Effective Earthing System in the Corrosive Soil of Niger Delta

Hachimenum Nyebuchi Amadi

Abstract - In order to perform its basic function of safeguarding life and property, every power system needs an earthing profile that is effective and efficient. Recent studies carried out in the Niger Delta show that its soil is corrosive and frequently attacks the earthing system thereby rendering same ineffective thus posing a great danger to human life and property. This paper reviewed several scholarly literature related to the study for possible causes of earthing system failures and found that corrosive soils, poor workmanship, wrong choice of earthing materials, lack of maintenance etc. were dominant factors hindering effective and sustainable earthing system in the Niger Delta. The paper, therefore, recommends the regular use of experienced workmen, choice of quality earthing materials, periodic testing, inspection and maintenance as strategies to improve the earthing condition in the area.

Index Terms: Corrosion, Earthing, Electricity, Niger Delta, Protection

I. INTRODUCTION

The Niger Delta is situated in the southern part of Nigeria. It is bordered to the south by the Atlantic Ocean and to the East by Cameroon and occupies a surface area of about 112,110 square kilometres. The climate of the Region varies from the hot equatorial forest type in the southern lowlands to the humid tropical in the northern highlands and the cool montane type in the Obudu plateau area. The wet season is relatively long, lasting between seven and eight months of the year, from the months of March to October. The dry season begins in late November and extends to February or early March, a period of approximately three months [1]. The basic reason for earthing of electrical installations is to ensure safety of life and property. Every earthing system performs two safety functions. Firstly, the system serves as a bond connecting together any exposed conductive metalwork which can be touched. Most electrical equipment is usually housed inside metal enclosures which if a live conductor comes into contact with, temporarily also becomes live. Bonding these together ensures that, should such a fault develop, the potential on all normally exposed conductive metalwork is virtually the same with only minimal potential differences. Under this situation, if a person is in contact simultaneously with two different pieces of exposed metalwork, a bonding conductor, ensures that the person does not receive a shock, as the potential difference between equipment should be insufficient for this to occur [2,3]. Secondly, the earthing system ensures that, in the event of an earth fault, any fault current which does result can return to source through a predetermined path such that damage to equipment or injury to individuals does not occur. To make this possible, the impedance of the earthing system is low enough so that sufficient earth fault current can flow to initiate the correct operation of protective devices e.g. circuit breakers or fuses to interrupt the flow of current [2]. Despite being one of the most important aspects of electrical design and installation, earthing continues to be one of the least understood or rather misunderstood concepts in the electricity industry [3]. It is also among the most expensive when errors are made due to the fact that the dollar value of equipment in-operation and/or loss not to mention the potential liability associated with earth related faults can be staggering [4]. Poor considerations and design failures also have let to many electrical shock accidents. As a result of these accidents, research on earthing systems have always been given much considerations such that earthing design is considered the single most important parameter to determine the earth fault behaviour in a power system [5,6]. Expert design and skilled workmanship help to ensure effectiveness of the earthing system so as to achieve equipment and personnel protection as well as guarantee the satisfactory performance of any electrical or electronic system [7].

Geotechnical data of soils in the Niger Delta have been fairly well documented and published works are readily available [8,9,10]. In the recent few decades, corrosion of materials has become a major issue [11]. Corrosion has been responsible for much failures in plant infrastructure and machines which are usually costly to repair in terms of monetary loss, environmental damage and human safety [12]. Tests conducted recently in the Niger Delta confirmed that due to its geographic location and closeness to the ocean, the soils were very corrosive. The term corrosion is derived from Latin word "corrosus" that means consumed by degrees or eaten away [11]. Two types of corrosion are chemical corrosion and electrochemical corrosion. See Fig. 1.

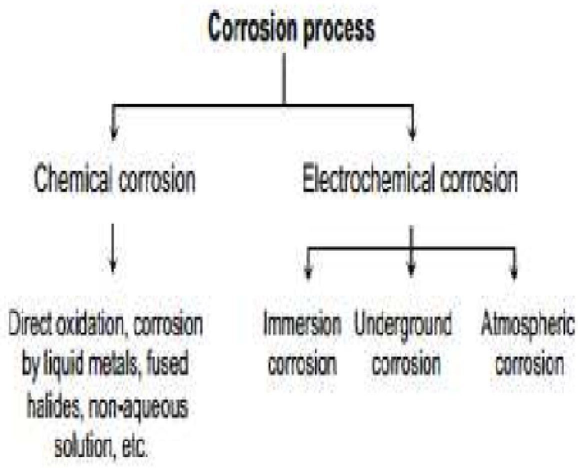

Fig. 1: Classification of Corrosion Process

[11].This research, however, is about the latter type of corrosion i.e. underground or galvanic corrosion, in which the dissolution of metal is the anodic reaction and reduction of oxygen dissolved in water is the cathodic reaction. Corrosion attacks every electrical equipment and materials, especially earthing systems, buried underground making

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them ineffective barely a few years after installation [13,14,15,16] thus endangering the lives of the same persons and property which they should protect. This paper investigated the causes of failures of earthing systems in the corrosive soils of Niger Delta region and recommended appropriate measures to ensure effective and sustainable earthing profile.

II. WHAT IS EARTHING AND WHY EFFECTIVE EARTHING?

The term earthing is used in Europe, in North America however, the term "grounding" is more common. Earthing or grounding of equipment describes the connection of non-current carrying parts of electrical equipment to the earth to maintain earth potential. Earthing sometimes simply called "earthing system" is the total set of measures used to connect an electrically conductive part to earth. See Fig. 2. The earthing system is an essential part of power networks at both high- and low-voltage levels and is fundamental for safety of factories, plants, equipment, property and human beings as well as animal life. It ensures that there is no loss of life and property in the event of earth fault conditions [17]. To be effective, an earthing system must satisfy the following conditions:

1. Ensure safety of the property and life from hazards of electric shock and electric fires.

2. Provide an equipotential platform on which electronic equipment can operate.

3. Ensure that system voltages on healthy lines remain within reasonable limits under fault conditions thereby preventing insulation breakdowns.

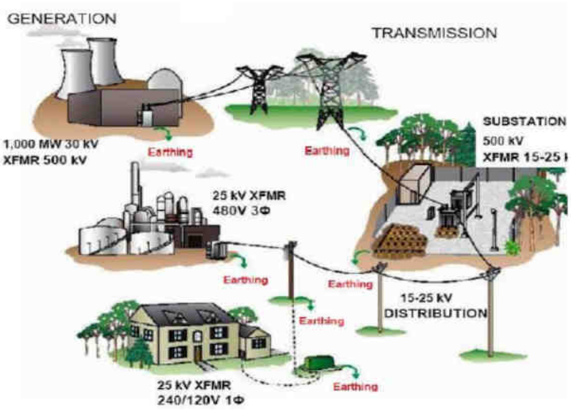


Fig. 2: A Typical Earthing System [18]

4. Ensure that under every condition of fault, the system neutral is held close to the ground potential thus limiting the over-voltage.
5. Provide a low impedance path to facilitate the satisfactory operation of protective devices under fault conditions.
6. Provide an alternative path for induced current and minimize the electrical noise in cables.
7. Minimize arching burn downs by providing an easy means of detecting and tripping against phase to earth arching fault breakdowns.

An earthing system is expected to provide a direct route to the soil for fault current whilst minimising touch and step potentials; and in addition help mitigate disturbances and serve as a common voltage references for sensitive electronic equipment. An earthing system therefore must be designed as an overall system such that it fulfils the safety of life and equipment performance requirements [17]. Every earthing system should possess the following unique properties:

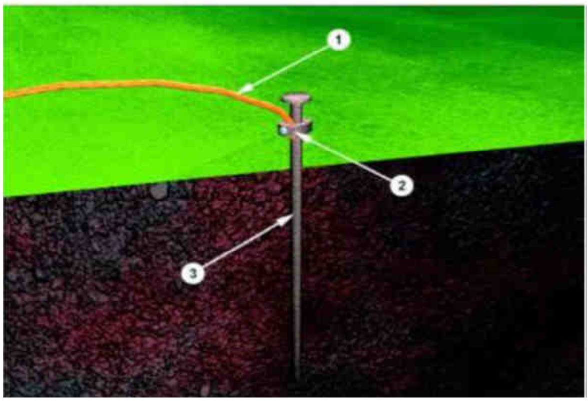
- Low earthing resistance
- Adequate current carrying capacity
- Long durability

An effective earthing system, therefore, is one which is capable, at all times, of creating an alternative path for the flow of fault current safely into the ground in the presence of minimal resistance or impedance. In other words, effective earthing systems should be capable of continuously avoiding the presence of dangerous potentials on equipment during electrical faults conditions. It must be noted that an effective earthing system may not necessarily be one that is effectively earthed. "An effectively earthed system" is one, "in which the value of the phase to earth voltage of the healthy phases during an earth fault, never exceed 1.39 times the pre-fault phase to ground voltage" [19]. Without an effective earthing system, human lives could be exposed to the risk of electric shock, not to mention instrumentation errors, harmonic distortion issues and a host of possible but unimaginable incidents. If fault currents have no path to the ground through a properly designed and maintained earthing system, the same will find unintended paths that could include human beings.

Good earthing system does not only provide safety, it also prevents damage to industrial plants and equipment and improves the reliability of equipment while reducing the likelihood of damage arising from lightning or fault currents [20,21,22]. To achieve good earthing system, the value of the resistance in ohm between the earth electrode and the earth should be relatively small [22].

III. COMPONENTS AND CONDITIONS FOR EFFECTIVE EARTHING

The overall effectiveness of any earthing system is determined by the choice of the individual components that are used to construct the system and the manner in which these components are interconnected. The earthing system comprises such conductive materials as bonding conductors etc. above ground, metal electrodes within the soil and the surrounding soil itself each contributing towards the overall impedance value of the system. Great care must be taken, therefore, with regards to choosing the following components:



1. Earth Conductor 2. Earth connector 3. Earth electrode

Fig 3: **Components of an earthing system** [18]

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1. The earthing conductors: Cables and the accessories used for earthing must be tested to ensure compliance with the required safety standards.

Similarly, cable glands and their fixing accessories and earth tags must be selected correctly to make sure personnel coming into contact with exposed live parts due to inferior earth connection is not subject to electric shock. These earthing components must also be installed by competent personnel according to engineering best practices (See Fig. 3).

2. Earth connector: The earth connector serves as a link between the earth conductor and the earth electrode. It must be of a material that has sufficient electrical and mechanical strengths and is durable and obviously resistant to corrosion.

3. The earth electrodes: The earth electrode is the main component of the earthing system, which is in direct contact with the ground and, thus provides a means of releasing or collecting any earth leakage currents. Earth electrodes are designed to maintain ground potential on all the connected conductors so that they can dissipate currents into the ground conducted by these electrodes. Earth electrodes are available in various lengths, diameters, shapes, and metals. By carefully analyzing and determining the demand of each work site and understanding the variety of installation options available, right decisions can be taken that could guarantee that the installation functions as designed.

There are three types of earth electrode: Earth rods, earth plates and underground structural metalwork [23]. The single most important factor in deciding which type of electrode to use is resistance capacity of the soil in the ground. The earth electrode should be of a material that has good electrical conductivity and should not corrode in a wide range of soil conditions. Copper bond, solid copper and stainless steel are generally the preferred materials [3].

Although aluminium is sometimes used for above ground bonding, it is in most cases forbidden as an earthing electrode, due to the risk of accelerated corrosion and because its corrosion by-product, the oxide layer on the electrode is non-conductive in nature and could reduce the effectiveness of the entire earthing arrangement.

IV. DESIGN, INSTALLATION AND TESTING/INSPECTION OF EARTHING SYSTEMS

The overall performance of the earthing system is mostly influenced by the soil characteristics, especially the resistivity. Soil resistivity usually measured in ohms depends on the physical composition of the soil, moisture content, dissolved salts, seasonal variation and current magnitude [24]. See Figs. 4 and 5. The soil composition, moisture content, and temperature all impact the soil resistivity. Most soils are not homogenous and has resistivity varying geographically and at different soil depths. Moisture content is rarely stable but changes seasonally, varying according to the nature of the earth sub-layers and the depth of the permanent water table. Since soil and water are generally more stable at deeper strata, it is often recommended that the earth rods be placed as deep as possible into the earth and at the water table if possible. Also, earth rods should be installed where temperature is stable. For an earthing system to be effective, it must be designed such that it is capable of withstanding the worst possible conditions.

A good knowledge of soil resistivity is necessary due to the fact that components of earthing system buried in soil are often subjected to harsher conditions than those installed above ground. Such harsh conditions include the fact that these components are immersed into wet and corrosive soil which freely attack and cause them to give up their electrical and chemical characteristics and sometimes their physical composition as well.

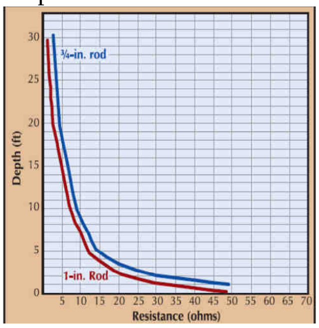

Fig.4: Ground rod Resistance varies with Depth and rod diameter [25].

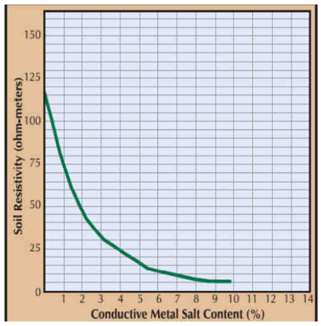

Fig.5: Soil resistivity decreases as conductive metal salt content increases [25].

The performance of an earthing system further depends upon the effective operation of several installed components: the grounding conductor, the grounding connector, and the grounding electrode as their constituent characteristics interact inside the soil where they are buried.

Should any one of these components fail due to corrosion, the entire earthing system becomes ineffective; its service lifetime being shortened and the danger to human life is increased. The determination of soil resistivity value and initial selection of the components used in the earthing system, therefore, is of critical importance to its long-term effectiveness. The components should possess excellent electrical conductivity, be mechanically robust, be able to withstand repeated fault and surge currents, and be resistant to corrosion [26]. When installing electrodes, there are three conditions which must be satisfied [2]:

- the work must be carried out efficiently to minimise installation costs,
- the backfill used must not have a pH value which will cause corrosion to the electrode; and
- any joints or connectors used below ground level must be so constructed that corrosion of the joint/connector will not take place.

Table 1: **Seasonal Variation of Soil** [16]

Depth of Electrode in Meters	Coefficient of Seasonal Variation		
	Brass (Coastal soil)	Ogbia (Tidal freshwater swamp soil)	Amassoma (Fresh Alluvial soil)
0.5	3.9	2.9	4.6
0.8	1.5	2.8	2.9
1.2	1.05	1.8	1.8
1.5	1.11	1.45	1.6

After commissioning of the installation, it is vital to check that the electrical earthing system meets the design criteria. A test should be conducted to measure the actual earth resistance of the completed earthing system to make sure that this measured value corresponds to the calculated earth

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resistance value based on the measured soil resistivity value. It is also vital to periodically retest this earth resistance in order to ensure the integrity and continued safety of the system [27]. This is also to ensure that corrosion or changes in the soil resistivity do not have an adverse effect due to the fact that the earthing system may not appear faulty until a fault occurs and a dangerous situation arises [28].

Soil resistivity tests are conducted to obtain a set of measurements which may be interpreted to yield an equivalent model for the electrical performance of the earth as seen by the particular earthing system. Any of the following methods is usually employed: the Schlumberger arrangement (4-pole unequally spaced method), the Fall-of-Potential (Three-pin method) or the Wenner Array (4-pole equally spaced method). However, the Wenner method (See Fig. 6) is considered as the most efficient and commonly used technique by many due to the fact that it offers the best ratio of received voltage per unit of transmitted current [27,29].

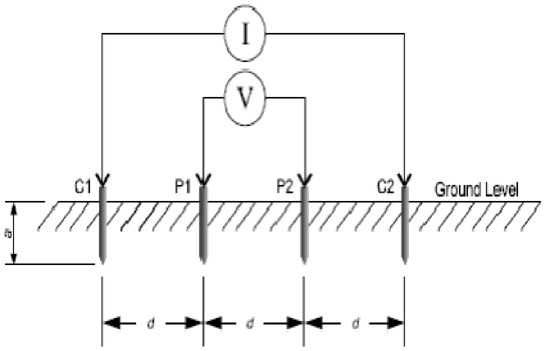

Fig.6: **Wenner Array Method**

It can be stated that:

$$\rho_{aw} = 2\pi a \frac{\Delta v}{I} \quad \text{........................(1)}$$

Which reduces to,

$$\rho_{aw} = 2\pi aR \quad \text{..........................(2)}$$

Where ρ_{aw} *= apparent resistivity* (Ω)

a = *probe spacing (m)*

Δv = *voltage measured (volts)*

I = *injected current (Amps)*

R = *measured resistance* (Ω)

V. FACTORS AFFECTING EFFECTIVE EARTHING IN NIGER DELTA

Several reasons are responsible for the present deplorable condition of the earthing system in the Niger Delta. These include:

i. Nature of the soil: The major cause of failure of earthing systems, underground pipe-lines and equipment in the Niger Delta is indeed the corrosive nature of the soil [3,10,14,31].

ii. Unskilled manpower: Good earthing requires good workmanship. But where untrained persons lacking in the right knowledge are used to design, install and maintain earthing systems, non-performance and failure of the system becomes the order [3,23].

iii. Wrong choice of earthing components/materials: To achieve good earthing, the proper materials must be carefully selected and skillfully installed [23,32].

iv. Economic situation: Lack of funds sometimes force people to improvise and settle for cheap earthing materials which have adverse effects of the overall performance of the earthing system [3].

v. Climatic condition and seasonal variations. Earthing systems are installed in widely differing soil types and subject to a range of climatic conditions [27]. The humid climatic condition of the Niger Delta contributes to the rusting or corrosion of the earthing system and helps to render it inefficient and ineffective.

vi. Lack of proper maintenance policy. All forms of installation should be subject to two types of maintenance namely: (1) Inspection: A frequent inspection of all the earthing components which are, or can readily be made accessible and then (2) Periodic maintenance: A closer examination of the entire earthing arrangement than possible by inspection, possibly including testing.

Table 2: **IEE Recommended Inspection Periods**

Nature of Premises	Maximum Time between Inspections
Commercial	Max 5 years
Industrial	Max 3 years
Hotels and Public Houses	Max 5 years
Shops and Offices	Max 5 years
Domestic	Max 10 years or at change of occupancy
Residential	Max 5 years or at change of occupancy
Launderettes	Max 1 year
Community Centres/Village Halls	Max 5 years
Churches	Max 5 years
Educational	Max 5 years
Places of Public Entertainment and Theatres	Max 3 years
Leisure Complexes (excluding Swimming Pools)	Max 3 years
Swimming Pools	Max 1 year
Construction Sites/Temporary Installations	Every 3 months

VI. CONCLUSION AND RECOMMENDATIONS

This paper identified the use of unskilled personnel, choice of wrong and cheap earthing materials, wrong earthing design, lack of good maintenance policy etc. among the crucial factors that contribute to earthing problems in the Niger Delta. The paper recommends, therefore, the following measures to improve and sustain good earthing system in the region:

1. Only skilled and qualified personnel should be engaged

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for all electrical installation works including the design, construction and maintenance of the earthing system. The design also must be practical, maintainable and easily constructible at minimal cost.

2. Time must be invested in ensuring good earthing design from inception. In the same vein, adequate care must be taken while installing each component of the earthing system to ensure the highest level of professionalism. Hurried design or installation work cannot guarantee an effective earthing arrangement and is therefore a dangerous venture.

3. Regular inspection and periodic maintenance of the earthing system. The earthing system must be periodically inspected and maintained to ensure its effectiveness and continuity. Be sure to regularly inspect it, using an approved ground-testing instrument to test electrical resistance and continuity.

4. Proper choice must be made in the selection of earthing materials to make sure that they are of standard mechanical and electrical strengths and are capable to withstand corrosive attacks over a long time.

5. Earthing is basically to safeguard property and human life, funds should be invested to procure only earthing materials that are of standard and acceptable quality. To compromise the quality of earthing materials is a sure invitation to earth defects and failures.

6. Corrosion technology needs to be further improved through research, development, and implementation.

7. The Niger Delta region soil is naturally salty and does not need additives.

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