Electrical Resistivity Tomography Using Wenner β-Schlumberger Configuration for Anomaly Detection in The Soil

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Abstract. In the subsurface exploration investigations there are many methods used, one of them is Electrical Resistivity Tomography (ERT). ERT method is able to measure the electrical properties of the material below the earth surface based on the value of the resistivity of the material by injecting electric current and measure the potential at the surface. Based on the data obtained then will be inputted into RES2DINV software for final processing of 2D image. This research has been created by testing 2 configurations Wenner-Schlumberger and Wenner β-Schlumberger for detecting anomalies in homogeneous soil. A wooden box containing homogeneous soil is used for the test. Three anomalies (wood, stone, and wet soil) were placed in different positions and the variation of resistivity was detected. We found that the Wenner β-Schlumberger configuration results in a smaller resistivity value error than the Wenner-Schlumberger configurations.

Keyword: ERT, Wenner β-Schlumberger, anomaly detection

1. Introduction

In the field of imaging method, Electrical Resistivity Tomography (ERT) is a method that is widely used in exploration field especially subsurface exploration [1,2]. ERT can measure the electrical properties of the material below the surface that are based on the value of resistivity of the material by injecting electric current and measure the potential at the surface [3,4,5]. Improvement in their imaging methods leads to more popular use in the field of subsurface exploration. In addition, the popularity is also due to the easy-to-carry equipment, easy and cheap to operate, and the measurement of data accuracy is reliable [6,7,10].

In the application there are various configurations ERT methods used such as Wenner, Schlumberger, Dipole-Dipole, Pol-Dipole and incorporation of two types of configurations (Wenner-Schlumberger) [8,9]. This research has been created to develop the latest configurations. The purpose of this development is to get the image result for more effective than latest configurations.

Based from above, there is exist the incorporation of two configuration as Wenner and Schlumberger that become Wenner-Schlumberger. The incorporation of these configuration is to get maximal of the image result. But in this research, has been created the development from Wenner-Schlumberger configuration that was proven to produce images that are more effective and accurate image. This configuration is Wenner β-Schlumberger configuration. The development of this
configuration is make a modification from the Wenner configuration becomes Wenner β. actually
Wenner configuration has 3 types as Wenner α, Wenner β and Wenner γ. Wenner configuration used
previously was Wenner α which has weaknesses that are less sensitive in detecting non-homogeneity
of horizontal layers. By the modification of the wenner configuration and incorporate d with
Schlumberger (Wenner β-Schlumberger) was proven to produce images that are more effective and
accurate image than Wenner-Schlumberger.

2. Method

2.1. Geoelectric Resistivity of Method

Geoelectric method is an imaging method that can measure the electrical properties of the material
below the surface that are based on the value of the resistivity of the material by detecting from the
surface [11]. This method is performed by injecting electric current to a pairs electrodes and
measuring the potential data to the other pairs electrodes. [12,13]. From the results of current and
potential measurements then can be obtained resistance value each layer below the measuring point
[14].

The distribution of current is spread out to hemispherical surface with an area $2\pi r^2$, so that:

$$ J = \sigma E $$

$$ J = \frac{I}{A}; \; \sigma = \frac{1}{\rho}; \; E = \frac{V}{r} $$

$$ V_r = \frac{\rho l}{2\pi r} $$

$\rho$ resistivity of the surface (Ωm), V is electric potential in distance r (Volt), I is electric current supply
(A), $J$ electric current density (A/m$^2$), $\sigma$ is conductivity of the system (Ω⁻¹m⁻¹), and $E$ is electric field
(V/m).

2.2. Wenner-Schlumberger Configuration

Wenner-Schlumberger configuration is the configuration of the system which has constant spacing
rules. For this configuration comparison distance between the current electrode $C_1$ and potential
electrode $P_1$ ($C_1-P_1$) is placed at a distance $na$ and so does the distance between $C_2-P_1$ electrodes.
While the $P_1-P_2$ electrodes is placed at a distance $a$ (can be seen in figure 2). Determining process of
resistivity using four pieces of electrodes placed in a straight line [10].

Figure 1. Potential Around current injecting point on Earth's surface. [8]
By substituting the value of electrodes distance, so that:

\[ \Delta V = V_1 - V_2 = \frac{\rho I}{\pi} \left( \frac{1}{n \alpha (n+1)} \right) \]  

(4)

\[ \Delta V = \frac{\rho I}{K} \]

(5)

\[ K = \pi n \alpha (n+1) \]

\( \rho \) is resistivity (Ωm), \( \Delta V \) is electric potential between electrodes \( P_1P_2 \) (Volt), \( I \) electric current between electrodes \( C_1C_2 \), dan \( K \) geometric factor (m).

2.3. Wenner β-Schlumberger Configuration

Wenner β-Schlumberger configuration is the configuration which has spacing pattern rules are almost same as the Wenner-Schlumberger configuration, but this configuration has the distinction on the laying of the current electrodes and potential electrodes. The electrodes \( C_2C_1 \) (current electrodes) and electrode \( P_1P_2 \) (potential electrodes) placed respectively at the same distance of \( n \alpha \). While the electrode current \( C_1 \) and potential electrode \( P_1 \) (C1-P1) placed at distance \( \alpha \) (as shown in figure 3).
\[ \Delta V = \frac{\rho I}{K} \left( \frac{a(n+1)(2n+1)}{n^2} \right) \]  

(7)

\( \rho \) is resistivity (\( \Omega \text{m} \)), \( \Delta V \) is electric potential between electrodes \( P_1 - P_2 \) (Volt), \( I \) electric current between electrodes \( C_1 - C_2 \), dan \( K \) geometric factor (m).

### 2.4. Procedure

This research is a laboratory scale that has been created in Laboratory of Electronic, Department of Physics Bogor Agricultural University. In the test, will be made a wooden box as the system (size 120 cm x 30 cm x 20 cm) that containing homogeneous soil. Then, will be used two configurations (Wenner-Schlumberger dan Wenner \( \beta \)-Schlumberger) by measuring range is 100 cm of each configurations and the smallest spacing value is 4 cm \((a = 4 \text{ cm})\). This measurement have been created by moving the potential electrode at the constant current electrodes, then the electrode displacement currents on the space \( n \) followed by the displacement of potential electrode along the system up on that last point of measurement in the system.

![Figure 4. The procedure of measurement. [8]](image)

### 3. Result and Discussion

![Figure 5. Result of the 2D image without anomalies by Wenner \( \beta \)-Schlumberger configuration.]

\( \text{Distribution of water which moving down} \)

\( \text{Dist run electrode sring e1.90 n.} \)
Figure 5 describes the 2D image of system without anomalies with resistivity values measured in the range of 11.4 Ωm-19.2 Ωm. Based on the figure, it can be seen that the bottom of the system detected a small resistivity, it indicates the distribution of water seeping into the bottom of the system. It was proved by testing the water content in the soil by taking soil samples of 10 grams for each in points (point 1 and 2). The test has been done by heating the samples into oven at 105°C for 24 hours and then measure its mass. The result obtained that sample 1 has 28% of water content, while sample 2 is 21% water content. Based on these results can be seen that sample 1 has a high water distribution than the sample 2.

Figure 6 describes the 2D image of system with anomalies. The results obtained that the range of resistivity values measured between 7.60 Ωm-26.7 Ωm. This change was happen because the anomalies exist in the system. Clearly, the wood anomaly detected in position range 18 cm-34 cm with range of resistivity value between 18.7 Ωm-26.7 Ωm, the stone anomaly in the position range 44 cm-60 cm with range of resistivity values between 18.7 Ωm-31.1 Ωm, while the wet soil anomaly in the position range 72 cm-84 cm with range of resistivity values between 9.1 Ωm-15.6 Ωm. Based on these results can be seen that the differences of all anomalies resistivity value can be detected as wet soil anomaly that has the smallest resistivity values, followed by wood anomaly and stone anomaly that has the greatest resistivity values. Surely in this study also contained an error value in the detection of 6.3% for the system without anomalies and 6.2% for systems with anomalies. This error value will be a references for researchers in the stage of analyzing the data and accuracy of detection of the position and resistivity.
Figure 8. Result of the 2D image with anomalies by Wenner-Schlumberger configuration.

Figure 7 describes the 2D image of system without anomalies by Wenner-Schlumberger configuration with resistivity value measured in the range of 14.3 Ωm-22.8 Ωm. Based on the figure can be seen that the bottom of the system also detected a small resistivity as well as the detection of Wenner β-Schlumberger configuration which indicates the distribution of water seeping into the bottom of the system. While in figure 8, describes that the results of the 2D image of the system with anomalies. The results obtained that the range of resistivity value measured between 7.94 Ωm-33.0 Ωm, the same as the previous explanation above that these changes occurred because of three anomalies in the system. Clearly, the wood anomaly detected in position range 12 cm-30 cm with the range of resistivity value 17.9 Ωm -26.9 Ωm, the stone anomaly in the position range 42 cm-54 cm 17.9 Ωm-33.0 Ωm, while the wet soil anomaly in the position range 70 cm-86 cm with the range of resistivity value 9.73 Ωm-14.6 Ωm. Surely in this study also contained an error value in the detection of 8.8% for the system without anomalies and 10.1% for systems with anomalies

4. Conclusion
Based on the results obtained that all of anomalies (wood, stone, and wet soil anomaly) can be detected by both configuration (Wenner-Schlumberger and Wenner β-Schlumberger), but have the error levels were different. Wenner β-Schlumberger configuration has an error value is relatively low at 6.2% than using Wenner-Schlumberger configuration that has error value 10.1%. Based on these differences, it can be concluded that the developing of this configuration (Wenner β-Schlumberger), was proven to maximize the results of the image.

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