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Earth Resistivity Determination and its Importance in Constructing Electric Power Substation

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ABSTRACT

Earth resistivity of electrical substations in Enugu State was investigated. From the resulted obtained, it was observed that New Heaven transmission substation in Enugu State had a low resistivity value than that of Emene, Enugu Substation. This shows that the electrical installations were installed in areas of low resistivity which is a major factor in choosing the site for building substations. The earth is used to conduct fault current when there are ground faults on the systems. Hence proper earth resistivity test needs to be carried out before installation of electrical substation to reduce danger in case of fault and lightning.

Keywords: substation, resistivity, electrical power installation, electrodes, earthing.

INTRODUCTION

Resistance is the property of a conductor which opposes the flow of electron when a voltage is applied across the two ends [1, 2, 3, 4, 5, 6]. The resistance of a conductor depends on the atomic structure of the material or its resistivity. The resistivity of a material measures its ability to conduct electricity. Therefore materials with a low resistivity is behaves as a good conductor while one with low resistivity behaves like bad conductor. Then those materials that have extremely high resistivity are often regarded as insulators. Hence earth resistivity is the resistance of the earth to conduct electricity [1, 2, 3, 4, 5, 7].

Earth resistivity of ground medium, which is the inverse of conductivity of the earth, is of prime importance in citing high voltage direct current ground electrodes on the ground [5,8]. Earth resistivity does not have a constant value throughout a particular area, but varies widely in lateral directions as well as showing large and abrupt changes in the vertically distinct strata. Therefore, it is important in the investigation of site for ground electrodes for accurate data to be obtained for adequate evaluation of sites before installation of substation. Electrodes are used for earthing system, which is a general

connection to general mass of earth in such a manner as to ensure an immediate discharge of electrical energy to the earth without danger. The earth electrodes are generally classified into two main classes: natural electrodes and artificial electrodes [6, 7, 8, 9, 10, 11].

NATURAL ELECTRODES

These are the electrodes that are not meant for the purpose of conducting current away from the earth. These natural electrodes comprise of water pipes, framework of buildings, and cable for armoring. The water pipe earth is the most commonly used in circulating water in the power stations. For earthing houses and building installation, water pipe systems are often used. These electrodes have a low resistance which is electrically satisfactory. The disadvantages of these electrodes are that they break down when repair or maintenance are carried out in a distribution substation [6, 7, 8, 9, 10, 11, 12, 13].

ARTIFICIAL ELECTRODES

These are electrodes that are used in earthing systems which conduct current away from the earth and they are specifically designed for function. They include copper, steel rod, solid section wire and earth rod. Electrically, a good earth rod should have a low intrinsic resistance and are to be of sufficient section to carry high currents without damage.For earth resistivity measurement, the voltage of the driven rod and the buried electrode should be considered.

VOLTAGE OF A DRIVEN ROD

From the first principle, resistivity is given as $\rho = 2\pi ar$ [4, 6, 7, 8, 9, 10, 11].

But $R = \frac{\rho}{2\pi}(ln\frac{4l}{a} - 1)\Omega$

But $V = IR$

$\therefore V = I.\frac{\rho}{2\pi}(ln\frac{4l}{a} - 1)$

Where the equivalent radius of a hemisphere is given as

$r = (ln\frac{\frac{1}{4l}}{a} - 1 \quad , \quad l = the\ driven\ length\ of\ rod, a = the\ radius\ of\ the\ rod, \rho = resistivity\ of\ the\ soil, I = circulating\ current$

RESULTS

The data obtained in earth resistivity for vertical and horizontal measurements in New Heaven, Enugu Transmission sub-station for wet state were presented in Tables1 and 2.

Table 1: Earth resistivity vertical measurement at Emene Enugu State Sub-Station during wet season

Spacing a(m)	Depth d(m)	Current (mA)	Voltage (volts)	Resistance (Ω)	Resistivity (Ωm)
15	0.5	7.7	5.0	650	458.0
15	0.7	7.8	4.8	615	462.7
15	0.9	7.9	4.6	580	649.6
15	1.2	8.3	4.5	542	765.6
15	1.5	8.9	4.5	502	845.2
20	0.5	8.0	5.2	650	458.0
20	0.7	8.3	5.0	602	551.8
20	0.9	8.7	5.0	574	550.0
20	1.2	9.2	4.8	520	740.1
20	1.5	9.6	4.8	500	847.6
25	0.5	10.2	4.6	450	320.9
25	0.7	10.2	4.4	430	394.0
25	0.9	10.2	4.2	410	459.2
25	1.2	10.3	4.0	390	551.0
25	1.5	10.3	4.0	384	644.2

Table 2: Earth resistivity horizontal measurement at Emene Enugu State Sub-Station during wet season

Spacing a(m)	Depth d(m)	Current (mA)	Voltage (volts)	Resistance (Ω)	Resistivity (Ωm)
10	0.5	7.5	5.0	666	475.7
15	0.5	7.7	5.0	652	465.7
20	0.5	8.0	5.2	650	464.3
25	0.5	10.2	4.6	625	321.4
10	0.7	8.0	5.0	615	570.3
15	0.7	7.8	4.8	600	563.7
20	0.7	8.3	5.0	430	550.0
25	0.7	10.2	4.4	600	494.2
10	0.9	8.3	5.0	580	678.8
15	0.9	7.9	4.6	575	658.3
20	0.9	8.7	5.0	410	650.6
25	0.9	10.2	4.2	575	464.0
10	1.2	8.9	5.0	562	796.9
15	1.2	8.3	4.5	542	768.6
20	1.2	9.2	4.8	520	740.1
25	1.2	10.3	4.0	400	569.3

Table 3: Earth resistivity vertical measurement at New Heaven Enugu State Sub-Station during wet season

Spacing a(m)	Depth d(m)	Current (mA)	Voltage (volts)	Resistance (Ω)	Resistivity (Ωm)
15	0.5	14.9	5.0	335	240.0
15	0.7	15.2	4.8	315	288.8
15	0.9	15.1	4.6	304	343.9
15	1.2	15.5	4.5	290	412.7
15	1.5	15.9	4.3	270	454.6
20	0.5	17.0	5.1	300	214.3
20	0.7	16.1	4.8	298	273.2
20	0.9	16.8	4.7	280	316.8
20	1.2	18.3	4.6	250	356.0
20	1.5	19.6	4.5	230	387.3
25	0.5	17.3	5.2	300	214.3
25	0.7	18.5	5.0	270	247.5
25	0.9	19.2	4.8	250	282.8
25	1.2	22.9	4.7	205	290.7
25	1.5	21.5	4.3	200	336.8

Table 4: Earth resistivity horizontal measurement at New Heaven Enugu State Sub-Station during dry season

Spacing a(m)	Depth d(m)	Current (mA)	Voltage (volts)	Resistance (Ω)	Resistivity (Ωm)
10	0.5	7.5	5.0	666	475.7
15	0.5	7.7	5.0	652	465.7
20	0.5	8.0	5.2	650	464.3
25	0.5	10.2	4.6	450	321.4
10	0.7	8.0	5.0	625	570.3
15	0.7	7.8	4.8	615	563.7
20	0.7	8.3	5.0	600	550.0

25	0.7	10.2	4.4	430	494.2
10	0.9	8.3	5.0	600	678.8
15	0.9	7.9	4.6	580	656.3
20	0.9	8.7	5.0	575	650.6
25	0.9	10.2	4.2	410	464.0
10	1.2	8.9	5.0	562	796.9
15	1.2	8.3	4.5	542	768.6
20	1.2	9.2	4.8	520	740.1
25	1.2	10.3	4.0	400	569.3

DISCUSSION

From table 3 and 4, it was observed that New Heaven substation has better earth resistivity than what was obtained in Emene Enugu substation hence offers better protection in the case of faults. Proper earth resistivity with good earthing helps to save human life from danger of electrical shock or death, protect buildings, machinery & appliances under fault conditions, maintain the voltage of any part of an electrical system so as to prevent over current or excessive voltage on appliances or equipment; prevents over voltage to electrical distribution as a result of lightning and surges and finally helps in voltage stabilization.

Therefore, earth resistivity is a major factor in design of electrical substations and the knowledge of how it varies with the depth of the soil is very important in designing the grounding system in the substation or lightning conductors. This is needed for design of grounding (i.e. earthing) electrodes for substations and high voltage direct current transmission systems. The earth is used to conduct fault current when there are ground faults on the systems. Hence proper earth resistivity test needs to be carried out before installation of electrical substation.

CONCLUSION

Proper earth resistivity determination is necessary and needs to be carried out before installation of electrical substations in Nigeria. This will help to save a lot of damages and life that will result in case of faults in the system.

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