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# Proper Selection of Earth Electrode in Corrosive Soil of Niger Delta

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**Abstract:** An earlier study carried out on corrosive effect of soil on earth electrode in the coastal areas of Niger Delta reveals that eight out of ten houses earthed for ten year and more loose their earth electrode connection. It was necessary to carry out an investigation in Rivers State to identify the reasons of the problems and find possible recommendation for better performance of earth electrode. Six sites were selected in Port Harcourt, one of it was an industrial area. Ten sites were selected in other part of Rivers State, five of them are from the coastal areas. For each site, twenty houses were selected and the type of earth electrode, year of installation and condition of electrodes were checked. From the selected sites, measurements were taken for resistivity using the four point measurement, the pH and the moisture levels were also determined. The results show that the soil was corrosive especially the coastal soil but several factors also contributed to the poor performance of the earthed electrodes. These are lack of proper knowledge of the function of earth electrode, wrong choice of materials as a result of untrained personnel and wrong installation methods.

**Key words:** Earth electrode bonding, earth resistivity, earthing system, galvanic corrosion, permanent moisture level, physico-chemical properties

## INTRODUCTION

It is a well known fact that people forget about earthing once installed and no one checks unless something goes wrong. Even though it is an intrinsic part of the electrical system it still remains a misunderstood subject, even sometimes by well qualified Engineers.

In recent years there have been rapid developments in the modeling of earthing systems at power frequencies and higher, mainly facilitated by computer hardware and soft ware (Ala *et al*., 2009; Ala and Di-Silvestre, 2002; Gonos and Stathopuslos, 2006).

This has increased our understanding of the subject, at the same time that the design task has become significantly more difficult and the emerging standards are requiring a more detailed and safer design. There is thus an opportunity to explain concept more clearly and a need for this to be conveyed to earthing system designers and installers so that a greater understanding may be gained.

A popular misconception is that the earthing system is only required during fault conditions but it serves a number of vital role during routine operations.

For example, many power supplies now include a connection to earth through which residual and harmonic currents are dispersed to ground. Current which flows to ground returns to source and forms a loop. These loops will create potential difference which, although small cause noise, hum and possible damage to electronic equipment (Husock, 1981; Sakamoto, 2001; Sakamoto and Sekiguchi, 2001). This process together with the increasing amount of harmonic current being injected into the public supply network is a growing cause of significant power quality problems. Some equipment contain earth screens, which operates continuously to reduce the field produced outside the case or reduce the impact of external fields on the equipment performance.

Generally, earthing means an electrical connection to the general mass of earth and is primarily to ensure safety (Laver and Griffiths, 2001; Bhatia, 2001; Nahman and Strojanavic, 1998). Earth (earth system) is a conducting connection, whether intentionally or accidental, by which an electric circuit or equipment is connected to the earth mass or some conducting body of relatively large extent that serves in place of the earth.

The earthing system is normally designed to provide two safety functions. The first is termed bonding. Bonding equalizes potential within a site that the resulting potential differences are minimal, that is, an equipotential platform is thus created.

The second function of the earthing system is to ensure that in the event of an earth fault any fault current which does result can return to sources in a controlled manner. By a controlled manner it means that the return path is predetermined such that damage to equipment or injury to individuals does not occur.

What links the system to earth itself is the earthing electrode. For good earthing connection the following conditions are necessary:

- Low electric resistance to earth
- Good corrosion resistant and must be sufficient in size to carry the required current
- Ability to carry the required current repeatedly
- A reliable life of at least 30 years

Electrodes must have adequate mechanical and electrical properties to continue to meet the demand on them over long periods.

Materials used include copper, galvanized steel, stainless steel and cast iron. Aluminum is sometimes used for above ground bonding but most of the standards forbid its use as an earth electrode due to the risk of accelerated corrosion. The corrosive product - an oxide layer is non conductive so could reduce the effectiveness of the earthing.

**Copper bond rods:** Copper bond earth rods are ideal driven electrodes as they offer the installer an economical and efficient rod grounding (earthing) system, pure electrolyte copper is uniformly molecular bonded into a high tensil steel core to a minimum of 0.254 mm, thus ensuring excellent corrosion resistance and eliminating electrolytic action.

**Solid copper earth rod:** These rods are used where extremely high corrosion resistant and exceptionally long life is required. Manufactured from hard drawn copper with purity and mechanical properties to B.S 2874. (Used for more aggressive soil conditions, for example when there is a high salt content).

**Stainless steel rods (austenitic steel to B.S 970, grade 316S12):** These rods are designed for use where problem may be caused by galvanic corrosion due to dissimilar material buried in close proximity. In such environment copper rod may react adversely with the buried metals.

A low electrical resistance to earth depends not only on the resistance of the earth electrode but also on the soil structure and resistivities. Soil chemistry, moisture content, temperature and depth of rod penetration into the soil all influence the earth resistance path (Laver and Griffiths, 2001; Ala *et al*., 2008).

Water alone is not a good conductor but the salt content and the pH value result in the electrolylitic action of the soil, hence enhances the conduction of current and reduces the resistivity of the soil. When metals (earth electrodes) are exposed to the environment of different soil, they are subjected to all of corrosion mechanism. Corrosion mechanisms include the effect of dissimilar metals (galvanic corrosion), soil conditions, different aeration, stray current and bateria effect.

The life span of the buried electrodes varied when sampled for different areas within the same soil. In addition to the corrosive nature of the soil it was obvious that factors like economy and human factors were also responsible for the short life span of the earthing systems in the area. The investigation was therefore done on the materials of the electrodes used, the method of earthing and connections on different materials.

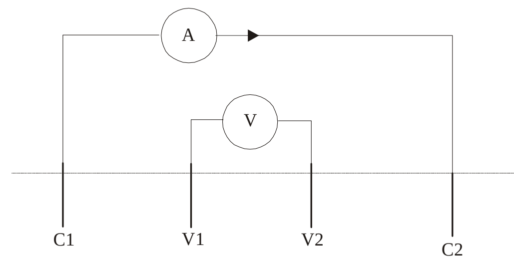


Fig. 1: Wenner configuration

This will enable researchers have a wider scope of the environmental problems, the human problems and the economic factors that are responsible for the short life span of the earth electrodes. Concrete recommendations was made on the findings and proper selection of material could be made for such corrosive soil.

## MATERIALS AND METHODS

Rivers State was particularly chosen because of its position in the Niger Delta. It has sixty percent of land areas (upland) and forty percent of the coastal areas. The study was carried out within two years (2007 to 2009). Due to the two main seasons (the dry and rainy seasons), the test was carried out within October to January each year. Six locations (site) were chosen in Port Harcourt, these areas are Elekahia Housing Estate, Woji Estate, Marine Base Estate, GRA phase II, Agip Estate and Trans Amadi Industrial Layout.

Five sites were chosen from coastal areas, these are Bonny, Finima, Kula, Degema and Opobo. The sites from the upland are Ahoada, Omaguwa, Emohua, Okehi and Bori.

**In each of the sites twenty buildings were sampled and the following details were taken:**

- The type of installed electrodes and the connecting earthing wire.
- The size and depth of Earth electrode.
- The period of installation
- Present electrode condition

From each site, the resistivity measurement was taken at a depth of 1.5 m using the four point earth electrodes measurement instrument. The instrument connection layout is shown in Fig. 1.

The soil pH was also tested in the laboratory. The moisture content was analysed in few areas. In the

Table 1: Summary of house type and earth electrode connections

| | Type of usage | | Supply type installation | | Earth rod reconnected | | | No. of years of installation | | Condition of earth | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site Location | Residential | Commercial | 1 Φ | 3Φ | Copper | Copper bond | Steel | Less 10 yrs | More 12yrs | Connected electrode | No. earthing | Refurbish and Less than 10 yrs | Lightning |
| Port Harcourt | | | | | | | | | | | | | |
| Elekahia H/ Estate | 16 | 4 | 2 | 18 | 5 | 15 | - | 3 | 15 | 4 | 14 | 2 | Non |
| Worji H/ Estate | 17 | 3 | 5 | 15 | 2 | 18 | - | 2 | 18 | 3 | 16 | 1 | Non |
| Agip H/ Estate | 14 | 6 | 3 | 17 | 8 | 12 | - | 1 | 19 | 6 | 10 | 4 | Non |
| GRAPhase II | 10 | 10 | - | 20 | 10 | 8 | 2 | 5 | 15 | 8 | 7 | 5 | 8 |
| Marine Base | 18 | 2 | 12 | 8 | 6 | 14 | - | - | 20 | 2 | 18 | - | - |
| Coastal | | | | | | | | | | | | | |
| Bonney | 20 | - | 8 | 12 | 5 | 15 | - | 7 | 13 | 2 | 17 | 1 | 3 |
| Finima | 20 | - | 17 | 3 | 2 | 18 | - | 9 | 11 | 3 | 17 | - | 1 |
| Kula | 10 | - | 10 | - | - | 10 | - | 8 | 2 | - | 10 | - | - |
| Degema | 18 | 2 | 14 | 6 | 2 | 18 | - | 7 | 13 | 3 | 17 | - | 1 |
| Opobo | 20 | - | 12 | 8 | 6 | 14 | - | 8 | 12 | 5 | 15 | - | 2 |
| Upland | | | | | | | | | | | | | |
| Ahoada | 16 | 4 | 12 | 8 | 8 | 11 | 1 | 8 | 12 | 8 | 12 | - | 2 |
| Emohua | 18 | 2 | 17 | 3 | 8 | 10 | 1 | 11 | 9 | 10 | 10 | - | 1 |
| Okehi | 15 | - | 13 | 2 | 2 | 13 | - | 5 | 10 | 6 | 9 | - | - |
| Bori | 20 | 2 | 14 | 6 | 5 | 15 | 1 | 7 | 13 | 9 | 11 | - | 2 |
| Omagwa | 17 | 3 | 14 | 6 | 2 | 18 | - | 8 | 12 | 12 | 8 | - | 1 |

Total electrodes investigated in the 15 sites = 285 No; Copper bond = 209; Solid copper = 71; Steel electrode = 5

Table 2: Earth of Electrode in selected industries

| S.No. | Site location | Supply typeand transform | Method of earth system | Period of connection | Type of production |
|---|---|---|---|---|---|
| 1. | Trans Amadi Industrial layout | 3Φ Transformer 500 KVA | Galvanized Pipe dia 3 m x 50 mm | 25 yrs | Manufacturing production of polytene materials |
| 2. | Trans Amadi Industrial layout | 3 phase supply No transformer | 1 steal electrode 3 m x 50 m | 18 yr | Welding and fabrication |
| 3 | Elekahia | 3 phase supply 1 transform 200 KVA | 5N0s galvanize 3 m x 50 mm rod | 22 yrs | Ice block production |
| 4. | Trans Amadi | 3 phase supply 200KVA Transf. | 1 galvanize rod 3 m x50 mm | 29 yrs | Offices workshop ware house |

coastal areas, the ground water table was at a depth of about 1.5 m

## RESULTS

From the analysis the average values of various results were summed up and the records are shown in Table 1. The total number of electrodes are 285 out of which copper plated (bond) was 209, solid copper was 71 and steel was 5. From the results, steel electrodes are mainly used for transformer earthing and some industrial earthing.

The pie chat describes the distribution of the electrodes and is shown in the Fig. 2.

The problem was related mostly to domestic installations but few industries (small) were chosen in Port Harcourt for the study. The reading from the four industriall sites are shownin Table 2.

The industrial sites were selected in Port Harcourt and the readings are shown in Table 2. The results of the previous test on soil resistivity carried out in Rivers State (not yet published) are shown in Table 3 From the results the graph was drawn as shown in Fig. 3. From the resistivity values the permanent soil moisture level could be established.

The resistivity of the upper layer varied from a point to another, probably reflecting differences in water content in the upper soil layer due to local topography and drainage but it was convenient to group them into the following:

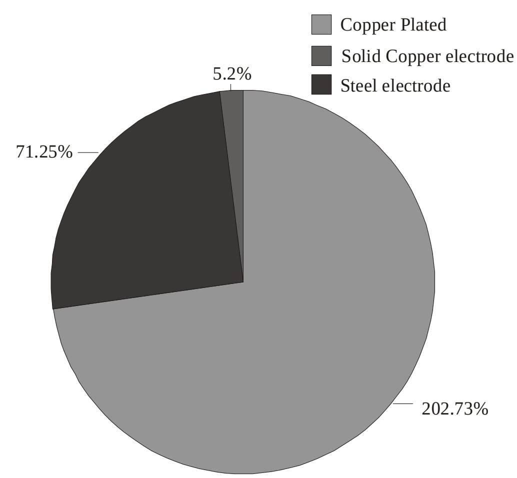


Fig. 2: Ratio of used electrodes

Table 3: Resistivity values at different depth

| Depth of electrode meters | Resistivity of soil at different Bonney | Ahoada | Eleckahia |
|---|---|---|---|
| 0.5 | 85 | 410 | 390 |
| 0.8 | 45 | 280 | 270 |
| 1.2 | 29 | 120 | 105 |
| 2.0 | 22 | 55 | 51 |
| 3.0 | 21 | 30 | 26 |

- The Port Harcourt sites
- The Upland sites and
- The Coastal sites

Table 4: Test results of resistivity humidity pH and soil Temperature

| Site group | Average resistivity at 2 m (Ω-m) | Average air temperature | Average pH | Average air humidity |
|---|---|---|---|---|
| Port Harcourt | 40 | 38.1 | 4.81 | 78 |
| Upland site | 42 | 37.0 | 4.75 | 72 |
| Coastal area site | 16 | 36.0 | 6.12 | 81 |

Table. 5: Electrode material and cost

| S.No. | Material description | Size/Length | Cost ratio | Availability (%) |
|---|---|---|---|---|
| 1 | Solid copper | 1.8 | 4 | 25 |
| 2. | Solid copper | 1.2 | 3 | 30 |
| 3 | Copper plated steel | 1.2 | 1 | 50 |
| 4. | Stainless steel | 1.5 | 1.2 | 50 |
| 5. | Galvanized steel | 1.5 | 1.1 | 10 |
| 6. | Aluminum | - | - | - |

All cost referred to copper plated steel electrode

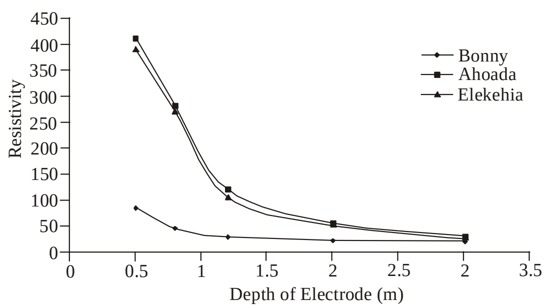


Fig. 3: Resistivity of soil at different depth for 3 sites

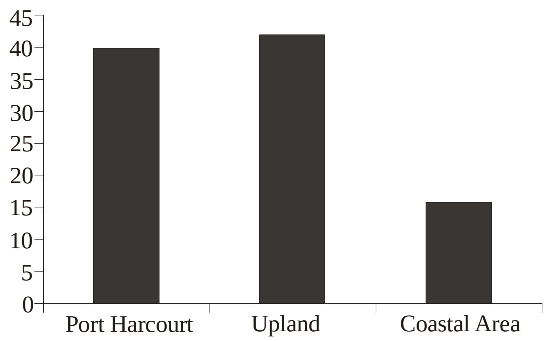


Fig. 4: Measured Resistivity values for the three main soil division

In some domestic installations, electrode depths are between 1.5 to 2 m, therefore the measured results of soil resistivities from a depth of 2 m are practical results obtained for the area. These values are tabulated and are shown in Table 4.

From the values shown in Table 4, the resistivity values were drawn as shown in Fig. 4

The use of material is influenced by the availability and cost therefore a market survey was carried out and the results are shown in Table 5.

## DISCUSSION

The record in Table 1 showed that copper plated electrodes were 74% of the total installed electrodes. The market survey also showed that the availability of these electrodes is about 70% in the market.

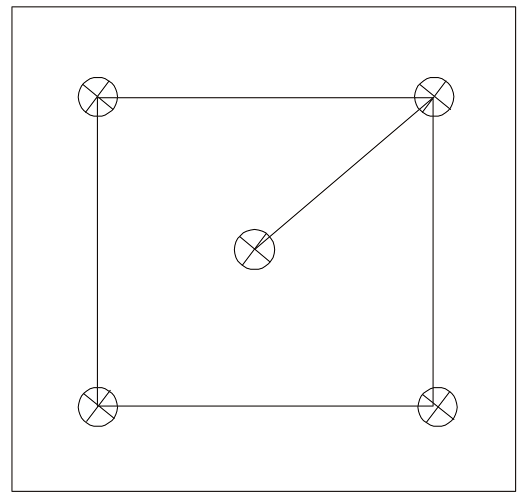

Fig. 5: Five Parallel steel earth rods bonded together

It will be recalled that during the economic recession in 1986 the standard materials and equipments were not within the reach of every body, therefore importers resort to importing substandard materials. The electrical industry was not spared and these materials are still with us in the country.

The copper plated electrode material due to the thin coating (substandard) crack even during handling and especially at the head when installing thereby exposing the iron to sever corrosion. This enhances bimetallic corrosion (Bhatia, 2001; Liu *et al*., 2004). Therefore in very aggressive soil like the coastal soil these electrodes corrode about five to six years.

In the GRA site more copper electrodes were used and the loose earth connections were fewer. The reason was that most house owners are knowledgeable and they were able to afford standard materials.

The price difference between the solid copper electrode and the copper plated steel electrode was about three times, but due to lack of understanding contractors take advantage of it to maximize profit. Due to lack of government proper supervision the Elekahia Housing Estate, Woji and Agip Estates became victims. Almost all electrodes used were copper plated steel type which were not the standard types.

The diagramme of Fig. 5 was an illustration of a newly constructed earth pit from one of the industrial sites extention.

Five (5) galvanized steel rod of 1.8 m were planted within the area of 600×600 cm and were bonded together with a copper wire. Sodium chloride and powdered coke were poured directly and were backfilled.

From the practical experience the following points could be highlighted

- All the resistance area of the electrodes were overlapping thereby making the use of many electrodes of no advantage (Sekioka *et al*., 2006)
- Bonding steel with copper wire promote galvanic corrosion due to their position in the electrochemical series
- The method of application of salt was wrong and also not necessary. The presence of salt and coke will only provide a good environment for corrosion process (Mousa, 1994)

From this experience it was seen that if the electrode will last for 10-years with normal application, it will be effective for 2-years due to wrong use of materials and lack of understanding..

Also the use of five electrodes for a small area can only result to economical waste.

## CONCLUSION

The soil of the Niger Delta, especially the coastal soil is corrosive but the human factor contributed to the short life of the earth electrode. Due to the scarcity of job opportunities many people find themselves into these jobs without good foundational knowledge on this important aspect of electrical engineering. They are cheap labours and are easily patronized by the low income earners.

The purpose of earthing is for safety of life and property, therefore any one that down play this aspect is placing life in danger. The proper government agency must deal with the human factor but the following recommendation for the choice of material in the Niger Delta is ideal.

- In the coastal areas, the ideal electrode for earthing is the solid copper or the copper bond to the required standard.
- For the upland areas, copper bond may be used but the required standard must be maintained, while for steel electrode the appropriate allowance given in the literatures must be followed.
- For three phase installation inspection chambers are necessary for frequent servicing. This applies to industrial installations also.
- In no part of Niger Delta chemical treatment is necessary.

## ACKNOWLEDGMENT

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