Explanation of Budunhua copper mine based on the electromagnetic method

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Abstract

The transmitted waveform of the transient electromagnetic method plays an important role in the exploration results. Due to the rectifier inverter circuit using the existing transient electromagnetic transmitter have some shortages, when the transmitter work after a period of time, the internal voltage can along with it drop, the transmitted waveform distortion, resulting in inaccurate measurements. According to these disadvantages, improving the original circuit, three-phase PWM rectifier circuit take the place of the original three-phase controlled rectifying circuit. This can imrove the stability of DC current and voltage and power factor of the circuit. And add filter capacitance on the inverter part to filtering harmonics, ensuring the quality of the output current waveform so as to improve the accuracy of the measurement. Simulation experiment in MATLAB/Simulink and draw the waveform of the transient electromagnetic method needed.

Keywords

Electromagnetic method; MATLAB/Simulink; three-phase PWM.

1. Introduction

In order to expand the copper prospective reserves and look for hidden ore deposits, since long ago, our country scholars have made great efforts and considerable research in the geological exploration aspect. Solve the related geological problem using these domain knowledge [1-2]. They attach great importance to use the transient electromagnetic method in exploration. From the field source nature, it can be divided into direct current method, alternating current method, transitional field method, etc [3]. The direct current method observes and researches the changes in the spatial distribution of stable current field, also known as time domain electrical method; The alternating current method researches spatial distribution or along with frequency change characteristic of electromagnetic field or electromagnetic wave in quasi-stationary state, also is called the frequency domain electrical method; The transitional field method observes and researches establishment of artificial electromagnetic field or variation of the attenuation process, also known as establish-field method. Among them, Time domain electrical method mainly researches the relations of electromagnetic field response and time, and frequency domain electrical method study on relationship between response and frequency. This article mainly analysis and research unique geological, geophysical characteristics of Budunhua copper mine, and the transient electromagnetic method was applied to it. Establish an electromagnetic model, respectively analysis secondary field time and frequency characteristics of transient electromagnetic field in Budunhua copper mine, and simulate in MATLAB, draw the corresponding characteristic curve. Than, calculate some geological parameters. Avoid lengthy interpretations of Budunhua copper mine, and explain the copper mine area more scientific.

2. The establishment of electromagnetic field model

After summarizing and analyzing the geological situation of mining area, it can be seen the copper ore has weak magnetic, high polarizability and low specific resistance, and obvious differences with surrounding rock; Long granite rock has strong magnetic, low polarizability, but high specific resistance; Stratum rock of different age has generally weak magnetic, extremely low polarizability, but greatly changing specific resistance. In order to facilitate research, we simplify and simulate copper mine area, as shown in Figure 1.

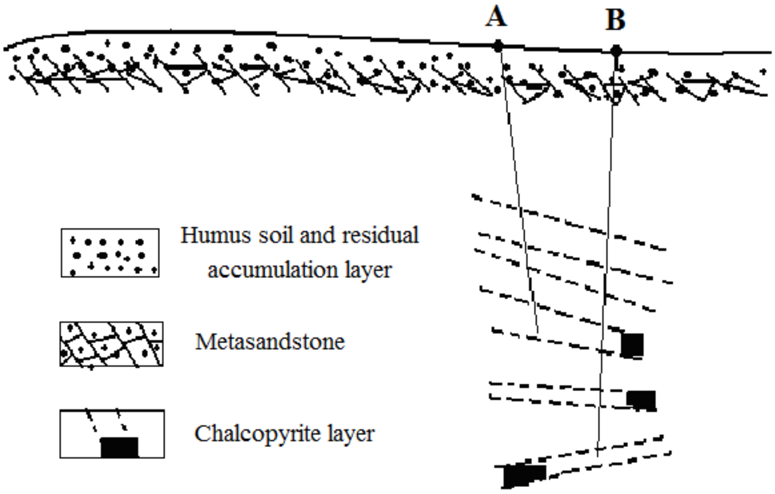

Figure 1. Simplified copper mining distribution

Assume respectively laying transmitting coil and receiving coil in point a and point b. Transmitting coil adopt central loop device T, receiving coil adopt overlap coil R. T adopts device 30×20, length $a=20m$, width $b=10m$, turns $N=50$; R adopts device 10×10, Length and width are 10 meters, turns $N=25$; transmitted waveform is bipolar pulse rectangular square wave of introduced in third chapter, maximum current is 80A, investigation depth is $20\sim 400m$. It can be equivalent to one kind of electromagnetic induction model of benign electric conduction geologic body, as shown in Figure 2.

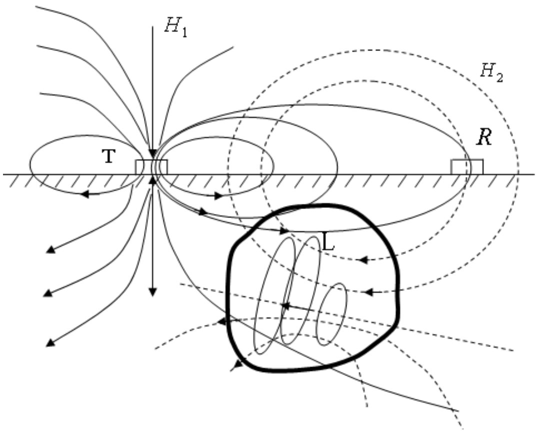

Figure 2. Electromagnetic induction model based on TEM

Induced voltage value of the above model is $U=1200$. When bipolar pulse rectangular wave $I_1=40A$ pumped in transmitting coil T, pulse current will around the stratum produce changing electromagnetic field and primary magnetic field is H_1. The induced electromotive force expression of underground media:

$$\varepsilon=-\frac{d\Phi}{dt}=-M\frac{dI_1}{dt}=-i\omega MI_1 \tag{1}$$

Coefficient of mutual inductance $M=1.39\times 10^{-4}$, M refers to the mutual effect between transmitting coil and underground conductor.

Underground conductive media is considered as series circuit which is composed of resistance R and inductance $L=20mH$, so the induced current I_2 in the equivalent circuit is:

$$I_2=\frac{\varepsilon}{R+i\omega L} \tag{2}$$

By the formula (1) and (2), it is concluded that:

$$I_2 = -iMI_1 \frac{\omega}{R + i\omega L} \quad (3)$$

Another expression is:

$$I_2 = -MI_1 \left(\frac{\omega^2 L}{R^2 + \omega^2 L^2} + i \frac{\omega R}{R^2 + \omega^2 L^2}\right) \quad (4)$$

Due to the different electrical properties of underground media, the induced current will produce secondary magnetic field. The secondary magnetic field of a certain point is:

$$H_2 = MI_1 G \left(\frac{\omega^2 L}{R^2 + \omega^2 L^2} + i \frac{\omega R}{R^2 + \omega^2 L^2}\right) \quad (5)$$

$G = 3.6$ refers to geometrical factor, H_2 refers to the expression form of complex number. In the whole process of transient electromagnetic field, receiving coil is only a certain component of the total receiving magnetic field. They can express their mutual relations using Phase vector diagram, as shown in Figure 3.

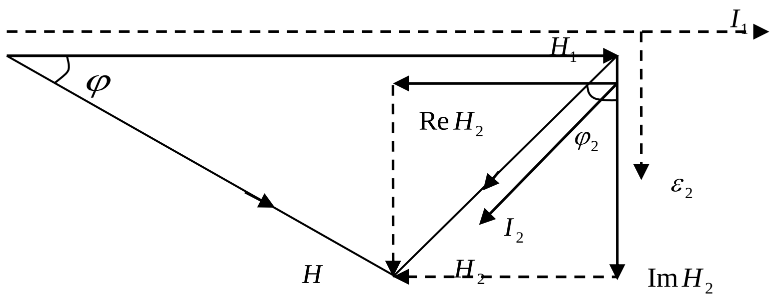

Figure 3. Phase vector diagram of primary and secondary magnetic field

Figure 3 shows that real component of primary and secondary magnetic field has not only the same direction, but also the same phase. They merely superimpose their algebraic sum, and superposition result becomes real component of total magnetic field. Imaginary component of secondary magnetic field is total imaginary component. Due to imaginary component pull ahead real component $\pi/2$, so the same spatial direction but different phase vibration superposition can't be obtained using the method of algebraic sum. In the phase vector diagram, Real component Express directed line along the real axis, and imaginary component Express directed line along the imaginary axis. Their respective lengths are proportional with the amplitude. Then, these two directed line serve as adjacent sides form parallelogram, and diagonal line represents total magnetic field. H_2 lags H_1 $\pi/2 + \varphi_2$, from Figure 3, we can see that:

$$\varphi_2 = tg^{-1} \frac{\mathrm{Re}\,H_2}{\mathrm{Im}\,H_2} \quad (6)$$

From formulas (5) and (6), we can get:

$$\varphi_2 = tg^{-1} \frac{\omega L}{R} \quad (7)$$

The analysis of the mathematical model suggests that φ_2 of electromagnetic induction model has nothing to do with the observation point position. But the size of the secondary magnetic field will change with different observation points. Therefore, the amplitude of total magnetic field and phase angle will change with observation point changes, so it will produce abnormal changes of electromagnetic field, which is beneficial to the interpretation of underground mineral analysis.

3. The parameter calculation in transient electromagnetic field

In the electrical prospecting, the parameters of electrical conductivity change of the reflecting measuring target body, called the apparent resistivity. In transient electromagnetic method, apparent resistivity is equal to under the same transient electromagnetic system and measuring device, electrical resistivity of homogeneous conductive half space of producing at the same time with the observed value same transient response.

There are two main methods to calculate the apparent resistivity. One kind is to calculate the asymptotic formula of early and late apparent resistivity, then fit a set of approximate curves diagram of all-time apparent resistivity; another is to use the iterative computation of step response and numerical analysis, and obtain all-time apparent resistivity. This article calculates apparent resistivity of Budunhua copper mine in Inner Mongolia using these two methods respectively, thus analyses distributed situation of underground copper mine.

Early period of transient electromagnetic process refers to $\tau / r \to 0$, at this time, attenuation speed of electromagnetic field becomes faster with the increase of distance. Therefore, the early induction current concentrates on the launch site source. The transmitter coil of this paper adopts central loop, so the early apparent resistivity expression is:

$$\rho_\tau^B = \frac{2\pi r^4}{3M} E_\varphi(t) \tag{8}$$

M refers to coefficient of mutual induction between transmitting coil and underground good conductor; r refers to of exciting loop; E_φ refers to electric field intensity of early electromagnetic field.

Late period of transient electromagnetic process refers to $\tau / r \to \infty$, and the magnetic field intensity of late period has nothing to do with the position. This shows that the induced current of the underground media can diffuse to the infinite deep and the infinite far place. When adopt coincident loop or central loop unit, the late apparent resistivity expression is :

$$\rho_\tau = \frac{\mu_0}{4\pi} \left(\frac{2\mu_0 SNsn}{5}\right)^{\frac{2}{3}} t^{-\frac{5}{3}} \left(\frac{I}{V(t)}\right)^{\frac{2}{3}} \tag{9}$$

S, N respectively refer to area and turns of exciting loop; s, n respectively refer to area and turns of receiving loop; I refers to the intensity of emission current; t refers to delay time; $V(t)$ refers to the measured induction voltage values; μ_0 refers to permeability of vacuum.

Programming in MATLAB, respectively obtain early and late apparent resistivity of the transient electromagnetic field curves as shown in Figure 6:

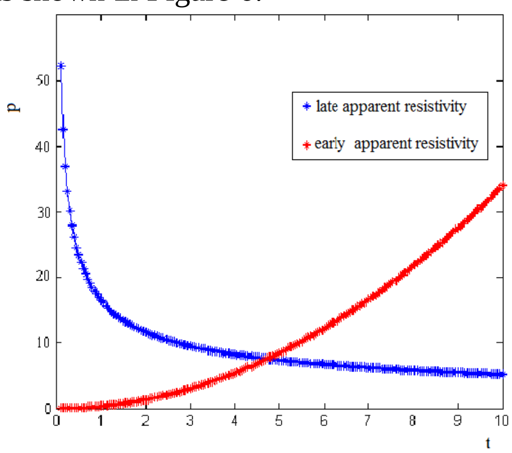

Figure 4. Simulating diagram of the early and late apparent resistivity curve

From Figure 4, we can see variation conditions of the early and late apparent resistivity: when $t = 2ms$ or so, apparent resistivity of transient electromagnetic field nearest field source starts to change rapidly, but after primary magnetic field separation, late apparent resistivity of secondary magnetic field generated by electromagnetic induction has begun to have the obvious downward trend. This shows that when $t = 2ms$, transient electromagnetic field abnormally changes, copper mine appears. From the analysis of the early apparent resistivity, it can be seen, with the increasing of distance and time, the attenuation of early electromagnetic field is very fast. This shows that the launch site source neighbor has the appearance of induced current, and the magnetic field along with the time change into linear, which have nothing to do with the external environment factor. From the analysis of the late apparent resistivity, it can be seen, when the observation of later period transient electromagnetic field, the conductive good geological environment has stronger signal level which is good for the observation, but when the horizontal coil or return wire observation, transmitting and receiving devices can not bring significant influence to the observed result. Due to the late transient field with the attenuation of time change quickly, so it is necessary to have sufficient time range to observe signal.

4. Summary

In summary, in the forecast foundation, select the earth surface of zone 1 to carry on induced polarization (IP) measurement and choose the abnormal reaction good location to verify it. The results show that the copper mine has 6 layer respectively in 82.6m~83.42m and 207.95m, the accumulated thickness is 23.04m, the average grade of the copper ore body is $0.6 * 10^{-2}$, reflecting the good ore prospecting effect.

Budunhua Copper Mine area has good mineral vision. This paper applied transient electromagnetic method to explanation of the Budunhua Copper Mine area. First of all, establish the electromagnetic induction model, analyze frequency and time characteristics of the secondary magnetic field in transient electromagnetic field, program through the MATLAB software and draw the corresponding characteristic curve. Then by comparing calculating results of early and late apparent resistivity and all-time apparent resistivity, get the parameter variation of apparent resistivity of the transient electric magnetic field when mine area change, and draw the corresponding data conclusion. At last, using grid functions of MATLAB, process data and simulate the abnormal changes of transient electromagnetic field of Budunhua copper mine area, completing the explanation of the mine area. From the analysis results, the explanation results of the transient electromagnetic method are more accurate than that of the geophysical data. After the improvement, not only improve the work efficiency, and also improve the accuracy of explanation.

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