Application of multi-source information intelligent early warning system for coal and gas outburst

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Abstract. The construction and application of a multi-source information comprehensive early warning system for coal and gas outburst in Xinjing Mine is described. First of all, through a large number of statistical analysis work of mine gas dynamic phenomenon, master the internal laws and characteristics of coal and gas outburst events in Xinjing mine, and use scientific reasoning and analysis methods to establish a multi-source information alarm index system in line with the actual situation of the mine. Secondly, design a professional and efficient early warning data chain structure. Finally, from the information collection end, professional analysis subsystem, the intelligent early warning system is built in three aspects of database to realize the online monitoring, intelligent identification and real-time early warning of prominent hazards. The overall accuracy of the early warning system in Xinjing Mine test period is over 91%, the overall false alarm rate of no outburst danger is less than 9%, and there is no occurrence of the phenomenon of no outburst danger, so the system has a high accuracy of early warning.

1. Introduction

With the increase of mining depth and the expansion of production capacity, coal and gas outburst accident has become one of the typical power disasters in coal mines, which puzzles the managers of coal mining enterprises [1]. The scientific prevention and control of coal and gas outburst accidents has also become the key link of scientific research in the process of intelligent construction of coal mines [2]. Early warning, as an important technical means to prevent and control coal and gas outburst [3-4], gradually plays an indispensable role in coal mine safety production. The author's team has done a lot of research work on early warning technology in recent ten years [5-9]. This paper describes a set of multi-source information intelligent early warning system based on the latest research results of the team. The construction of the system gets rid of the fixed mode of the original early warning index, and establishes a dynamic multi-source information early warning index system by using scientific methods and combining with the actual situation of the mine. At the same time, the system has complete software and hardware foundation of data acquisition, data storage, data analysis and scientific display, which can realize real-time and efficient analysis of different "time" and "space" multi-source information data.
and capture of danger information. The early warning system has been tested in Xinjing mine of Yangquan Coal Group, and the early warning ability has been verified.

2. Establishment of early warning index system
According to the field investigation and statistics, there are 209 recorded gas dynamic phenomena in Xinjing mine. Based on the statistics of these gas dynamic events, the characteristics and laws of coal and gas outburst in the mine are summarized as follows: 94 gas dynamic phenomena in the heading face, 115 gas dynamic phenomena in the coal mining face, 12 outburst accidents, 4 extrusion accidents and 193 outburst accidents. There are 66 times of gas dynamic phenomenon in fault area, 12 times in fold structure area, 29 times in scour zone area, 6 times in composite structure area and 96 times in non structure area, and there are 207 times of gas dynamic phenomenon, and the K1 value on that day is greater than 0.4 ml/g.min\(^{1/2}\); among them, the abnormal thickness of coal seam is 16 times, the jet hole and sticking are 15 times, the spalling is 8 times, the coal blasting is 110 times, the abnormal structure of coal body is 134 times, and the no abnormal phenomenon is 50 times.

At the same time, according to the fault tree analysis method of coal and gas outburst proposed by Zhao Xusheng et al. [10], reasoning is carried out from four aspects of production system defects, objective outburst risk, outburst prevention measures defects and outburst prevention management hidden danger, and combined with the characteristics and laws of coal and gas outburst in Xinjing mine, the early warning index system of coal and gas outburst in Xinjing mine is established, as shown in Figure 1.

![Figure 1. Early warning index system of coal and gas outburst in Xinjing mine](image)

3. Structure design of early warning data link
The early warning data link mainly includes monitoring and detection, information collection, risk identification, early warning analysis, result release and other data transmission nodes. Firstly, the monitoring system and detection equipment are used to comprehensively monitor and detect the early warning indicators; secondly, through the data acquisition interface program and transmission network, all kinds of safety information of monitoring and detection are automatically collected in real time and stored in a special database; thirdly, the monitoring and detection data are analyzed to automatically identify the risk of coal and gas outburst, and calculate all kinds of coal and gas outburst early warning indicators; then, according to the established adaptive early warning model, make a comprehensive analysis of the early warning indicators, and determine the outburst early warning level of the working face; finally, use the website, mobile terminal app and other ways to timely distribute the early warning results, remind the relevant personnel to take measures to prevent coal and gas outburst, as shown in Figure 2.
4. Construction of early warning system

According to the designed data chain structure, the overall framework of multi-source information intelligent early warning system for coal and gas outburst is built. The whole system includes three modules: monitoring and acquisition module, professional analysis module, outburst early warning module and supporting database. The monitoring (detection) acquisition module is responsible for the monitoring and automatic collection of basic safety information related to coal and gas outburst, including 8 types of information: gas parameters, outburst parameters, geophysical information, drilling construction, gas monitoring, drainage monitoring, mine pressure monitoring, manual observation, etc. According to the different sources and data types of various kinds of information, the ground automatic acquisition, underground automatic upload, automatic monitoring acquisition and other acquisition modes are adopted. The professional analysis module provides specialized, informatized, and automated office tools for coal mine business departments. It manages and analyzes basic safety information by specialty, and automatically recognizes coal and gas outburst risks. It includes 7 subsystems: geological survey management analysis system, gas geological dynamic analysis system, drainage borehole management analysis system, drainage compliance automatic evaluation system, outburst prevention dynamic management system, gas emission dynamic analysis system and rock pressure analysis system.

Outburst early warning module is mainly used for early warning analysis and result release, real-time calculation of coal and gas outburst early warning indicators, comprehensive analysis of early warning indicators, automatic determination of outburst early warning level, and real-time release of early warning results through website and mobile terminal app. At the same time, based on the principles of hierarchical autonomy and summary analysis, a corresponding supporting database will be built. Data storage is divided into four layers: monitoring and detection layer → information collection layer → professional analysis layer → early warning analysis layer. After the coal mine site uses the monitoring system and testing equipment for monitoring and testing, the basic coal mine safety information obtained is stored in the monitoring and testing equipment’s own database or storage device. The information collection interface and transmission program are used to control the monitoring system or testing equipment. Data is collected and uploaded to the information collection database through the underground ring network and the surface office network. Each professional analysis subsystem extracts the original information from the information collection database, transfers the data to the corresponding professional analysis layer database, and performs calculation analysis on it. The above work is to extract and store the basic early warning information of the major in the comprehensive database. The intelligent early warning analysis service extracts various basic early warning information from the comprehensive database for intelligent analysis, and the final early warning result is obtained after the analysis. The intelligent early warning analysis service stores the early warning index parameters and the early warning result information in the intelligent early warning database, so that the intelligent early warning website and APP can extract, query and release this part of the data.
5. Field application

During the investigation phase of the intelligent early warning system, the author tracked and counted the early warning results of 8 mining working faces, and the total accuracy of the early warning system reached more than 91%. The underreporting rate of outburst risk is 0. The false alarm rate of no outburst hazard is less than 9%. In general, the Xinjing coal and gas outburst intelligent early warning system has good early warning accuracy and can provide accurate early warning of outburst dangers at the working face.

Meanwhile, real-time monitoring through the early warning platform showed that there was a red warning on driving working face of the 3109 ventilation roadway in Baoan mining area 3# coal at 8:00 on January 16, 2019, as shown in Figure 3. According to the comprehensive analysis of the statistical results of various indicators in 3109 ventilation roadway, the gas emission indicator A on January 15 was 0.56 (as shown in Figure 4), which has an upward trend compared with the previous day. The predicted result of the eight o'clock shift was 0.31mL/g.min$^{1/2}$, $K_1$ value is normal (as shown in Figure 5), and the working face advances 6.8m normally. On January 16, the gas emission index A continued to increase to 0.66 (Figure 4), and the prediction result of the eight o'clock shift was 0.53 mL/g.min$^{1/2}$ (Figure 5). The $K_1$ value increased and exceeded the standard, and the thickness of the coal seam suddenly decreases, the coal thickness is 1.7m, and the coal thickness change rate is -28.74%, and during the construction of the predicted drilling hole, the phenomenon of sucking drill occurs, and the early warning platform issues a red warning at this time. Subsequently, the 3109 return air lane was tentatively scheduled for excavation operations and implemented partial measures to drill holes until the 8 o'clock shift on February 12, the result of the efficiency inspection was 0.34mL/g.min$^{1/2}$ (Figure 5), after the $K_1$ value is normal, the working face is allowed to continue to advance.

Figure 3. Early warning result of working face in 3109 return air roadway

Figure 4. A-index statistics of gas emission in the driving face of 3109 return air lane
Figure 5. Daily prediction of working face of 3109 return air roadway-statistical chart of analysis indexes of drilling cuttings

Through the analysis of the historical statistical data of each indicator of the instance event, it is concluded that the early warning result of the early warning platform is highly consistent with the actual working face dangerous situation, and the early warning result is accurate.

6. Conclusion

(1) Statistical analysis of gas dynamic phenomena in Xinjing Mine, mastering the characteristics and laws of coal and gas outbursts in the mine, and combining coal and gas outburst fault tree analysis methods, from outburst prevention measures, objective outburst hazards and production system defects Inferring from three aspects, the early warning index system for coal and gas outburst of Xinjing Mine was established.

(2) The early warning data chain structure of Xinjing Mine includes monitoring and testing, information collection, risk identification, early warning analysis, and results release.

(3) The construction of the early warning system of Xinjing Mine mainly includes safety information collection interfaces, professional analysis subsystems, prominent early warning websites and apps, databases, etc., and finally realizes online monitoring, intelligent identification and real-time early warning that highlights hidden disasters.

(4) The intelligent early warning system for coal and gas outbursts was applied on-site, and the early warning model adaptability and accuracy of early warning results were tracked and investigated. The results showed that the early warning model has self-learning and self-evolving characteristics, and the outstanding early warning is always accurate. The overall rate has reached more than 91%, and the false alarm rate of no outstanding hazards is overall less than 9%, and no outstanding hazard underreporting has occurred. The system has good early warning accuracy.

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