal energy is transferred by phonons and electrons through heat transfer or conduction in a solid.Thermal conductivity is expressed as

$$K = K_e + K_{ph} \quad \textbf{(1)}$$

Natural metals such as gold, silver, copper, and aluminum; the heat or current associated with the electrons transferis by a small contribution due to the flow of phonons. For alloys, the contribution of K_{ph} to K is no longer negligible. Semiconductors materials are materials whose conduction is between conducting Materials (metals) and non-conductors or insulating materials (such as ceramics). Semi-conductors are pure elements, such as silicon or germanium compound such as gallium arsenide or cadmium selenide. If a small number of impurities are added to pure semiconductors during doping, the impuritytriggers substantial changes in the conductivity of the material. While an insulator is any material or object that keeps energy such as electrical energy, heat, or cold from easily being transferred through it. Designing of effective earthing system must take into consideration key and major elements such as earth electrode materials to be use, and its properties. Earth electrode being the conductive part which may be embedded in the soil or specific medium to improve the system earthing, can be of metallic plate, copper wire, copper rod, galvanized pipe with properties such as high conductivity, low resistivity, and low temperature ability.

B. Effect of Depth on Electrode Resistance

The depth of buried Electrode has considerable influence on both the resistance and conductivity of material as the water content of soil is in abundance at the sub soil,the abundance water content in the soil in turn helps temperature reduction at thesoil. Water content of sub soil decreases the soil resistivity anddecrease in soil resistivity results in electrode resistance reduction which in turn increase electrode conductivity.

The water content at the sub soil apart from decreasing the soil resistivity perform another significant role of reducing the acidity concentration of soil salt content which can introduce corrosion against the earth electrode. At 47m depth, the rate of decrease of soil resistivity begins to decline with depth, which means that this 47m depth marks an inflection point for soil resistivity reduction.[6].

C. Effect of Electrode Spacing on Electrode Resistance

Earth Electrode is buried in the soil within a few metersfrom soil surface. The resistance area of earth electrode should be as large as possible , so that there will be no overlap of several electrodes that are connected in parallel and evenly spaced. However, the decrease in electrode resistance because of electrode spacing is not significant. Plates and strips should similarly be spaced evenly. This method required large resistance area to be covered, using several small electrodes during installation will be economical than small number of large electrodes[9]

D. Effect of Cross -Sectional Area on Electrode Resistance

Electrode resistance is inversely proportional to increase in electrode cross sectional area. This implies that larger the cross-sectional area of the electrode, the lower the electrode resistance. This is achieved as the cross- sectional area is increased, more electrons will flow through the electrode when the voltage is injected across the electrode.The electrode resistance reduction is not significant though, this is because the length of the electrode does not change and so the drift in speed of electrons do not change neither. The movement of more electrons shows increase in current movement which implies decrease in electrode resistance. This decrease in resistance achieved by increase in cross-sectional area is not as remarkable as decrease in resistance when the electrode length is increased deeper into subsoil.

III. METHODS OF ELECTRODE RESISTANCE REDUCTION

In general, electrode resistance reduction can be achieved in several ways [3]. Electrode resistance reduction can be achieved through the following ways: - Soil treatment, Electrode spacing, Increase electrode cross-sectional area, Electrode vertical deeper driven.

A. Soil treatment

In high soil resistivity spots such as rocky sites where long- term effective earthing and lightning system performance is required; it may be considered necessary to utilize a conductive concrete material to improve earth contact resistance around an earth electrode or strip (tape) where relevant. There are accessible materials can be used to achieve the effective performance effectively. Care should be taken to understand how thematerials work during design and installation to ensure that materials remain in contact with the electrode or strip and do not cave in or swell away after drying out [2]. Electrode resistance reduction is not the method of soil resistivity reduction, rather reducing soil resistivityaround electrodes can help achieve the desired electrode resistance reduction.

a) Water Retention
Most soil lose water and moisture content when it receives direct sunlight. The heat of the sun onearth mass causes the water content in earth mass to rise to the surface and vaporize into the atmosphere. The duration of the heating process dries the soil. Draining of the soil water content can also quickly allowthe soil salts to easily dry out the deeper strata of the soil.Without soil moisture content, an electrical connection to earth mass becomeseasily unachievable[8].

b) Chemical treatment
Chemical treatment is the use of chemical compound such as sodium chloride, magnesium sulphate (Epsom salt), copper sulphate (blue vitriol), and calcium chloride to reduce soil resistivity around the earth electrodesin other to reduce earth electrode resistance to the earth mass. The most used chemical is magnesium sulphate. It is Low-cost, and has strong electrical conductivity, it also has little corrosive effect.Sodium chloride isan exceptional conductor of electricity but highly corrosive. The corrosive nature and effect of sodium chloride may cause some nearby metal object to deteriorate. In spite being an admirable conductor of electricity, the corrosive effect of sodium chloride excludes sodium chloride from the list of preferred chemicals.Chemical treatment incidentally increases the diameter of earth electrode by changing earth electrode’s surrounding soil. If the soil is porous, the chemical solution permeates quickly into large volume of earth mass and makesthe earth electrode large in corresponding diameterwith quick results. In contrast, the chemicals take time to spread and produce slowresults when the

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soil dries out. However, the method of soil treatment with chemical requires caution, as some local authorities may prohibit the use of chemicals if chemicals are not considered environmentally friendly [8]

c) Use of Bentonite
The use of bentonite is another method of chemical application to the soil in other to reduces soil resistivity and the electrode resistance. Bentonite as a fine-grained of high plastic clay, is formed by volcanic action. It may be replaced as soil replacement and filter material for electrical earthing in places with high soil resistivity. Bentonite clay is sodium activated, chemically hydrated and innately stable.It absorbs moisture from the surrounding soil and swell up the soil up to several times of its dry volume. Bentonite adheres to the surface of the earth electrodes and cables which are laid in trenches to reduce the contact resistance. The water content in the pores allows the electrical charges to move through bentonite. The performance of Bentonite is mostly dependent on the volume of rainfall, soil moisture content, and temperature of the site. In hot climates, bentonite does not perform optimally as desired because of drought. It may separate from electrodes, and the separation increases the resistance to the earth mass [8].

Aizat et al [1], in their review of the use of enhancement materials for grounding system posited that, the natural materials do not alter the original properties of the soil**.** Hence, the soil condition can be maintained. On the other hand, the chemical enhancement materials could alterthe soil properties such as PH level, Fertility and Mineral**s** significantly. They maintained that in high soil resistivity area such as rocky soil, Bentonite is most and favored due to its ability to absorb moisture while maintaining humidity.

d) Chemical Rod
Chemical Rods are ultra-efficient rods designed to provide low impedance whenever it contacts soil. Chemical rods are suitable for areas where there is limited earth mass for earthing and lightning protection systems. Chemical rod is in a tubular form, filed with mineral salts which is evenly distributed. It has holes alongside its length, to allow the entry of soil moisture. The soil moisture combines with the salts to dissolvethe salts. The saline solution then seeps out through the hole and soaks into the surrounding soilcontinually to condition the large volume of soil around chemical rod.

e) Ground Enhancement fill
Ground enhancement fill is another method of soil treatment. In the method of ground enhancement fill, all or part of the soil around an electrode with high resistivity is replaced with pitchof low resistivity which facilitates the achievement of low electrode resistance. If earth swap has high percentage of the low resistivity,theelectrode resistance will be low as required. Grounding enhancement fill may have as low as 50**Ω**-cm (much lower than bentonite).It works in trenches, around earth electrode or substation earthing conductors, either in dry or in slurry.The properties of Ground enhancement fill are constant resistance, low resistivity,moisture content stability support, low freezing point, resistant to leaching, non-corrosive, and maintenance free.

While all methods of soil treatment are effective, the choice will depend on the site's particular conditions and the ability to conduct proper maintenance when required[8].

B. Electrode Spacing

Kalyani [9], the resistance of the buried electrode in the soil is within a fewmetersbelow thesoil surface.The resistance area should be as large as possible. Several electrodes are connected in parallel are evenly spaced apart as far as possible to ensure that the spaced electrodes do not overlap within the resistance area. Plates and strips should be similarly treated. The best way of making the resistance area covered by the electrode as large as possible is to install several numbers of small electrodes rather than a small number of large ones considering the installation cost.

C. Increase Electrode cross-sectional Area

Increase in cross -sectional area of the Electrode is another way to reduce the resistance of the electrode. As the cross- sectional area of the electrode is increased, the resistance of the electrode decreased with increase in the cross -sectional area of the electrode. Though the length of the electrode does not change so, the movement of the electrons did not get faster through the electrode but with increase in cross sectional area more electrons move through the electrode. Movement of more electrodes implies increase in current movement. Increase in current implies increase in electrode conductivity which shows reduction in electrode resistance reduction.

Jiguparmar [7], Apart from considerations of mechanical strength, there is little advantage to be gained from increasing the earth electrode diameter with the object in mind of increasing surface area in contact with the soil. The depth to which an earth electrode is driven to has much more influence on its resistance qualities than has its diameter.

D. Deeper driven Electrode

One of the key major players in any effective earthing performance is water content of the soil. Dry soil account majorly for high resistance which is also associated with hot temperature.Well known undisputed and proven fact is that high resistivity is directly proportional to high electrode resistance.Deeper driven electrode is the sure way to meeting abundance of water in the sub soil without any form of soil treatment or addition of any form of salt in the quest of resistance reduction. So many authors have alluded to this fact with the several results of their studies, experiments and works as explained in the earlier related literature.

Considering this over other methods, deeper driven should become the preferred method considering firstly humans, economic cost, electrical conductivity of electrode, low temperature in the subsoil, availability of abundance of water content in subsoil, non-addition of chemical or any of the salts that may trigger corrosion in the long term and shot term life span. Again, merits of deeper driven outweighs other method of achieving electrode resistance reduction though subject to the conditions of the environment where installation is to be made.Deep-driven of earthing rods, if possible, should always be used under all situations. The advantage of doingso as said in earlier sections is to be able to reach the moistenedpart of soil deep underground thus lowering the earthing resistance. However, implementing this method in rocky soil is verycostly and may damage the rods if forced into the hard ground during installation [10]

IV. COMPARISON, SIMILARITIES, DIFFERENCES, MERITS AND DEMERITS OF METHODS

Method	**Similarity**	**Differences**	**Merits**	**Demerits**
Soil Treatment	Electrode resistance reduction, Decrease soil resistivity,	Application of chemicals and other mineral salts such as magnesium sulphate (Epsom salt), copper sulphate (blue vitriol), and calcium chloride.	Application in rough hard and rocky environment, soil treatment becomes the preferred option, Ability to absorb moisture while maintaining humidity.	Soil pollution by chemicals application may result. Salts such Sodium Chloride and other mineral salt may introduce corrosion at long run. Also,enhancement fill, and soil replacement are economically friendly.
Increase in electrode Cross-Sectional Area	Reduces electrode resistance.	The size of electrode increasesthe flow of more electrons to reduce resistance.	More electronMovement when the size of electrode is increased leading to decrease electrode resistance. Electrode resistance is subject to seasonal variation	Increase in number of electron movement does not increase the speed of electrons hence the resistance reduction is not significant as the length of electrode remains the same.
Electrode Spacing	Reduces electrode resistance.	More electrodes are installed in equidistant spacing especially when the electrodes are in parallel	Overbearing of high electrode resistance by a single electrode is managed. Electrode resistance is subject to seasonal variation	The speed of electron does not increase as desirable, adding more electrode is not economically wise as increase in spacing does not produce significant reduction in electrode resistance compere to other methods.
Deeper driven	Reduces electrode resistance with depth and decrease soil resistivity	Increase in length and depth of the electrode vertically.	Allows electrode to go deeper to sub soil of abundance water content. Not susceptible to corrosion as abundant water of subsoil dissolves corrosive salts, Electrode resistance is stable as the electrode resistance is not influence by seasonal variations.	In hardy, rocky, and mountainous environment Deeper driven may not be possible and not economically wise.

Table 1

V. CONCLUSION

The studies compare the similarities, differences, merits, and demerits of various methods of electrode resistance reduction. While comparing the different methods of Electrode resistance reduction for effective performance, it was observed that there is no method that overshadow another depending on the environment where the construction of Earthing Lightning protection system is sited. While deeper driven method is the best in several instances, it becomes disadvantageous in rocky, hardy, and mountainous environment. Soil treatment and chemical application which could be best in a hardy, rocky and mountainous environment may not be suitable in other space because of its environmental impact. Since equipment and Human Lives must be protected from devastating effect of Lightning and thunder strike, designers of Earthing and Lightning protection systems should carefully consider the environment or the site for the construction and make the choice of the best suitable method to be applied in the construction.

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