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Evaluation of Steel Reinforcement Earthing in Swamp Building

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Abstract-Safety of life and property is important in power generation, transmission and distribution. In order to achieve this, an effective earthing system is needed. Previous studies carried out on steel reinforcement earthing (SRE) shows that SRE improves the earth resistance value. This paper reviewed several related literatures to the study on how to reduce the resistance value of an earthing system and focus on evaluation of SRE earthing in a swamp building. Three (3) points method was used in evaluating the resistance of each steel reinforcement column in the studied area and convectional earthing was also using 1.8m long, $16mm^2$ diameter iron rod each and the combining the two, the SRE was interconnected and combined with convectional earthing. Comparison was done for convectional earthing and SRE in a non-swamp area in the same campus of the studied area. The result obtained show that earthing value (columns) of the studied area before interconnected steel reinforcement connection or contribution do not meet the international standard of 4Ω of international Electrochemical commission (IEC) and 10 Ω of British International standard (BIS). The result also revealed that the interconnected SRE, alone, is 560% better than non- swamp interconnected SRE in the same campus of the studied area. The 1st rod, the 2nd rod and combination of the two iron rods earth resistances of the convectional earthing in the studied area is 1.3Ω -2 Ω which conform to the IEC and BIS recommendations. These values are lower than the equivalent of non-swampy convectional earth testing in the same campus. However, it was found that the addition of steel reinforcement reduced the value of the conventional earth resistance by 43 times as against 16 times of the non-swamp area. It is therefore advisable that SRE should be encouraged in addition to a conventional earthing and that Industries in swamp area should be employing SRE.

Keywords- *Steel Reinforcement Earthing, Iron Rod, Swamp Building, Convectional Earthing, Non-Convectional Earthing*

I. Introduction

A normal designed earthing network is crucial for electrical installation to circumvent fault currents problems [1]. Earthing system is used to protect equipment and personnel in electrical system. A low resistance Earth Termination System aims to provide the security for people by preventing electrical shock, equipment malfunction or damage and to eliminate the cause for fire outbreak. Earth is considered as physically consists of a conductive pipe or rod driven into the earth [2], [3].

In areas where driven rods are not likely to yield a desired result, Ufer grounding system is outstanding for low fault currents application [4]. High current faults such as lightning also need earthing to discharge the lightning current to the ground. It was found that isolating the foundations from the other parts of the grounding system is impossible. Concrete is able to absorb moisture from its surrounding earth which assists in reducing the resistance of the embedded steel reinforcement. In arid situations however, physical damage may occur to the concrete due to its non-homogeneous properties and moisture content. In the event of a fault, a path from the rebar to the surrounding soil through the concrete will have a lower resistance than any other. In addition, water heating and vaporization occurs when fault currents flow through the path thus causing the concrete to crack or spill [5]. In this case, the steel reinforcing will still work and this provide path of low resistance.

Under unfavorable conditions of the soil, the concrete encased metal objects otherwise contributed in the effectiveness of improved grounding [4]. Steel reinforcing earthing is superior to conventional earthing, [4], [6]. According to [6], the steel reinforcement earthing contributes 162% decrease to the earthing value when connected to the convectional earthing.

II. Literature Review

Earthing of equipment describes the connection of current carrying parts of electrical equipment to the earth. According to [7], earthing system is the total set of measures used to connect an electrically conductive part to earth to limit or removed the electrical fault and its associated problems.

A. Earth Pit

The earth pit is the path of discharge of fault current to the general mass of the earth to avoid damage of equipment and injury to personnel. To make this possible, the resistance of the earthing pit must be low enough so that the fault current can flow through it [7].

1) *Types of Earth Pit Installations*

a) Strip/conductor

In this type of earthing, galvanised iron or copper strips or conductors are buried horizontally with depth more than 0.5 meter below ground level. Length of buried strip/conductor should be minimum 15 meter to obtain required earth resistance. It may be increased on the basis of soil resistivity and other factors affecting earthing. [8] , [9].

b) Rod earth

It comprises solid rod of 12.5 mm dia. Cu or 16 mm diameter. Galvanized iron (GI) which penetrate vertically by manual means or pneumatic hammer up to minimum depth of 1.5 meter. No digging or excavation required in this type of earth pits, hence it is cheap. This is used in rocky soils because of difficulties in excavation and temporary installations [8].

c) Pipe earth

It is installed with 40mm diameter. Galvanized Iron (GI) medium class pipe, 3.45 to 4.5 meter long with no joints. GI pipe cut tapered at bottom and holes of 12 mm Ø, at 75 mm spacing up to 2m length from bottom. Pipe buries vertically and keeps top of pipe 20 mm below ground level. If full length is not possible due to water table/rocks, reduce the length to achieved required value of earth resistance with or without additional electrodes. It may also be installed in horizontal formations [9].

d) Plate earth

This is the most common and best system of earthing in comparison with same earth and moisture condition, [8]. Plate size will be 600 x 600 x 6 mm for GI and 600 x 600 x 3 mm for Cu. Cross section of strip should me minimum 100 mm2 for GI and 40 mm2 for Cu or 8 SWG Cu wire. Top of earthing plate shall be minimum of 1.5 meter below ground and less than 3meter, with vertical faces. Gap between Pits to pit shall be minimum 3 meter and keep 2 meter away from building. 20mm Ø medium GI watering pipe attached to electrode for periodic maintenance. Keep Funnel with mesh on the top of pipe and chamber specifications is same as of pipe earth. Terminate earthing lead on plate with nut/bolt/check nuts and washers [8], [9].

B. Swamp

An area of low-lying land that is frequently flooded, especially one dominated by woody plants. A lowland region saturated with water [10]. A land that is always very wet or covered with a layer of water is also called swamp [11].

C. Soil Properties Variation

Soil is one of the most important natural resources, and a must for the existence of plants and animals. Soils are formed by the combined work of rocks, topography, climate and plants. Soils of different country may be different. Soils are classified based on their colours structure and place where they are found. The wetter the soil, the lesser its resistance. This account for buildings have their own earth connection and do not rely on earth point at the distribution transformer [9].Soil resistivity is directly proportional to earth resistance, the lower the soil resistivity the lower the resistance [9], [12].

TABLE I. SOIL LAYER RESISTIVITY [9], [13]

Type of Soil	Soil Resistivity (Ω-M)
Swap Soil	2-50
Farming Clay and Loaming Soil	100
Sandy Clay Soil	150
Moist Sandy Soil	300
Concrete 1:5	400
Moist Gravel	500
Dry Sandy Soil	1000
Dry Gravel	1000
Stoney Soil	30000
Rock	10^7

D. Effective Earthing System

In Nigeria electricity distribution industry today, safety is not practiced as expected [3]. The safety of person using electricity has been of great concern to the supply authorities, government, employers of labour, individuals and the general public. Using electricity without being safety conscious could be hazardous due to its irreparable damage to life and property. Hence the reliability, integrity, and safety of any electrical installation, power system, and residential buildings depend on the sensitivity, the effectiveness of protection schemes, safety devices, coordination of relays, circuit breakers depends on the effectiveness of the earthing system in substations [3]. However the overall performance of the earthing system is highly influenced by the soil properties, especially the resistivity. Soil resistivity usually measured in ohms-meter depends on the physical composition of the soil, moisture content, dissolved salts, seasonal variation and current magnitude [7], [14].

According to [7], soil and water are generally more stable at deeper strata, earth rods should be placed as deep as possible into the ground for effective dissipation of fault current. This is the case in swamp soil [7]. Figure 1 and Table 1 illustrate deepness of earth rod as a function of ground resistance reduction. [7], [13].

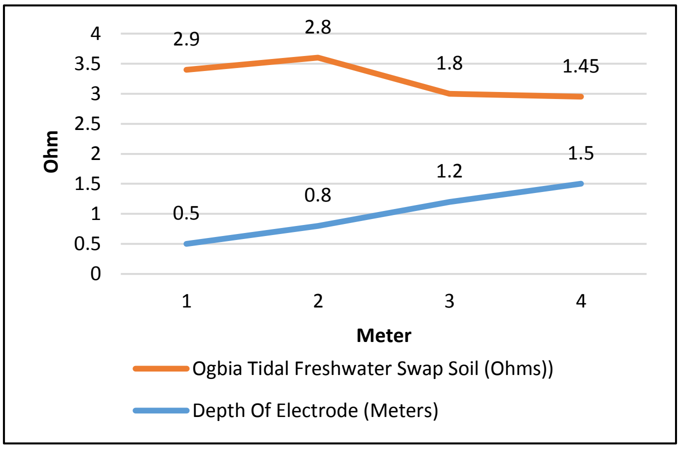

Figure 1. Deepness of Earth Rod as a Function of Ground Resistance Reduction [7]

TABLE II. DEEPNESS OF EARTH ROD AS A FUNCTION OF GROUND RESISTANCE REDUCTION [14]

Type of Soil	Ground Electrode Depth (m) / Resistance(Ω)		
	3 m	6 m	10 m
Swap Soil	10 Ω	5 Ω	3 Ω
Farming Clay and Loaming Soil	33 Ω	17 Ω	10 Ω
Sandy Clay Soil	50 Ω	25 Ω	15 Ω
Moist Sandy Soil	66 Ω	33 Ω	20 Ω
Concrete 1:5			
Moist Gravel	160 Ω	48 Ω	48 Ω
Dry Sandy Soil	330 Ω	100 Ω	100 Ω
Dry Gravel	330 Ω	100 Ω	100 Ω
Stoney Soil	1000 Ω	300 Ω	300 Ω
Rock			

From Figure 1 and Table 2 it shows that the swamping soil has the best earth resistance (10 Ω).

E. *Earth Resistance Value Improvement*

1) Used of steel reinforcement bar (rebar's)

The use of rebar's that are either bare or have zinc coating in an earthing system can be used to improve conventional earthing system. [4], [6].

For steel reinforcement earthing in a minimum of 55mm of concrete, Concrete is in direct contact with earth, Located within and near the bottom of a concrete foundation or footing, and be bonded together by the use of steel tie wire [4], [15].

However, [4] emphasised that for good continuity of steel reinforcement, steel tie wire is unsuitable for joining the rods. Joining products particularly for the rebar's are available in the market. An appropriate connection of the reinforcement steel enhance low resistance path to earth for earth current faults. In this research, steel wire is used for joining. [6], accounted for conventional and non-conversional earthing tests as presented in Figure 2.

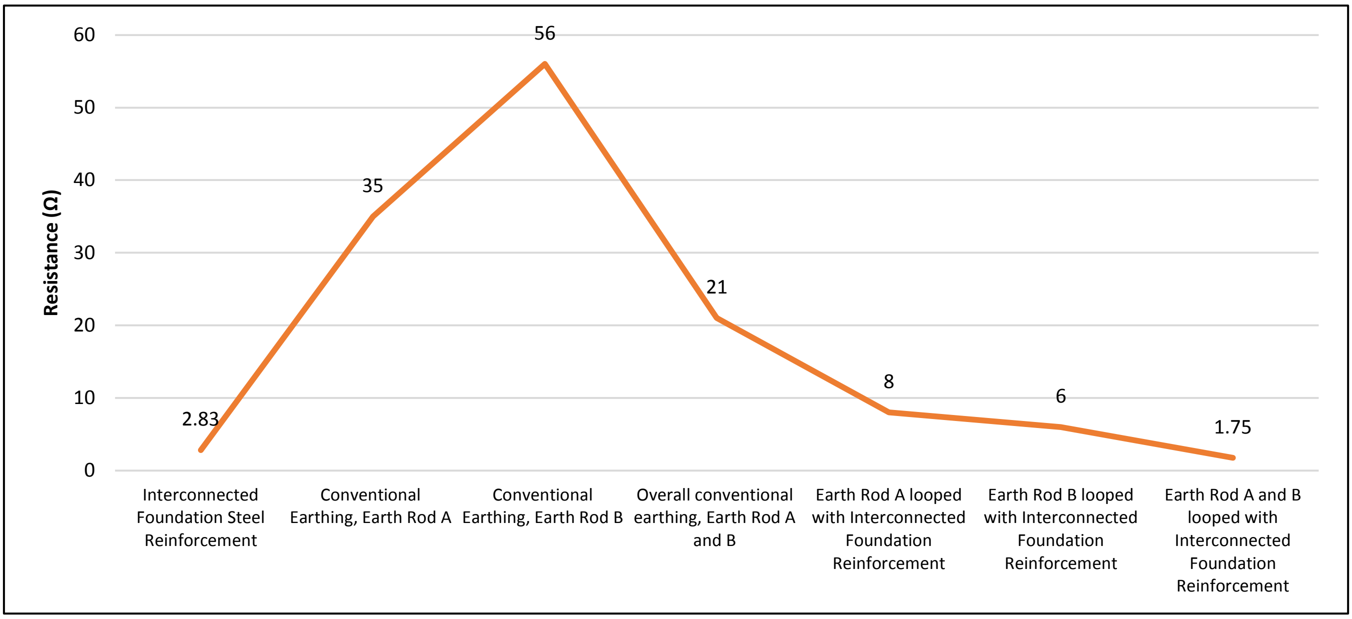

Figure 2. Conventional and Non Conversional Earthing Tests

2) Used of backfills materials

In high resistive soil, a common method to achieve low soil resistivity is to cover the electrodes with conductivity material also known as backfill materials. The backfill material has the benefit of generating good earth resistance in space-restricted areas with very high soil resistivity by reducing the soil resistivity. [4], [16].

3) Other methods of reducing the earth resistance

Increasing of pit depth, increasing of plate area, and increasing number of electrode in parallel.

The practice for pit depth is to increase the depth level to 2m [7], [8]; steel reinforcing is analogical to increasing of plate area since number of steel reinforcement is a function of plate area [6]. However, consistent inspection of all earthing components which are accessible must be done at a regular interval according to IEE inspection standard. As a result of this, termination of steel reinforcement earthing and convectional earthing should follow this IEC standard.

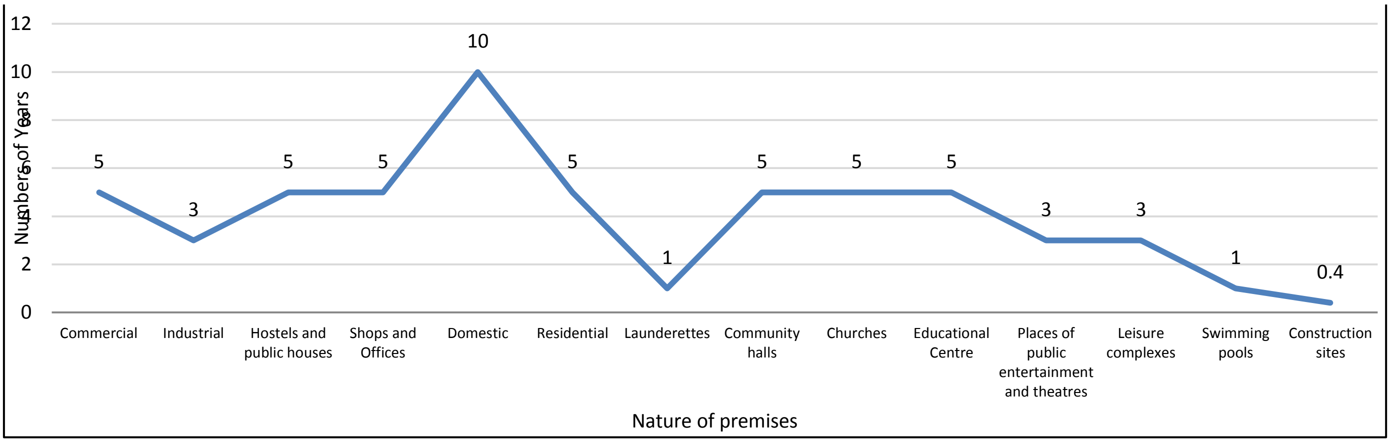

Figure 3. Maximum Inspections Time for Different Premises (Adapted From [7])

This research used steel reinforcement for earthing in a swap building.

III. METHODOLOGY

The methodology explains how the earthing system is implemented and the relevance of the earthing method used. The methodologies for this research work include the earth measurement of steel reinforcement resistance using kyoritsu digital earth tester for postgraduate school extension building located in a swamp area in the North campus of Federal University of Technology Akure, Nigeria as shown in Figure 4.

Figure 4. Picture of Steel Reinforcement of School of Post Graduate, FUTA

A. The Earth Soil Resistance Test

3-point measuring technique using the kyoritsu digital earth tester is to be used to measure the soil resistance and compute the soil resistance because it is the most thorough and reliable test method. Each column earth resistance will be measured with the soil resistivity meter and using equation carried out with the soil resistivity meter and using equation 1.

$$\rho = \frac{RA}{L} \quad (1)$$

Where ρ is the soil resistivity; R is the resistance of the soil; and L is the length of the rod.

$12mm^2$ earth rod will also be placed very close the reinforcement steel and measurement will also carried out, Figure 4.

The steel reinforcement columns are too many and difficult to carry out test because of the water around the building. So, 8 columns were picked for the test as shown in Figure 5.

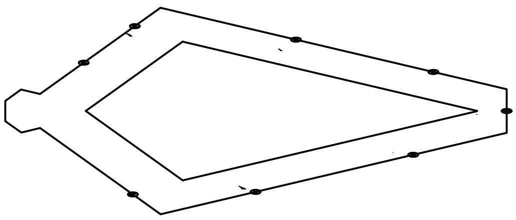

Figure 5. Sketch of the eight Selected columns Plan of the Building

1) Materials Used for this Work

The materials used for this research are kyoritsu digital earth tester , Figure (6a); 1.8m, 18mm diameter earth rods, Figure (6b); Steel reinforcement of a building (16mm diameter);$1.5mm^2$ copper conductor; Abrasive (Sand paper; Multi meter and Measuring tape.

(a) (b) (c)

Figure 6. 3-point Method of Earth Resistance Tester, Model 4105. a) Earth Resistance Tester, b) Earth Tester Electrodes, c) Connecting cables

B. Effective Steel Reinforcement Resistance Test

Kyoritsu digital earth tester was used to measure the effective steel reinforcement resistance. This is done by cleaning the reinforcement steel with abrasive, electrically join the 2.5mm^2 wire with it and brought it to the ground level. The earth resistance tester was connected and measurement taken in ohms for eight columns and the results is presented in Figure 7.

C. Earthing design for the building.

The methodology here is sizing the earth conductor at half of the phase current carry conductor (IEE Standard), equation (2).

$$C_{ec} = \frac{1}{2} C_{Pc} \quad (2)$$

Where C_e is the earth conductor; C_P is the phase conductor.

Temporary earth design was done for the building since the electrical installation is yet to be done and no access to the building design as at the time of doing the research.

However, 12mm^2 earth rod was driven to the soil at first and record was taken with the soil resistivity meter. In attempt to obtain lower resistance value, second earth rod of the length and dimension was also driven to the ground and value was also taken. The results were presented in (Figure 8). Analogically, the two rod were looped together and earth resistance taken. The results were presented in (Figure 8).

D. Comparison of Earth Resistance Value of Swamp Area and Non-Swamp Area

Equation (3) is used to calculate the percentage of earth resistance value of swamp area when compared with non-swamp area.

$$\%R_{EC} = \frac{R_{ens}}{R_{es}} X\ 100\% \quad (3)$$

Where $\%R_{EC}$ is the percentage earth resistance value, R_{ens} is the non-swamp earth resistance Value and R_{es} is the swamp earth resistance value.

E. Comparison of earth resistance value using iron rod and steel reinforcement

Equation (4) is used to calculate the percentage of earth resistance value when using steel reinforcement earthing compared with the convectional iron rod earthing.

$$\%R_{evis} = \frac{R_{eir}}{R_{esr}} X\ 100\% \quad (4)$$

Where R_{evis} is the of earth resistance value of iron rod and steel reinforcement, R_{eir} is earth resistance value of iron Rod and R_{esr} is the earth resistance value of steel reinforcement.

IV. Results, Analysis, Conclusion and Recommendation

A. Results

Results of the research are presented in Figures 7-8.

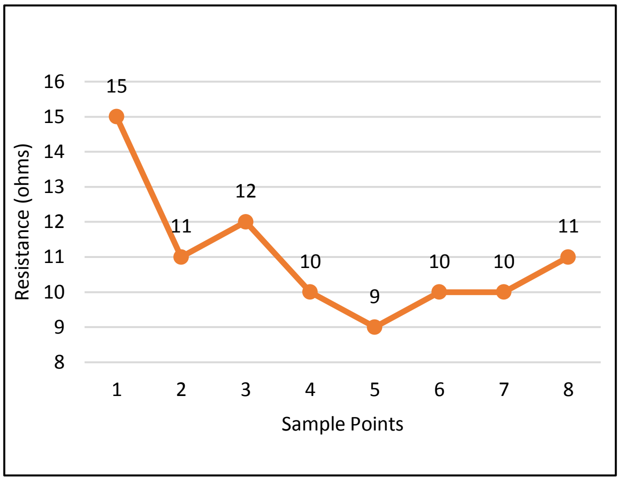

Figure 7. Earth Resistance Value of steel Reinforcement

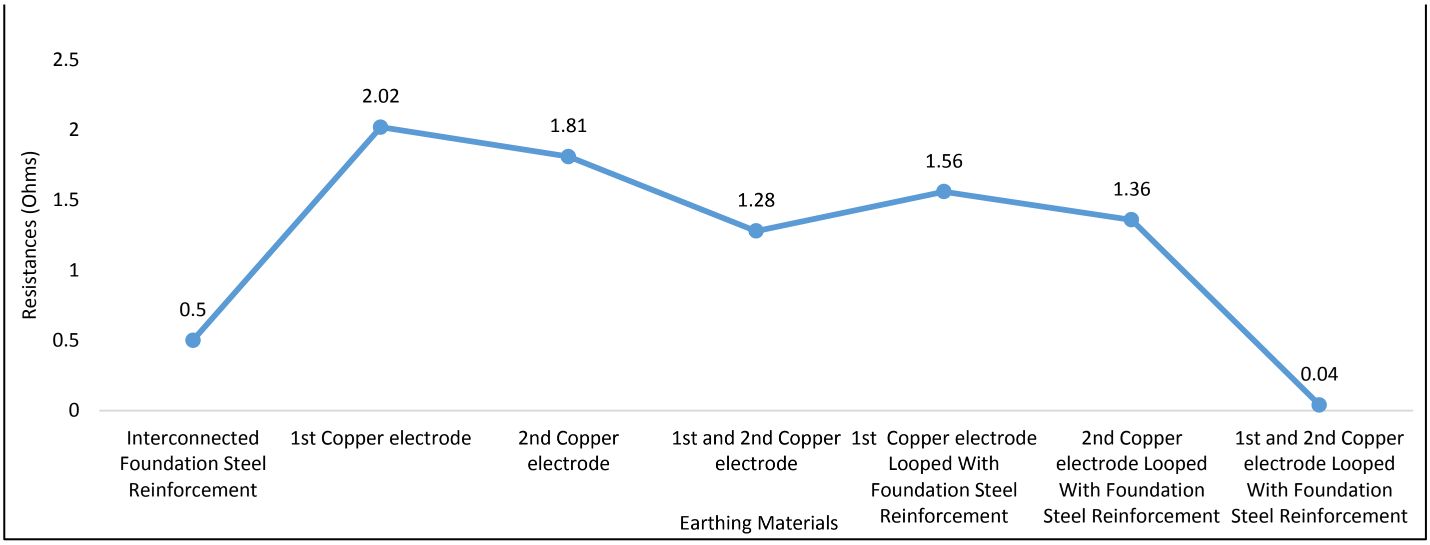

Figure 8. Interconnected Earthing Vs Conventional Earthing

B. Analysis of Results

For columns resistance values, from Figure 2, the soil resistance test for each point varies for each randomly selected points in the swamp building 9 Ω to 15 Ω. Out of 8 samples, only one point value (11%) met international standard of British international standard (BIS) 10 Ω. The other 7 points (87.5%) do not meet the (BIS) of 10 Ω and international electrochemical commission (IEC) of 4Ω. In comparison with non-swamp building test (Figure 2), all the values are lower than selected 12 columns earth test in non- swamp building in the same campus.

From Figure 2 and 8, the interconnected steel reinforcement test value, without connection to convectional earthing, is 2.83 and 0.5 Ω respectively. This implies that interconnected steel reinforcement earthing, alone, is 560% better than non- swamp earthing in the campus. From figure 8, the 1st rod and the 2nd rod and combination of the two iron rods earth resistances are 2.02 Ω, 1.81 Ω and 1.28 Ω respectively. These values are lower than the equivalent of non-swampy earth testing (Figure 2).

From figure 8, 1st iron rod; 2nd iron rod; and combination of the two iron rods looped with interconnected steel reinforcing is 1.56, 1.36 and 0.04 Ω respectively. This implies that earth resistance in swamp area is lower than non-swamp area (Figure 2). This implies that steel reinforcement earthing in swampy area contributed largely to convectional earth value reduction (4300%) as against 162% for non-swampy area.

C. Conclusions

i. The earthing value (columns) of the studied area before steel reinforcement connection or contribution do not meet the international standard of 4Ω (IEC) and 10 Ω (BIS).

ii. The interconnected steel reinforcement earthing, alone, is 560% better than non- swamp earthing in the same campus.

iii. The 1st rod, the 2nd rod and combination of the two iron rods earth resistances is 1.3Ω -2 Ω which IEC and BIS. are values are lower than the equivalent of non-swampy earth testing (21 Ω - 56 Ω)

iv. However, it was found that the addition of steel reinforcement reduces the value of the conventional earth resistance by 4300% in the studied area as against 162% of the non-swamp area.

v. Two parallel earth rods are better than one number of earth rod.

D. Recommendations

i. Steel reinforcement earthing should be encouraged in addition to a conventional earthing.

ii. Steel reinforcement earthing in swamp area contributed largely in earth value reduction.

iii. Industries in swamp area should be employing steel reinforcement earthing.

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