Development of Data Acquisition Instrumentation and Inversion System for Earth Resistivity Survey in a Smart Integrated System

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Abstract. This research has developed an integrated system of data acquisition and inversion process for earth dc resistivity survey in smart and compact instrumentation. Data acquisition system was developed based on microcontroller which is embedded to a PC. The microcontroller will choose the appropriate electrode sensor by command of PC. The data of a measurement and it’s electrodes configuration will be saved in PC. Once the data acquisition process is complete, automatically the system will start the inversion process based on finite difference method. Finally, the result of survey process will be shown in a 2D cross section image.

1. Introduction

Over the last 25 years, there have been revolutionary improvements to the resistivity method where two-dimensional (2-D) surveys are now routinely conducted. Three-dimensional (3-D) surveys are widely used in areas with complex geology, while there have been significant interest and developments in four-dimensional (4-D) surveys. This has been made possible by recent developments in field instrumentation, automatic interpretation algorithms, and computer software. With the new tools, complex variations of the subsurface resistivity in both space and time can now be accurately mapped (Loke, 2013).

DC resistivity data acquisition using computer controlled multi-electrode arrays is becoming increasingly popular, as it allows efficient and complex data acquisition strategies that are inconceivable with manual methods. The trend is expected to continue because there is an increasing demand for detailed knowledge about sub-surface features in environmental, hydrogeological and engineering applications. A variety of commercially available acquisition systems are available on the market, and the capacity of the instruments will increase in the future. The continued development of efficient techniques for data inversion and imaging facilitate interpretation and presentation of the data (Dahlin, 1998).

Current commercial resistivity systems offer automated switching capabilities for driving current and measuring potentials, so users install an array of electrodes, often ~30-100. Then a sequence of readings is taken by addressing pairs of current and potential electrodes within the array. Most surveys conducted today are two-dimensional (2D); a series of electrodes are laid out in a straight line. Typically electrodes are evenly spaced along the line (kiflu, 2016). To connect a system with a transmitter, a single receiver channel, and 30 electrodes requires 4 X 30 = 120 switch-points.
(LaBrecque, 2014). The resistivity meter selects only four active electrodes used for each measurement (Nazaruddin, 2017).

The relationship between the electrical resistivity, current and the electrical potential is governed by Ohm's law (Loke, 2013). Figure 1 illustrated that the current (I) will flow from Voltage source/battery (V) into the medium which has surface area (A), length (L). From the measurement the value of resistance (R) and resistivity (ρ) can be calculated as

\[ R = \frac{V}{I} \text{ ohm}, \quad \rho = R \frac{A}{L} \text{ ohm.meter} \]

![Figure 1. Current in the medium](image)

Electrical resistivity surveys are based on the response of the earth to the flow of electrical current. Artificially generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface (Telford et al., 1990). In practice, current are injected into the ground using separated electrodes. The current will flow from positive pole (point A) to negative pole (point B) passing the subsurface and the voltage as subsurface’s response are measured at point M and N as illustrated in figure 2.

![Figure 2. Measurement current and potential](image)

Automation of resistivity data acquisition, using PC or microprocessor controlled monitoring systems for remote deployment with permanently installed electrode arrays, has facilitated monitoring at the spatial and temporal resolution required to capture smallscale transient events associated with these types of applications (Loke, 2013).

2. Motivation : Standard Instrumentation

Generally, in DC resistivity survey, data acquisition and data processing were conducted in different time and different place as illustrated in figure 3. The surveyor will conduct data acquisition in the field and usually will conduct data processing in other place such as in studio or in the office. Therefore, there is time gap between data acquisition activity and data processing. The time gap is for mobilizing or transferring data from instrument to another instrument.
3. Objective

The objective of this research to design an integrated system of data acquisition tool and data processing in one compact instrumentation as illustrated in figure 4. Therefore, the geophysicist can obtain the result of the survey immediately in the field. The scope of the research is to develop an instrument can flow current from high voltage current-source into the subsurface, datalogger, automatic of electrodes switch, and data processing system to display subsurface's resistivity.

4. Instrumentation Design

The instrument was designed with laptop as main controller and for data processing, microcontroller for choosing appropriate electrodes/switching system, voltage Source (600 Volt DC) with constant Current (110mA), and 16 bit sigma-delta ADC to measure injected current and voltage response.
Figure 5. The design of Instrumentation

Figure 5 shows that there are number of electrodes of n. There are only four active electrodes at the same time. Two electrodes as current source (A and B) and two others as sensor (M and N) to obtain voltage response of subsurface. The main processor has a task to select four appropriate electrode, records the data, and displaying the result.

The parameters required for data processing are location, the combination of four active electrodes those determined by configuration of measurement method, potential value \( V \), self potential value \( V_{sp} \), current values \( I \), and space between electrodes \( a \), and number of layer \( n \). Some parameters were set by the user such as location, four active electrodes, \( n \), and \( a \) while the parameters \( V_{sp} \), \( V \), and \( I \) were obtained from measurement. Figure 6 is frame of setting for input of required parameters as mentioned. The input of "time injection" to determine time duration of current that flow in the subsurface.

Figure 6. Frame of setting

Frame of Configuration (Figure 7) to select one of six popular method of dc-resistivity survey. Frame of Measurement (Figure 8) to display on going measurement result (\( V \) and \( I \)) and will be replaced by next step measurement value and the existing value will be moved to table of measurement data (Figure 9).

Figure 7. Frame of Configuration

Figure 8. Frame of Configuration
Frame of Measurement Data (Figure 9) is a table of recorded data. This table contains the values of V, Vsp, I, and appropriate electrodes (A, B, M, and N). Save button to save the table to the file and load button to load the previous file/data. Once measurement was completed the result will be displayed in the frame of display (Figure 13) based on the value of ρ (apparent).

![Figure 9. Tabel of measurement value and appropriate electrode](image)

5. Result and Conclusion

Field test of the instrumentation was conducted in Cimanintin Village which is located about 70km east of Bandung.

![Figure 10. Field test location](image)

The test was conducted in the plantation area using 32 electrodes of Wenner configuration that has 155 datum points. The length of the survey was 160m with space between electrodes was 5m. The weather was very clear after rain. The result, all the data of 155 datum points can be acquired in 16 minutes and measurement data of I and V were displayed in the table (figure 9). Pseudo-section of rho-apparent can be displayed less than 1 minute (figure 11). It means that the instrument can deliver the result of measurement less than 20 minutes.
Figure 11. The display of data processing result

The range of measurement’s value of $\rho$ (apparent) in this field test is between 0.5 to 4 ohm meter as shown in color bar in the right side of display frame, figure 11. The blue color means the lowest resistivity and the red color is the highest resistivity. The result of measurement shows that the area dominated by low resistivity or high conductivity. This is understandable because the field test was conducted in the plantation area and carried out after the rain, therefore the high water content in subsurface influenced the value of resistivity tends to the low value.

Figure 12 is a complete GUI snapshot of the instrumentation system. By the result of this research, the surveyor / geophysicist was expected can obtain the results of the survey immediatelly in the field after data acquisition was completed.

Figure 12. Instrumentation setting and display
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