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Measurement of Soil Resistivity by Sampling Method

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ABSTRACT
Resistivity is a fundamental parameter of any substance. Investigation of soil resistivity at substation provides useful information of soil homogeneity and soil layers at different depth. Measurement of soil resistivity by sampling method is useful for design of foundation of large buildings, bridges, transmission line tower footing, laying of underground petroleum and gas pipelines, for finding minerals in mines, water table below ground , irrigation of different crops in agriculture sector and so on. Lower soil resistivity reflects the highly corrosive soil and high soil resistivity is poor conductor of electricity. In this research, laboratory tests were conducted on various soil samples to measure the soil resistivity by sampling method and to evaluate the effect of moisture contents, sodium chloride, potassium chloride, soil compaction and temperature on soil resistivity. Moreover, how to make test apparatus, soil sample? Method of finding percentage of moisture content, percentage of dissolve substances such as sodium chloride, potassium chloride in the soil sample. The test results obtained are almost matched with results given in IEEE standards 80-2013 and 81-2012.
Keywords: agriculture**,** compaction of soil, moisture, sampling, soil.

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I. INTRODUCTION

The soil resistivity is governed by various factors such as soil type, nature of soil, grain size, compactness and dissolved substances, temperature, moisture content etc. [1-2]. Out of various factors, concentration and composition of dissolved substances, temperature and moisture content of the soil will vary from season to season resulting into increasing ground resistance substation [3-4].

Higher the moisture content in the soil, lesser the soil resistivity and lesser the moisture content, higher is the soil resistivity [5,6,7]. Highly corrosive soil is indication of lower soil resistivity. While design of foundation of large buildings, bridges, transmission line tower footings, laying of petroleum pipelines, it is necessary to keep safety factor due to soil corrosion [8-9].

Homogeneous soil is seldom found. Soil resistivity vary place to place and different geological conditions. Even in the same substation location, it varies location to location. It varies horizontally as well vertically. The horizontal variations are gradual. It depends on soil strata, cut and filled soils [10].

Number of soil resistivity tables are available in reviewed literature. It provides general information of types of soil, such as loamy soil, mixer of sand, rocky soil. The resistivity figures are indicative only. Therefore, measurement of soil resistivity is very essential to get actual data [11].

In this research paper, the measurement of soil resistivity by sampling method, the various soil samples can be obtained by drilling the hole in the ground. The soil samples at different depth can be collected and tested. The tests have been conducted to find effect of moisture content, dissolved substances such as NaCl, KCL, effect of temperature and soil compactness on soil resistivity. The paper is organized as follows. The introduction is followed by test methodology in section II. The tests have been conducted in section III & the test results and conclusion is discussed in section IV followed by references in V.

II. METHODOLOGY

The soil resistivity has been measured in the laboratory by sampling method to analyses the effect of various factors on soil resistivity. The factors that are considered for the analysis are moisture content, sodium chloride, potassium chloride, soil compaction and temperature.

A. TEST APPARATUS

The arrangement for soil resistivity measurement is as shown in figure 1. It consists of rectangular plastic box of dimensions 23 x 13 x 7.5 cm. It is fitted in the wooden box of little oversize to provide mechanical support during compaction of soil sample. The two electrodes of size 12 x 7 cm of galvanized iron (GI) having thickness 20 SWG are fitted using BTI terminals for electrical connections as shown in figure 2. The hole of 5 mm was made on the top cover of plastic box to house the thermostat in the sample for measurement of its temperature, refer figure 1. For the compaction of soil sample, the pressure was applied on it using hydraulic machine. The equal pressure was applied to every sample to have equal compaction of soil sample as shown in figure 3. As soil sample is loose, to get natural soil, which is normally in compact state; compaction is essential. The electric circuit consist of single-phase dimmer stat, digital multi meter, voltmeter, digital thermostat and soil sample box as shown in figure 4. The AC 200 V was applied across the soil sample and current flowing through the sample was measured. The resistivity of sample is given by

$$\rho = \frac{R \times a}{l} = 0.0404 \times \frac{V}{I} \qquad (1)$$

Where
a = area of cross section of soil sample normal to the current.

$$\frac{a}{l} = \frac{w \times h}{l} = \frac{o.13 \times 0.715}{0.23} = 0.0404$$

Here, h= 0.715 m after compaction of soil.

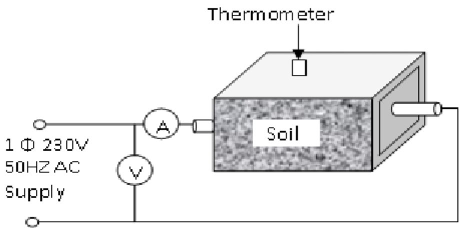

Figure 1: Soil resistivity measurements by sampling method.

Figure 2: Test box for soil resistivity measurement

Figure 3: Compaction of soil sample

Figure 4: Test set up for soil resistivity testing by sampling method

B. PREPARATION OF TEST SAMPLE

It is very essential to determine the percentage of moisture content in the soil to analyze the effect of moisture on soil resistivity. The capacity of test box is to accommodate 2.5 kg of soil sample. The percentage of moisture is given by

$$\%\, of moisture = \frac{weight of test sample - weight of dry sample}{weight of test sample} \times 100 \qquad (2)$$

It is necessary to dry the test sample completely by keeping it in electrical dryer for 12 hours at temperature of 100℃ or more.
Let, weight of test sample = 2.5 kg and dry weight of sample=2.276 kg, then

$$\%\, of moisture = \frac{2.5 - 2.276}{2.5} \times 100 = 8.96$$

Further, it is also essential to find the percentage of added content in the sample. The typical case of added % of NaCl by weight in soil as shown in table 1.

$$\%\, of NaCl = \frac{weight of NaCl}{weight of soil sample + weight of NaCl} \times 100 \qquad (3)$$

For example, weight of NaCl= 25 gm and weight of soil sample =2475 gm then,

$$\%\, of\ NaCl = \frac{25}{2475 + 25} \times 100 = 1$$

Table 1: % of NaCl by weight in soil sample.

Sr. No	NaCl content (gm)	Soil weight (gm)	% of NaCl
1	00	2500	00
2	25	2475	1
3	62.5	2437.5	2.5
4	125	2375	5
5	187.5	2312.5	7.5
6	250	2250	10
7	312.5	2187.5	12.5
8	375	2125	15

III. EXPERMENTATION

A. EFFECT OF MOISTURE ON SOIL RESISTIVITY

Moisture content in the soil affect the soil resistivity. The moisture content in original soil sample has been obtained by the procedure laid in section II part A. By adding water, various soil samples were obtained which are listed in table 2. For each soil sample, fixed voltage 200V is applied and current is measured using DMM and resistivity is calculated. All samples were tested at 30 ℃. The test measurement results obtained by increasing moisture in the given soil sample are tabulated in table 2 and its effect has presented graphically in figure 5.

Table 2: Effect of moisture on soil resistivity

Water added (mL)	% moisture	Current (mA)	Resistance (Ω)	Resistivity (Ω m)
pure	5.0	8.759	22834	922.5
10	8.6	25.68	7787.1	314.6
25	11	42.11	4750	191.9
50	13	116.8	1712.4	69.18
75	14.8	190.0	1052.7	42.53
100	17.7	323.7	617.8	24.96
125	19.2	357.4	559.6	22.61
150	22.20	471.4	424.3	17.14

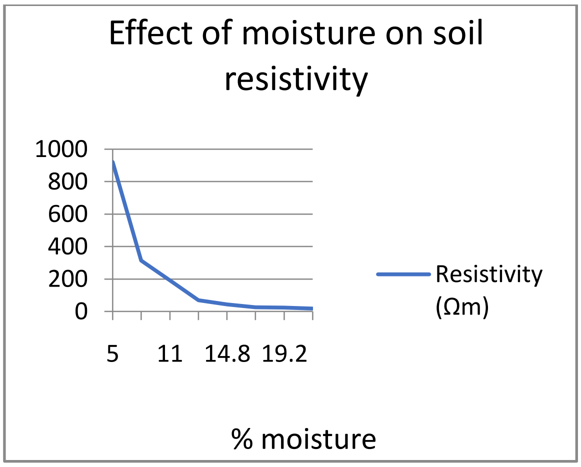

Figure 5: Effect of moisture content on soil resistivity

As the moisture content in the soil increases, soil resistivity decreases as shown in fig 5. As soon as moisture content in the soil falls below 14.8 % by weight, the soil resistivity increases drastically very high. However, when the moisture content exceeds 20 % by weight, the decrease in soil resistivity becomes negligible. These results match with results published in literature by [3,5,7].

B. EFFECT OF ADDED NACL ON SOIL RESISTIVITY

The test measurement results obtained by adding NaCl in the given soil sample are tabulated in table 3 and its influence has depicted in figure 6. The initial moisture content in the soil was 8.96%.

Table 3: Effect of added NaCl on soil resistivity
% age of moisture= 8.96

NaCl content (gm)	% of NaCl	Current (A)	Resistance (Ω)	Resist-ivity (Ωm)
Pure	00	0.1935	1033.6	43.82
25	1	0.49	408.16	17.3
62.5	2.5	1.03	194.17	8.23
125	5	1.45	137.93	5.85
187.5	7.5	1.52	131.58	5.58
250	10	1.63	122.7	5.20
312.5	12.5	1.66	120.48	5.10
375	15	1.68	119.05	5.05

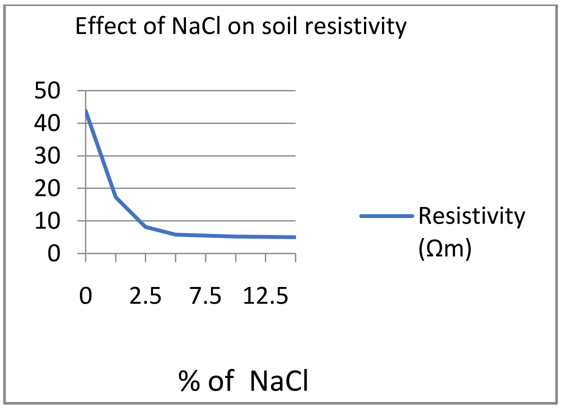

Figure 6: Effect of added NaCl on soil resistivity

As % of added NaCl in the soil increases, soil resistivity decrease. The effect becomes negligible, when added NaCl exceeds 10% by weight. Due to raining, over the period of time, NaCl leaches in the ground and soil resistivity increases.

C. EFFECT OF TEMPERATURE ON SOIL RESISTIVITY

The measurement results are listed in table 4 and shown graphically in figure7. The moisture content in the soil sample was 9.28 %. When the temperature falls below 0°C , moisture in the soil starts freezing and soil resistivity increases exponentially high. However, the effect becomes negligible, when temperature becomes more than 4°C [12].

Table 4: Effect of temperature on soil resistivity.
% age of moisture= 8.96

Temp. °C	Current (mA)	Resistance (Ω)	Resistivity (Ω m)
-8	7.88	25381.2	1025.4
-4	14.35	13933.2	562.9
0	42.91	4660.9	188.3
4	141.0	1418.3	57.3
8	211	948	38.3
12	253.3	787.6	31.9
16	267.5	747.5	30.2
20	295.9	675.7	27.3
24	309.6	646	26.1
30	324.5	616.3	24.9

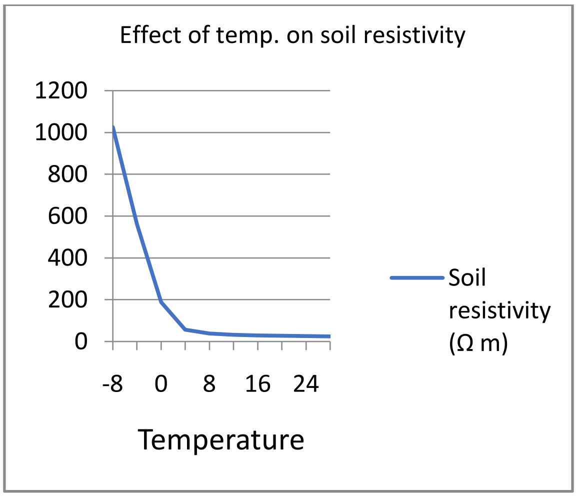

Figure 7: Effect of temperature on soil resistivity

D. EFFECT OF ADDED KCL ON SOIL RESISTIVITY

Test measurement results of effect of KCl on soil resistivity are listed in table 5 and depicted graphically in figure 8. As the added KCl increase, soil resistivity decreases. The effect becomes negligible, when KCl content becomes more than 4 % by weight. Further, the addition of NaCl has more pronounce effect on reduction in soil resistivity. However, over the time, added NaCl and KCL may wash out resulting higher ground resistance [13,14].

Table 5: Effect of added KCl on soil resistivity

KCL (gm)	% of KCl	Current (mA)	Resistance (Ω)	Resistivity (Ωm)
Pure	00	66.2	3121.1	122.0
25	1	158.1	1265.0	51.11
50	2	249	803.2	32.45
75	3	270	740.7	29.92
100	4	390	512.8	20.72
125	5	450	444.4	17.95

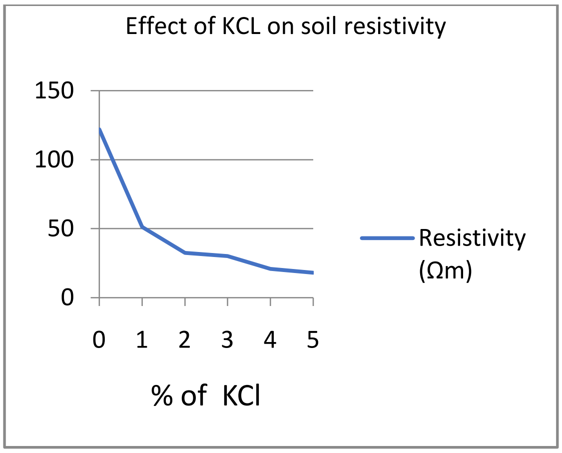

Figure 8: Effect of added KCl on soil resistivity

E. EFFECT OF SOIL COMPACTION

The effect of the compaction of soil on soil resistivity obtained by laboratory measurements are listed in table 6 and shown graphically in figure 9.

Table 6: Analysis results by compaction of soil.

Sr No	Soil thicknesss h (mm)	Current (mA)	Resistance (Ω)	% more compaction	Resistivity (Ω m)
1	71.5	8.759	22834	1.0	922.5
2	68.0	10.86	18416	5.15	707.8
3	65.0	12.01	16653	10.0	611.8
4	63.0	13.12	15244	13.5	542.8
5	61.0	14.0	14286	17.2	492.6
6	60.5	14.57	13727	18.2	469.4
7	60.0	14.95	13378	19.2	453.7

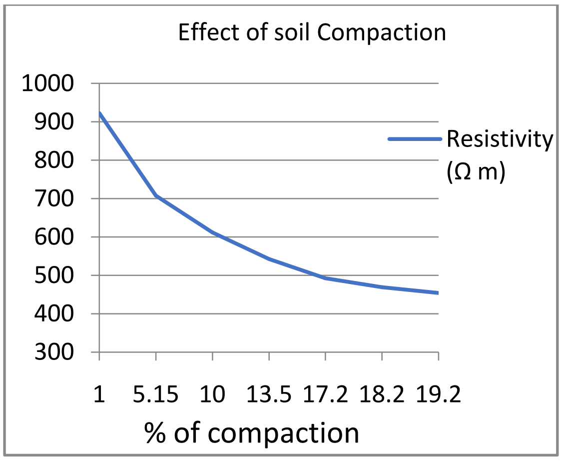

Figure 9: Effect of compaction of soil on soil resistivity

As the compaction increases, a soil grain makes good contact with each other and therefore, soil resistivity decreases. The effect diminishes, as compaction becomes more than 20%.

IV. CONCLUSION

As the moisture content in the soil increases, soil resistivity decreases. As soon as moisture content in the soil falls below 14.8 % by weight, the soil resistivity increases drastically very high. However, when the moisture content exceeds 20 % by weight, the decrease in soil resistivity becomes negligible. The result indicates that there is no use to keep on watering of ground electrode often.

As the added NaCL&KCl increases, soil resistivity decreases. The effect becomes negligible, when NaCL&KCl content becomes more than 10 % &4 % by weight respectively. Further, the addition of NaCl has more pronounce effect on reduction in soil resistivity. However, over the time, added NaCl and KCL may wash out resulting higher ground electrode resistance. Many countries have imposed ban on adding these contents to avoid soil pollution.

As the temperature falls below 0℃ , moisture in the soil starts freezing and soil resistivity increases exponentially high. However, the effect becomes negligible, when temperature becomes more than 4℃ . This becomes the challenge to design the substation grounding grid in the regions where icing & thawing takes place such as Himalayan regions of India.

As the moisture content decreases, soil resistivity increase. This property can be utilized for automatic irrigation of crops. As soon as, moisture content falls below the threshold value, initiate the automatic starting of irrigation pumps. This system not only saves the water but also saves the electricity bill and keeps the crops in healthy condition.

As the low resistivity soils are highly corrosive, by keeping safety factor, the life of substation grounding grid can be enhanced. Further, the life of petroleum pipelines, foundations of electricity towers, building and brides also extended making cost effective design. In this way, this research will be useful to power engineers, Civil engineering, commercial, industrial and agriculture field.

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