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Soil Resistivity Measurements In Rwanda For Safety Grounding System

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Abstract

Rwanda has experienced many damages for many years, including life losses, severe and minor injuries of humans, animals and infrastructure due to lightning strikes. According to the Rwanda Ministry of Disaster Management and Refugee Affairs (MIDIMAR) statistical records from 2011 to 2015 and NASA satellites records, have classified Rwanda among the top high risk regions affected by lightning strikes, hence there is a need to mitigate the effects of lightning strikes. One of the best ways to protect lightening strikes is to have high quality grounding. The soil resistivity is one of the key factors that influence the performance of a grounding electrical installation. In this

work, we used Four-point measurement method to measure the soil resistivity. Using this method, ground resistance measurements in four provinces out of five of Rwanda were measured and data recorded where their corresponding soil resistivity values were calculated. The measured, calculated and recorded data may be used by different institutions in the design and implementation of their lightning protection systems in the country.

Keywords: Soil resistivity, Grounding, Lightning hazards

1. INTRODUCTION

Rwanda has high lighting frequency as indicated in the table below, hence a high need of proper grounding for safety. With satellites, NASA researchers have discovered that more than 1 200 000 000 (1.2 billions) lightning flashes occur annually throughout the world. Their Optical Transient Detector (OTD) measurement has shown Rwanda to be having the highest number of flashes per square kilometer [6].
The Rwanda Ministry of Disaster Management and Refugee Affairs (MIDIMAR) reports show that since 2011, due to lightning strikes, above 250 people have been injured and about 180 people have been killed. In 2015, leaving alone the loss of farm animals, infrastructures and properties, above 12 people were killed [5]. The resistance of an earth electrode is strongly dependent on the resistance of the surrounding soil in which is inserted. During grounding installation design, it is very important to calculate soil resistivity, which is a very crucial parameter [2]. Therefore, in this paper, a four-point measurement method is used, as for most applications it is considered to be the most accurate method [3].

Table 1: Optical Transient Detector (OTD), Mean Annual Flash Density: Africa [1]

Rank	Place name	(OTD), flash $km^{-2}yr^{-1}$	Latitude (N)	Longitude (E)	Thunder days
1	Kamembe, Rwanda	82.7	−1.25°	27.75°	221
2	Boende, Dem. Rep. Congo	66.3	0.25°	20.75°	118
3	Lusambo, Dem. Rep. Congo	52.1	−4.75°	24.25°	119
4	Kananga, Dem. Rep. Congo	50.3	−5.75°	18.75°	139
5	Calabar, Nigeria	47.4	5.25°	9.25°	216
6	Franceville, Gabon	47.1	−2.25°	14.25°	-
7	Miandrivazo, Madagascar	35.9	−19.25°	45.75°	146
8	Mamfe, Camaroon	35.6	5.7°	8.3°	201
9	Kindia, Guinea	35	10.75°	−12.75°	111
10	Bahar Dar, Ethiopia	33.1	12.25°	36.75°	-
11	Ouanda Djalle, Central African Republic	31.5	8.25°	22.25°	-
12	Macenta, Guinea	31.4	8.25°	−10.25°	151
13	Jos, Nigeria	29.4	9.25°	8.25°	139
14	Kumasi, Ghana	26.1	6.25°	−1.25°	157
15	Entebbe, Uganda	23.4	0.0°	32.6°	206
16	Sikasso, Mali	23	10.75°	−5.75°	123
17	Bloemfontein, South Africa	23	−29.75°	28.75°	60

Changes in earth resistivity don't only result from soil type but also from changes in temperature, level of compactness, moisture and salt concentration. The values of earth resistivity changes up to 10^9 Ω.m for sandstone and from 0.01 to 1 Ω.m for sea water. Decreasing slowly temperatures from 25°C increases the Earth resistivity, whereas resistivity increases rapidly for temperatures below 0^oC [4].

2. PROPOSED METHODOLOGY

Resistivity measurement methods are of different types among which ***4-point methods*** is used in most applications and considered to be the most accurate method [3]. Hence in this research we used four-point method.

2.1 Four-point Method Measurements

The 4-point method is the method that was used during this research measurements exercise. As the name implies, it requires the insertion of four equally spaced and in-line electrodes into the test area. A known constant current generator is passed between the outer electrodes. The potential drop (a function of resistance) is then measured across the two inner electrodes. The instrument used is calibrated to read directly in ohms.

2.1.1 Used Formula (Wenner formula)[7].

$\rho = 4\pi AR$

Where :

ρ = soil resistivity (Ω.cm)

π = Is a constant equal to 3.1414

B= electrode depth in centimetre

R= direct resistance read on the instrument in ohms (Ω)

A = distance between two electrodes in cm. ρ= 2πAR (with A in cm).

The value ρ= 2πAR is the average resistivity of the ground at a depth equivalent to the distance **A** between two electrodes. The distance **A** between the electrodes must then be equivalent to the depth at which average resistivity is to be determined. Using Wenner formula, the more simplified formula (ρ= 2πAR), the electrode depth must be 1/20 th of the electrode spacing.

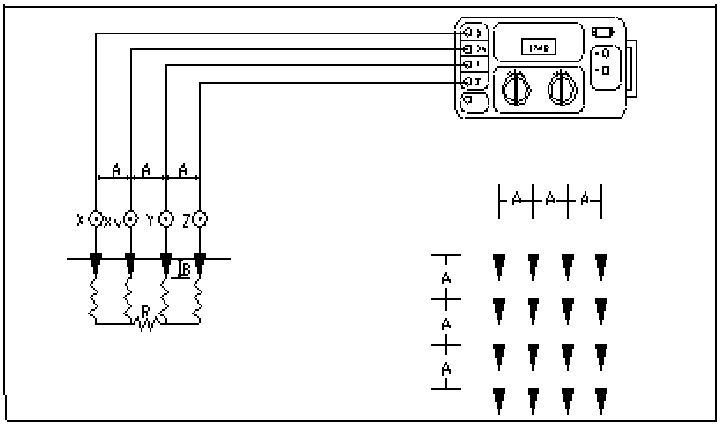


Figure 1: Soil resistivity measurement (Four point measurement)

2.2. Positioning The Auxiliary Electrodes While Taking Measurements.

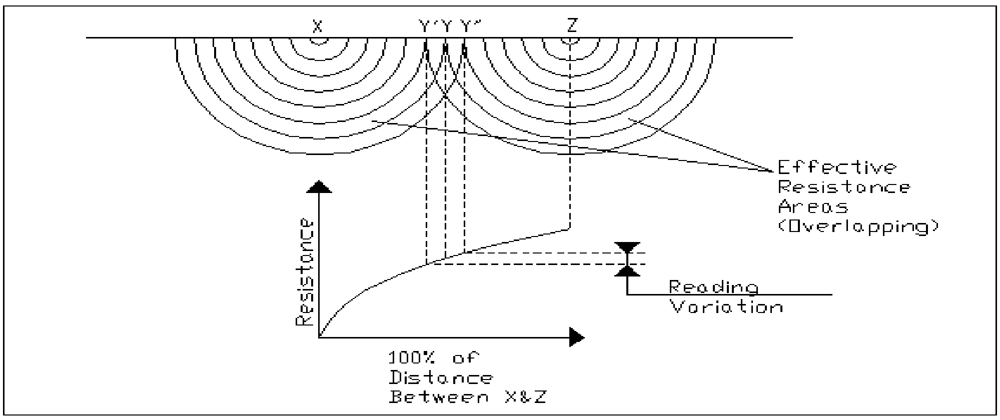
Explaining the figure below, illustrating Rod spacing when taking measurements, the distances between rods should be carefully determined.

While measuring the resistance to ground, the auxiliary current electrode **Z** should be placed further enough from the ground electrode X under test. This will result into auxiliary potential electrode **Y** to remain outside of the resistance areas of both the auxiliary current electrode Z and the ground electrode X.

In this measurement process, we should avoid measuring the resistance to the ground when sensitive areas overlap. If we take any measurement when sensitive areas are overlapping, the measurement reading will be erroneous [7].

3. MEASUREMENTS RESULTS

The following table represents the ground resistance measurements for different regions of the country, from which their corresponding soil resistivity values were calculated.



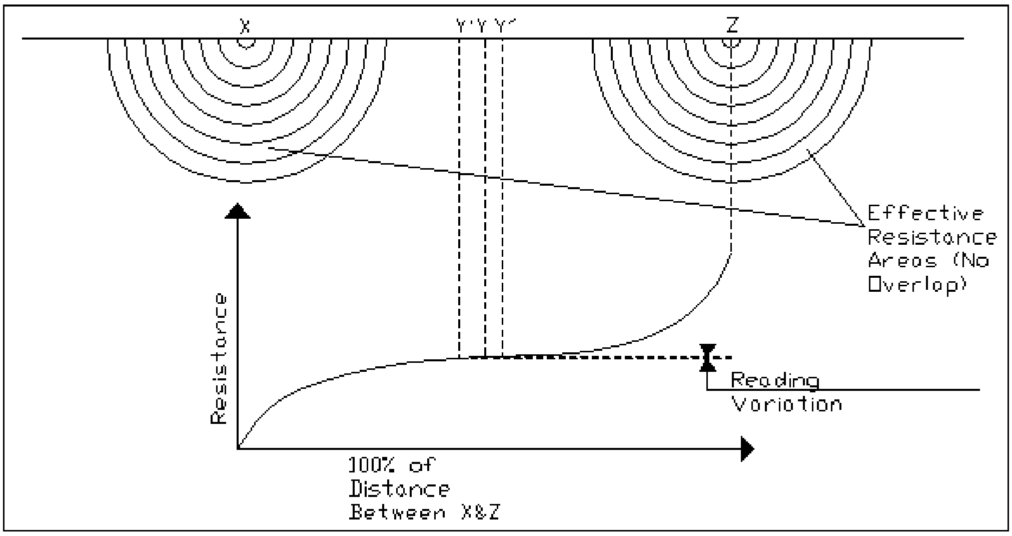
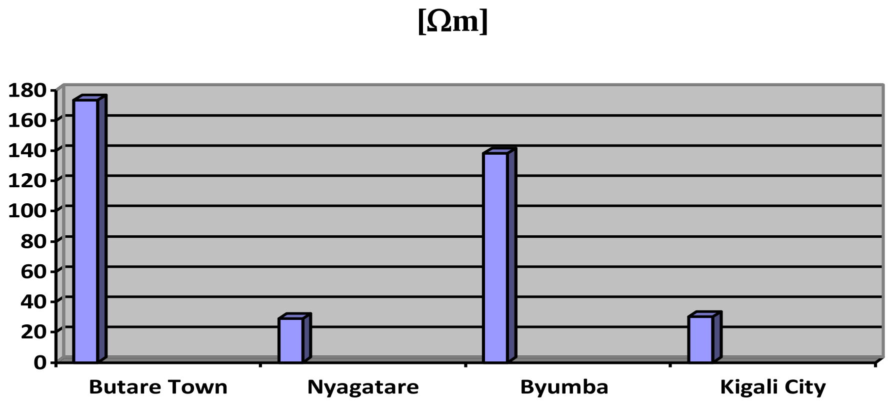


Figure 2: Rod spacing

Table 2: Soil Resistivity Measurements

	SITES	Distance A [in m]	Resistance R [in Ω]	ρ=2πAR [in Ωm]
1	***Butare Town***	20	1,38	173,41
2	***Nyagatare***	20	0.23	28.9
3	***Byumba***	20	1.1	138.23
4	***Kigali City***	20	0.24	30.15



Graph 1: Representation for Soil Resistivity Measurements

4. CONCLUSION

The measured, calculated and recorded data may be used by different institutions in the design and implementation of their lightning protection systems in the country.

Due to the fact that different areas are having different grounding resistivity, National Installation practices should consider grounding resistivity variations while practicing grounding.

REFERENCES

[1]. Hugh J. Christian, Richard J. Blakeslee, Dennis J. Boccippio, William L. Boeck, Dennis E. Buechler, Kevin T. Driscoll, Steven J. Goodman, John M. Hall, William J. Koshak, Douglas M. Mach, Michael F. Stewart "Global frequency and distribution of lightning as observed from space by the Optical Transient Detector"; Journal of Geophysical research, Volume 108, Issue D1, 16 January 2003, Pages ACL 4-1-ACL 4-15

[2] Gabriel A. Adegboyega and Kehinde O. Odeyemi "Assessment of Soil Resistivity on Grounding of Electrical Systems: A Case Study of North-East Zone, Nigeria " Journal of Academic and Applied Studies, Vol. 1(3) September 2011, pp. 28-38

[3] Paul Gill, "Electrical Power Equipment Maintenance and Testing, Second Edition" CRC Press Taylor & Francis Group Boca Raton London New York

[4]. Gary Gilbert. Soil Modelling Techniques, International Journal of Materials Science and Applications. Vol. 1, No. 1, 2012, pp. 8-13. doi: 10.11648/j.ijmsa.20120101.12.

[5] REMA Newsletter issue N^{o} 026 2015

[6] http://www.nasa.gov/topics/earth/features/nox_lightning.html, visited on 24th April, 2016

[7] http://www.aemc.com/techinfo/appnotes/Ground_Resistance_Testers/App-Ground-SoilResistivity.pdf, visited on 27th May 2016.