Nigerian Journal of Technology (NIJOTECH)
Vol. 32, No. 1, March, 2013, pp. 49–53.

ISSN 1115-8443

PERFORMANCE ASSESSMENT OF SUBSTATION SITE EARTHING USING FLUKE 1625 GROUND TESTER

C.N. Obeta[a], **D.B.N. Nnadi**[b]

[a]Electrical/Electronic Engineering Department, Enugu State University of Science and Technology, Enugu State, Nigeria. ***Email:*** *obetaelectrical@yahoo.com*
[b]Department of Electrical Engineering, University of Nigeria, Nsukka, Nigeria. ***Email:*** *nwoye.nnadi@unn.edu.ng*

Abstract

This study utilizes the automatic frequency control (AFC) feature in Fluke 1625 ground tester to analyze earth impedance in five power substations. Other conventional methods like the use of megger for impedance test runs short of responding to variation in supply frequency and not trustworthy. Earthing is the fundamental requirement for protection in all electrical installations. The result shows that the use of the Fluke 1625 for ground testing is very reliable, hence the need for the performance assessment of this instrument as compare to the conventional system.

Keywords: substation, ground tester, earth impedance, protection

1. Introduction

The electrical properties of the ground are characterized by the earth resistivity ρ. In spite of the relatively simple definition of ρ given above, the determination of its value is often a complicated task for two main reasons:

- the ground does not have a homogenous structure, but is formed of layers of different materials
- the resistivity of a given type of ground varies widely and is very dependent on moisture content.

The calculation of the earthing resistance requires a good knowledge of the soil properties, particularly of its resistivity ρ. Thus, the large variation in the value of ρ is a problem. In many practical situations, a homogenous ground structure will be assumed with an average value of ρ, which must be estimated on the basis of soil analysis or by measurement. There are established techniques for measuring earth resistivity. But this paper uses Fluke 1625 ground tester to test the resistance of the substation sites.

Fluke 1625 is a ground tester that uses a 55Hz for computation of complex impedance [1]. This calculation is very close to voltage operating frequency, hence the measurement is very close to the value at the operating frequency. Using this feature of the Fluke 1625, accurate direct measurement of ground impedance is possible [2].Resistivity has direct relationship with supply frequency [3]. In AC circuits one must consider essentially the impedance of an earthing, which is the impedance between the earthing system and the reference earth at a given operating frequency. The earthing resistance R of an earth electrode depends on the earth resistivity ρ as well as the electrode geometry.

A substation is a subsidiary station on a transmission and distribution system where voltage is normally transformed from a high value to a low value [4]. A typical substation will contain the line termination structures, high voltage switch gears, one or more power transformers, low voltage switch gears, surge protection, control and metering [5].

All the installations are prone to fault current and should be earthed to avoid creating a shock hazard [6]. Poor grounding is dangerous and it exposes to the risk of electric shock, leads to instrumentation errors, harmonic distortion, power factor problems, unnecessary down time and a host of other possible intermittent dilemmas [7].

The National electric code (NEC) article 100 defines the ground as "a conducting connection, whether intentional or accidental between an electric circuit or equipment and the earth, or the same conducting body that serves in place of the earth" [8]. The purpose of grounding besides the protection of people, plants and equipment is to provide a safe path for the dissipation of fault currents, lighting strikes, static dis-

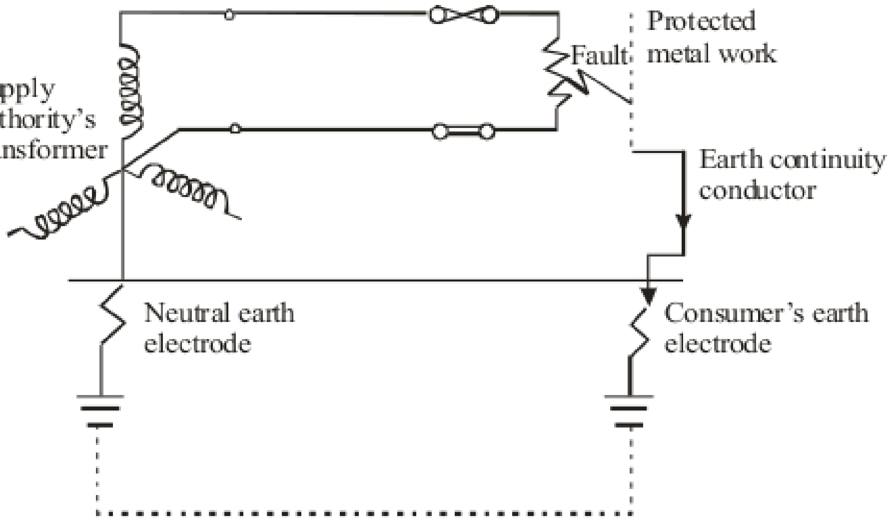


Figure 1: Earth fault loop-path.

charges and signal interferences [9].

The Institute of electrical and electronic engineering (IEEE) recommended a ground resistance value of 5.0 Ohms or less [10]. The National electric code (NEC) 250.56 stated that system impedance to ground must be less than 25 Ohms. It went further to state that in facilities with sensitive equipment, it should be 5.0 Ohms or less [8], which power substation is among. The telecommunication industry has often used 5.0 Ohms or less as their value for grounding and bonding.

Power substation is typically grounded with earth mesh and will have series of ground strikes connected by earth wire and clamp [1]. Depending on the size of the substation and the resistance value that it was designed to achieve, the number of ground rods varies.

2. Earth Loop-Path

When a fault to earth occurs, fault current flows around the earth fault loop-path as shown in the figure 1 below. The path taken by the current is from the life terminal, L, of the supply transformer along the live conductor to the fault, and then to the metal work affected. From the metal work, the current flows via the earth continuity conductor (ECC), earthing lead and consumers earth electrode through the general mass of earth and back to the neutral terminal, N, of the supply transformer. The earth-loop possesses impedance which may be measured in Ohms. The value of the fault current is limited by this impedance. If the impedance area is low enough, sufficient current would flow to operate the over current protective device

$$I_f = V/R \tag{1}$$

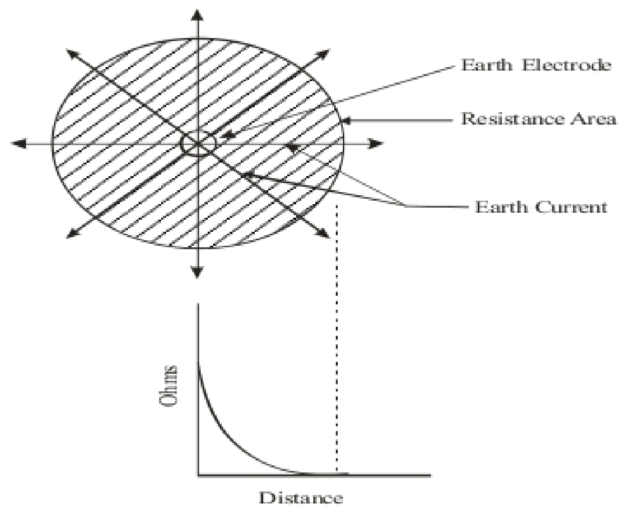


Figure 2: Earth electrode resistance area.

If fault current have no path to ground through a properly designed and maintained grounding system, they will find unintended paths that could include human beings.

2.1. Earth electrode resistance area

The electrical properties of earthing depend essentially on two parameters:

- earthing resistance;
- configuration of the earth electrode.

Earthing resistance determines the relation between earth voltage VE and the earth current value. The configuration of the earth electrode determines the potential distribution on the earth surface, which occurs as a result of current flow in the earth [11].

A basic model of the earth electrode configuration as shown in figure 3a is hemispherical in shape and embedded in the ground surface. The earth current flowing to such an electrode is assumed to flow radially to the earth. The surface of the hemisphere as well as all hemispherical cross-sections d_x of the ground, are assumed to be equipotential, and the current lines are therefore perpendicular to these surfaces. Under these conditions the resistance of the hemispherical element of thickness d_x and the radius x is expressed as follows (with rho assumed constant):

$$dR = \frac{\rho}{2\pi x^2} dx \tag{2}$$

The resistance of the hemisphere-earth electrode is given by:

$$R = \frac{\rho}{2\pi} \int_r^\infty \frac{dx}{x^2} = \frac{\rho}{2\pi r} \tag{3}$$

Where r is the electrode radius and x is destination from the center of the electrode The ground electrode is made up of concentric shell, all having the same thickness. A current flowing to earth must overcome not only the resistance of the earth, but also the resistance of the surrounding soil. Those shells closest to the ground electrode have the smallest amount of area resulting in the greatest degree of resistance. As current leaves the electrode, it spreads out, and as it travels farther from the electrode, the effective cross-sectional area of the soil through which it flows is increased

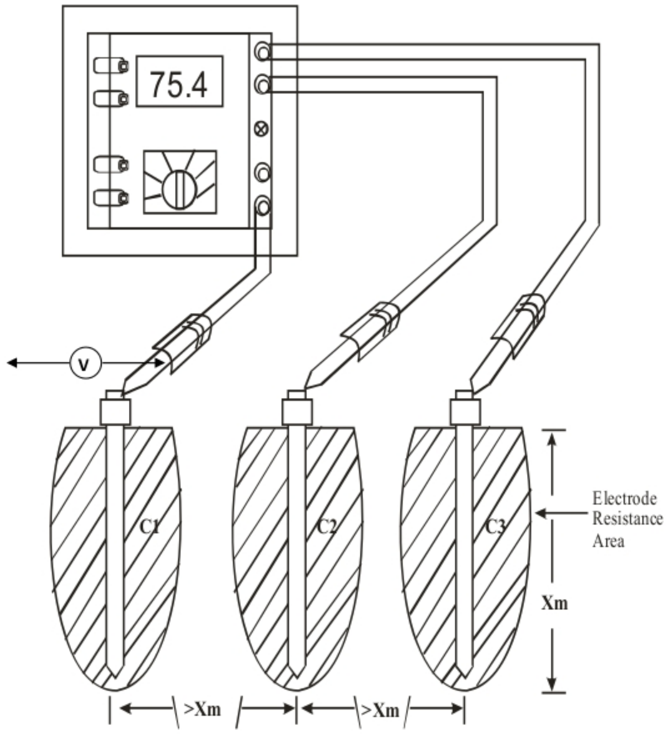
$$R = \rho L/A \tag{4}$$

Each subsequent shell incorporates a greater area, resulting in lower resistance. The overall effect is to produce a graded resistance which is concentrated mainly in the soil immediately surrounding the electrode. This finally reaches a point where the additional shells offer little resistance to the ground surrounding the electrode.

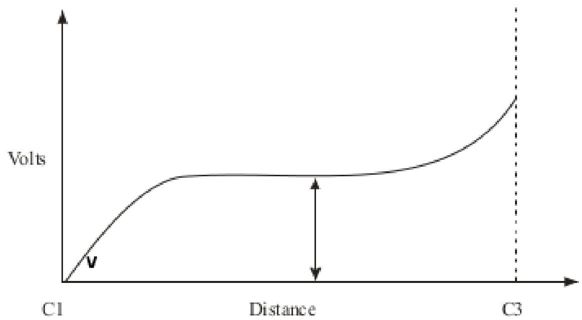
3. Earth Resistance Measurement

Test materials and equipment: To perform the earth resistance measurement, basic materials and equipment which the under listed items should be used. These include;

(a) Soil sample: Various samples of the soil collected for the test include - swampy soil, mixture of loamy and clay, mixture of sandy and clay, moist sandy, dry sandy and stony soil.
(b) Fluke 1625 was the equipment employed.
(c) While three earth rods were the materials employed during the testing activities.



(a) Setup for testing soil resistivity using the fluke 1625



(b) Voltage magnitude as C2 moves from C1 to C3

Figure 3:

3.1. Test procedure

Three earth electrodes which are usually hard drawn bare copper rods were driven vertically into the soil for a depth of about 2, 3, 6 and 10 meters in succession and spaced in a straight line at not less than three times the depth as shown in figure 3.

The spacing is to achieve the highest degree of accuracy as they are placed outside the sphere of each other's influence. If not, the effective area would overlap and invalidate the measurements. When the START button of the tester was pressed, a known current of about 200mA is generated by the fluke 1625 and injected between electrodes C_1 and C_3. The resulting potential difference between the earth electrode and general mass of Earth is measured between

Table 1: Test result.

Type of soil	Depth of electrode (m)	Ground Resistance (Ω)
Swampy	0.9	3
Clay	1.2	3.5
Moist Sandy	1.4	4
Dry Sandy	1.8	4.3
Stony	2.0	5

C_1 and C_2. By Ohm's laws

$$V = IR \tag{5}$$

hence known as 3-pole fall-of-potential test. The fluke tester automatically calculates the soil resistance which is the actual value of the ground under test. The test is used to measure the ability of an earth ground system or an individual electrode to dissipate energy from site. See figure 3a and figure 3b.

To confirm the accuracy of the result and to ensure that the electrodes are outside the sphere of their influence, reposition the inner electrode one meter left and right, and then take reading. Increase the distance between the outer electrodes until the measured values remain fairly constant. These tests were carried out in five power substations in Enugu metropolis. The power substations include Emene junction power substation which was swampy, Abakpa Nike power substation having clay soil, New Haven by lower Chime power substation that was moist sandy, Thinkers Corner Crescent power substation which has dry sandy and Uwani by Edozie power substation with stony soil.

4. Results and Discussion

Soil has key chemical characteristics. The surfaces of certain soil particles, particularly clay, hold groupings of atoms known as ions. These ions carry negative charges (anions) which attract positive ions (cations). The cations include those of calcium, magnesium and potassium. This is responsible for the good electrical conductivity of clay soil.

Geophysicists have determined from the effect of induce currents or geomagnetic variation that conductivity increases with depth in mantle. To obtain low resistance, hence good conductivity, different types of soil need different electrode depth. So type of soil and depth of earthing electrode influence the ground resistance.

Secondly, the diameter of earth electrode also affects the resistance but this was constant in all power substations visited.

Table 2: The existing test result with Megger tester.

Type of soil	Depth of electrode (m)	Ground Resistance (Ω)
Swampy	0.9	1.0
Clay	1.2	1.5
Moist Sandy	1.4	2.0
Dry Sandy	1.8	2.3
Stony	2.0	3.0

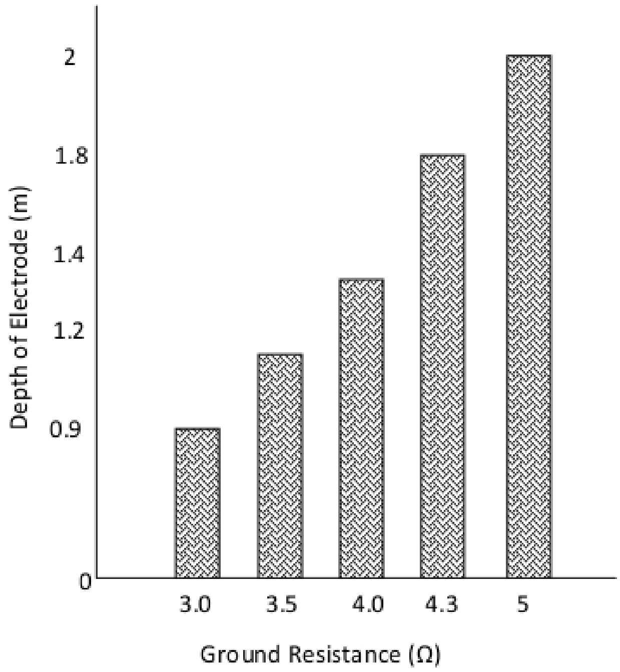


Figure 4: Histogram of test Result from fluke 1625 tester.

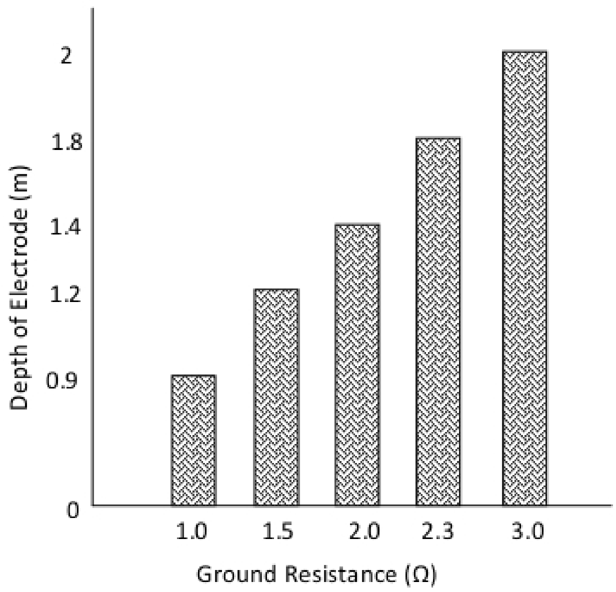


Figure 5: Histogram of the Result from Megger tester.

5. Conclusion

The most significant finding of the study is the relatively poor earthing in some power substations. This is as a result of the earthing method and arrangement adopted, emanating from ignorance of the factors that influence resistivity and the type of testing instrument used in the verification of proper earthing. As could be seen from the result, the convectional use of Megger for the impedance test is deceptive when compared to the use of fluke 1625 ground tester; hence Megger tester could lead to danger with the assumption that the resistance area is safe. To obtain low resistance path for fault current to meet the required Ohmic value as stated in electrical codes and regulation requirements, precautions should be taken at substation sites to guard against the effect of soil type, depth and diameter of earth electrode on earth resistivity. Fluke 1625 is a simple and direct equipment to measure and analyse ground resistances.

References

1. Barbara, H., Jim, C. *Measuring ground resistance.* Fluke corp. USA manual, June, 2006. http://www.fluke.com. Accessed on April 4, 2010.
2. Barbara, H., Jim, C. *What are the methods of earth ground testing.* Fluke Corp. USA manual, June, 2006. http://www.fluke.com. Accessed on April 4, 2010.
3. Olafuyi, A.O., Ikhuria, A.A and Akintola, S.A, Electrical Resistivity Measurement of Down-scaled Homogenous Rocks for Network Model Validation, Nigerian journal of Technology, Vol. 30, Number 2, June 2011
4. Weedy, B.M. *Electrical power system.* John willey and sons New York, 1977.
5. Wadhwa, C. L. *Electrical power system.* Wiley, Eastern New Delhi, 1983.
6. Nwankwo, F. A *Maintenance of power stations and transmission lines.* Proc. of the Workshop on Engineering Maintenance of Equipment and Infrastructure, organized by Nigerian Society of Engineers, Benin branch, 1988.
7. Francis, T.G. *Electrical installation work.* Longman Group Ltd., 5th Ed., 1971.
8. Idele, M. O. *Maintenance of electrical installation in buildings* Proceeding of Workshop on Engineering Maintenance of Equipment and Infrastructure, organized by Nigerian Society of Engineers, Benin branch, 1988.
9. Jon Davies. *Earth resistivity.* www.wikipedea.com. Accessed on April 5, 2010.
10. Young, A. H., Latimer, D.W.M. *Earthing arrangements and protective conductors.* Institute of Electrical Engineers, 15th Ed., 1981.
11. Henry k. Markiewicz and Antoni Klajn. *Earthing Systems - Fundamentals of Calculation and Design.* Submitted to Leonardo Power Quality Initiative (LPQI) board for European education and training programme supported by the European Commission, June 2003.