Dual-Frequency Induction Polarization Electric Field Focusing Based on Intelligent Algorithm for Coal Mine Electric Exploration

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Abstract. As the most important and dangerous front-end production link, coal mining operations will inevitably face geological disasters such as water inrush, rock burst, collapse, and fire, posing a great threat to the life and safety of miners. Among the five major geological disasters (gas, dust, water, fire, roof) in coal mines, the threat of flooding is very serious and it is one of the main disasters in coal mines. The research and development of dual-frequency excitation technology and its application in coal mine exploration have realized the elimination of potential safety hazards, improved the work efficiency and safety factor of prospectors, and realized the automated operation of the exploration process. This article explores the electric field of the intelligent algorithm's focused dual-frequency induced polarization method in coal mine electrical exploration, and summarizes some of the advantages of the intelligent algorithm's focused dual-frequency induced polarization method in coal mine surveying on related materials, and then conducts related experiment, through the experiment of focusing on the dual-frequency IP method in the coal mine survey, obtained the result, in the abnormal point detection experiment, the change trend of the two curves is the same, the increase is more obvious at 1.3-1.5m, and at 1.5m When reaching the limit value, when it exceeds 1.5m, it starts to fall. It shows that when there is a water-bearing anomalous body directly in front of the tunneling section, the measurement results of the two survey lines are roughly the same. Compared with the no anomaly body, the apparent resistivity and the apparent amplitude frequency both change significantly, and reach the extreme in a certain direction. However, the actual anomalous body is located 1.0m directly in front of the tunneling section, which means that the actual position of the anomaly cannot be determined based on the apparent resistivity and the extreme point position of the apparent amplitude frequency.

Key words: Focus on Dual Frequency, Dual Frequency Induced Polarization, Coal Mine Electrical Method, Electrical Exploration

1.Introductions
Most coal mines in our country are mined by underground workers, and there are many natural disasters [1-2]. During the mining process, the shaft and the road itself have to pass through different geological units, and they will inevitably face geological disasters such as water inrush, rock burst, collapse, and fire [3-4], which poses a great threat to the life safety of mine workers, and regular losses [5-6].

Focusing on the intelligent algorithm of the dual-frequency induced polarization electric field in the study of coal mine electrical exploration, for the study of coal mine electrical exploration, the induced polarization method has significant advantages: non-polarization that interferes with the geological interpretation of the resistivity method rocks or uneven terrain will not cause induced polarization anomalies. Only electronically conductive geological bodies can cause significant induced polarization anomalies. In this way, the influence of the ambiguity of geophysical anomalies can be effectively reduced [7-8]. The polarization method has gradually become an indispensable and important method for the exploration of various metal sulfide minerals, especially when looking for disseminated metal minerals, it has more obvious advantages than the resistivity method [9-10]. At the same time, the induced polarization method has also achieved fruitful results in other fields such as searching for oil, gas and water resources. Aiming at the research of the focused dual-frequency IP method, the dual-frequency IP instrument is developed on the basis of the "variable frequency method" that changes the frequency to measure the induced polarization effect. Through the self-developed dual-frequency current transmitter, it can emit two different frequencies at the same time. Using the self-developed receiver at the measuring point to measure the potential difference of two different frequencies at the same time, according to its measurement principle, it is called a dual-frequency IP instrument [11]. The working principle of the dual-frequency IP instrument has outstanding advantages. The instrument itself is small in size, light in weight, fast in observation and reading, high in efficiency, and high in measurement data accuracy. It has strong anti-interference ability in actual work. It is gradually used in the field of mineral resources exploration. It is widely used [12].

This article focuses on the intelligent algorithm of the focus dual-frequency induced polarization method electric field in the coal mine electrical exploration, based on the relevant literature data on the application advantages of the focused dual-frequency induced polarization method in the coal mine electrical exploration, and then conducts the coal mine survey the focused dual-frequency IP method experiment, according to the relevant results of the experiment.

2. Focus on the Research of Dual-Frequency Induced Polarization Method

2.1 Focus on the Characteristics of Dual-Frequency Induced Polarization

(1) The dual-frequency IP transmitter (SQ-5 type) provides four groups of dual-frequency current signals, which can be selected by the user during work according to the needs of different working areas and different targets.

The fundamental frequencies of the four groups of signals differ by 13 times, and the amplitude ratio of the high and low frequencies is 12:13. There is no need to increase the current to increase the width of the main to solve the difficult technology in the singular harmonic shape of F5, AV G and AV D that cannot be read with high accuracy without increasing the size of the transmission signal.

(2) The dual-frequency IP method effectively reduces the influence of the unstable transmission current on the measurement results.

Some data show that under the same conditions, the influence of the dual-frequency measurement results is one to two orders of magnitude smaller than the influence of the odd harmonic shape and the frequency conversion mode. The transducer of the frequency conversion method must be equipped with a constant current device to reduce the influence of unstable current on the measurement result, make the structure of the transmitter more complicated, increase the weight of the instrument, and reduce the power supply. The interference of the transmission signal factor in the data read by the dual-frequency IP is very weak and does not need to be considered, thus simplifying the structure of the instrument and effectively optimizing the power utilization and the weight of the instrument.

(3) The stability, observation accuracy and anti-interference ability of the dual-frequency IP instrument are better than other methods.

The dual-frequency IP method simultaneously transmits dual-frequency signals through self-built equipment, and incorporates methods such as synchronous detection and comprehensive sampling into the receiving end. Simultaneously measure the potential difference between the high-frequency and low-frequency currents, and calculate the potential difference between the high-frequency and low-frequency currents. Of the two fusion methods, the former can effectively suppress co-channel interference signals, and the latter can avoid symmetrical interference to a greater extent. The application of the above technology enables the dual-frequency
IP method to effectively suppress various external field interference signals in actual work, which is beneficial to improve the observation accuracy of the dual-frequency IP instrument. In addition, due to the synchronization of the spraying process, interference factors such as temperature and humidity can be removed at the same time. The interference of these factors on data reading is reduced, and the stability of the device is better than other methods.

2.2 Principles of Focused Dual Frequency IP Method

The technical core of the dual-frequency induction polarization method is the use of dual-frequency transmitters to synthesize currents, including high-frequency and low-frequency, and the special waveforms in the dual-frequency current are suitable for being underground. The dual-frequency receiver simultaneously receives two frequencies carried by the earth. The type of current response frequency use the observed high-frequency potential difference \( \Delta V \) and low-frequency potential difference \( OV \) to calculate the apparent frequency amplitude \( F, F_1 = (\Delta V - \Delta V_1) / QV \times 100\% \), and calculate the position difference \( OV \), power supply current \( I \), and power supply current \( I \), according to the high-frequency voltage. Device coefficient \( K \), apparent resistance \( \rho = KOV / \rho \). The apparent rate of dual-frequency IP, apparent metal coefficient \( Mp \) and IP \( G \) can also be calculated. The physical essence of the two derivative parameters is the use of apparent conductivity and anti-weight \( F \):

\[
M_F = \frac{\rho_{sl} - \rho_{sh}}{\rho_{sl} + \rho_{sh}} = F_s \cdot \sigma_{sl}
\]

\[
G_s = K \cdot \frac{\Delta V_1 - \Delta V_1}{I} = F_s \cdot \rho_{sh}
\]

3. Focus on the Experiment of Dual-Frequency Induced Polarization Electric Field in Coal Mine Electrical Exploration

3.1 The Purpose of the Experiment

Terrestrial channel model testing is one of the most effective physical simulation methods for advanced forward detection and modeling. This article is based on the theoretical basis of the principle of similarity of natural phenomena, mining and detecting the coal body effect of IP road construction is similar to the geoelectric model, and testing and testing the unrestricted IP effect and the simulated IP effect respectively.

3.2 Design of Physical Model Test of Soil Channel

(1) Design of soil tank test site
It is relatively convenient to excavate soil trench models on the ground, but two similar conditions must be met: similar geometric dimensions and similar material properties. Similar geometric dimensions require that the model is similar to the original geometric shape, and the corresponding proportions of the length dimensions are equal everywhere, that is the length scale \( G \) is a dimensionless constant, including the length of the tunnel, the size of the tunnel section, the size of the abnormal body carried by the water, and choose the length scale \( G \) to 10 for the distance between the abnormal body and the section, the distance between the electrodes, etc. Make the environmental rock medium consistent with the actual geology, that is, \( \rho \) (\( i = 1 \ldots n \)) is consistent with the working conditions of road coal, where \( P \) is the average resistance of the earth's surrounding rock, which can be directly measured with a ground resistance tester. After multiple measurements in different directions within the selected grounding width, the average grounding resistance is estimated to be about 18Qmp; it is the resistance of different abnormal bodies. This test takes different concentrations of seawater as anomalous bodies, adds salt to tap water, and determines the resistance of the saltwater by controlling the concentration of seawater. The resistance value changes with concentration.

(2) Test content and procedures
After completing the preparations for the excavation of the soil trench, carry out the unconstrained IP effect test of no anomalous body, the focused IP effect test of no anomaly body, the unbound IP effect test of anomalous body with water and the focused IP effect test of anomalous body with water.

1) Connect the test device
Arrange the measuring lines according to the fixed-point power supply three-pole device and the focus detection device respectively, connect the detector transmitter and receiver, power on the system for self-check, and set the system parameters (emission current amplitude of each electrode, system Working frequency), start
to prepare for measurement.
2) Check the grounding resistance
Display the grounding resistance of each path through the transmitter. If the grounding resistance is found to be too large, pour an appropriate amount of water or salt water to the transmitter electrode and the grounding electrode to fully reduce the grounding resistance.
3) No abnormal body induced polarization effect test
Don’t carry out the non-abnormal body-induced effect test according to the fixed-point power supply three-pole device and the focus detection device. After each measurement point is completed, after the measured data (high and low frequency potential difference, apparent amplitude frequency and apparent resistivity, etc) are stabilized, choose to store the data, carry out the measurement of the next point in sequence, and use the data of all the measurement points as the background value of the non-anomalous body induced electric effect test of the fixed-point power supply three-pole device and the focus detection device, so as to compare with the water-bearing geological structure data.
4) There is a water-bearing abnormal body induced polarization effect test
The abnormal cavity was injected with 0.2m3 and 0.3m3 salt water in one step, and the unconstrained IP effect and focused IP effect tests of the water-bearing abnormal body were carried out respectively, and the test results were compared and analyzed.
5) There are two water-bearing abnormal body induced polarization effect tests
The salt water content of the abnormal cavity 1 was kept unchanged at 0.3m3, and 0.4m3 salt water was injected into the abnormal body 3. The unconstrained IP effect and the focused IP effect test of the water-bearing anomaly body were carried out respectively, and the test results were compared and analyzed.

4. Analysis of Experimental Results

4.1 The Existence of a Water-Bearing Abnormal Body Induced Polarization Effect Detection

Inject unequal amounts of 0.2m3 and 0.3m3 salt water into the abnormal cavity in 1 step, and the main electrode emission current is still set to 20mA. Perform measurements according to the above process, export test measurement data, and use MATLAB software to draw the apparent resistance of each line rate change curve and apparent amplitude frequency change curve. When the salt water content is 0.2m3, the experimental results are shown in Table 1:

|                | There is an abnormal body x-0 survey line | There is an abnormal body x-0.2 survey line |
|----------------|------------------------------------------|--------------------------------------------|
| 0              | 3.0                                      | 3.0                                        |
| 0.5            | 3.8                                      | 3.1                                        |
| 0.7            | 3.9                                      | 4.3                                        |
| 0.9            | 4.0                                      | 4.0                                        |
| 1.1            | 4.9                                      | 4.5                                        |
| 1.3            | 4.8                                      | 4.4                                        |
| 1.5            | 6.7                                      | 6.8                                        |
| 1.7            | 6.0                                      | 5.9                                        |
| 1.9            | 4.9                                      | 4.9                                        |
| 2.1            | 4.8                                      | 4.8                                        |

It can be seen from Figure 1 that the change trend of the two curves is the same, the increase is more obvious at 1.3-1.5m, and the limit value is reached at 1.5m, and it starts to decrease when it exceeds 1.5m. It shows that when there is an abnormal water body in front of the tunnel section, the measurement results of the two survey lines are roughly the same. Compared with the abnormal body, both the apparent resistance and the apparent amplitude change significantly, and reach the limit in a certain direction. However, the actual abnormal body is located 1.0m directly in front of the tunnel section, which means that the actual position of the abnormal body cannot be determined based on the position of the extreme point of apparent resistance and the apparent amplitude frequency.
There is an abnormal body x-0 survey line
There is an abnormal body x-0.2 survey line

Distance between measuring electrode and section

Figure 1. The existence of a water-bearing abnormal body induced polarization effect detection

4.2 There Are Two Water-Bearing Anomalous Body Induced Polarization Effects Tests

The abnormal cavity 1 was injected with 0.2m3 of salt water, and the abnormal body 3 was also injected with 0.2m2 of salt water. The measurement was carried out along the three survey lines according to the above method. The results obtained are shown in Table 2:

| Distance between measuring electrode and section | There is an abnormal body x-0 survey line | There is an abnormal body x-0.2 survey line |
|-------------------------------------------------|----------------------------------------|-------------------------------------------|
| 0                                               | 3.5                                    | 3.5                                       |
| 0.5                                             | 4.1                                    | 4.2                                       |
| 0.7                                             | 4.9                                    | 4.9                                       |
| 0.9                                             | 5.0                                    | 5.1                                       |
| 1.1                                             | 6.0                                    | 6.0                                       |
| 1.3                                             | 6.3                                    | 6.2                                       |
| 1.5                                             | 8.8                                    | 8.8                                       |
| 1.7                                             | 8.7                                    | 8.6                                       |
| 1.9                                             | 10.0                                   | 10.0                                      |
| 2.1                                             | 8.7                                    | 8.7                                       |

It can be seen from Figure 2 that the settings of the two curves are roughly the same. The increase is the largest at 1.3-2.1m, reaches the limit at 1.9, and starts to decrease when it exceeds 1.9, and with the distance between the measuring point and the cross section, when there are no irregular objects, the apparent resistance and apparent frequency range of the corresponding measuring point are closer. This indicates that the presence of lateral irregularities near the center of the road will have some influence on the apparent resistance and apparent
width frequency measurement. The measurement results of the two measurement lines at their respective measurement points are not much different. According to the position of the extreme point of the apparent resistance frequency and the amplitude of the apparent frequency, the true position of the abnormal body cannot be determined.

5. Conclusions

This article focuses on the intelligent algorithm’s focused dual-frequency induced polarization method for electric field exploration in coal mines. After conducting related coal mine survey experiments, the results of the experiments show that with the distance between the measuring point and the cross section, when there are no irregular objects, the apparent resistance and apparent frequency range of the corresponding measuring point are closer. This indicates that the presence of lateral irregularities near the center of the road will have some influence on the apparent resistance and apparent width frequency measurement. The measurement results of the two measurement lines at their respective measurement points are not much different. According to the position of the extreme point of the apparent resistance frequency and the amplitude of the apparent frequency, the true position of the abnormal body cannot be determined.

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