Research Journal of Physical Sciences ISSN 2320–4796
Vol. **6(5),** 1-7, October **(2018)** *Res. J. Physical Sci.*

Design and construction of a simple resistivity meter for resistivity measurement

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Available online at: www.isca.in, www.isca.me
Received 6th August 2018, revised 17th September 2018, accepted 3rd October 2018

Abstract

A simple resistivity meter was designed and constructed using cheap and locally available electronic components which included two reversing switches (DPDT), 500W "modified" sine wave inverter, a bridge rectifier, 2.2µF capacitor and a 12V DC car battery used as the power source. The data/result obtained using the constructed resistivity meter was quite comparable with that of the IGIS Resistivity Meter (model SSR-MP-ATS) data. The apparent resistivity value using the Schlumberger array for a current electrode spread of 60m of the IGIS resistivity meter ranges from 301.38 – 1087.49Ωm while that of the simple resistivity meter ranges from 272.67 – 1045.12Ωm. However, the use of this meter is limited to shallow investigations with depth of penetration at less than 50m as the simple meter gives readings that are significantly different from that of the standard meter at deeper depth of penetration. Efforts are being made to improve on the performance of the simple resistivity meter.

Keywords: Design and construction, resistivity meter, resistivity, measurement.

Introduction

The geophysical method that involves the detection of surface effects produced by electric current flow in the earth's subsurface formation is usually electrical resistivity. The method is used in different areas such as in exploration for ground water, in engineering surveys to locate subsurface cavities, faults and fissures, permafrost, and mineshafts[1]. Resistivity meter is the equipment used in the actualization of the purpose of this method. It can be used to identify the composition of various earth strata and the depth at which they occur and by detecting changes in the earth composition, to the point existence of buried objects.

Apparent soil resistivity is the earth parameter which this resistivity meter measures. It is the key factor that determines the resistance of the soil and the depth extent. It is done by driving or injecting direct current (DC) into the soil and measuring potential difference across the electrode. The current must be driven to obtain low ground resistance. This implies that the apparent resistivity is a function of measured impedance and electrode configuration[2]. All soil conducts electric current some of which are good electrical conductors (having good conductivity). The resistivity or inverse of conductivity of the soil is obtained using resistivity meter[3].

The different types of popular resistivity meter available in the market are listed in Awotoye and Selemo[4].

In this paper, a simple resistivity meter will be demonstrated how it was designed and constructed then applied to test its functionality in the site in which resistivity survey had previously been carried out.

The meter finds its application in archaeology and in the mining of alluvial gold or gemstone[5]. The need for safe, portable and potable water globally is so great and sustainability in water production is highly needed. To achieve this, training of workers with skills to drill, develop, complete and maintain good well is essential[6]. To explore for groundwater, prior knowledge of the contrast in physical properties between the overlying unconsolidated materials and the bedrock can be known using the electrical resistivity technique to determine the approximate depth to bedrock of an area[7,8].

Geophysicists, geologists and students in southern part of the country find it difficult to hire resistivity meter for their research. Where one is found, the cost of hiring it, paying, accommodating and feeding the operators throughout the period make it more difficult for the students. Due to these constraints, it was expedient that this equipment be designed and constructed to serve some purposes such as to test the workability of the equipment on the field by acquiring data with it; and to process and compare its data with the data obtained with other resistivity meters in the same site.

Location and geology of the test site environment: After the construction of the meter, its workability was tested in the University of Calabar campus. The campus is located between latitude 4˚56'39" and 4˚57'30"N and longitude 8˚20'38" and 8˚21'43"E with an elevation of about 15m above sea level. The area is accessible through tarred road from the university main gate.

Geologically, the site falls within the coastal plain sands known as the Benin formation which is the uppermost unit of Niger Delta complex, and overlies the Agbada formation. The Benin formation comprises of sediments whose age ranges from tertiary to recent and was deposited down dip towards the Atlantic Ocean[9].

It consists of fine-medium coarse grained sands which sometimes are poorly sorted[10].

Table-1: VES data previously acquired in the test site using IGIS resistivity meter (model SSR-MP-ATS).

AB/2	MN/2	KR
1	0.25	301.38
1.5	0.25	398.38
2	0.25	358.48
3	0.25	464.44
4	0.5	520.63
4	0.25	546.83
5	0.5	569.20
6	0.5	602.09
8	0.5	673.01
10	1.0	741.88
10	0.5	705.17
15	1.0	819.93
20	1.0	965.32
30	1.0	1087.49

Materials and methods

Some of the materials used for the construction of the simple resistivity meter were: i. 12 volts DC car battery (power source), ii. Bridge rectifier, iii. 500watt inverter, iv. 2.2 microfarad capacitor, v. Two DPDT switch (reversing switches), vi. Two digital multi-meters.

The construction of the resistivity meter is based on the application of direct current where artificial sources of current (in this case, a 12V DC car battery) was used to produce an electrical potential field in which current was driven into the ground by means of two current electrodes and the potential difference was measured by the potential electrodes.

The equipment was constructed and assembled in accordance with the circuit diagram shown in Figure-1. A 500 watt "modified" sine wave inverter that produces an AC sine wave from the 12 volts DC source was used to increase the voltage required value to hundreds of volts (220V). The bridge rectifier was connected in parallel to convert the inverter output into direct current at the same output. A 2.2μF capacitor was connected in parallel to the circuit to smoothen the output of direct current at high steady DC voltage. The circuit diagram also includes two reversing switches (DPDT) - one for the ammeter and one for the voltmeter. The two multi-meters which serve to measure current and voltage output were connected to the simple resistivity meter via connectors where current and potential electrode cables were also connected to the simple meter.

Field testing: Schlumberger electrode configuration was adopted in testing of the equipment in the field. The method was adopted because the data in Table-1, which were to be compared with the ones acquired using the fabricated meter were obtained by the same electrode array. Additional equipment used for the field test were five electrodes, four cable on reels, two measuring tapes and two sledge hammers.

The two current electrode cables were connected to the fabricated resistivity meter through connectors on the current electrode terminals and connected to the current electrodes which are used to inject current into the ground to create an electric field while another two potential electrodes also connected to the simple meter via cables measures the potential difference. The two multi-meters, one for current measurement and the other for voltage measurement were also connected to the simple resistivity meter. The electrodes were connected first before connecting the power source to the system to avoid the risk of electric shock.

After the above setup was done, a 12volt DC car battery was connected to the resistivity meter and the multi-meters were switched on. The multi-meter for measuring current is set at 200mA while the multi-meter for voltage measurement was set at the 20V range. The power switch was turned on to take the first readings after which the system was switched off so that the current electrodes could be expanded for depth penetration of current before the system is powered on again to take the next readings.

Results and discussion

The results from the field test was recorded and the ground resistance, R was computed using ohm's law (V=IR). The resistance was multiplied by the geometric factor, K of each electrode spread to get the apparent resistivity, of the earth. The results are in Tables-2 and 3 while the generated curves are shown in Figures-4 and 5.

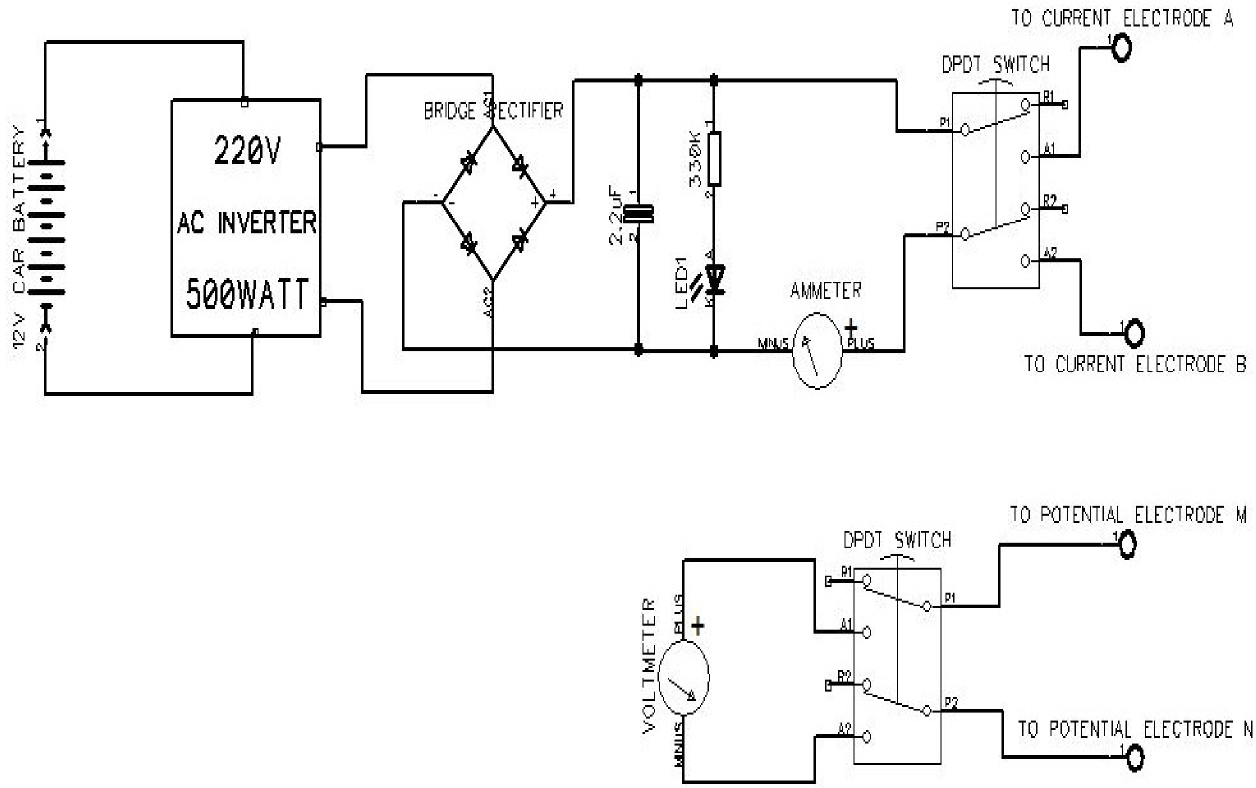

Figure-1: The schematic circuit diagram of the simple resistivity meter.

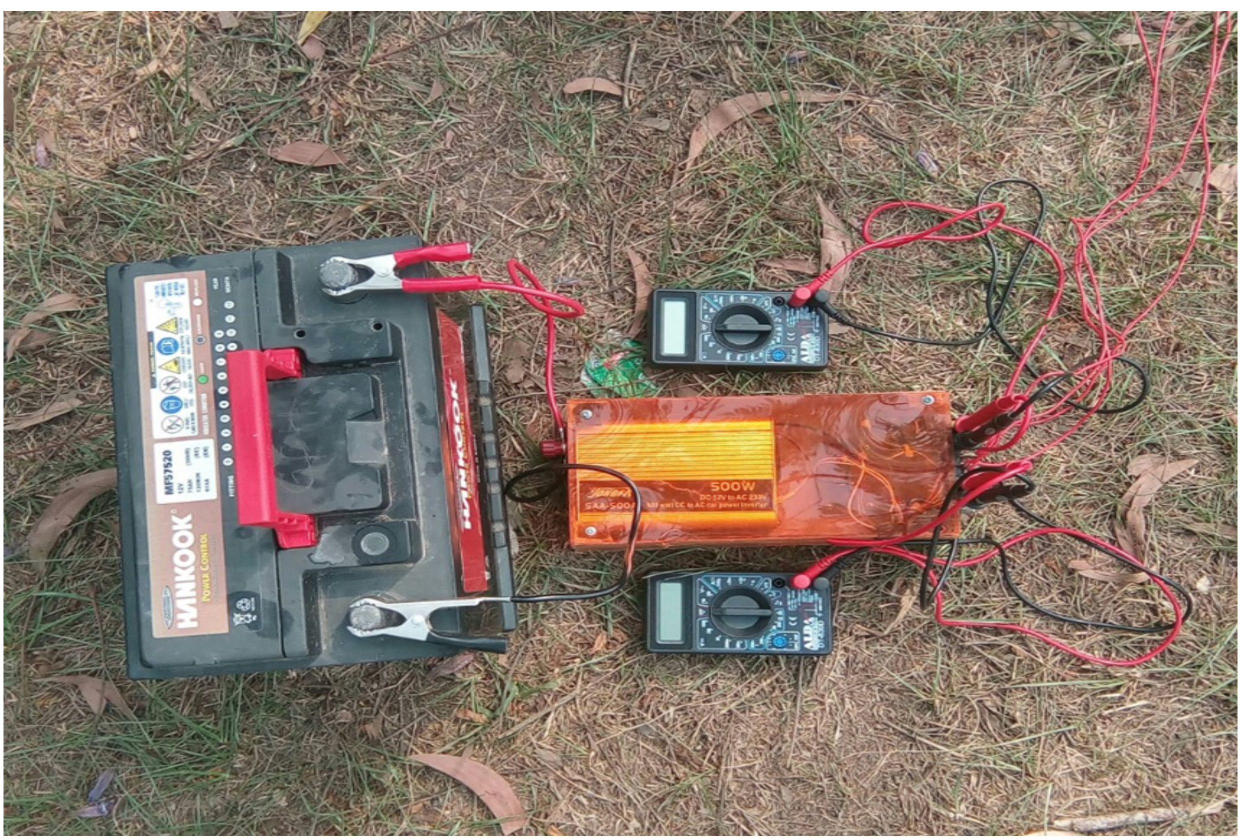

Figure-2: The constructed simple resistivity meter and its components.

Figure-3: Field layout during the field test of the equipment.

Table-2: The data obtained using the constructed resistivity meter.

AB/2	MN/2	V(v)	I (A)	R(Ω)	K	KR
1	0.25	1.5	0.028	53.57	5.09	272.67
1.5	0.25	0.91	0.0332	27.40	13.75	376.89
2	0.25	0.79	0.0440	17.95	24.74	444.08
3	0.25	0.40	0.0385	10.39	56.16	583.50
4	0.5	0.44	0.0312	14.10	49.49	697.81
4	0.25	0.23	0.0319	7.21	100.15	722.08
5	0.5	0.48	0.0458	10.48	77.76	814.92
6	0.5	0.32	0.0430	7.44	112.33	835.74
8	0.5	0.16	0.0418	3.83	200.30	767.15
10	1	0.17	0.0347	4.89	155.53	760.54
10	0.5	0.08	0.0376	2.12	313.41	664.42
15	1	0.09	0.0435	2.07	351.90	728.43
20	1	0.05	0.0385	1.29	626.83	808.61
30	1	0.02	0.0270	0.74	1412.33	1045.12

Table-3: Comparison of apparent resistivity data from Tables 1 and 2.

AB/2	MN/2	K	IGIS meter (Ωm)	Constructed meter (Ωm)
1	0.25	5.09	301.38	272.67
1.5	0.25	13.75	398.62	376.89
2	0.25	24.74	358.48	444.08
3	0.25	56.16	464.44	583.50
4	0.5	49.49	520.63	697.81
4	0.25	100.15	546.82	722.08
5	0.5	77.76	569.20	814.92
6	0.5	112.33	602.09	835.74
8	0.5	200.30	673.01	767.15
10	1	155.53	741.88	760.54
10	0.5	313.41	705.17	664.42
15	1	351.90	819.93	728.43
20	1	626.83	965.32	808.61
30	1	1412.33	1087.49	1045.12

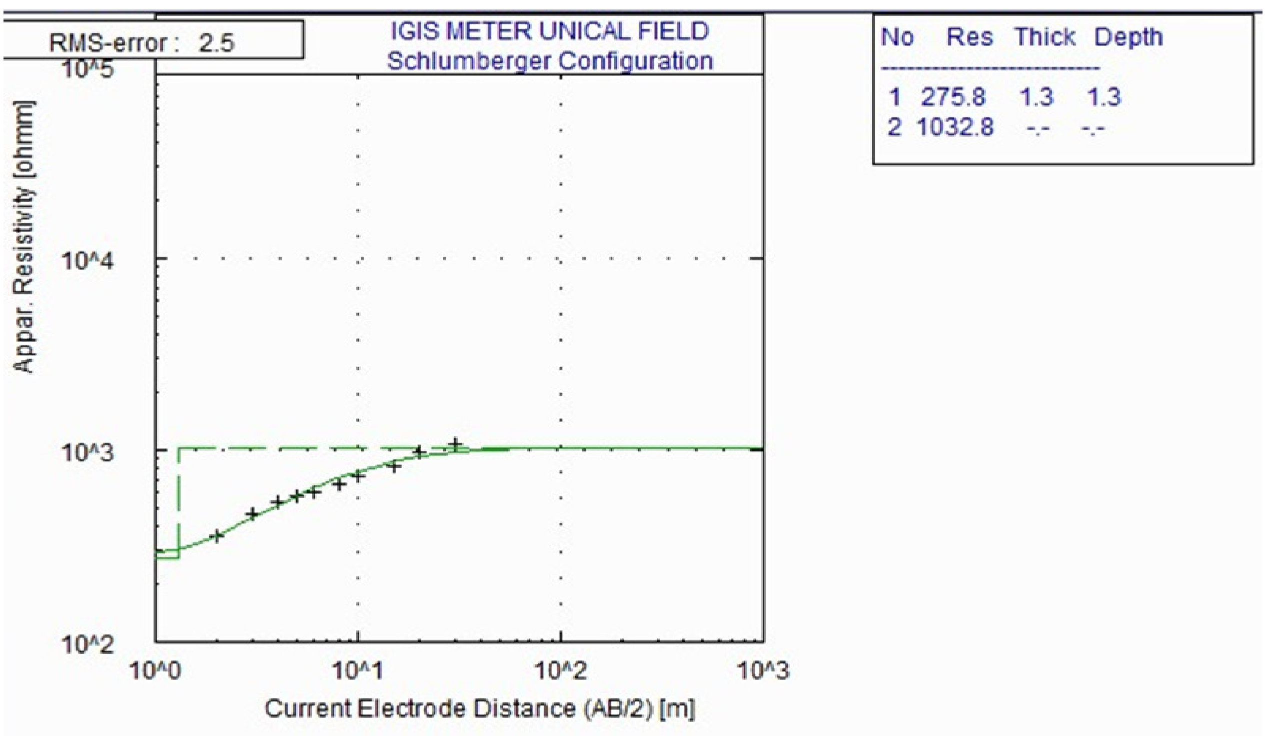

Figure-4a: VES curve the previously of the acquired data (data from Table-1) using Winresist software.

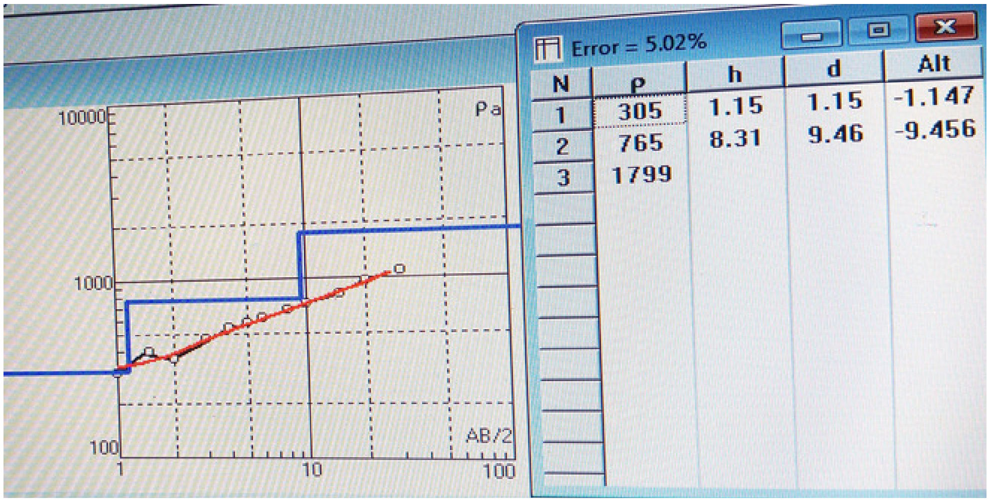

Figure-4b: VES curve the previously of the acquired data (data from Table-1) using IPI2win software.

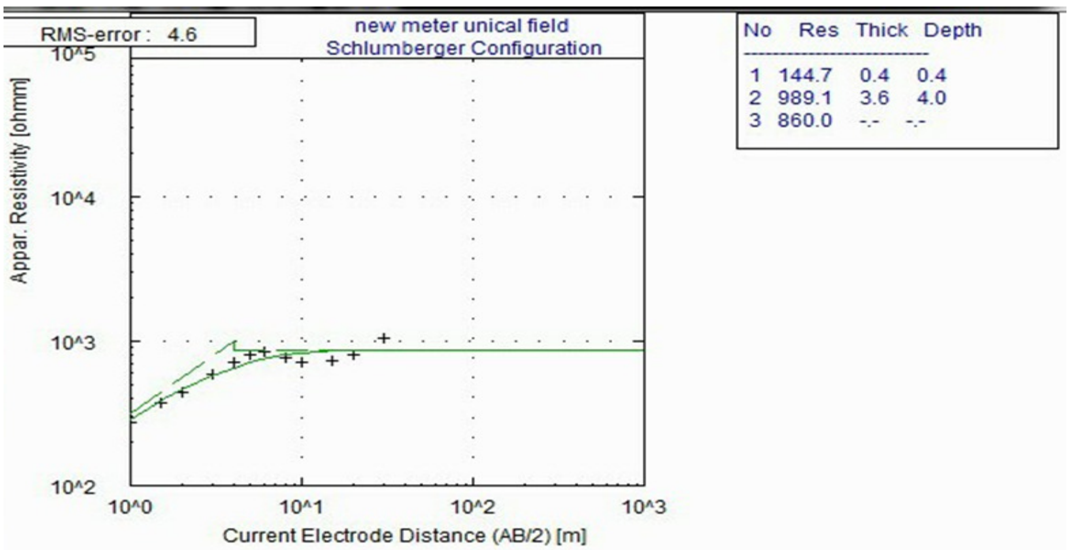

Figure-5a: VES curve of the acquired data (data from Table-2) using win Resist software.

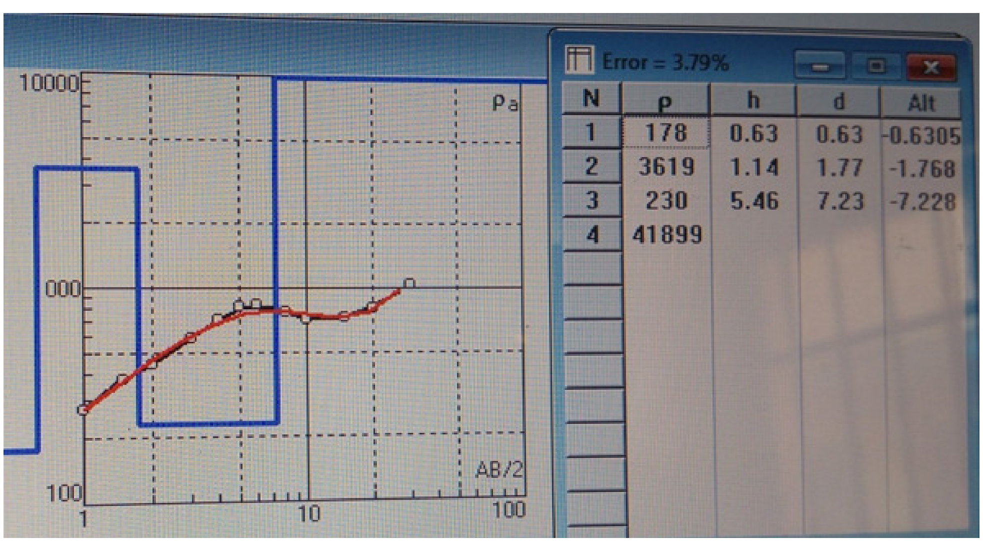

Figure-5b: VES curve of the acquired data (data from Table-2) using IPI2win software.

Studying the Tables-1 and 2 above, it can be seen that there is a steady trend of increases in the resistivity values of the site. Though the data are not exactly the same which may be owed to some factors, which may include the condition of the equipment during data acquisition, the specification of the equipment, injected current, etc. In Table-1, the highest resistivity of 1087.49Ω was obtained at AB/2 = 30m and at MN/2 = 1.0m. In Table-2, it could be seen that the highest resistivity of 1045.12Ω is also obtained at the same AB/2 = 30m and MN/2 = 1.0m.

Furthermore, the lowest recorded resistivity in Table-1 is 301.38Ω at AB/2 = 1.0 and MN/2= 0.25m. At these same depths, the lowest resistivity of 272.67Ω is also obtained, as shown in Table-2.

The results of the data have good resolution. The analysis was done using two VES software; win Resist and IPI2win as shown in Figures-5a and b with minimum root means square errors 3.2 and 3.79% respectively.

Conclusion

From the result of both instruments, we can conclude that the fabricated equipment showed some degree of accuracy when compared to the IGIS resistivity meter, but the constructed meter needs some improvement for better depth of penetration as the equipment reading no longer corresponds with that of the standard resistivity meter. The use of the constructed equipment should be limited to shallow geophysical investigation where the depth of interest is less than 50m *e.g.* ground water exploration and engineering site investigations. The equipment can be improved upon by integrating the current and voltage measurement together such that the ground resistance can be measured directly.

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