ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0030

Study on the IP Effect of Magnetotelluric Method in Polarized Horizontal Layer Based on DIAS Model

Xuan Zhang[1, a], Jin Yang[1, b, *] and Wei Zhang[2, c]

[1]China University of Geosciences, Beijing 100083, China.

[2]North China Institute of Science & Technology, China.

[a]zx19821106@sina.com, [b]yangj@cugb.edu.cn, [c]42273245@qq.com

Abstract

Based on the forward modeling theory of layered one-dimensional medium model and the DIAS model, the forward modeling of the homogeneous half space model and the polarization layer model of the middle layer of the three-layer geoelectric section are carried out in this paper. The apparent resistivity, impedance phase, apparent resistivity ratio and sum of the three-layer geoelectric section o model of the magnetotelluric sounding method are calculated under the premise of considering the IP effect Impedance phase ratio, through comparing the apparent resistivity amplitude ratio and impedance phase ratio before and after polarization of the polarization layer, discusses the feasibility of using them as parameters to extract the IP effect.

Keywords

DIAS model; magnetotelluric sounding; IP effect; polarized horizontal layer.

1. INTRODUCTION

The traditional MT method using natural field source does not consider the IP effect, but in practice, the medium has IP effect under the action of electromagnetic field, so the IP effect will bring errors to the forward and inversion calculation. If the IP effect is considered, not only the calculation results will be closer to the actual situation, but also before the field data collection amount is increased We can get more physical parameters and get more accurate results. The field equipment of induced polarization method is rather heavy, which greatly limits the development of this method in more work. Based on the two advantages of MT method, the study of extracting the induced polarization parameters from the magnetotelluric sounding data came into being. The first exploration using natural field source combined with IP method began in 1970s. Yang Jin, Fu liangkui and other scholars have studied and demonstrated the feasibility of this method. At present, the main research idea in this field is to replace the real resistivity of the earth medium in MT method with the complex resistivity response model of polarizer, and observe the apparent resistivity and impedance phase based on this Parameters.

According to the IP effect of underground polarization layer and the forward modeling theory of magnetotelluric layered medium, this paper studies the IP response of three layers of geoelectric cross-section type with uniform half space and middle layer as polarization layer, calculates its apparent resistivity amplitude and impedance phase, and discusses the feasibility of using the large magnetotelluric method to develop IP method.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0030

2. PRINCIPLE OF THEORETICAL METHOD

2.1. DIAS Model

At present, the commonly used dielectric complex resistivity models include DIAS model, Cole-Cole model, Warburg model, etc., among which the DIAS model has five parameters, each of which has a clear physical meaning, and the description of the induced polarization effect is more realistic; FIG. 1 is the equivalent circuit diagram of the DIAS model. The complex resistivity expression of the model is:

$$\rho = \rho_0 \left[1 - m \left(1 - \frac{1}{1 + i\omega\tau' \left(1 + \frac{1}{\mu} \right)} \right) \right] \tag{1}$$

Where $m = \frac{\rho_{\omega\to 0} - \rho_{\omega\to\infty}}{\rho_{\omega\to 0}}$ represents the charging rate, $m \in [0,1)$; ω represents the circular frequency, ρ_0 represents 0-frequency resistivity; $\mu = i\omega\mu + \sqrt{i\omega\tau''}$; $\tau = rC_{dl}$; $\tau' = \tau(1/\delta)(1-\delta)/(1-m)$; $\tau'' = \tau^2\eta^2$; $\delta = r/(r+R_s)$; τ represents the relaxation time, η represents the electrochemical parameter, it means the correlation between the induced current component and the diffusion current component, and δ represents the pore resistance ratio affected by the polarization source, $\delta \in [0,1)$.

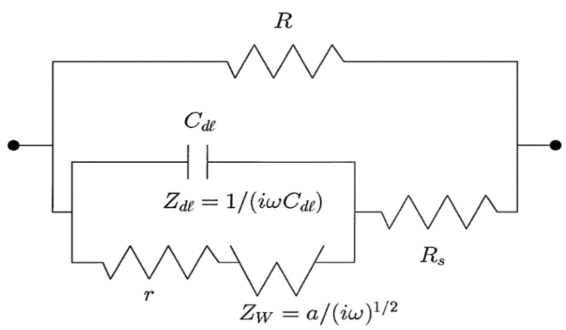

Figure 1. Dias model

2.2. Theoretical Calculation Method

According to the magnetotelluric theory, the wave impedance measured on the ground surface of the uniform earth with the incident resistivity of plane electromagnetic wave is:

$$Z = \sqrt{\omega\mu\rho}\, e^{-i\pi/4} \tag{2}$$

The apparent resistivity is:

$$\rho_s = |Z|^2 / (\omega\mu) \tag{3}$$

When the earth medium is a horizontal layered isotropic medium, for the H-layer layered medium, the thickness and resistivity of each layer are known, and the value is: $h_1, h_2, h_3 \dots h_n$, $\rho_1, \rho_2, \rho_3 \cdots \rho_n$; According to the one-dimensional forward recurrence formula of magnetotelluric horizontal layered medium, the ground wave impedance is:

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0030

$$\left.\begin{array}{l} Z_m = Z_{0m}\dfrac{1-\dfrac{Z_{0m}-Z_{m+1}}{Z_{0m}+Z_{m+1}}e^{-2k_mh_m}}{1+\dfrac{Z_{0m}-Z_{m+1}}{Z_{0m}+Z_{m+1}}e^{-2k_mh_m}} \\ Z_n = Z_{0n} = -i\omega\mu/k_n \end{array}\right\} \quad (4)$$

The value range of M is: $1, 2, 3\ldots, n-1$; $k_m = \sqrt{-i\omega\mu/\rho_m}$, Z_{0m} represents the characteristic impedance of layer m, Z_n represents the top wave impedance of bottom layer, which is known. In this way, the top wave impedance of the above layer can be calculated successively, and the wave impedance to the surface can be calculated all the way.

3. FORWARD CALCULATION OF HOMOGENEOUS HALF SPACE MODEL

According to formula (1) - (4), the parameters of DIAS model are given first, and then the complex resistivity calculated by DIAS model is used to replace the real resistivity in the layered forward calculation, so that the apparent resistivity and phase of the homogeneous half space and layered medium surface can be obtained. Take the earth's zero frequency resistivity $\rho_0 = 100\Omega\cdot m$, The following default values are used for other IP parameters without explanation: $\tau = 0.5s$, $\eta = 9s^{-1/2}$, $\delta = 0.2$, When the charging rate m is changed, the calculated apparent resistivity and impedance phase diagram are shown in Figure 2. It can be seen that when $m = 0$, the apparent resistivity and impedance phase do not change with the frequency, and the apparent resistivity and impedance phase are both straight lines. When $m \neq 0$, the resistivity of the DIAS model is only reflected in the real resistivity r of the model in the high frequency band, and the capacitance and inductance part cannot be fully charged and discharged due to the high frequency With the decrease of frequency, the inductive reactance increases gradually, which makes the total resistivity tend to zero frequency resistivity; with the increase of m, the change range of apparent resistivity and impedance phase curve increases; and the peak value of phase basically corresponds to the point with the largest slope of apparent resistivity curve. The image is consistent with the spectrum in the related literature, which can verify the correctness of the program used in this paper.

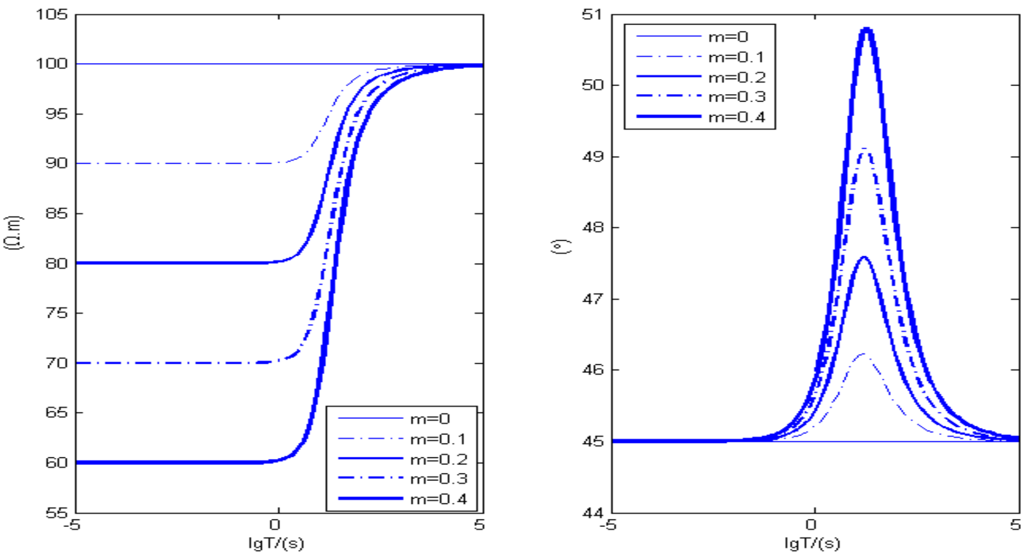

Figure 2. Homogeneous half space model

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0030

4. FORWARD CALCULATION OF THREE-LAYER O MODEL

Figure 3 shows the geoelectric section of O-type model which is a kind of the three-layers model. $\rho_1 = \rho_2 = \rho_3 = 400\,\Omega$.m, h_1=100 m, h_2=200 m. If the intermediate polarization layer is unpolarized($m_2 = 0$),then the apparent resistivity curve is a straight line with a value of 400$\Omega \cdot$m. When $m_2 = 0.2$, The curve of apparent resistivity ρ_T^* has a minimum value near the frequency of 800 Hz, indicating the existence of a polarized layer. Take $B\rho_T = \rho_T^* / \rho_T$, then it can be seen that in the frequency band outside the anomaly, $B\rho_T$ tends to 1 gradually. Because $B\rho_T$ reflects the relative change of the abnormal value and the unpolarized value, it can more directly reflect the existence of the polarizing layer; The biggest difference of $B\rho_T$ curve was 11.41%. The lower half of Fig. 3 is impedance phase curve, from which we can see that when polarization layer $m_2 = 0$, impedance phase $\Phi_T = 45^\circ$ is a straight line; when $m_2 = 0.2$, the maximum and minimum value of impedance phase Φ_T^* curve correspond to the maximum slope of apparent resistivity ρ_T^* curve respectively, and the frequency point of phase curve passing through 45° line corresponds to the minimum value of ρ_T^* curve. Take $B\Phi_T = \Phi_T^* / \Phi_T$, It can be seen that $B\Phi_T$ curve tends to be 1 when the frequency gradually decreases, and other characteristics are the same as Φ_T^* curve. The maximum difference of $B\Phi_T$ curve amplitude is 4.2%.

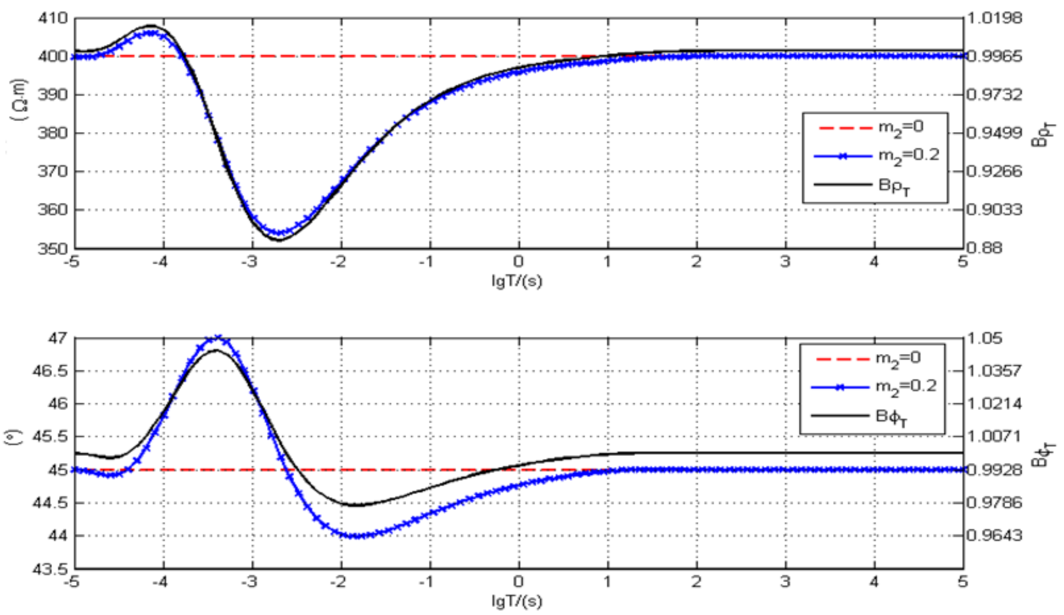

Figure 3. three-layer o model

5. CONCLUSION

In this paper, through forward calculation of O-type model section of one-dimensional middle layer polarization model, the effect of DIAS model to characterize the induced polarization effect is studied and analyzed, which proves that the induced polarization method of natural field source is feasible.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0030

REFERENCES

[1] Yang Jin: Iterative Finite Element Method using in Geophysical Numerical Simulation (Geological Publishing House, Beijing 1996).

[2] Li Y,Pek J: Adaptive finite element modelling of two-dimensional magnetotelluric fields in general anisotropic media, Geophysics, vol. 175(2008) p942-954.

[3] Madden TR: Transmission systems and network analogies to geophysical forward and inversion Problem, ONR Technical Report,1972, p72-83.

[4] Mackie RL, Smith TJ: 3-D electromagnetic modeling using difference equations[J]. The Magnetotelluric Example,Radio Sci.,vol. 29(1994), p923-935.