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Seasonal and Temperature Variation of Soil in Port Harcourt City and Planting Depth of Electrodes

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ABSTRACT: *The aim of the research is to study the seasonal Variation and Temperature of the soil to effectively determine the best electrode performance in Port Harcourt city. Seven sites were chosen and at depths of 0.8m, 1.5m, 2.5m and 3.0m, tests were carried out for five months of the year. These months were within the peak and transitional periods of the rain and dry seasons. The temperature variations were also determined at four different depths (0.2, 0.5m, 0.8m and 1.0m) for February and September for two sites. From the results the permanent moisture table was within 2.5m to 3.0 meters and at 0.8 meterthe temperature effect was normal. It could then be concluded that any electrode planted to a depth of 2.5meter will give a satisfactory performance and may not require artificial treatment of soil.*

KEYWORDS -Permanent Moisture table, temperature variation, electrode depth, soil resistivity, signal ground

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I. INTRODUCTION

The strategic position of Port Harcourt in the Niger Delta region has made the city one of the fastest growing cities in Nigeria. The presence of the oil companies has attracted several small and medium scale industries. All small, medium or large-scale companies require the use of electricity and electrical equipment's, therefore require proper and safe earthing system. The electrical, electronics and Telecommunication industries require various grounding method, therefore it is necessary to study the seasonal variation and temperature effect on the grounding systems for effective performance. Resistivity is an expression of all the physio-chemical properties of soil and depends on the physical composition of the soil, moisture content, dissolved salts, seasonal variation, current magnitude and soil temperature. Different soil compositions have different average resistivity but moisture has great influence on the resistivity value of soil Earthing forms an intrinsic part of the electricity system but it still remains in general a misunderstood subject, even sometimes by well qualified engineers. In recent years there have been rapid developments in the modelling of earthing systems at power frequencies and higher, mainly facilitated by computer hardware and software [1,2]. This has increased our understanding of the subject at the same time that the design task has become significantly more difficult and emerging standards are requiring a more detailed, safer design. There is thus an opportunity to explain earthing concepts more clearly and a need for this to beconveyed to earthing system designers and installers so that a greater understanding may be gained. Earth may be defined generally as the reference point in an electrical circuit from which other voltages are measured and also a common return path for electric current or a direct physical connection to the earth. Sometimes earth (ground system) can be described as a conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth or some conducting body of relatively large extent that serves in place of the earth mass [3,4]. Earthing systems typically fall into (but not limited to) one of the following categories [4, 5]. (i) Power Generation, transmission and distribution, (ii) Lightning protection, (iii) control of undesirable static electricity and Telecommunications.

The paper is organized as follow; section 2 gives an overview of power system earthing. The section also discussed the thermal heating in soil and soil ionization while section 3 looks at the ground signal. The methodology used in the investigation is presented in section while the result and discussion are presented in section 5.

II. POWER SYSTEM EARTHNING

In power system wiring, earthing is to connect with an electrical earth point of an equipmentto the earth electrode. By connecting the cases of electrical equipment to earth, any insulation failure will result in current flowing to ground that would otherwise energize the case of the equipment. A proper bonding to earth will result in the circuit over current protection operating to de-energize the faulty circuit. A power ground serves to provide a return path form faulty currents and therefore allows a fuse or breaker to disconnect the circuit [6, 7].

A particular concern in design of electrical substation is earth potential rise. When very large fault currents are injected into the earth, the area around the point of injection may rise to a high potential with respect to distance points. This is due to the limited finite conductivity of the layer of soil in the earth. The gradient of the voltage may be so high that two points on the ground may be at significantly different potential, creating a hazard to anyone standing on the ground in the area. That is why in substation design the touch voltage, step voltage and the grid potential rise are of great importance [8, 9]. If the person's weight is expected to be at least 70kg the interval tolerable step and touch voltages can be computed as

$$E_{step} = \frac{0.157(1000+6C_s\rho_s)}{\sqrt{t_1}} \quad (1)$$

$$E_{step} = \frac{0.157(1000+1.5C_s\rho_s)}{\sqrt{t_1}} \quad (2)$$

Where ρs is the interval crushed rock wet resistivity, Cs is the reduction factor and can be approximated as

$$C_s = \frac{(\frac{\rho_s - \rho}{\rho_s})}{2h_2+0.09} \quad (3)$$

It is necessary to compute the interval ground potential rise (GPR) to the interval tolerable voltage E_{touch}. GPR is calculated as GPR = $I_G R_g$.The interval Mesh voltage E_m is

$$E_m = \frac{\rho I_g K_m K_i}{L_c+[1.55+1.22\left(\frac{L_r}{L_x^2+L_y^2}\right)]L_R} \quad (4)$$

Where, L_c is the total length of the conductor in the horizontal grid. $L_r$is the length of ground rod at each location L_R is the total length of ground rods, L_x and L_y are lengths of the substation respectively. K_i is the correction factor for grid geometry. Km is the spacing factor for mesh voltage.

Some HVDC power transmission systems use the ground as second conductor. This is especially common in schemes with submarine cables as sea water is a good conductor. Buried grounding electrodes are used to make the connection to the earth. Direct and Indirect lightning stroke could produce undesirable effect as well as unwanted electromagnetic interference among electrical and electronic systems, hence require effective earthing. High pulse transient current can cause the electrical field on the surface of the electrode to overcome the electric field in the soil, thus ionization occurs and the conductive plasma paths locally grow. In the soil zone affected by ionization, the value of the conductivity considerably increases with respect to its value obtained with low magnitude and frequency input. Thus, it is extremely useful to take into consideration the real soil behavior during the breakdown phenomenon, in order to correctly design the earth electrodes. The non-linear effect due to soil ionization could be described to be due to the ionization process and some other thermal processes.

2.1 Thermal Heating in Soil

In this process, the current is conducted by water filled paths. Due to heating in the soil, the temperature of the water increases which increases the conductivity and reduces the resistivity of the bulk soil. Thus, there is an increase in current magnitude and a relative reduction in resistance. The thermal process in soil could also be enhanced by ionic conduction depending on the amount of water, type of salts and composition that exists in the soil.

2.2 Soil Ionization

Numerous tests [2, 10] have been conducted to suggest that the measured non-linear conduction and breakdown phenomena are the consequences of soil ionization. The mechanism was often described as being due to field enhancement in voids enclosed within the soil. Due to the large dielectric difference between wet soil and air voids, it would therefore be possible for electric field inside the air voids to be enhanced and under high enough fields, the ionization process in air voids would occur.

III. SIGNAL GROUND

An electrical connection to earth can be used as a reference potential for radio frequency signals for certain kinds of antennas. The part directly in contact with the earth (the earth electrode) can be as simple as a metal rod or stake driven into the earth or a connection to buried metals. Because high frequency signals can flow to earth through capacitance, capacitance to ground is an important factor in effectiveness of signal grounds. An ideal signal ground maintains zero voltage regardless of how much of electrical current flows into ground or out of ground. The resistance at the signal frequency of the electrode to earth connection determines its quality and that quality is improved by increasing the surface area of the electrode in contact with the earth, increasing the depth to which it is driven, using several connected ground rods, increasing the moisture of the soil, improving the conductive mineral content of the soil, and increasing the land area covered by the ground system. In television stations, recording studios and other installations where sound quality is critical, a special signal ground known as a technical ground is often installed to prevent ground loops. This is basically the same thing as an a.c power ground but no appliance ground wires are allowed any connection to it, as they may carry electrical interference. In most cases, the studios metal equipment racks are joined together with heavy copper cables (busbars) and similar connections are made to the technical ground [11, 12]. The study therefore will enable earth system designers, installation engineers to have available records of earth parameters in this growing city so that safe and reliable earth system could be provided.

IV. METHODOLOGY

In order to determine the seasonal and temperature variation in Port Harcourt, the city was divided into seven zones. In each of the zones two tests were carried out on the resistivity at the depths of 0.8m, 1.5m, 2.5m and 3.0 meters. These tests were done during the months of February, April, June, September and December. This was an ongoing project but the measurements were concluded in December 2015. The periods (months) reflect the dry seasons, rainy season and the close of the dry and harmattan seasons. The temperature of the soil was also measured at depths of 0.2m, 0.5m, 0.8m and 1.2m for the same months and at the same areas.

The four-point measuring instrument (Wenner Method) was used for the resistivity measurements. Due to the different planting depth the spacing of electrodes also varies. Current terminal was connected to the outer electrodes C1 and C2, while the voltage terminals were connected to V1 and V2 as shown in Fig. 1

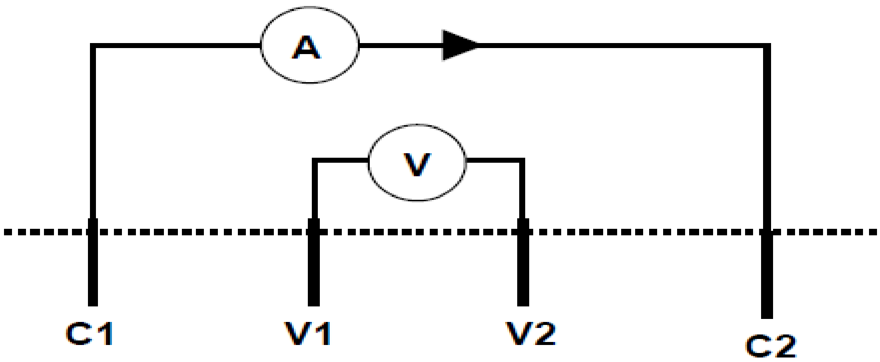

Fig. 1: Four-point measuring instrument method (Wenner Method)

The ratio of the measured potential to the calculated current for the given spacing is known as the apparent resistivity value. If b is much less than D (b<<D), the resistivity can be calculated as

$$\rho=2\pi DR \qquad (5)$$

Where ρ = soil resistivity in ohm-m, D = Distance between two successful electrodes, R = the value of a V / I in ohms.

V. RESULT AND DISCUSSION

The results of the measurements for soil resistivity for the seven zones are presented in Table 1. For the purpose of analysis, (U.S.T/ Diobu) and G.R.A areas were selected. The reason was that the soil formation is the same with the same topography except in few hilly and depressed areas which is localized to such areas. These results for the analysis are shown in Table 2a and Table 2b. The temperature variation results are shown in Table 3. The geological and the meteorological factors have considerable influence on soil resistivity. The dominant soil type is clayey soil and has flat plane in most part of Port Harcourt and its environs. That is why soil performance in one area can describe soil in several other areas in Port Harcourt. The only exceptions are some depressed areas and where river canals cut into the land. Such areas are swampy and ponds after prolonged heavy rains. Other areas are those reclaimed swampy areas in some part of the city.From records in Table 2 (a and b), the coefficient of seasonal variation at topsoil was between4-6 during the dry and the harmattan seasons, but at a depth of 2.5 to 3 meters the soil resistivity was low for every season indicating a permanent moisture level at that depth. Moisture content of soil has the greatest effect on resistivity especially in porous and permeable soil. The resistivity of the soil reduced during the rainy seasons having a coefficient of seasonal variation of about 2-2.5 [13]. When rain falls in the area, some will pond, and some will run off into local surface drainage streams, others may be to natural or artificial drainage, only the remainder will linger long enough to significantly affect electrical resistivity of the soil.

From the table of Fig. 2, the resistance was lowest during September because of the prolonged period of rain on the land. In the GRA site, the resistivity of the soil is lower than any other area (site) because of the topography of the area. The soil resistivity reduced drastically after the first rain. The reason was that the soil has a high-water acceptance potential, that is, the few months of the rain was enough to make part of the soil saturated especially those areas that are swampy.Temperature affects the topsoil up to 0.5-meter depth, during the dry and the harmattan periods. This is due to the drying of the topsoil and may even bake due to prolonged hot seasons. At a depth of 0.2 to 0.5 meters the temperature was higher than the ambient temperature. The values are shown in table 3. At a depth of about 0.8 the temperature effect reduces and become lower than the ambient temperature at a depth of 1.0 meters. During the rainy seasons the temperature of the soil is always lower than the ambient temperature.

Table 1: Resistivity Values at Different Depth in Port Harcourt

Month	**Depth**	**Zone 1**		**Zone 2**		**Zone 3**		**Zone 4**		**Zone 5**
		Borokiri/ Ndoki		**U.S.T/Diobu**		**Trans-Amadi Ind. Layout**		**GRA Phase1**		**Mile 4**
Site		**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
February	0.8	573	610	672	630	812	750	420	621	740
	1.5	350	310	402	390	451	432	298	330	400
	2.5	152	120	130	140	130	125	120	130	150
	3.0	60	55	45	56	60	61	61	68	70
April	0.8	440	450	460	400	420	400	360	390	400
	1.5	220	230	261	225	200	210	200	210	202
	2.5	102	95	90	98	105	95	87	90	85
	3.0	52	48	45	50	48	50	52	48	48
June	0.8	280	320	330	315	340	340	205	300	325
	1.5	120	130	140	110	130	140	95	125	130
	2.5	90	95	101	100	95	110	95	98	100
	3.0	60	52	48	45	48	50	48	40	42
September	0.8	200	215	200	211	200	190	180	195	190
	1.5	90	95	100	110	95	91	85	89	85
	2.5	48	52	45	48	40	42	40	40	40
	3.0	40	42	38	40	35	36	35	36	34
December	0.8	324	510	480	500	528	508	320	480	450
	1.5	260	280	210	220	230	215	210	210	230
	2.5	110	120	100	101	100	105	105	115	115
	3.0	50	55	48	48	44	45	48	48	48

	Zone 6		Zone 7	
	Choba		**Eliozu**	
B	**A**	**B**	**A**	**B**
615	702	660	756	670
365	430	402	440	410
135	160	140	165	150
63	72	65	65	65
400	420	405	390	405
251	260	240	211	215
92	98	95	90	93
92	55	52	48	50
311	350	335	290	311
125	108	135	120	120
95	91	92	90	95
48	52	44	40	45
180	185	200	180	190
90	92	92	90	90
45	48	50	48	90
37	40	41	42	40
480	515	520	490	512
220	240	250	220	210
105	120	110	112	105
45	51	48	46	44

Table 2a: Resistivity value for U.S.T / Diobu Site

Dept of Elect.	**Febuary**	**April**	**June**	**September**	**December.**	**Coefficient of Soil Variation**
0.8	672	440	380	105	524	6.4
1.5	410	220	120	87	260	4.7
2.5	130	95	95	48	110	2.7
3.0	50	48	46	40	50	1.5

Table 2b: Resistivity value for G. R. A. Site

Dept of Elect.	**Febuary**	**April**	**June**	**September**	**December.**	**Coefficient of Soil Variation**
0.8	420	360	205	180	320	4.3
1.5	298	200	195	85	210	3.5
2.5	120	87	95	40	105	3.0
3.0	61	52	48	35	48	1.7

Table 3: Temperature variation of different soil depth

Temperature in ^oC				
Depth of meter	**February**	**September**	**February**	**September**
0.2	48	27	42	26
0.5	45	26	39	26
0.8	28	24	28	24
1.2	26	22	25	22
Amb. Temp.	35	35	33	27
Humidity Hg	65	79	69	79

VI. CONCLUSION

Soil resistivity is not only a useful measurable that reflects subsurface structure but also a basic parameter to the design of effective ground and lightning prevention and or protection system. of several parameters that control soil resistivity (porosity, permeability, mineralization of soil, fraction, ionic content and temperature of pore fluids), only water content and temperature of soil may vary in measurable time scales. The resistivity of the upper layer significantly varied from one point to another, probably reflecting differences in water content in the soil layer due to local topography and drainage. It is necessary therefore to carryout resistivity tests on project sites before undertaking an installation work. Such local measurement will enable the installer the true situation that will provide a better working data. As much as possible the figures given in the tables are true values of the conditions of the soil both in the dry and wet seasons.

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