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Research Paper

Evaluation of Geoelectrical Data Stability: Manual Quadrupole vs. Multi-Electrode Switch Panel Prototype

M. Fachrul Rozi Kurniawan[1*] ,Yudha Agung Pratama[2] , Dzikru Aminulloh[3]
[1,2,3] UPN "Veteran" Yogyakarta, Indonesia

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Abstract

A contructed multi-electrodes switch for geoelectric-resistivity method was designed and built. The instrument was built to perform data acquitition that coverage the line survey and increase the optimation of data acqutition. The data field test was conducted by comparing by using single-electrode moving manually each datum point and multi-electrodes fixed electrodes coverage all point data. Sounding profiling was used to perform the instrument by using Wenner configuration. The resisvity of medium at shallow (depth factor, n=1) used single-electrode and multi-electrodes are 460 Ω.m and 463 Ω.m with the standard deviation 0,60 % and 0,87 %, respectively. At more deeper depth (depth factor, n=2) used single-electrode and multi-electrodes are 51 Ω.m and 26 Ω.m with the standard deviation 9,80 % and 24,47 %, respectively. Eventhough the development of multi-electrodes instrument will continue in quality control od data quality and its system build in automatic perform.

Keywords: *Single-Electrode, Multi-Electrode, Instrument, Resistivity*

INTRODUCTION

Geoelectric-resistivity is a common geophysical method which use electrical concept in subsurface exploration. Electrical Resistivity Tomography (ERT) is a frequently used method for estimating subsurface models based on resistivity distribution of the rock. This method is carried out by injecting direct current (DC) and measuring the potential difference between two points in the earth-surface (Stummer et al., 2002). Geoelectric applications have been widely used to mapping the distribution of environmental pollution as a leachate (Alao et al., 2024), landslides monitoring (Chambers et al., 2022), and exploring groundwater and minerals (Wahyuni et al., 2024), as well as in other geotechnical fields (Sharma et al., 2024). The data acquisition technique in geoelectrical-resistivity is generally performed with a single electrode, which involves manually moving the electrodes for each data point according to the configuration. The moving of these electrodes has several disadvantages, including poor contact between the electrodes and the surface soil if repeated insertion and removal are carried out at the same point, a higher possibility for the electrodes to shift from design position, and, most importantly, the inefficiency of data acquisition in terms of both operational time and cost.

A comprehensive approach is needed in the development of geoelectric-resistivity acquisition to achieve operational efficiency in data acquisition. Multi-electrodes systems are considered a solution to the problems of geoelectric data acquisition before. Multi-electrodes systems use a large number of electrodes to cover all electrode positions along a survey line. The use of multi-electrodes can be maximized for multi-dimensional geoelectric imaging, allowing for the imaging of complex geological structures (Loke et al., 2013).

Each electrode can function as a current electrode (A/B) and a potential electrode (M/N) where is controlled by a multi-electrodes switch unit. The multi-electrodes main unit is a separate device from the main geoelectric/resistivity meter. The multi-electrodes device is developed by

Corresponding author's email: mfachrulrozi@upnyk.ac.id

utilizing electronic switch components to control which electrodes will be activated. The advantage of the developed multi-electrodes unit is that it has an low cost development and maintenance, and is easy to operate while the covarage is wide. One of the instrument-controls built into the system is that a electrode just only act as one function (A, B, M, or N).

In this study, a statistical parameter as variance and standard deviation ware conducted to determine the level of dataset and the precision of the geoelectrical measurement. The test was performed on resistivity data using both a single-electrode and a multi-electrodes system as a step in the quality control of the multi-electrodes instrument unit.

LITERATURE REVIEW

Geoelectric-Resistivity

Geoelectrics is a geophysical method that focuses on the interconnected physical parameters of current (I), electrical potential (ϕ), and resistance (R), so its related activities can be explained based on Ohm's Law. If an electrical current source is located at position r, the current propagation is modeled as shown in Figure 1, and the potential caused by the current is mathematically expressed as:

$$\nabla.\left(\frac{1}{\rho(x,y,z)}\nabla\phi(x,y,z)\right) = -\frac{\partial j_c}{\partial t}\delta(x_s)\ldots (1)$$

Where ρ is resistivity and ϕ is potential as a function of space, and j_c is the electric charge density. Thus, the potential value at each point, both on the surface and within the medium, can be determined.

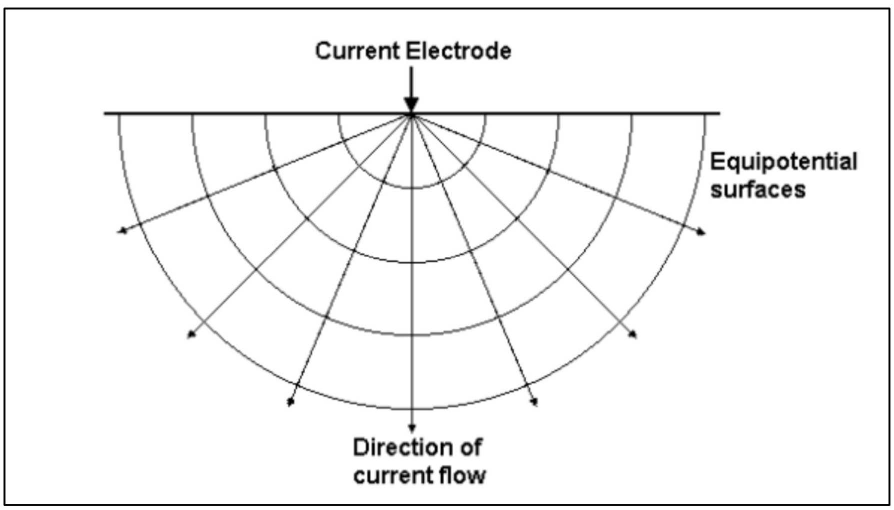

Figure 1. Current distribution (arrow line) from a point source and the equipotential lines that perpendicular toward to current lines. The equipotential area coverage a half of spherical (Loke, 2004).

The equation (1) has a solution how the potential can be determined, it is assumed that the Earth's layers have a homogeneous resistivity distribution, so the resistivity as the apparent resistivity (ρ_a). Considering the electrode array (geoelectrical configuration), the distance between point source and any point that will be calculated the potential electrik becomes a transformation of the geometric factor K. Therefore, the measured resistivity value can be calculated using the following equation:

$$\rho_a = K\frac{\Delta\phi}{I} \ldots (2)$$

Multi-electrode System

The field measurement of geoelectric-resistivity has rapidly flourish, which is instrument and technical measuring data. The development of the system has proven the low cost operational and high effectiveness data acquitition in complex area. However, the coverage area more possible to imaging data in multi-dimensional (2-D dan 3-D) with higher resolution (Loke et al., 2015; Wilkinson et al., 2012). The multi-electrodes switch has been build by 24 channel of electrodes and potentially add more electrodes. The 24 electrodes directly connect multi-electrodes switch by multi-electrodes cable as shown in Figure 2. The multi-electrodes instrument is rapidly increase optimation of dataset of geoelectric-resistivity data (Chávez et al., 2014; Loke et al., 2013). The error of data measurement conventional geoelectric can be caused by the moving of electrode every datum point. To minimize the effect, needed fix electrodes which is all covered area (Vega et al., 2021).

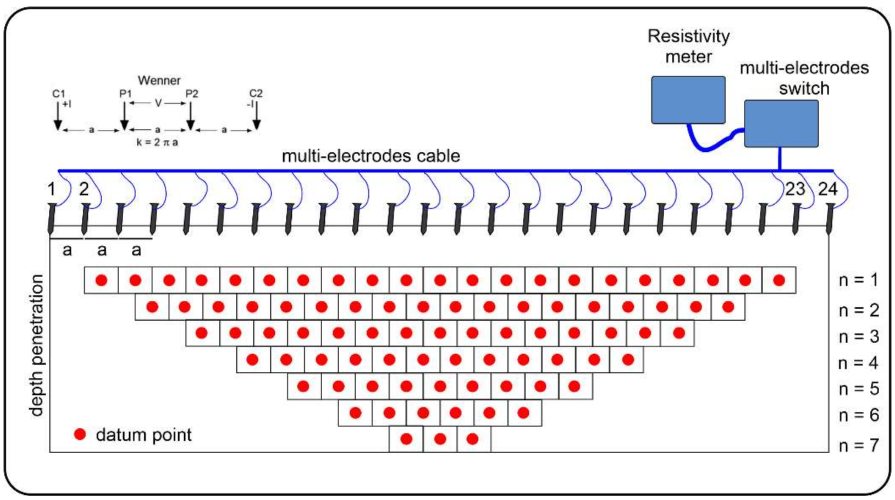

Figure 2. Schematic measurement datum point by Wenner configuration with 24 electrodes controlled by multi-electrodes switch.

Electronic System Development of Multi-electrodes

The develomptent of switch multi-electrodes satisfy the safety, simplicity, and durability. Intrument of the multi-electrodes has a safety break circuit to protect the main unit of resistivity from the current short cut. To activate the electrode, we used toggle switch (ON-OFF-ON) and controlled by LED to show how the electrodes have been actived. Another control is a buzzer to ensure the electrodes active just in single function (A/B/M/N).

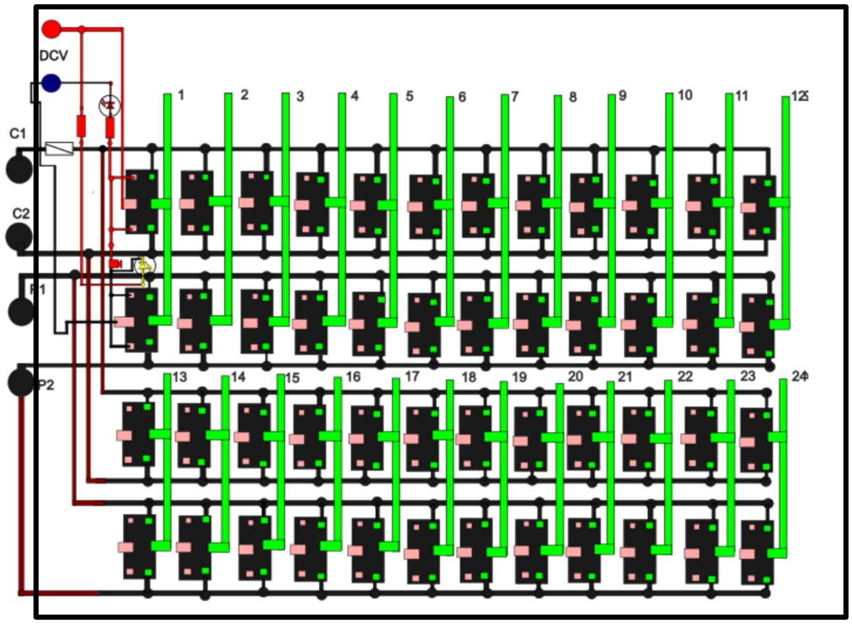

Figure 3. Panel design of the multi-electrodes which toggle switch to activated the each electrodes function either potential or current.

RESEARCH METHOD

In the field test was performed in UPN "Veteran" Yogyakarta to verify the data between single and multi- electrodes. The resistivity meter using six current level to inject direct current into the earth. The currect injected has non-stationer value and it is depend on the configuration of the electrodes. In the experiment, while n = 1 the current level varies from ~20 mA (1), ~40 mA (2), ~60 mA (3), ~75 mA (4), ~90 mA (5), and ~110 mA (6) and n = 2, the current level varies from ~15 mA (1), ~30 mA (2), ~40 mA (3), ~50 mA (4), ~65 mA (5), and ~75 mA (6). We use a Wenner configuration to test the geoelectrical data between single-electrode and multi-electrodes by using spacing of electrode is 10 meter.

To enrich the data, we use a number of variations experimental. First, we use the electrode spacing n = 1, then injected current level varies from level 1 to 6 and calculated the resistivity by geometrical electrodes. The measurement of the potential difference was performed by 15 times for each current level (1-6), so we can evaluate data using statistical parameter (standard deviation of resistivity). Next we use n = 3, the value was choosen for coverage datum point in horizontal fixed location with different depth.

FINDINGS AND DISCUSSION

To evaluate the performance of constructed multi-electrodes instrument, we measure two vertical datum points repeatly and compare data using single-electrode. The total data of resistivity is 360 data both multi-electrodes and single-electrode system. The current level in different electrode spacing (different *n*) has not same the current value. Current value depend on the potential difference read by potential sensor. The larger electrode spacing, a higher current is needed to achieve a readable potential difference.

Tabel 1 shows the average apparent resistivity and its standard deviation for depth factor and current level. Depth factor reperesents the depth of the datum point, which is larger n has more larger deeper datum point. Resistivity in the shallow depth has ~ 460 $\Omega.m$ and go deeper depth has ~25 - ~50 $\Omega.m$. The standard deviation shows that STD multi-electrodes has lower value than single-electrode, the event because of posibility shifting of the single-point-electrode.

The relative STD of resistivity using multi-electrodes (n = 1) varies from 0,03% to 0,98% with average 0,60% and using single-electrode varies from 0,42% to 1,79% with average 0,87%. However, The relative STD of resistivity using multi-electrodes (n = 2) varies from 5,21% to 29,46% with average 9,80% and using single-electrode varies from 6,96% to 55,61% with average 24,47%.

Table 1. The average resistivity each current level and standard deviation

	Current Level	**ST DEV Multi-E**	**ST DEV Single-E**	$\bar{\rho}_a(\Omega\cdot m)$ **Multi-E**	$\bar{\rho}_a(\Omega\cdot m)$ **Single-E**	**% ST DEV Multi-E**	**% ST DEV Single-E**
n = 1	1	4,561	7,744	463,405	467,621	0,98%	1,66%
	2	3,458	6,506	458,821	465,034	0,75%	1,40%
	3	2,594	3,652	460,829	462,252	0,56%	0,79%
	4	2,556	2,133	459,477	462,515	0,56%	0,46%
	5	1,460	2,234	458,964	460,454	0,32%	0,49%
	6	1,814	1,933	458,316	462,818	0,40%	0,42%
n = 2	1	14,902	14,378	50,580	25,857	29,46%	55,61%
	2	3,892	4,341	49,770	25,937	7,82%	16,74%
	3	2,956	4,817	50,755	26,761	5,82%	18,00%
	4	2,571	1,916	53,604	27,506	4,80%	6,96%
	5	3,021	3,498	53,364	27,651	5,66%	12,65%
	6	2,757	7,800	52,931	21,174	5,21%	36,84%

Figure 4 and 5 show the trend of STD toward to current level in each depth factor n = 1 and n = 2, respectively. In general the trend of STD shows decreasing trend as increasing current level. In some point of current level, the trend has not lineary same, the phenomenom can be caused by electrical noise as time acquitition. To adjust the parameter, we need to test in field that has low noise field.

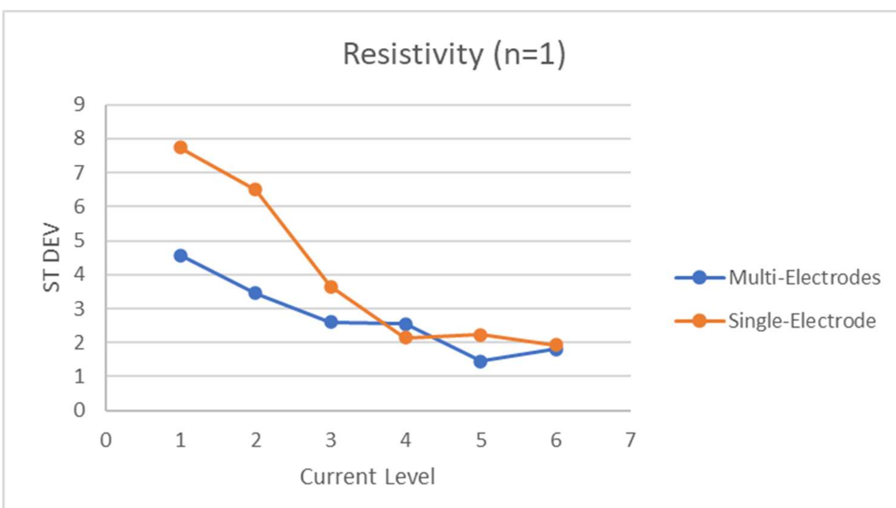

Figure 4. STD of resistivity toward current level when depth factor is 1.

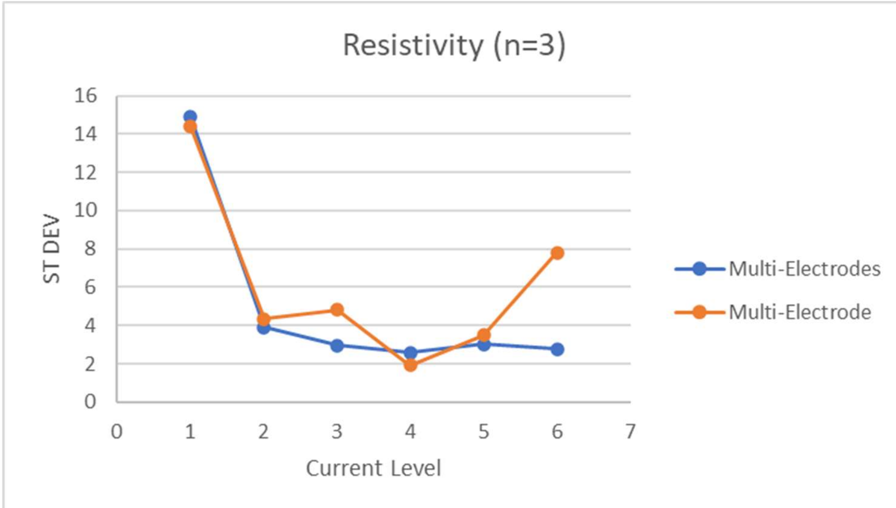

Figure 5. STD of resistivity toward current level when depth factor is 3.

CONCLUSIONS

The individual measurements both single and multi electodes were yielded good results as convergence the apparent resistivity and small standard deviation. Nevertheles, the main difference between two methods is the operational cost and time consuming to acquitition the data field. The result shows that the contructed multi-electrodes switch has good result compared by single-electrode (conventional geoelectric-resistivity) eventhough more smaller STD value. The instrument of multi-electrode has possibility developed by using more electrodes (48, 72, or multiple by 24 electrodes). The other hand, acquitition can be develop in automatic version that saving data arrange as we want the purpose of the research.

LIMITATION & FURTHER RESEARCH

The limitations of the study are those characteristics of design or methodology that impacted or influenced the interpretation of the findings from your research. Further research should suggest the number of gaps in our knowledge that follow from our findings or to extend and further test of the research.

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