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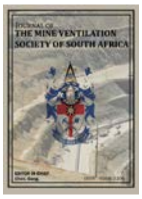

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RESEARCH AND DESIGN OF INTELLIGENT COAL MINE SAFETY MONITORING SYSTEM BASED ON INTERNET OF THINGS

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ABSTRACT

In order to timely monitor the safety of underground coal mines, this paper analyzes the design and analysis of coal mine safety monitoring system based on the intelligent Internet of Things, and analyzes it through surge interference method, conducted interference method and large equipment interference method. The results show that 100 V surge voltage can be coupled to 1-8 V disturbance voltage on the signal line. Finally, the conclusion is drawn that the longer the parallel distance of the cable is, the larger the area of ground to receive interference and the greater the intensity of interference. Downhole monitoring system signal port conduction interference is large, there is not only high frequency (1MHz) pulse group interference, but also power frequency interference. The mine safety monitoring system developed by using the Internet of things technology can locate and monitor downhole moving targets accurately and in real time.

KEYWORDS

Internet of Things; intelligence; coal mine safety; monitoring system.

INTRODUCTION

The geological conditions of coal mines in China are complex, and natural disasters such as gas, fire, roof power and impact ground pressure are serious, and disaster prevention and disaster resistance are large. Moreover, China's coal mines are mainly based on underground mining, and the number and output of wells and coal mines account for more than 90% of the total coal mines and production in the country. The conditions of the pipeline network in the underground mine roadway have increased the difficulty of disaster prevention. Once an accident occurs, it is easy to induce other disasters and cause serious accidents. Among the various types of coal mine accidents, coal mine gas disasters are one of the major disaster types. Therefore, the development of coal mine safety monitoring technology has always been highly valued by the state. The State Council's Notice on Further Strengthening Enterprise Safety Production (Guo Fa [2010] No. 23) regards safety monitoring as one of the six major coal mine systems. Coal mines across the country are required to be installed. The National Medium- and Long-Term Science and Technology Development Plan outlines the “early production accident warning and rescue” as a priority theme in this field. Coal mine safety monitoring system is the main means of early warning and safety management of major disasters in coal mines. Only by improving the technology and level of coal mine safety monitoring can we find hidden dangers in time, improve the safety production early warning capability of coal mines, and effectively manage the safe production of coal mines.

Based on the Internet of Things, this paper studies and designs the intelligent coal mine safety monitoring system and analyzes the coal mine safety monitoring system through the surge interference method, the conducted interference method and the large equipment interference method. Finally, a series of conclusions are drawn to prove that the coal mine Internet of Things technology is an emerging technology, which realizes the precise positioning and safety of moving targets in coal mines through radio frequency identification, infrared sensors, global positioning systems, laser scanners and other technical means monitor.

LITERATURE REVIEW

According to the research status at home and abroad, the Internet of Things was first proposed by Professor Kevin Ash-ton of the Massachusetts Institute of Technology in the United States. In the research, the RFID technology was combined with the Internet to realize the identification and management of objects (Ash-ton, 1994). In his research, pointed out that the Internet of Things is the application of RFID technology to enable computers to automatically identify everyday objects, then track and monitor them, and manage them (Melon, 2008). A study pointed out two dimensions of Internet of Things applications, namely information collection and analysis, as well as automated control processes (Roberts, 2010). After studying the Internet of Things technology, domestic scholar a research pointed out that the definition of the Internet of Things is a network that uses sensors to sense and transmit various types of information in the real world (Haitao, 2018). Three technical theories of Internet of Things applications, namely information identification, dynamic monitoring and intelligent monitoring, and pointed out the business model applicable to the Internet of Things (Yong, 2011). A recent study gave the design method of monitoring system for ADS technology and proposed the design principle based on autonomous distributed signal system (Chao, 2013).

RESEARCH METHOD

Surge interference method

Surge interference caused by conduction between cables is caused by rapid changes in current, mainly through line-to-line inductance (magnetic field) coupling. The figure below is a schematic diagram of the coupling between the interference source and the interfered body. Although the intrinsic safety equipment in the coal mine is not grounded, the shell of the intrinsic safety equipment is effectively grounded (such as fixed on the roadway wall through the wire), and there are usually dozens to hundreds of picometers of capacitance between the intrinsic safety circuit and the equipment shell, so inductive coupling paths of downhole parallel cables exist (Lilic, 2010). Obviously, the longer the parallel distance of the cable, the larger the area between the cable receiving interference and the ground, and the greater the intensity of receiving interference.

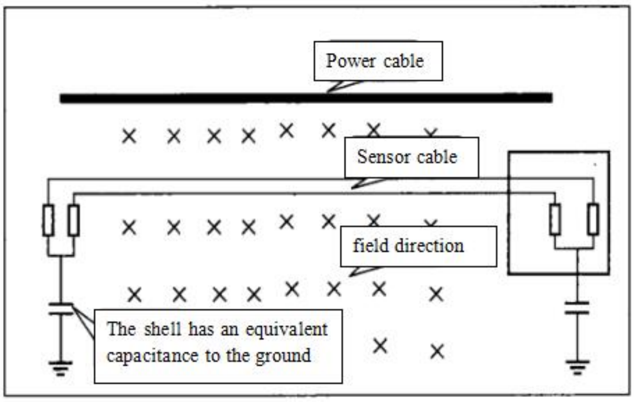

Fig. 1: Schematic diagram of surge interference coupling between cables

HBYV wire is also used as the interference receiver, which is laid near the interference source cable during field measurement. One end of the core wire can be directly grounded, and the other end can be grounded through 1000pF capacitance. The maximum interference signal at both ends of the capacitance can be captured by digital oscilloscope, as shown in the figure below.

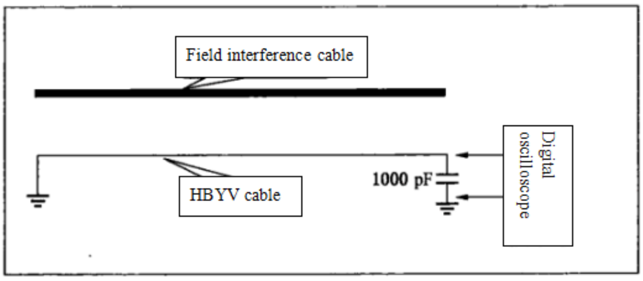

Fig. 2: field measurement of surge interference between cables

Conduction interference method

According to field experience, when the security monitoring sub-station is disturbed, there are usually high-power power equipment around, so it is necessary to test the interference on the power line (Liu, 2014). However, general instruments cannot be directly connected to the underground power line for testing, so the interference on the power line can only be non-contact tested by using the current probe. A power quality analyzer was used to connect the current probe to test the population of the power box in the substation. In the test, it was found that the voltage sag and sag on the downhole power line were serious. The sag of 127V was as serious as 23% and lasted as long as 3s, while the sag of about 20% on 660V was also very common. The current probe or voltage probe of portable oscilloscope was used to directly test the port interference of the monitoring system. During the test, it was found that the signal port of the downhole monitoring system had large conducted interference, including both high frequency (1MHz) pulse group interference and power frequency interference.

Large equipment interference method

Due to the numerous underground interference sources, it is impossible to make accurate measurement. Therefore, a direct measurement method for large equipment interference transmission on the ground is designed. For specific excavators and fully mechanized mining machines, we conducted interference measurement on their power lines, and the spectrum analyzer further learned about the external interference through power lines when large equipment interfered (Chen, 2014). This measurement method is shown in the following figure: on the power line of large equipment, the measurement method in figure 3 uses a current probe connected with a spectrum analyzer to measure the interference frequency signal on the power line. Although it cannot be compared with the power supply impedance stability network used in the standard test in the laboratory, the interference source can also be understood by comparing the static background noise with the working state of the load in the field test.

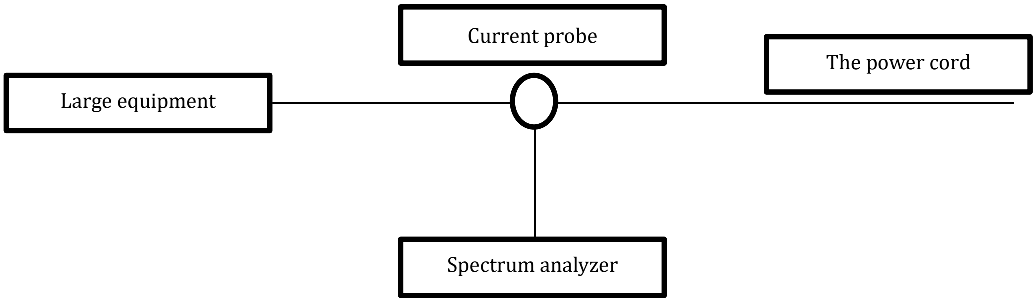

Fig. 3: Measurement method3

RESULTS ANALYSIS

The following test data are obtained based on the above tests.

Table 1: Electrostatic interference test

Location	Static electricity	Place	Static electricity
Sensor	-1.29KV	control	-1.23KV
Incoming box	-1.13KV	auxiliary transportation lane substation	-1.4KV
Level 1 and 1	-1.32KV	303 work face substation	-1.35KV
Level 1 and 2	-1.36KV		

As can be seen from the data in table 1, downhole static electricity is very small and will not affect the equipment work. In conclusion, the following conclusions can be drawn: (1) The main sources of downhole pulse group interference are switch on and off, power converter, etc., and the interference intensity is above standard 500V; The main source of underground surge interference is power cables, and the interference intensity is above the standard level of 1400V (Yongli, 2018). (2) When there is no wireless communication emission around the coal mine, the electromagnetic radiation interference level is low and there is no threat to the reliable operation of the equipment. (3) When testing downhole power lines, it is found that there is a significant voltage sag in ac: the amplitude can be up to 23%, and the duration can be up to 30s. (4) In the test, it is found that the signal port of downhole monitoring system has large conduction interference, which includes both high frequency pulse group interference and power frequency interference. (5) Low downhole static electricity, no threat to the reliable operation of equipment.

According to the test data in the early stage, the modeling and simulation analysis are carried out in theory, so as to conform to the actual situation and replace the inconvenience of field test for various analysis and calculation. Time-domain finite element difference method is a widely used numerical calculation method of electromagnetic field, which requires less memory, is easy to deal with complex objects, and the algorithm is simple, especially suitable for the time-domain analysis of electromagnetic field (Xueping, 2014). FIG. 6 shows the magnitude of signal line interference of downhole power line calculated by time-domain finite element difference method and multi-conductor transmission line theory (Haoyue, 2013).

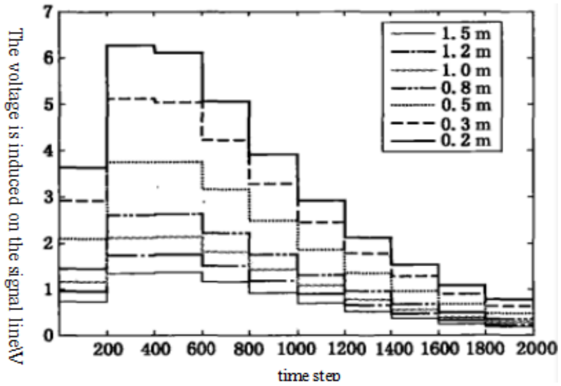

Fig. 4: calculation results of FDTD method with different distances between power line and signal line under step excitation

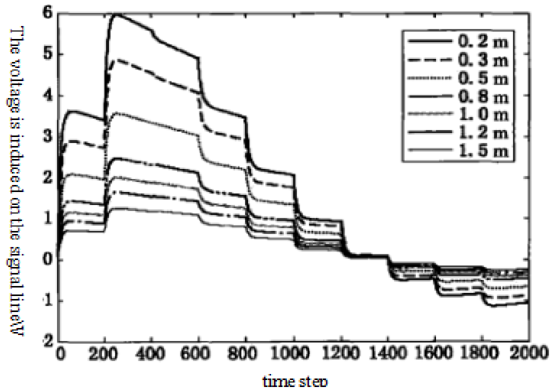

Fig. 5: Calculation results of FDTD method with different distances between power line and signal line under surge excitation

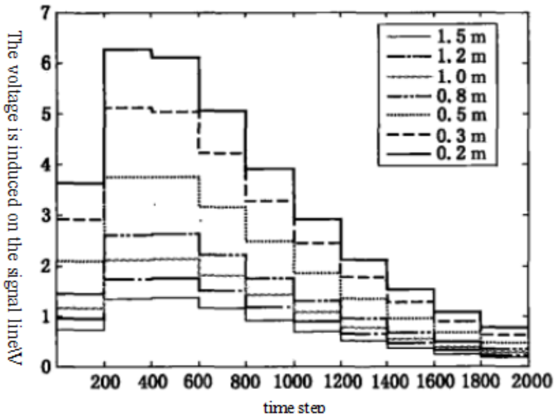

Fig. 6: calculation results of FDTD method with different heights of power line and signal line from the ground under step excitation

The step signal with amplitude of 100V on the power line is calculated in FIG. 4. The power line and signal line are 1m away from the ground. The distance between them is 0.2m, 0.3m, 0.5m, 0.8m, 1m, 1.2m and 1.5m respectively from top to bottom. The radius of the power line is 6.182mm, the radius of the signal line is 0.688mm, and the parallel distance between them is 100m. The voltage time change at a point on the signal line is shown in the figure. It can be seen that with the difference in the distance between the two, the electromagnetic interference through conduction will be very different. When they are 1.5m apart, the interference voltage is 15%-20% when they are 0.2m apart.

The surge signal with amplitude of 100V taken by the interference source is calculated in figure 5. The power line and signal line are 1m away from the ground. The distance between them is 0.2m, 0.3m, 0.5m, 0.8m, 1m, 1.2m and 1.5m respectively. The radius of the power line is 6.182mm, and that of the signal line is 0.688mm. The parallel distance between them is 100m, and the voltage at a point on the signal line varies with time as shown in the figure. It can be seen that with the difference in the distance between the two, the electromagnetic interference through conduction will be very different. When they are 1.5m apart, the interference voltage is 15%-20% when they are 0.2m apart.

The step signal with amplitude of 100V taken by the interference source is calculated in figure 6. The distance between the power line and the signal line from top to bottom is 2.0m, 1.8m, 1.5m, 1.2m, 1m, 0.8m and 0.5m respectively. The distance between them is 0.2m. The radius of the power line is 6.182mm, and that of the signal line is 0.688mm. The parallel distance between them is 100m. It can be seen that the electromagnetic interference through conduction mode will vary greatly with the height from the ground. When the two cables are 0.5m away from the ground, the interference voltage is 40% of that when the two cables are 2m away from the ground.

It can be seen that the 100V surge voltage can be coupled to 1-8v disturbance voltage on the signal line, and this result can be mutually verified with the experimental results, confirming that the model-based calculation is basically consistent with the actual situation.

CONCLUSION

In the future for a long time, China will still be a coal as the main energy country. Keeping close contact with reality, combining politics, production, study and research, and constantly carrying out technological innovation and application of theory are the key to the construction of new modern digital mine, which is of great significance to guarantee the safety of coal mine production. Coal mine Internet of things technology is an emerging technology that uses RFID, infrared sensors, global positioning systems, laser scanners and other technical means to achieve precise positioning and safety monitoring of moving targets in coal mines. At present, the Internet of Things technology has been widely used in military, petrochemical, non-coal mines and other fields, with good results.

This paper discusses the current status and functions of coal mine safety production systems at home and abroad, and analyzes the feasibility and effectiveness of the coal mine safety monitoring system based on the Internet of Things. On this basis, we focus on the design of intelligent decision-making functions of the system, and explain in detail the ideas, principles, processes and implementation of specific procedures. Through the study of the theory and the writing of the thesis, the knowledge of establishing a coal mine safety monitoring system based on the Internet of Things has been mastered, and the characteristics of the coal mine safety monitoring system have been further understood. The application research of Internet of Things technology in coal mines has just started. With the development of coal mine information technology, the application of Internet of Things technology to digital mine construction to achieve less humanized and unmanned coal mining is the ultimate development trend of mine comprehensive automation.

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