Design, Construction And Performance Evaluation Of Soil Resistivity Meters At Six Geophysical Sites In Osustech, Okitipupa – Nigeria

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ABSTRACT
This paper presents the design and construction of two soil resistivity meters that were tested at six different geophysical sites in Ondo State University of Science & Technology, (OSUSTECH) Okitipupa, Nigeria. In a related research work conducted by two Scientists, Igboama, W.N. and Ugwu, N.U., in the year 2011, a soil resistivity meter was designed and constructed. However, it was discovered that this soil resistivity meter was expensive, complex and not very accurate in its readings. It has been observed that the two soil resistivity meters designed and constructed (the serial resistivity meter, SRM, and the parallel resistivity meter, PRM) in this research work are simple, low-cost and are of high accuracies. Their soil resistivity readings for the chosen six sites in Okitipupa, Nigeria compare favorably well with corresponding standard terrameter soil resistivity readings. The corresponding mean square errors and square mean errors in the soil resistivity measurements were found to be relatively small.

Keywords: *Accuracy, Errors, Geophysical Sites, Soil Resistivity Meter, Terrameter, Wenner.*

I. INTRODUCTION

The soil resistivity is a measure of how much the soil resists the flow of electricity. It is a critical factor in the design of systems that rely on passing current through the Earth's surface. An understanding of the soil resistivity is necessary to design the grounding system in an electrical substation. It is needed for the design of grounding electrodes for substations and High-voltage direct current transmission systems [1].The earth is used to conduct fault current when there are ground faults on the system in most substations. There is some maximum step voltage must not be exceeded to avoid endangering people and livestock. Though the soil resistivity value is subjected to great variation, due to moisture, temperature and chemical content. To achieve this objective, a suitable low resistance connection to earth is desirable [2, 13]. However, this is often difficult to achieve and depends on a number of factors such as soil resistivity, stratification, size and type of electrode used, depth to which the electrode is buried, chemical content and moisture of the soil under study. These investigations include a number of geotechnical and geophysical tests sufficient for defining the soil/rock characteristics, groundwater conditions, and other existing features of importance to foundation design [3]. Several geophysical methods are routinely used to image the subsurface of the earth in support of subsoil investigations. Commonly employed geophysical methods include seismic tomography, ground penetrating radar, *electrical resistivity*, electromagnetic and gravity methods [4]. However, in terms of spatial resolution, cost-effectiveness and target definition, ground penetrating radar and electrical resistivity methods ranked first and second respectively. In view of this, electrical resistivity method was used to investigate the subsurface stratigraphic relationships or variation of subsurface materials in Ondo State University of Science and Technology (OSUSTECH) Okitipupa, Nigeria, as an aid to construction engineers. Geo-electrical measurements are an important and integral component of geophysical investigations connected with environmental problems [5, 6]. In recent years, electrical resistivity surveys have progressed rapidly from the conventional sounding survey, which provides layer depths and resistivity values at a single place, to techniques which provide two-dimensional electrical pictures of the subsurface. Four-electrode profiling has been employed in soil practices since 1931 for evaluating soil water content and salinity under field conditions. An electrical cell used to measure the conductivity of soil solution or saturated soil pastes were developed [7, 8]. The method of four-electrode profiling was also used for evaluation of some other soil properties, such as soil water content [9, 10], structure bulk density, porosity, and texture [11, 12].

In the present study, we fabricated a resistivity meter using available materials that could measure soil resistivity or its inverse. This was necessitated by the high cost of importation of ready-made products today. The aims of this research work are to design and construct two resistivity meters (namely: parallel resistivity meter and serial resistivity meter) and to determine resistivity values of the soil samples at six geophysical sites in Ondo State University of Science and Technology (OSUSTECH) main campus.

II. MATERIALS AND METHOD

Wenner's four-point electrode arrangement was deployed in the construction of the resistivity meter in this study. The probes were affixed to the front of the box with the aid of connectors. The calibration was done using a standard value obtained from an existing terrameter. The system block diagram is displayed in figure 1 and is the basic block diagram of the fabricated resistivity meters and it makes use of four probes; two of the probes carry current while the other two electrodes carry voltage. Figure 2 and 3 is the circuit diagram of the serial resistivity meter, SRM, and the parallel resistivity meter, PRM respectively. The circuitry was connected as shown in Figure 2 and 3 below. The fabricated meters were used to take readings at six geophysical sites in the permanent side of Ondo State University of Science and Technology, Okitipupa Nigeria, to test the workability of the device and the results obtained were analyzed.

The circuit diagram shown in figure 2 is the schematic layout of a serial resistivity meter with the test probe configuration arrangements.

From Ohm's law:

$$V = IR \quad (1)$$

$$V = I\,(R + R_{SS}) \quad (2)$$

$$\frac{V}{I} = M_{SS} = R + R_{SS} \quad (3)$$

$$R_{SS} = M_{SS} - R \quad (4)$$

$$R_{SS} = M_{SS} - R = \rho_{SS}\frac{L}{A} \quad (5)$$

Where:

$M_{SS} \rightarrow$ Gradient.

Length (L) is measured six times by using micrometer screw-gauge, while the diameter D of the cross-section of the test probe used is measured at six different places along its length, and the average values are taken and recorded.

Cross-sectional area.

$$A = \frac{\pi D^2}{4} \quad (6)$$

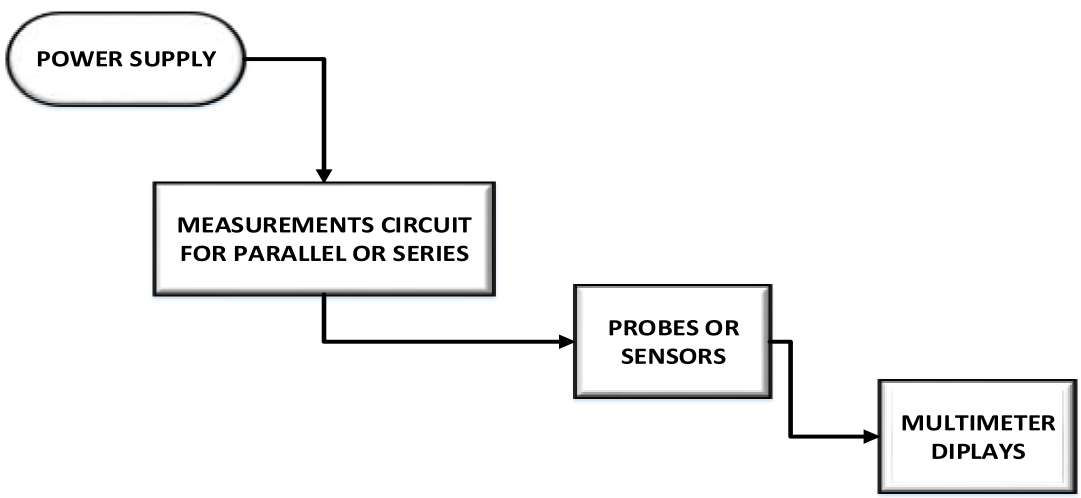

Figure 1: Typical block diagram for both the fabricated parallel and serial resistivity meters.

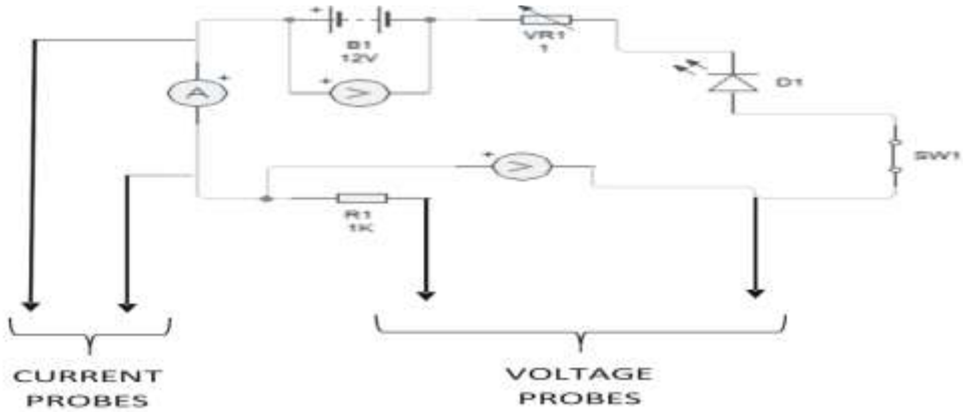

Figure 2: Circuit layout of a serial resistivity meter.

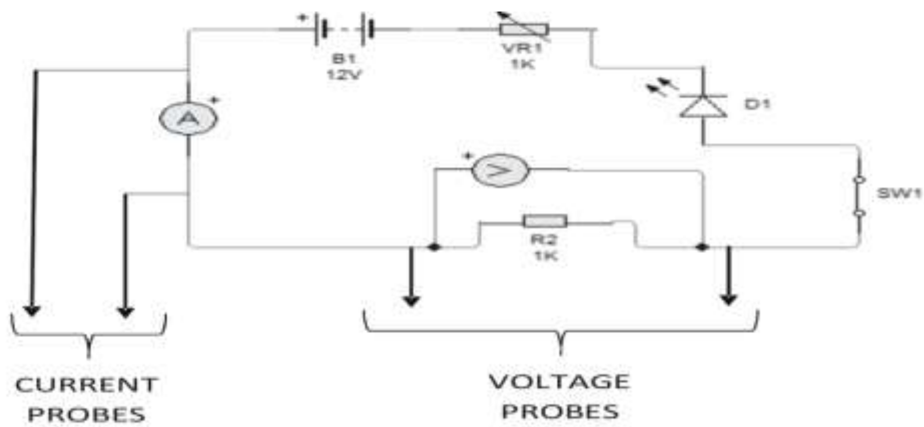

Figure 3: Circuit layout of a parallel resistivity meter

III. RESULTS AND DISCUSSIONS

The readings obtained from the six geophysical on different sites visited for geophysical data collections using serial resistivity meter, parallel resistivity meter and terrameter.

Table 1 Data obtained using the Fabricated Parallel Resistivity Meter (PRM) for site one

S/N	HCS AB/2	HPS MN/2	GF G	V_I (V)	V_F (V)	($\Delta V = V_I - V_F$) (mV)	I (mA)	A (∏D^2/4)	L (m)	R (Ω)	P (Ω.m)	ΔX	ΔX^2
1	1	0.25	6.28	8.78	8.70	80.00	10.00	0.0000414	0.12	8.00	0.00276	0.00320	0.00001
2	2	0.25	25.13	8.78	8.56	220.00	10.00	0.0000414	0.12	22.00	0.00759	-0.00759	0.00006
3	3	0.25	56.55	8.78	8.56	220.00	10.00	0.0000414	0.12	22.00	0.00759	-0.00759	0.00006
4	3	0.25	100.53	8.78	8.53	250.00	10.00	0.0000414	0.12	25.00	0.00863	-0.00863	0.00007
5	4	0.25	226.19	8.78	8.70	80.00	10.00	0.0000414	0.12	8.00	0.00276	-0.00276	0.00001
6	6	0.5	113.1	8.78	8.55	230.00	10.00	0.0000414	0.12	23.00	0.00794	-0.00794	0.00006

7	6	0.5	201.06	8.78	8.70	80.00	10.00	0.0000414	0.12	8.00	0.00276	-0.00276	0.00001
8	8	0.5	452.39	8.78	8.52	260.00	10.00	0.0000414	0.12	26.00	0.00897	-0.00897	0.00008
9	12	0.5	706.69	8.78	8.55	230.00	10.00	0.0000414	0.12	23.00	0.00794	-0.00794	0.00006
10	15	0.5	353.43	8.78	8.63	150.00	10.00	0.0000414	0.12	15.00	0.00518	-0.00518	0.00003

Table 2: Data obtained using the Fabricated Serial Resistivity Meter (SRM) for site one

S/N	**HCS**	**HPS**	**GF**	**V_I** (V)	**V_F** (V)	($\Delta V = V_I - V_F$) (mV)	**I (mA)**	**A ($\prod D^2/4$)**	**L (m)**	**R (Ω)**	**P (Ωm)**	**ΔX**	**ΔX^2**
	AB/2	**MN/2**	**G**										
1	1	0.25	6.28	8.94	8.37	570.00	10.00	0.0000414	0.12	57.00	0.01967	-0.00059610	0.00000036
2	2	0.25	25.13	8.94	8.45	490.00	10.00	0.0000414	0.12	49.00	0.01691	-0.01691036	0.00028596
3	3	0.25	56.55	8.94	8.36	580.00	10.00	0.0000414	0.12	58.00	0.02002	-0.02001634	0.00040065
4	3	0.25	100.53	8.94	8.43	510.00	10.00	0.0000414	0.12	51.00	0.01760	-0.01760057	0.00030978
5	4	0.25	226.19	8.94	8.33	610.00	10.00	0.0000414	0.12	61.00	0.02105	-0.02105167	0.00044317
6	6	0.5	113.1	8.94	8.29	650.00	10.00	0.0000414	0.12	65.00	0.02243	-0.02243210	0.00050320
7	6	0.5	201.06	8.94	8.30	640.00	10.00	0.0000414	0.12	64.00	0.02209	-0.02208699	0.00048784
8	8	0.5	452.39	8.94	8.40	540.00	10.00	0.0000414	0.12	54.00	0.01864	-0.01863590	0.00034730
9	12	0.5	706.69	8.94	8.36	580.00	10.00	0.0000414	0.12	58.00	0.02002	-0.02001634	0.00040065
10	15	0.5	353.43	8.94	8.45	490.00	10.00	0.0000414		49.00	0.01691	-0.01691036	0.00028596
11	15	1	981.75	8.94	8.52	420.00	10.00	0.0000414		42.00	0.01449	-0.01449459	0.00021009

Table 3: Data obtained using Terrameter for site one

S/N	**HCS**	**HPS**	**GF**	**ΔV (mV)**	**I (mA)**	**A ($\prod D^2/4$)**	**L (m)**	**R (Ω)**	**P (Ωm)**	**P x 10^{-4} (Ωm)**	**ΔX**	**ΔX^2**
	AB/2	**MN/2**	**G**									
1	1	0.25	6.28	83.11	522	0.0000414	0.12	104.7	658	0.06580	-0.00393	0.00002
2	2	0.25	25.13	21.04	529	0.0000414	0.12	23.68	595	0.05950	-0.05950	0.00354
3	3	0.25	56.55	9.567	541	0.0000414	0.12	10.14	573	0.05730	-0.05730	0.00328
4	3	0.25	100.53	5.733	576	0.0000414	0.12	5.972	570	0.05700	-0.05700	0.00325
5	4	0.25	226.19	3.109	683	0.0000414	0.12	2.51	568	0.05680	-0.05680	0.00323
6	6	0.5	113.1	6.069	686	0.0000414	0.12	5.041	570	0.05700	-0.05700	0.00325

7	6	0.5	201.06	3.669	738	0.0000414	0.12	3.415	687	0.06870	-0.06870	0.00472
8	8	0.5	452.39	1.758	795	0.0000414	0.12	1.25	565	0.05650	-0.05650	0.00319
9	12	0.5	706.69	1.148	811	0.0000414	0.12	0.6936	681	0.06810	-0.06810	0.00464
10	15	0.5	353.43	2.043	722	0.0000414	0.12	1.9	672	0.06720	-0.06720	0.00452
11	15	1	981.75	0.919	902	0.0000414	0.12	0.679	667	0.06670	-0.06670	0.00445

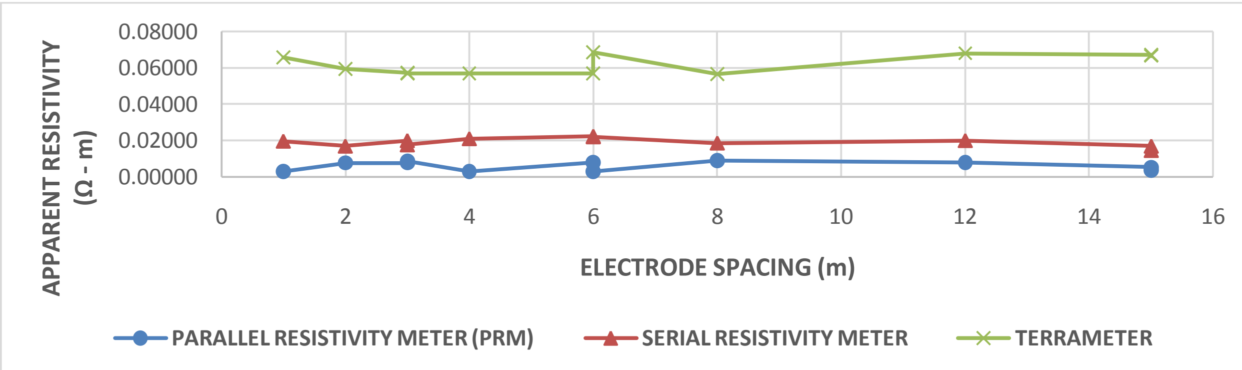

Figure 4.: Profile Analysis of the resistivity meters for site one

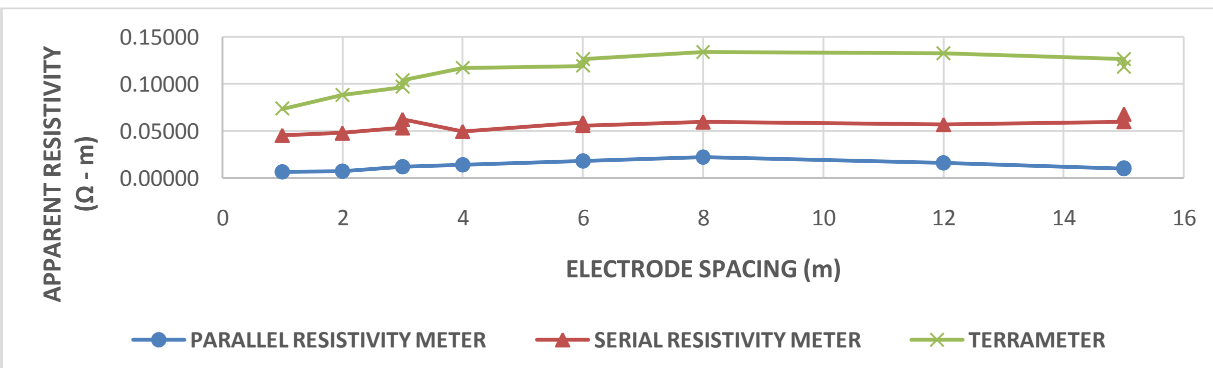

Figure 5: Profile Analysis of the resistivity meters for site two

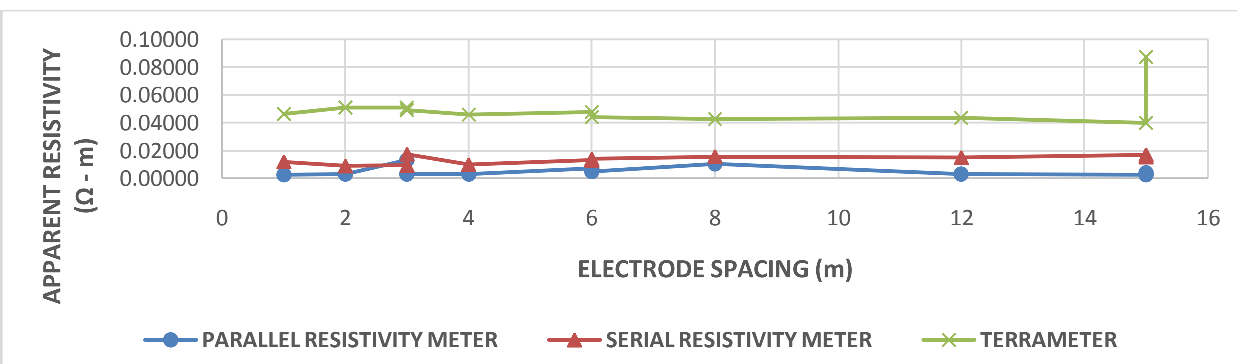

Figure 6: Profile Analysis of the resistivity meters for site three

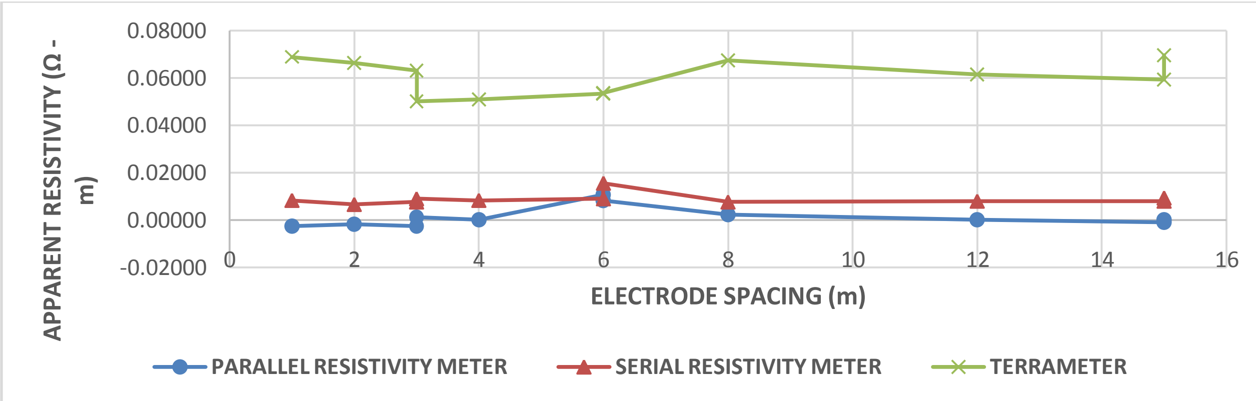

Figure 7: Profile Analysis of the resistivity meters for site four

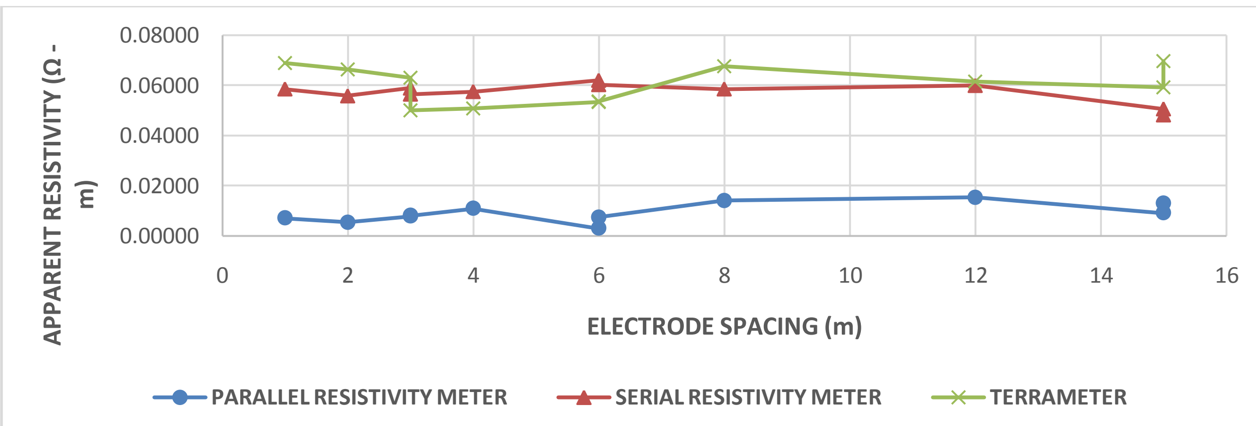

Figure 8: Profile Analysis of the resistivity meters for site five

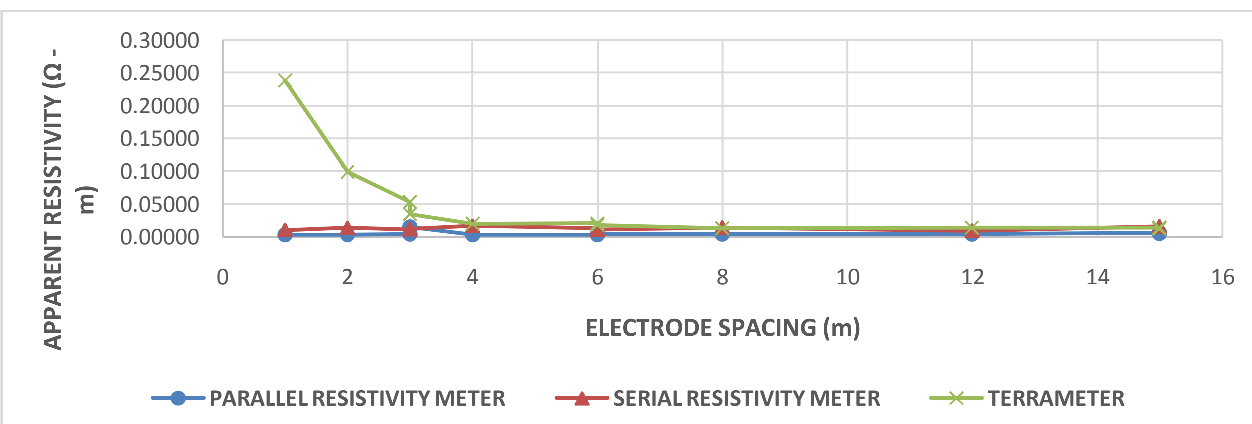

Figure 9: Profile Analysis of the resistivity meters for site six

IV. CONCLUSION

It has been observed that the two soil resistivity meters designed and constructed (Serial resistivity meter, SRM, and the parallel resistivity meter, PRM) are simple low-cost and are of higher accuracies. Their soil resistivity readings for the chosen six sites compare favorably well with the corresponding standard terrameter readings. The soil resistivity average for the site I was found to be 0.005961 Ω.m (using PRM) and 0.019075 Ω.m (using SRM), while the soil resistivity average for site II was 0.013616 Ω.m (using PRM) and 0.056253 Ω.m (using SRM). The soil resistivity average for site III was found to be 0.005365 Ω.m (using PRM) and 0.013553 Ω.m (using SRM), while the soil resistivity average for site IV was 0.001506 Ω.m (using PRM) and 0.008816 Ω.m (using SRM). The soil resistivity average for site V was found to be 0.009349 Ω.m (using PRM) and 0.057100 Ω.m (using SRM), while the soil resistivity average for site VI was 0.004957 Ω.m (using PRM) and 0.013208 Ω.m (using SRM). The Square Mean Errors (SMEs) and the Mean Square Errors (MSEs) of the soil resistivity readings (with the terrameter readings being used as standard values) were found to be very small.

V. REFERENCE

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