Soil Resistivity and Soil PH Profile Investigation: A Case Study of Delta State University Faculty of Engineering Complex

OYUBU A.O

ELECTRICAL/ELECTRONIC ENGINEERING DEPARTMENT, DELTA STATE UNIVERSITY,

ABRAKA, OLEH CAMPUS, NIGERIA.

Emal:akposweet@yahoo.com

Abstract: Electrical resistivity,the ground's potential to pass an electrical current, is utilised in designing grounding (earthing) system for buildings, substations or specialist plants, and for measuring the corrosion susceptibility of buried pipelines and other steel structures. Electrical resistivity is influenced by factors such as soil composition, moisture content, pore- water chemistry, presence of organic materials and chiefly soil pH. Therefore apart from the soil's resistivity, a knowledge of the soil's pH, a measure of the soil's acidity or alkalinity also becomes necessary in earthing system design. The Wenner four point method used for this investigation which was carried out on the Engineering Faculty complex of the Delta State University, Abraka, Oleh Campus was chosen over other methods because it helps overcome some of the problems associated with the requirement for knowing the electrical centre of the earthing system being tested. It employs four probes (stakes) digital earth resistance meter (Tester) such as Kewtech, Metrel, Metrohm, Seaward and Megger earth resistance meters (Testers) among others. Megger earth résistance meter (Tester) was used for this investigation.

Key Words: Resistivity, pH, Grounding, Wenner Four Point, Earth Resistance Meter.

—————————— ◆ ——————————

1. INTRODUCTION

Soil resistivity, a measure of the ground's capacity to pass an electrical current is very fundamental to designing earthing system-a system which provides safe connection between an electrical circuit and the ground for the dissipation of electrical faults, grounding lightning strikes and maintaining the correct operation of electrical equipment [1]

The correct design of an earthing system is dependent upon the knowledge of the local ground's resistivity. This is measured using many methods such as the Wenner four point method, Schlumberger Array, Driven rod (Fall of potential techniques) among others.

Determination of the local soil pH is also very essential to earthing system design, and other purposes ranging from soil corrosivity to agricultural practice. pH indicates the acidity or the alkalinity of a particular soil. Experimental evidences show that extremely high alkalinity lowers soil resistivity and increases soil corrosivity whereas mild alkalinity withstands corrosion for a longer time. Also, soils having a pH of 5 (acidic) or below can lead to extreme corrosion rates and premature pitting of metallic objects. A neutral pH of about 7 is most desirable to minimise the potential for damage and makes earthing Rods to withstand corrosion and carry out their protective functions on buildings/installations and appliances.

2. LITERATURE REVIEW.

2.1 pH

Soil PH is known as 'soil reaction', it is an indication of the acidity or alkalinity of the soil. Soil can have a wide range of acidity, reaching anywhere from 2.5 to 10. As pH level of 5 or below can lead to

ISSN 2229-5518

extreme corrosion rate and premature pitting of metallic objects, a neutral pH of about 7 is most desirable to minimise this potential for damage [2]

2.2 Resistivity

Soil resistivity is a critical factor in the design of earthing system. Resistivity indicates measures how much the soil resists the flow of electricity. Depending on moisture, temperature and chemical content, soil resistivity value can vary within wide ranges. Typical values are;

A. Usual values; from 1Ω-m to 100Ω-m.

B. Exceptional values; from 1 Ω-m to

10,000 Ω-m.

The electrical resistivity of soil may be measured with low frequency alternating current in which the current is applied at two locations and the potential difference (voltage) is measured between two points. Along this same method, direct current may be applied in lieu of an alternating current thus causing an induced polarisation in the subsurface features wherein the length of time the potential difference lasts after removing the current is noted for the purpose of identifying large surface conductors

2.3 Major concepts in measuring electrical resistivity of soil.

These basic concepts are employed when discussing the electrical resistivity of soil:

Resistance is the property of a conductor which opposes electric current flow when voltage is applied across the two ends. It unit of measure is the ohm (Ω) and the commonly used symbol is R. resistance is the ratio of the applied voltage (v) to the resulting current flow (I) defined by the well-known linear equation from ohm's law:

$$V = I \times R \quad (1)$$

Where:

V=Potential difference across the conductors (volts)

I= Current flowing through the conductors in (amperes)

R= Resistance of the conductors in (ohms)

"Good conductors" are those with a low resistance, "Bad conductors" are those with high resistance, "Very bad conductors" are known as insulators.

The resistance of a conductor depends on the atomic structure of the material or Resistivity (measured in ohm-m or Ω-m), which is the property of a material that measures it ability to conduct electricity. A material with a low resistivity will behave as a "good conductor" and one with a high resistivity will behave as a "bad conductor". The commonly used symbol for resistivity is 'ρ' (Greek symbol Rho) [3].

The resistance (R) of a conductor can be derived from the resistivity and vice versa as:

$$R = \rho \frac{L}{A} \quad (2)$$

$$\rho = R \frac{L}{A} \quad (3)$$

Where ρ = resistivity (Ω-m) of the material

L= length of the conductor

A= cross sectional area (m^2)

R= resistance of the material.

From the above equations, (2) & (3), resistivity (Ω-m) is the resistance between the opposite faces of a cubic material with a side dimension of 1metre.

Consequently, soil resistivity is the measure of the resistance between the opposite sides of a cube of soil with a side dimension of 1metre.Resistivity testing is therefore the process of measuring a volume of soil to determine the conductivity of soil [5]. The resulting resistivity is expressed in ohm-meter (Ω-m). Soil resistivity testing is the simple most critical factor in electrical grounding design. This is true when discussing simple electric design, to dedicated low resistance or grounding systems, or to the far more complex issue involved in grounding potential rise studies (GPR). Good soil models are the basics of all grounding designs and they are developed from accurate soil resistivity testing

2.4 Suitable location for testing electrical conductivity of soil.

Soil electrical resistivity testing should be conducted as close to the proposed grounding system as possible, taking into consideration the physical terms that may cause erroneous readings. There are two issues that may cause poor quality readings [2][3][4]:

1. Electrical interference causing unwanted signal noise to enter the meter
2. Metallic objects "short-cutting" the electrical path from probe to probe. The rule of thumb here is that a clearance equal to the stake spacing should be maintained between measurement traverse and any parallel buried metallic structures.
3. Testing in the vicinity of the site in question is obviously important; however it may not always be practicable. When left with no room or poor conditions in which to conduct a proper soil resistivity test, one should use the closet available open fields with a similar geographical soil conditions as possible.

2.5 Correlation between soil pH and soil resistivity.

The pH provides a general guide to the nature of possible corrosion. High alkalinity lowers soil resistivity and increases soil corrosivity. Acidic soils are corrosive, neutral soils are optimal.

From pH chart, soil resistivity greater than 100Ωm is slightly corrosive which indicates that buried length of earth rods will stay for a longer time before corrosion can occur. Same holds for other metallic materials buried within this region.

3. DESIGN METHODOLOGY

The design methodology employed in this work is broken into two sections. The first section deals with the measurement using the Wenner four point method, while the second section contains the soil pH profile measurement.

The Wenner four point method uses a 4-pole ground resistance meter and probes (stakes).For the resistivity test to be done the four probes must be inserted into the test area of the test site .In this work, the probes were inserted in a straight line and equally spaced. The probe, C1 was driven into the earth by the area to be measured, this area is designated point 0, then from that point, probes P1, P2 and C2 were driven into the earth at 5m spacing from each other (i.e. at 5m, 10m, 15m, respectively) from probe C1 in a straight line and at the same depth of 0.5m for all probes. It is instructive to note that while a known current is applied through the outer probes, C1 and C2, the resulting voltage is measured across the inner probes P1&P2.

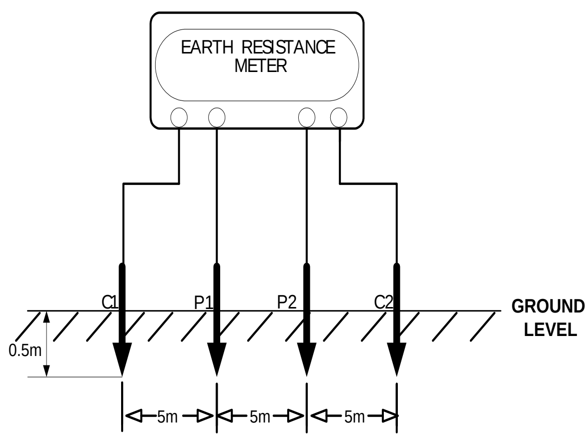

Figure 1.0: Connection for first Resistivity measurement at 5m spacing.

ISSN 2229-5518

Ohm's law is then applied to calculate the apparent resistance:

$$\mathbf{R} = \frac{V}{I} \quad (4)$$

The same procedure was used to calculate the apparent resistance for different spacing at different locations; each location testing was done at these spacing: 5m, 10m, 15m, 20m, 25m, and 30m.

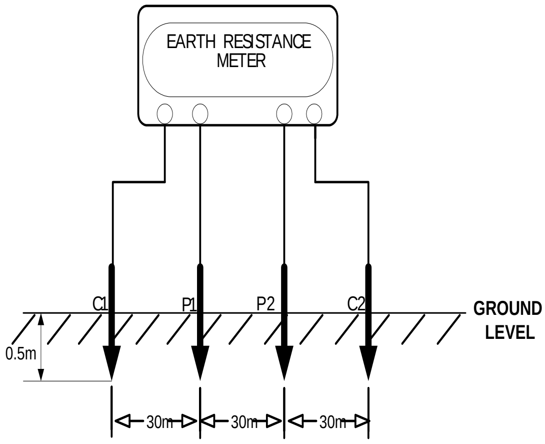

Figure 2.0: Connection for last Resistivity measurement at 30m spacing.

The second section of the methodology is devoted to the soil pH measurement which was done using a pH meter. A pH meter, an electronic device measures the pH (acidity& alkalinity) of a liquid (solution), and sometimes semisolid substance. Special measuring probes (a glass electrodes) connected to the (electronic) meter with digital readout were used for the measurement. For this work, the measurement of pH was done as outlined:

a. Loose soil samples were scoped with beakers from different test locations within the test site.
b. The clumps of soil were crushed and stones were excluded from the soil sample and kept in beakers.
c. The beakers containing soil were filled with distillers
d. Distilled water was added to the different soil samples and mixed with s spatula, shook vigorously and left for about 10 minutes to allow the salt in the soil to dissolve.
e. The pH scan electrode was dipped into the wet soil and the tester was turned on.

Readings were obtained for each sample after procedures a-e

4. RESULT

The results obtained from the investigation are presented in tables below. Table 1-4 shows the resistivity of different test locations within the test site, while tables 5&6 show the pH values of different test locations within the test site for top layer soil and subsoil respectively.

For the Wenner four point method, the resistivity is calculated from the probe spacing and resistance given by the equations (5) & (6) [3] [4] [5] [6].

$$\rho = 2\pi a \frac{\Delta V}{I} \quad (5)$$

$$\rho = 2\pi a R \quad (6)$$

Where ρ = resistivity in Ωm

a= Probe (stake) spacing (m)

ΔV= Voltage measured (volts)

I = Injected current (amps)

R = Measured resistance

TABLE 1
TEST LOCATION A

ISSN 2229-5518

Distance (m) Resistance (Ω) Resistivity (Ωm)

Distance (m)	Resistance (R)	Resistivity (Ωm)
5	8.69	273.04
10	7.49	470.67
15	9.38	602.32
20	4.38	550.48
25	4.19	658.25
30	2.52	475.07

TABLE 2
TEST LOCATION B.

Distance (m)	Resistance (Ω)	Resistivity (Ωm)
5	20.80	653.54
10	10.10	634.68
15	8.40	791.78
20	7.70	967.74
25	0.770	120.97
30	0.64	120.65

TABLE 3
TEST LOCATION C

Distance (m)	Resistance (Ω)	Resistivity (Ωm)
5	15.22	478.21
10	10.32	648.51
15	6.54	616.46
20	4.48	563.05
25	1.12	211.14
30	0.85	160.24

TABLE 4
TEST LOCATION D

TABLE 5
TOP SOIL PH FOR TEST LOCATIONS A-D

TABLE 6
SUB SOIL pH FOR TEST LOCATIONS A-D

Soil type: Subsoil		
Test location	**pH value**	**Nature**
A	**5.53**	**Strongly acidic**
B	**5.83**	**Moderately acidic**
C	**6.74**	**Neutral**
D	**6.44**	**Slightly acidic**

Soil type: Top soil		
Test location	**pH value**	**Nature**
A	**7.64**	**Mildly alkaline**
B	**6.22**	**Slightly acidic**
C	**7.11**	**Neutral**
D	**6.86**	**Neutral**

5. CONCLUSION.

As presented in the result (tables 1-4), the earth resistance has a direct relationship with the soil resistivity of the test location thus showing that the higher the soil resistivity, the higher will be the earth resistance value that can be obtained for any power system in that test location and vice versa. Since neither very low resistivity nor very high resistivity is good for human safety under power system fault conditions [7], establishing the values with a view of improving the resistivity is an imperative in the design of grounding system. The areas/ locations within the test site with high, medium and low resistivities within the test site have all been (empirically) known courtesy of this investigation; also areas with high, moderate and low acidity/ alkalinity have all been identified as well. The knowledge of the value of resistivity, acidity, alkalinity will not only help in designing the grounding system of the test site, it also gives an assurance that the earthing rods buried in the appropriate area/ location revealed by this papers will carry out their protective functions on the various building for a very long time without losing their quality to corrosion.

Conclusively, this investigation also depicts clearly how the Wenner four points method is used for Resistivity measurement.

REFERENCES

[1] Omar F.M (2012): Obtaining chemical properties through soil electrical resistivity http://journal.sapub.org/jce

[2] Hossein arbabi: corrosive soils, cause and mitigation. Testing engineers inc

[3] Earthing fundamentals: lighting and surge technologies

[4] www.esgroundingsolutions.com/what is soil resistivity testing

[5] http://hurricane193.wordpress/.../wenner- four-pin-method-for-soil-resistivity test

[6] R.D Southey & F.P Dawalibic (2005): Improving the reliability of power systems with more accurate grounding systems resistance estimates. Safe engineering services and technologies

[7] Dwarka. P and sharma H.C (2012): soil resistivity and earthing system