

Research and Application of Comprehensive Early Warning System for Coal and Gas Outburst

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Abstract: Coal and gas outburst is an extremely complex dynamic phenomenon in the production process of coal mines. In order to further accelerate the intelligent construction of coal mines, taking Xinjing Coal Mine as an example, the online comprehensive analysis and warning indicator system and rules for coal and gas outburst applicable to Xinjing Coal Mine were studied, and a comprehensive warning system for coal and gas outburst in Xinjing Coal Mine was established. Through on-site application, it has been shown that the system has achieved real-time intelligent warning of the danger of outburst in the working face, standardized and dynamic management of outburst prevention information in the working face, as well as real-time dynamic update and sharing of outburst prevention information, improving the efficiency of mine outburst prevention management and the level of mine safety.

Keywords: Coal mine, Coal and gas outburst, Early warning indicators, Early warning system, Intelligent construction.

1. Introduction

Coal and gas outburst is an extremely complex dynamic phenomenon in the production process of coal mines, which poses a serious threat to the safety of mine production [1-2]. The primary link of coal and gas outburst prevention is to judge the possibility and intensity of outburst based on the precursor information of the outburst. Highlighting the accuracy of forecasting plays a vital role in the prevention and treatment of prominent accidents [3-5]. A certain predictive index can only indirectly and partially reflect a certain aspect of the outstanding risk, and there is no early warning of the outstanding risk and its severity from multiple directions and perspectives, which has considerable limitations [6-8]. At the same time, with the development of computer technology and information technology, the informatization of coal mine safety management will also be an irreversible development trend [9-13]. Therefore, with the help of computer technology and information technology, a coal and gas outburst warning system suitable for the specific conditions of the mine is established to realize the information management of mine safety and the early warning of mine outburst disasters. This will be one of the important technical means for coal mines to effectively prevent and control outstanding disasters and ensure coal mine production safety in the future.

At present, the coal and gas outburst disasters in the mines of Yangquan Group are serious, and the outburst has become the main factor restricting the safe and efficient production of the outburst mines of the group. Taking the Xinjing Coal Mine of Yangquan Coal Group as the pilot unit, aiming at the problems existing in the current gas prediction and forecasting in the mine, comprehensive information such as gas geology, gas emission, and roof pressure in the outburst mine is integrated, there is an urgent need to establish a comprehensive early warning system for coal and gas outbursts suitable for Xinjing Company to enhance the mine's ability to prevent coal and gas outburst disasters and improve the safety management level, so as to promote the application of experience to other outburst mines of Yangquan Coal

Group.

2. Research on Early Warning Index System of Coal and Gas Outburst

The research on the early warning index system is the prerequisite and foundation for the implementation of the entire early warning system project. It is the development of early warning system software and provides a technical basis for the realization of comprehensive, intelligent, advanced and dynamic early warning of coal and gas outbursts in coal mines [14-16]. The system mainly focuses on the research of comprehensive early warning technology, and establishes a multi-factor and multi-index comprehensive early warning system for coal and gas outburst hazards in accordance with the principles of purpose, science, system, advancement and feasibility. The index system framework of the entire early warning system (as shown in Figure 1) mainly includes six aspects: gas geology, mining impact, daily prediction, gas emission, mine pressure, and outburst prevention measures. Under the guidance of this framework, examine the specific early warning indicators and rules suitable for Xinjing Company, and determine the critical value of each early warning indicator and its relationship with the degree of outstanding danger, and finally establish a prominent early warning indicator system that is in line with Xinjing Company's actual situation.

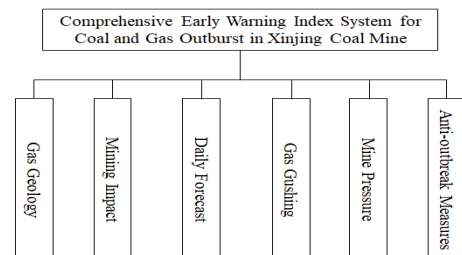


Figure 1. Framework of comprehensive early warning indicator system for coal and gas outburst in Xinjing Coal Mine

The salient warning levels of the working face are divided into two categories: state warning and trend warning, and each category is divided into different levels, as shown in Table 1. Early warning rules should include status warning rules and trend warning rules. Among them, the state early warning rules are the rules set to reflect the current state of the work face with outstanding hazards, and the trend early warning rules are mainly the rules formulated to reflect the changing trend of the prominent hazards in the front of the work face.

Xinjing's outstanding early warning rules are divided into 6 categories, a total of 57, including 11 gas geological categories, 26 mining impact categories, 7 daily forecast categories, 4 gas emission categories, 6 mine pressure categories, and 3 outburst prevention measures. In the production process, the value of each early warning indicator reflects the state of the early warning elements of the working face. In the process of highlighting the early warning, according to the value of each indicator in the early warning index system and the corresponding early warning rules in the early warning rule database, the corresponding primary warning result can be obtained, and then the secondary warning result can be obtained from the primary warning. Finally, the comprehensive early warning result is obtained from the second-level early warning result, and the highest level principle and the missing value principle are always followed throughout the early warning process.

Table 1. Warning system of coal and gas outburst early warning system

Type	Rank	Description
Status warning	Normal	Various indicators of the working face are normal and safe operation is possible.
	Threat	There is no danger or need to predict and confirm the work face, but it needs to focus on and strengthen management.
	Danger	The working face has protruding danger, it is necessary to stop the operation and take anti-outbreak measures or further confirm the protruding danger.
Trend warning	Green	The protruding danger ahead tends towards safety.
	Orange	There may be danger at a certain distance ahead, please call attention.
	Red	The prominent danger ahead tends to be serious, and we should focus on, strengthen management, and strengthen measures.

3. Construction of A Comprehensive Early Warning System for Coal and Gas Outbursts

The coal and gas outburst early warning computer system is a large-scale computer program based on the combination of GIS, C/S and B/S. It uses the existing local area network to connect the comprehensive early warning data server, the early warning data management system and the existing coal mine safety monitoring system. Then through the outburst

early warning module, the system analyzes the coal and gas outburst early warning data in the comprehensive early warning data server, and sends out early warning information according to the analysis results. According to the characteristics and related requirements of the outburst prevention and control work in Xinjing Coal Mine, the comprehensive early warning system for coal and gas outburst in Xinjing Coal Mine includes 7 subsystems and 1 outburst early warning website. Seven of the subsystems are mainly geological measurement management system, gas geological dynamic analysis system, gas outburst dynamic management and analysis system, gas emission dynamic analysis system, mining progress management system, mine pressure monitoring and early warning system, and gas outburst comprehensive early warning platform.

The stable operation of the coal and gas outburst early warning system is the prerequisite for accurate early warning. After the software adaptability adjustment and preliminary system test are completed, the system functions are gradually improved and the overall operation is stable. The specific performance is as follows:

(1) The hardware of the early warning system runs reliably. During the inspection, the early warning server and client computers were operating completely normally, and there were no machine failures such as crashes or abnormal shutdowns. After on-site testing, the UPS power supply can guarantee the normal operation of the early warning server for 20 minutes in the event of an abnormal power failure. The SMS publishing platform can promptly and accurately publish the warning result information.

(2) The early warning system software responds quickly. After many tests, the various subsystems of the early warning system open the local mine map generally within 10s. When the office network is normal, the time to open the server mine map directly is within 15s. Data synchronization and early warning analysis can generally be completed within 5 minutes under normal network conditions.

(3) The error rate of the entire early warning system is low. When the user operates and maintains the early warning system in accordance with the "Xinjing System Early Warning System Job Responsibility" and related operational requirements, the early warning system can calculate early warning indicators in a timely and accurate manner and release the early warning results in a timely manner. The system runs continuously and stably for longer than 3 months.

4. Application Effect Analysis

The daily forecast of No. 8 Coal East No.1 Main Lane in Lunan No.1 District exceeded the standard at 8 o'clock on July 4th. K_1 reached $1.49\text{mL/g}\cdot\text{min}^{1/2}$, and the K_1 value was too large, indicating that there is a greater risk of outburst in front of the work. The trend warning result of the zero o'clock shift on July 2 was "orange", and the status warning result was "normal". The trend warning result of the eight o'clock shift on July 2 remained "orange", and the status warning result was upgraded to "threatening". However, because the predicted K_1 value of the working face did not exceed the standard (the index value is $0.35\text{mL/g}\cdot\text{min}^{1/2}$), and there is no obvious gas dynamic phenomenon, the working face continued to move forward until the zero o'clock shift on July 3, the early warning result is upgraded to "red".

On the same day, the K_1 value still did not exceed the standard (the index value was $0.35\text{ mL/g}\cdot\text{min}^{1/2}$), and there was no dynamic phenomenon, so the tunneling operation was

still carried out according to the normal procedure until the K_1 value of the eight o'clock shift on July 4 exceeded the standard. The work face stopped work and construction measures were taken. Subsequently, the results of the trend warning and status warning of the shift at 8 o'clock on July 5 became "normal".

The triggering factor of this alarm was abnormal gas gushing, and it issued a prominent hazard warning 2 days ahead of Xinjing's daily forecast of K_1 value, indicating that the early warning is well advanced and can leave a sufficient

safety distance for the implementation of anti-outbreak measures. At the same time, from July 1st to July 3rd, the gas emission index showed a gradually increasing pattern of change (Figure 2), which was in full compliance with the general law of "zone and zone" distribution of prominent hazards. After July 4th, with the gradual elimination of the prominent danger of the working face, the warning level has also been reduced, which fully shows that the warning results have high reliability.

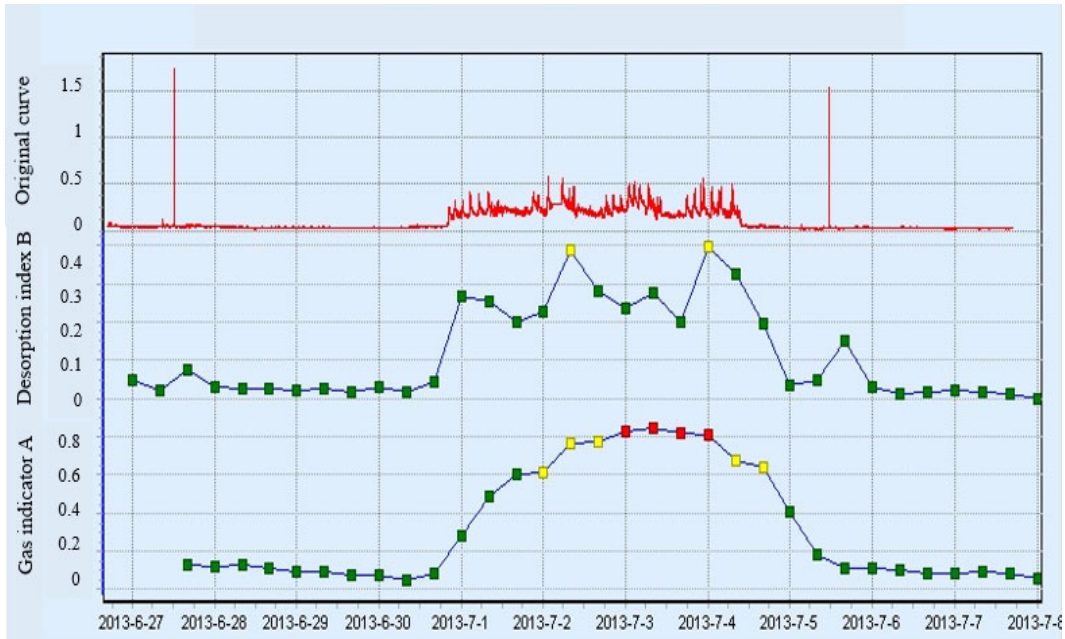


Figure 2. Early warning results of Dongyi main lane

The early warning result of Nanba main lane is shown in Figure 4. It can be seen from Figure 3 that the trend warning result of the early warning system at the eight o'clock shift on July 28 was "orange", and the trend warning result of the zero shift was upgraded to "red" on July 29, and the K_1 value of

the eight o'clock shift predicted that the K_1 value exceeded the standard on July 30. This time, the early warning system has advanced the K_1 value by 2 days from the angle of gas emission to provide early warning of the prominent danger in front of the Nanba main lane excavation work.

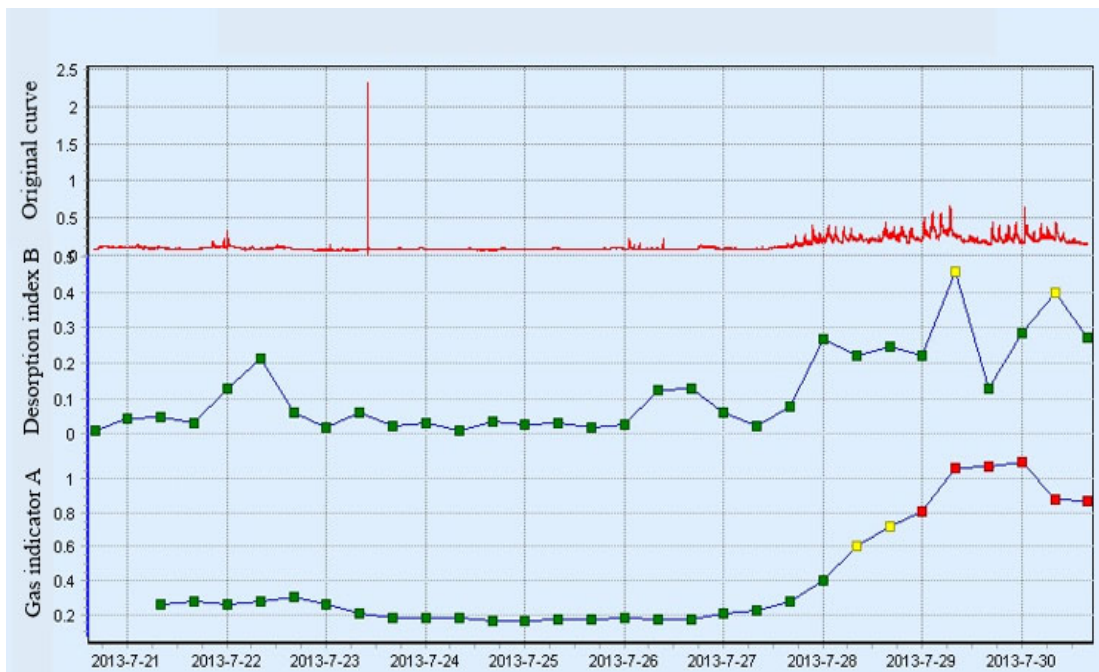


Figure 3. Early warning results of Nanba main lane

5. Conclusion

(1) Based on the actual site data and data of Xinjing Coal Mine, comprehensively analyzed the impact on the outburst hazard of the mining face of Xinjing Coal Mine, and established consideration of gas geology, mining impact, daily prediction, gas emission, mine pressure and Six factors including anti-outburst measures are applicable to Xinjing's coal and gas outburst online comprehensive analysis and early warning indicator system and rules.

(2) According to the characteristics and related requirements of the outburst prevention and control work of Xinjing Coal Mine, a comprehensive early warning system for coal and gas outbursts of Xinjing Company was established. The system mainly includes the geological survey management system, the gas geological dynamic analysis system, and the outburst prevention dynamic management and analysis. There are 7 subsystems and 1 prominent early warning website including the system, gas emission dynamic analysis system, mining progress management system, mine pressure monitoring and early warning system, and gas outburst comprehensive early warning platform.

(3) The comprehensive early-warning system for coal and gas outburst constructed in Xinjing Coal Mine has been inspected on site application effects and showed that the software and hardware of the comprehensive early-warning system can ensure the continuous and stable operation of the early-warning system, as well as timely and accurate release of early-warning results, and the early-warning results are accurate high performance, consistent with the actual outburst of danger on the working face.

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