Available Online at http://www.journalajst.com

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 08, Issue, 03, pp.4359-4362, March, 2017

RESEARCH ARTICLE

DESIGN OF DEVICE FOR SPECTRAL INDUCED POLARIZATION LABORATORY MEASUREMENTS IN GEOPHYSICS EXPLORATION

[1,*]Suparwoto, [1]Kirbani, [1]Ari Setiawan and [2]Agus Kuncaka

[1]Department of Physics, Gadjah Mada University, Yogyakarta, Indonesia
[2]Department of Chemistry, Gadjah Mada University, Yogyakarta, Indonesia

ARTICLE INFO

Article History:
Received 15th December, 2016
Received in revised form
24th January, 2017
Accepted 27th February, 2017
Published online 31st March, 2017

Key words:
Spectral Induced Polarization,
Complex resistivity,
Voltage and current measurement,
Variable frequency source,
Phse measurement,
Spectral IP response,
RC circuit.

ABSTRACT

Laboratory experiments to study the induced polarization (IP) phenomenon on natural and artificial samples are of great importance as they can explain on the cause and nature of the phenomenon. IP method has been the most successful in mining exploration, particularly in the search for metal oxide and sulphide mineralizations. The Spectral Induced Polarization or Complex Impedance Method is essentially a multi-frequency version of IP. The basic techniques for measuring complex impedance are amplitude voltage measurement, current measurement and phase difference detection between voltage and current as function of frequency. The device consist of two main part, the transmitter and receiver. Transmitter transmits sinus wave current with frequency varied automatically from 0,1 Hz to 1000 Hz. In order to improve the accuracy of the device, the high impedance differential instrumentation amplifier are used in the receiver. The outputs from voltage amplifier and current amplifier are sent to data logger. Experimental measurement on RC circuits were carried out to prelimininary evaluate the performance of the device. Different type of ore bodies can be distinguished based on typical shapes of their spectral IP responses. The result obtained by the device were found to be in good agreement with the teoretical computation obtained on RC circuits. Overall mean error of 2 % in magnitude and 0,7o in phase over frequency range of 0,1 Hz to 1000 Hz. The largest error in phase measurement occured at low frequency below 1 Hz.

INTRODUCTION

Laboratory measurement to study induced polarization phenomenon are of great importance as they can explain on the cause and nature of the phenomenon. Spectral Induced Polarization devices which are portable, low cost ,and capable of performing measurement with adequate accuracy will be highly desirable for this use. This paper describes a novel design of a portable SIP measurement system based on magnitude and phase difference detection. In resistivity method, low frequency alternating current is introduced into the ground by means of two current electrodes. The resulting potential difference measured by means of two potential electrodes, the apparent resistivity of the ground is proportional to the ratio of the potential difference and the current. Ohm's law defines resistance in terms of the ratio between voltage or the potential difference and the current, so the resistivity is not depend on the frequency. However, the real world contains circuit elements that exhibit much more complex behavior, that is the polarization effects.

Corresponding author: Suparwoto,
Department of Physics, Gadjah Mada University, Yogyakarta, Indonesia.

There are two principal effects as origin of induced polarization phenomenon, an electrode polarization and a membrane polarization. The electric current in the ground normaly carried by ions in the electrolytes present in the pores of rocks. If the passage of these ions is obstructed by conducting mineral particles, wherein current conduction take place by electrons, ionic charges pile up at the particle-electrolyt interface.The particle is said to be polarized if the pile up charges create a voltage thet tends to oppose the flow of electric current across the interface. When the current is interrupted, a residual voltage continues to exist across the particle, due to the pile up of ionic charges on both side of the particle. This voltage decreases gradually as the ions slowly diffuse back into the pore electrolytes. This process takes some seconds, and is called the induced polarization effects. This type of polarization is called electrode polarization because it is observed at the surface of the metal electrodes dipped in an electrolyte. The presence of clay particles in the ground also gives the IP effect, the phenomenon is termed membrane polarization. The surface of the clay particle is negatively charged and thus attracts positive ions from the electrolytes present in the capillary pores of the clay. When an electric current is flowed through the clay, positive ions are displaced and on interruption of the current the positive ions redistribute themselves in their former equilibrium pattern. This process of re-alignment generates a decaying voltage between two electrodes in contact with the clay. The development of a nett charge at the mineral ore surface affects the distribution of ions in the surrounding interfacial region, resulting in an increased consentration of ions in opposite charge to that of the particle, close to the surface. Thus an electrical double layer exists round each mineral particle. On a bare metal immersed in an electrolyte the double layer capacitance will be 20 to 60 microFarad per centimeter square. Diffusion process in an electrolyte can create an impedance called the Warburg-impedance. The impedance depends on the frequency, at high frequences the Warburg impedance is small since diffusing reactants don't have to move very far. The Warburg impedance and electrical double layer capacitance causes the impedance behavior of the ground, the resistance of the ground are depends on the frequency. Mineral ore occurs most commonly in nature either in the form of a vein, an ore-shoot or in lense, which causes polarization phenomenon. The frequency depedence of the observed apparent resistivity is strongly controlled by the presence of the mineral ore in nature.

Induced polarization method

If an electric current is injected into the ground by means of two current electrodes for several seconds and then intercepted, the voltage across the potential electrodes does not drop to zero instantaneously. It is found that the voltage across the potential electrodes to relax for several seconds starting from an initial value which is a small fraction of the voltage that existed when the current was flowing. This phenomenon has been termed as induced polarization (IP). There are three method of IP survey, i.e. Time Domain IP, Frequency Domain IP and Spectral IP. Time Domain IP, measures the integrated area under an IP decay curve between t_1 and t_2 normalized by the primary voltage, the parameter is called as chargeability (M). The unit of M is milisecond. Frequency Domain IP, measure the resistivity of the ground in two frequencies, low frequency (0,1 Hz) and high frequency (10 Hz). The parameter is called Percent Frequency Effect (PFE), i.e.the difference between low frequency resistivity and high frequency resistivity divided by high frequency resistivity multiplied by 100 %, the unit is in percent. Spectral IP, measures impedance of the ground and phase difference between current and voltage as function of frequency, the frequency range between 0,1 Hz to 1000 Hz. The result of this measurement are impedance and phase spectral.

Instrument design and calibration

The spectral induced polarization instruments consists of two main parts, namely the current transmitter and the voltage measurement section. The current transmitter section generate sinus wave current with frequency can be varied from 0,1 Hz to 1000 Hz. To reduce measurement time, frequency variatiaon is done discretly. For example in the range of 1 Hz to 10 Hz, the current source generates alternating current with frequency of 1 Hz, 2 Hz, 3 Hz and so on up to 10 Hz emitted in series. The time interval for each frequency emition is set for twice the period of the wave. Thus, in the frequency range of 0,1 Hz to 1000 Hz, the current source generates 40 kinds of sine wave emitted serialy. The blok diagram of the transmitter section is presented in Figure 1. The main component of the transmitter parts is a Function Generator IC, XR 2206 type, installed in a configuration of Voltage Controlled Oscillator (VCO). Electronic circuit consisting of a decade counter IC and Digital to Analog Converter IC, generates voltage out put as a voltage ladder or stair case. The voltage ladder out put are used to control the VCO, so the IC XR 2206 generates sine waves out put whose frequency changes higher and higher, Figure 2.

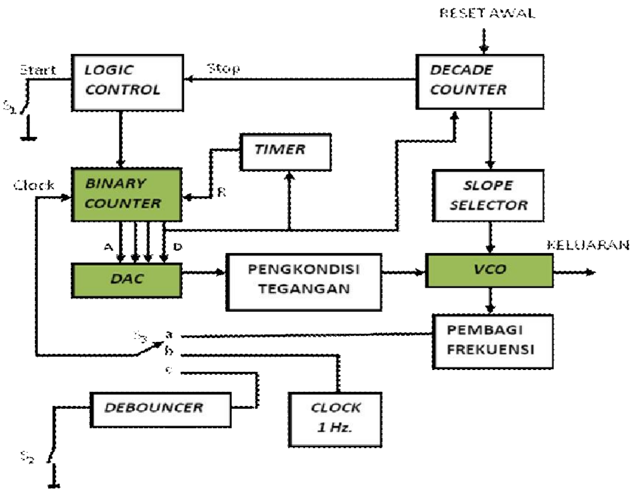

Figure 1. Blok diagram of the transmitter

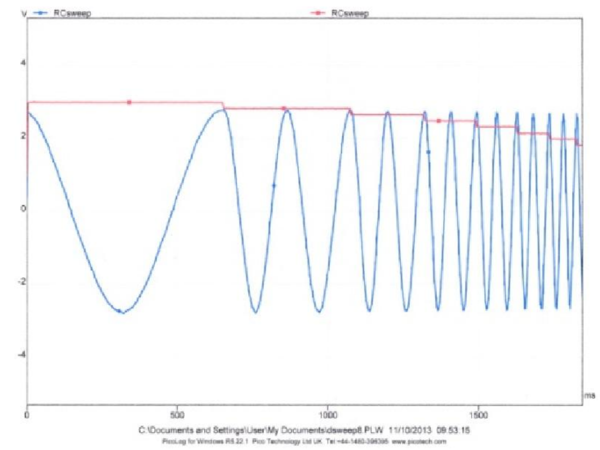

Figure 2. The output of the transmitter

The second part of the SIP instrument is the receiver or measuring voltage. This section is a voltage amplifier system that has high gain, high input impedance and a differential input system. The value of the current through the medium and voltage arising on it, are recorded simultaneously on the data logger. Therefore, it can be calculated the impedance value as a function of frequency and phase different between current and voltage as a function of frequency. In other words, the results obtained from the SIP methods are impedance spectra and phase spectra of the medium. Calibration of the SIP instrument is done by installing the known measuring object on the output lines (C1 and C2)., Figure 3. The first object of measurement is known resistor value of its resistance is 1000 ohm. Theoretically impedance spectra resulting from the measurement is a straight horizontal line shows 1000 ohm resistance value, and is accordance with the experiment result, Figure 4. Likewise, the phase difference spectra measurement results indicate a straight horizontal line shows zero degree value.

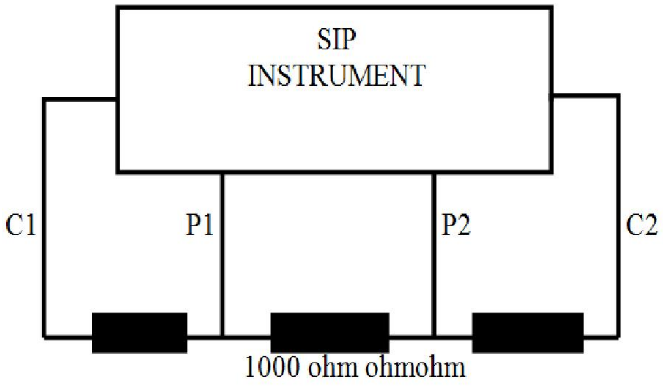

Figure 3. Calibration using known resistor Blok diagram

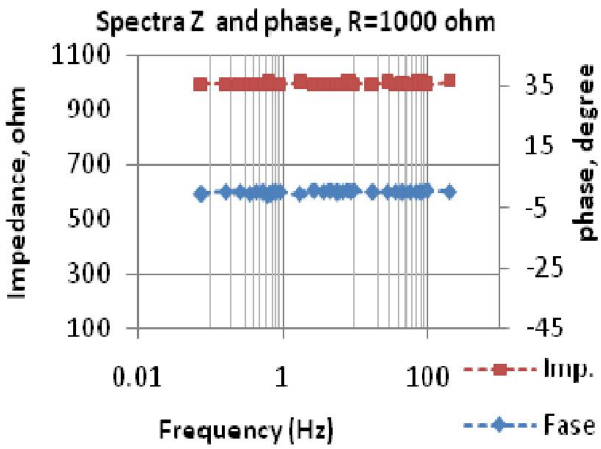

Figure 4. Impedance and phase spectra Experiment result

The equivalent circuit for a simplified Randle Cell is shown in Figure 5. R_S is solution resistance, conected in series with resistance of charge transfer R_{CT} , the double layer capactance C_{DL} is in parallel with the charge transfer resistance. Theoritically the value of the Randle Cell circuit can be calculated, as expressed in equation 1, equation 2 and equation 3, equation 4,for impedance, real part, imaginary part and phase respectively. Figure 6, is blok diagram of the SIP instrument calibration using Randle Cell Circuit as load. The impedance spectra and phase spectra of the Randle Cell presented on Figure 7. The spectra from the calculation reperesented by graph with a dotted line, while the data of the experimental results represented by red and blue data points. Data measurement results is in accordance with the results of theoretical calculations. The standard error of impedance measurement less than 2%, standard erro of phase measurement less than 0,7^o.

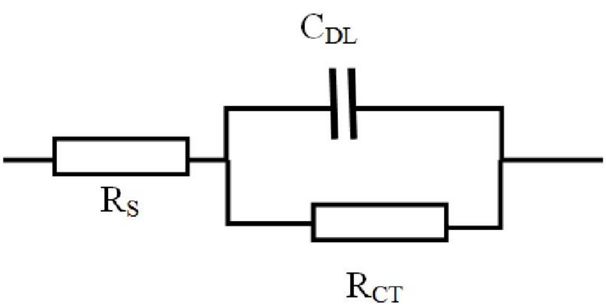

Figure 5. Equivalent circuit of Randle Cell

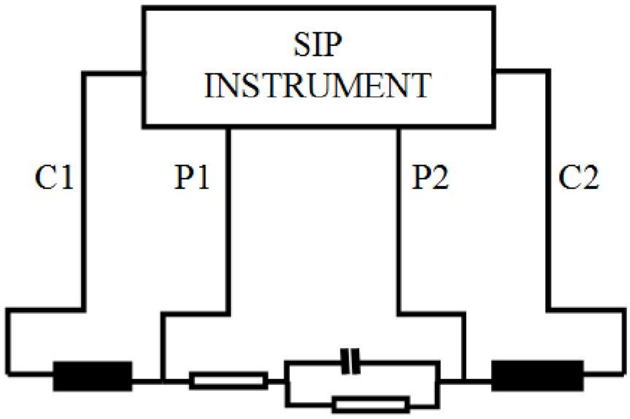

Figure 6. Calibration using Randle Cell

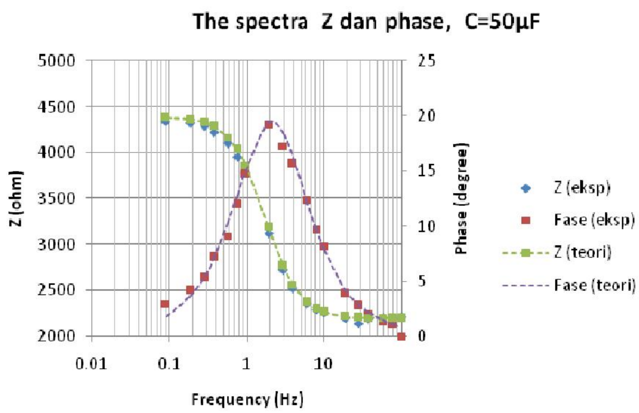

Figure 7. Impedance and phase spectra, Randle Cell, with $R_S = R_{CT} = 2200$ ohm, $C_{DL} = 50$ µF

$$Z(\omega) = \frac{R_S(1 + j\omega R_C C) + R_C}{(1 + j\omega R_C C)} \quad \ldots\ldots\ldots\ldots (1)$$

$$Re = \frac{(R_S + R_C) + \omega^2 R_S R_C^2 C^2}{(1 + \omega^2 R_C^2 C^2)} \quad \ldots\ldots\ldots\ldots\ldots.. (2)$$

$$Im = \frac{-j\omega R_C^2 C}{(1 + \omega^2 R_C^2 C^2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\tan\varnothing = \frac{-\omega R_C^2 C}{(R_S + R_C) + \omega^2 R_S R_C^2 C^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Rocks sample sip measurement

After calibration, the SIP instrument used to measure the polarization effects of rock samples were put in the water as solution. Measurement using porous-pot electrode as potential electrode. The blok diagram of measurement presented on Figure 8. The photo of rock sample presented on Figure 9. SIP measurement before the rock sample is inserted into the water, giving the results of impedance and phase spectra are straight lines, so there were no polarization effects. SIP measurement after the rock sampel is inserted into the water giving the results of spectra as shown in Figure 10. Figure 10 shows the polarization effects of the rock sample, that is the impedance values are declining at higher frequency, and phase spectra have a maximum value.

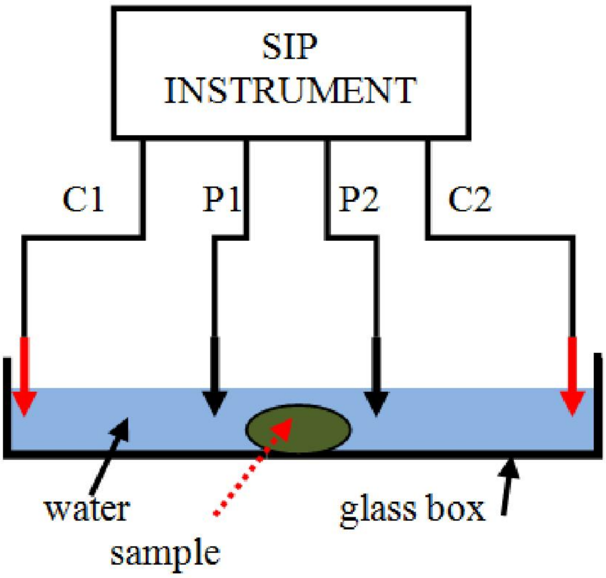

Figure 8. Blok diagram of sampel measurement

Figure 9. The photo of rock sampel, galena

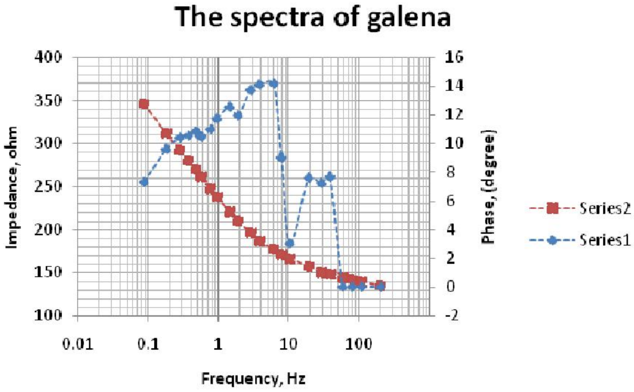

Figure 10. The impedance and phase spectra of galena rock sample. Red graph is the impedance, blue graph is the phase difference

Conclusion

From the research presented, it can be concluded that:

- SIP instrument that has been made succesfully measure the polarization effets of the rock sample.
- Error on the instrument can be reduced by using low noise amplifier
- Further resarch can be done using this SIP instrument.

REFERENCES

Apparao, A. 1999. Developments in Geoelectrical Methods, National Geophysical Research Institute, AA Balkema/ Rotterdam /BrookField.

Carr, J. 1991. Electronic Devices, Glencoe Tech Series, McGraw Hill International Edition.

Deoebelin, E.O. Measurement System, application and Design, McGraw Hill International Editions, Mechanical Engineering Series.

Ntarlagiannis, D., Doherty, R., dan Williams, K.H., 2010, Spectral induced polarization signatures of abiotic FeS precipition, *Geophysics*, Vol.75, No.4, hal.F127- F133.

Revil, A. 2010. *How useful is Spectral Induced Polarization,* Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) 2010, Keystone Colorado.

Telford, W.M., Gerdart, L.P., Sherif, L.P. 1990. Applied Geophysics, Cambridge University Press, New York USA.

Vanhala, H., Soininen, H. 1995. Laboratory technique for Spectral Induced Polarization response of Soil samples, Geophysical Prospecting Vol.43.

****