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LETTER TO THE EDITOR

The Design of Coal Distribution Information Detection System Based on Dual-Frequency IP Method

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Aiming at the problems of long detection time and poor detection accuracy of traditional coal distribution information detection system, a coal distribution information detection system based on dual-frequency IP method is proposed and designed. According to the dual-frequency IP method, a dual-frequency IP detection system consisting of coal distribution information detector, hydraulic detection emission electrode, multiple restraint electrodes and grounding electrodes is designed to detect coal distribution information. The hardware design of the system is used to determine whether there are geological anomalies such as water-bearing geological structure, faults, subsidence pillars and so on in front of the mining area. The experimental results show that the designed detection system has high detection accuracy and short detection time.

Dual-frequency IP method; Coal distribution information; Detection

1 Introduction

Coal resources are the material basis of coal industry construction. China is a big country of coal production. Not only is coal rich in reserves, but also the production and consumption of coal are in the forefront of the world. As the first energy source in China, the sustainable development of coal resources is related to the overall situation of national economy and energy security. At present, the contradictions of coal industry in system, resources, safety, environment and the development of conversion are becoming increasingly prominent. The sustainable development of coal industry and some coal-producing areas is facing serious challenges. How to detect the current situation and development trend of coal distribution information, provide timely and reliable information service for leading departments and production departments at all levels, and improve the management of coal distribution information and the safety level of coal resources mining is an urgent problem for scientific and technological workers. Generally used detection methods include transient electromagnetic method, ground penetrating radar method and seismic wave method, but in order to achieve advanced detection in coal mine, there are still a series of problems, such as separation of exploration, low accuracy of prediction, and complex underground environment in coal mine, so the electrical equipment must meet explosion-proof requirements, which has more stringent restrictions on the electrical parameters of equipment.

In 2019, D. Lin and L. Li published an article in the journal Ekoloji (Issue 107) entitled “Environmental Study on Mining Area Living Environment Satisfaction Evaluation-Taking an Example of Huainan City”, in order to properly evaluate the residents’ satisfaction with the living environment in the mining area and establish a mathematical evaluation model of attributes. The analytic hierarchy process was used to determine the index

weights, and the confidence rules of the residents' living environment of the coal mine were evaluated by setting the confidence rules according to the attribute metrics of each indicator and multiple indicators. The actual case were used to test the effectiveness of the method. The evaluation results showed that the attribute mathematical model was an effective method for assessing the residents' living environment satisfaction of mining area. It provided a scientific and reasonable evaluation tool for solving these problems. The experimental results showed that the system had higher detection resolution.

Zhongand Wang (2016) proposed method of detecting water-rich areas in coal mines by combined ground and underground transient electromagnetic method. In order to avoid water hazards, this method combined ground and underground transient electromagnetic measurement in the whole working face. The surface transient electromagnetic method was used to control the distribution range of water hazards from the plane, and the underground detection method was used to delineate the water-rich areas and guide the next pumping and drainage work. (Issayeva et al., 2017)The results of ground transient electromagnetic method was compared with the underground transient electromagnetic method, and the results of both methods were the same in water-rich areas. The joint detection reduced the problem of multi-solution of geophysical data and greatly improved the detection accuracy, but the detection time of this method was longer. Liuand Hao (2016) presented an application method of transient electromagnetic measurement in detecting goaf in coal mine, which was based on the electrical difference between goaf and surrounding media. The transient electromagnetic method was used to detect the mined-out area of coal mine. The results of drilling verification showed that the geophysical exploration of the mined-out area boundary was reliable and the expected geological effect was achieved, but the detection accuracy of this method was low. In view of the above problems, this paper proposes and designs a coal distribution information detection system based on dual-frequency IP method.

2 Idea Description

Dual-frequency IP method is based on the induced polarization phenomenon of rock. Under the action of artificial electric field (primary electric field), underground rock mass will undergo complex electrochemical process, forming a polarized electric field (secondary electric field) which increases with time. Their superposition is called total electric field. The dual-frequency IP advanced detection system includes the excitation signal transmitting system (hereinafter referred to as the transmitting system) and the IP signal receiving system (hereinafter referred to as the receiving system). The dual-frequency IP detection system is shown in Figure 1.

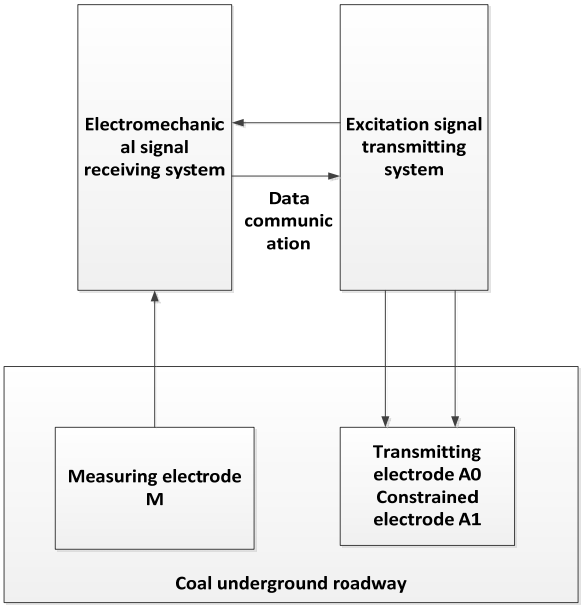

Figure 1 Dual-frequency IP detection system

The main electrode A0 and constraint electrode A1 of the emission electrode are arranged in the roadway section, the grounding electrode is arranged in the infinite distance behind the roadway, and the measuring electrode is MN, which is arranged in the back of the roadway (Liu et al. 2018). The amplitude ΔV_{L}, ΔV_{H} and phase difference ϕ_{L} and ϕ_{H} of IP voltage are obtained by signal processing. The apparent resistivity ρ_{s}, apparent amplitude frequency F_{s} and apparent phase frequency ϕ_{s} of IP effect parameters are calculated, as shown in the formulas (1) ~ (3).

$$\rho_{\mathrm{s}} = K\frac{\Delta V}{I} \tag{1}$$

$$\begin{aligned} F_{\mathrm{s}} &= \frac{\Delta V_L - \Delta V_H}{\Delta V_L} \times 100\% \\ &= \frac{\rho_{\mathrm{s}}(f_L) - \rho_{\mathrm{s}}(f_H)}{\rho_{\mathrm{s}}(f_L)} \end{aligned} \tag{2}$$

$$\phi_{\mathrm{s}} = \frac{\phi_L - \phi_H}{\phi_L} \times 100\% \tag{3}$$

2.1 Overall Architecture of the System

Coal distribution information detection system based on dual-frequency IP method is mainly used for coal distribution information detection. It consists of coal distribution information detector, hydraulic detection emission electrode, multiple restraint electrodes and grounding electrodes (Mishra etal. 2018). Among them, the advanced detector includes two parts: transmitting module and receiving module, transmitting module emits dual-frequency current through electrodes; receiving module receives and processes polarization information and

judges anomalous geological structure in front; detecting electrode emits dual-frequency current to surrounding rock in front of it to form detecting electric field; restraining electrode emits the same-frequency current with detecting electrode and constrain the electric field formed in the surrounding rock. By using the principle of electric field repulsion with polarity, the original propagation direction of detecting electric field can be changed so that its direction can be controlled(Yu 2017). The function of the grounding electrode is to make the electric field form a loop.

2.2 Hardware Design

KC01-43T, the intrinsically safe man-machine interface in mining produced by Weikong Technology is selected as the hardware part of the main control system. The software part is compiled by Levi Studio, which is composed of four subroutines: parameter setting program, system verification program, measurement display program and data query program. (Elija et al., 2017)The parameter setting program is mainly composed of the parameters of measurement area, measurement methods and devices, and signal conditioning system settings, time and date settings, etc.; system verification program includes self-verification and external verification; measurement display program includes the current data of transmitting system and the detection data of receiving system and real-time display of images; data query program can realize query of historical records (Zhangetal. 2017).

2.3 System detection method

After the electrodes are laid out, the emitter module of the detector emits dual-frequency synthesized wave current of the same frequency through the detection electrode and the restraint electrode, forming the detection electric field and the restraint electric field respectively in the medium of the tunneling area to be measured. The detection electric field propagates forward under the restraint electric field, and the polarization effect of the front medium will occur under the excitation of the electric field. (Siaudinis et al., 2017)The transmitting electrode is also used as the measuring electrode. The receiving module of the detector receives polarization information between the measuring electrode and the ground electrode. By magnifying and filtering the polarization information, the high and low frequency potential difference components are separated, and the geological anomalies such as water-bearing geological structures, faults and collapse columns are judged according to the PFE value and its changing trend.

3 Results

According to the characteristics of working environment in coal mine, the principle prototype system of advanced detection instrument for comprehensive coal excavation is developed. The main characteristics of the instrument system are as follows:

(1) The system is mainly composed of transmitting module (microprocessor, driving circuit, transmitting circuit), intelligent acquisition instrument, cable and electrode, etc. The electrodes are arranged on the driving surface of the simulated roadway.

(2) The main feature of the transmitter module is to transmit dual-frequency current with constant current, and the power supply current ranges from 1 to 50 mA.

(3) Intelligent acquisition instrument can receive, filter and display tiny signals in real time.

The traditional detection system is a good one in the existing research, and good research results have been obtained. The detection system designed in this paper is compared with the traditional detection system. The results are shown in figure 2.

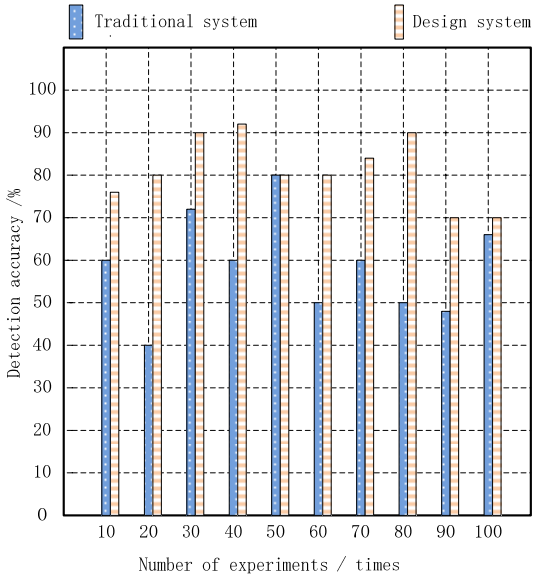

Figure 2 Comparison of detection accuracy

According to Figure 2, the detection accuracy of the detection system designed in this paper is generally higher than that of the traditional system. The maximum detection accuracy of the detection system designed in this paper can reach 92%, which shows that the detection performance of the detection system designed in this paper is better.

In order to further verify the effectiveness of the system, the detection time of the detection system designed in this paper is compared with that of the traditional system. The comparison results are shown in Figure 3.

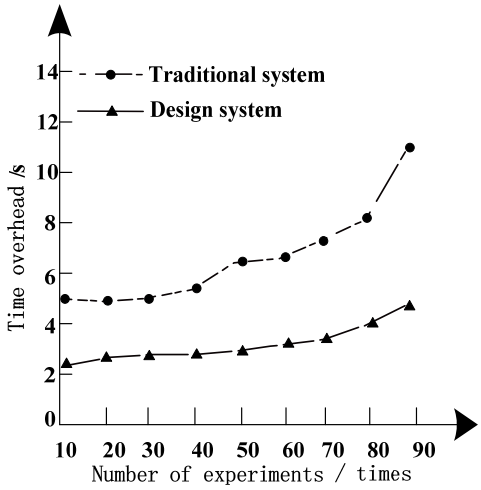

Figure 3 Comparison of detection time

The detection time expenditure curve of the traditional system. has been showing a gentle upward trend in the early stage, and a significant upward trend in the middle and late stages. The detection time of the detection system designed in this paper has been showing a steady trend. By comparison, the detection time expenditure of the detection system designed in this paper is lower than that of the Traditional system. It shows that the detection system designed in this paper has better detection efficiency.

4 Conclusion

This paper designs a coal distribution information detection system based on dual-frequency IP method. This system fully considers the safety standard of coal mine. It can be used for advanced detection of geological anomalies such as water-bearing geological structure, faults, collapse pillars in front of coal mining. It has considerable technological progress and practicability, and has extensive popularization value in industry. The experimental results show that the detection system designed in this paper has high detection accuracy and short detection time, which provides data basis for coal distribution information detection and protection.

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