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Research on precise monitoring and hidden danger intelligent identification technology of ventilation network in Yuka No.1 mine

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Abstract: *Stable and reliable operation of the ventilation system is a prerequisite to ensure efficient coal production. Yuka No.1 mine faces frequent level succession, many mining faces deployed at the same time, and a wide range of air demand points, which brings great difficulties to the distribution and control of mine airflow. For this reason, Yuka No.1 mine applies advanced CFD15 coal mine electronic anemometer and CPD120 mine intrinsically safe air pressure meter to the ventilation parameter monitoring of the key underground roadway, realizing the accurate monitoring of the ventilation network; based on the dynamic solution model of the ventilation network of the monitoring information, the abnormal analysis of the ventilation network and early warning technology, constructs the ventilation on-line monitoring and analysis and early warning system, realizing dynamic monitoring and intuitive display of the ventilation network, and providing the best solution for Yuka No.1 mine. It realizes dynamic monitoring and visual display of the ventilation network, and provides powerful support for the management and analysis of the ventilation system of Yuka No.1 Mine. The application of precise monitoring of ventilation network and intelligent identification of hidden dangers in Yuka No.1 mine is of great significance to the safe management of ventilation and safe production in the mine.*

Keywords: *coal mine ventilation; ventilation parameters; hidden danger identification*

1. Introduction

After the mine is built and put into operation, the ventilation system network structure and operation parameters are changing all the time as the mine production proceeds, therefore, the mine ventilation system is strictly a dynamic system, and it is also a very large and complex dynamic spatial network system with complicated spatial geographic attribute data. Moreover, mine ventilation information includes two types of ventilation data information and graphical information, and the relationship between the two is complementary[1~2]. The traditional mine ventilation system data and graphics can not be interrelated, there is no intuitive joint display, the network solution is based on pure data on the basis of its algorithmic derivation, and can not achieve the purpose of real-time, intelligent analysis[3]. Many coal mine safety production experts and scholars have carried out in-depth research and practice in the field of mine ventilation, formed corresponding theoretical models for ventilation system optimization, reliability evaluation, simulation and simulation, etc., and achieved certain research results[4~5]. However, there is still a lack of corresponding technical means for real-time monitoring, dynamic analysis, evaluation and early warning of mine ventilation system. At present, mine ventilation monitoring related to wind speed sensor, wind pressure sensor in the underground installation number is relatively small, ventilation system monitoring is still mainly by manual wind measurement, manual inspection, workload, low efficiency, poor reliability[7~8]. How to ensure the stability of the air volume and air flow of the mine ventilation system, optimize various regulation facilities, improve the reliability of the ventilation system, and realize the dynamic monitoring and real-time analysis of the mine ventilation system are problems that need to be solved urgently. With the increasing awareness of the importance of ventilation safety, it is imperative to carry out online monitoring and real-time solving of the ventilation system.

For this reason, the paper takes the ventilation of Yuka No.1 mine as the research background, and carries out the construction of Yuka No.1 mine ventilation network online monitoring and analysis system in terms of the determination of ventilation parameters of the main roadway, the establishment of the ventilation network solution model, the deployment of ventilation monitoring sensors, and the development of the ventilation on-line monitoring and analyzing early warning system, with a view to enhancing the ability of accurate monitoring and intelligent recognition of hidden dangers of the ventilation network of the Yuka No.1 mine, and to further enhance the stability of the ventilation system of the mine.

2. Overview of mine ventilation system

Yuka No.1 Mine adopts inclined shaft development method, the bottom level of the shaft is +2950 m. The mine has 4 inlet shafts and 2 return shafts. The inlet shafts are 1# main inclined shaft, 1# sub inclined shaft, 2# main inclined shaft, 2# sub inclined shaft, and the return shafts are the east wind shaft and the central wind shaft. The air volume of 1# main inclined shaft, 1# sub-inclined shaft, 2# main inclined shaft and 2# sub-inclined shaft is 1807m3/min, 3059m3/min, 829m3/min and 5089m3/min respectively, and the air volume of east wind shaft and central wind shaft is 5633m3/min and 5339m3/min respectively, and two BD-II-8 No.22 air compressors have been installed in the east wind shaft. There are two sets of BD-II-8 No.22 type explosion-proof counter-rotating axial flow ventilators installed in the east wind shaft, one of which is working and the other one is in standby or under maintenance. The ventilation resistance is 711.75 Pa, and the ventilation level hole of the east shaft is 3.34 m^2. According to the required air volume and negative pressure of the mine, two sets of explosion-proof axial-flow ventilators of FBCZ-8-№24C type have been selected for the central shaft, with one of them in operation and the other one in standby or under maintenance, the ventilation resistance is 680.21 Pa, and the ventilation level hole of the central shaft is 3.73 m^2.

Yuka No.1 Mine has complex conditions of coal seams, long mining history, wide distribution of mining range, and multi-coal seams mining, which leads to a variety of underground roadway projects and complex spatial relationships, making the mine ventilation system topology quite complex, increasing the difficulty of management and analysis of the ventilation system of the mine; low permeability of the mined seams, the poor standardization effect of the conventional extraction, and the large amount of gas outflow of the mine, which requires high reliability and stability of the ventilation system. Reliability and stability of the ventilation system are highly demanded. Therefore, Yuka No.1 ventilation network accurate monitoring and hidden danger intelligent identification technology is applied to ventilation system management and analysis, in order to improve the reliability of the ventilation network and intelligent control level.

3. Dynamic modeling of ventilation network in Yuka No.1 mine

3.1. Dynamic network solution model

On the basis of the ventilation network solving model, all the lanes in the ventilation network are categorized into four types according to the type of associated equipment: fan lanes, airflow monitoring lanes, resistance monitoring lanes and ordinary lanes.

The aisle equipped with main ventilation fan is set as fan aisle, which is associated with the corresponding main ventilation fan and participates in the solving by utilizing the fan performance curve; the aisle equipped with wind speed sensor is set as air volume monitoring aisle, which is associated with the corresponding wind speed sensor and participates in the solving by utilizing the real-time monitored wind speed value and the wind volume calculated by the aisle cross-section area; and the aisle equipped with differential pressure sensor is set as resistance monitoring aisle, which is associated with the corresponding differential pressure sensor and participates in the solving by utilizing the real-time monitored wind speed value and the air volume calculated by the aisle cross-section area. The roadway with airflow differential pressure sensors is set as a resistance monitoring roadway and associated with the corresponding differential pressure sensors, and the real-time monitored airflow differential pressure is utilized as the branch ventilation resistance to participate in the solution; the other roadways are set as ordinary roadways. When generating loops, fan alleys, airflow monitoring alleys and resistance monitoring alleys should be treated as independent branches.

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3.2. Wind network anomaly warning model

3.2.1. Alley wind flow status warning

Early warning of the airflow status of the roadway is to monitor in real time whether the airflow and air speed of each branch of the ventilation system meet the requirements, and to alarm when the airflow does not meet the requirements. Generally, only the minimum required air volume is set for the air location, and the value is the designed air volume of the air location, and an alarm is issued when the air volume is insufficient.

3.2.2. Early warning of ventilation in extractive face

The real-time monitoring data from the wind speed and wind pressure sensors installed in the extractive face are used to analyze the ventilation and safety conditions of the extractive face, and an alarm is issued when ventilation abnormalities and potential safety hazards are found.

3.2.3. Wind network warning mode

Alarms can be given for parameters such as wind speed in the roadway and wind pressure on both sides of the dampers. Different colors, sizes and transport speeds can be used to mark the characteristics of different wind locations in the ventilation system to show the distinction.

3.2.3.1. Alarm for wind speed exceeding the limit

According to the mine ventilation system diagram provided by the mine, draw the schematic diagram of the wind network online monitoring system, set the attributes of all the roadways, and set the upper and lower limits of the roadway wind speed alarms in strict accordance with the roadway wind speed intervals stipulated in the Coal Mine Safety Regulations, so that an alarm will be given once the monitored or solved wind speed of the roadway does not fall within the intervals. The alarm result can be queried by clicking the corresponding position in the table.

3.2.3.2. Wind Pressure Exceeding Limit Alarm

The wind pressure attribute can be set for the duct where the wind pressure sensor is installed. Once the monitored wind pressure is reversed or the value curve fluctuates greatly, an alarm will be given. The alarm result can be queried by clicking the corresponding position in the table data.

3.2.3.3. Color marking

Through the attribute setting in the roadway, the roadway can be set into three types of roadways with different wind locations, namely the inlet roadway, the wind roadway, and the return roadway. The wind direction and wind speed are marked with green arrows for the inlet roadway, the wind direction and wind speed are marked with blue arrows for the wind roadway, and the wind direction and wind speed are marked with red arrows for the return roadway.

3.2.3.4. Arrow labeling

The wind direction and wind speed of the roadway can also be divided by the size of the arrow. The system will calculate according to the monitored sensor data, and then arrive at the calculated wind volume of each roadway. The monitoring system will differentiate the size of the wind direction arrow according to the size of the calculated wind volume of the roadway, the arrow of the roadway with large wind volume will be large, and the arrow of the roadway with small wind volume will be small.

3.2.3.5. Dynamic speed labeling

In addition to the differentiation of color and size, the speed of the arrows is also set. The speed of the wind arrows corresponding to the lanes with larger wind speeds is relatively fast, while the speed of the arrows corresponding to the lanes with smaller wind speeds is relatively slow.

3.3. Correlation of monitoring sensors

The online monitoring and analysis of ventilation network is based on the static solution of ventilation network, and integrates the monitoring data of ventilation parameter monitoring sensors to realize dynamic solution. The wind speed sensor and wind pressure sensor are associated with the roadway in which they are located through the sensor point number. In the system, the sensor point number corresponding to the actual installation location of the sensor underground is input, and at the same time, the sensor point number is input in the roadway in which the sensor is located, so as to

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realize one-to-one corresponding association of the sensor and the roadway branch. The roadway associated with the wind speed sensor is set as a fixed air volume roadway, and its solution result is only calculated by the monitored wind speed; the roadway associated with the wind pressure sensor is set as a fixed wind pressure roadway, and its solution result is only calculated by the monitored wind pressure. When the ventilation online monitoring and analyzing system collects data from the mine monitoring system, the real-time solving result of the roadway associated with the sensor is based on the monitoring data, and the solving result of other roadways changes automatically due to changes in the monitoring data of the associated roadways.

4. Construction of Yuka No.1 Mine Ventilation Online Monitoring and Analyzing Early Warning System

4.1. System construction program

4.1.1. Ventilation abnormality analysis and alarm design

Based on the ventilation parameter information of the whole mine obtained from real-time monitoring and real-time solving, it analyzes and alarms the real-time ventilation anomalies of the whole mine through the pre-set alarm rules for ventilation anomalies including wind speed exceeding the limit, wind volume exceeding the limit, wind pressure exceeding the limit, wind direction reversal, etc., so as to facilitate the mine authorities to take relevant targeted measures in a timely manner.

4.1.2. Ventilation system simulation design

Based on the characteristics of the actual ventilation system of the mine, the actual production system transformation can be simulated in advance, so as to take corresponding preventive measures in advance for the ventilation abnormalities that may occur after the transformation of the system, and prevent the occurrence of related accidents.

4.1.3. Online monitoring system installation and commissioning

Through the separate study of the above major functions, the terminal structure and installation of the ventilation online monitoring and analyzing early warning system of the mine are carried out, and on-site inspection is carried out for the operation effect after installation, and timely debugging is carried out for the possible problems to ensure the operation of the main functions of the system.

4.2. Hardware construction of the system at Yuka No. 1 Mine

4.2.1. Installation of wind speed sensors

In the ventilation online monitoring sensor arrangement program, the sensors come from two parts: one part is the newly added wind speed and pressure sensors, and the other part is the original wind speed sensors of the system. Among them, the wind speed sensor (denoted by FS) is mainly used to monitor the wind volume and wind speed of the relevant roadway, and the monitored wind volume data of these roadways can be used for iterative calculations, and also alarm the abnormal wind volume of these roadways; the wind pressure sensor (denoted by FY) is mainly used to monitor the wind pressure at the key points of the ventilation system and the dampers of the digging face, and monitor and alarm the abnormal wind pressure of these places. Alarm.

The installation of underground wind speed sensors in Yuka No. 1 Mine is strictly in accordance with the requirements for installation of mine ventilation monitoring sensors, and the current sensor arrangement fully meets the requirements for on-line monitoring of ventilation and analysis of the early warning system, and will not be added.

At present, the wind speed sensors associated with Yuka No.1 mine are: 1# main shaft wind speed, 1# deputy shaftwind speed, wind speed of the return air lane of the first mining area, wind speed of the shaft of the east wind shaft, wind speed of the 2920 stone gate, 1177 transportation down the wind speed, wind speed of the return air lane of the 1179, wind speed of the 2750 east machine-track combined lane, wind speed of the shaft of the 2# main shaft, wind speed of the shaft of the 2# deputy shaft, wind speed of the central wind shaft, wind speed of the shaft of the second mining area The wind speed of the return alley, the wind speed of the 1272 return tunnel, the wind speed of the 1272 transportation tunnel, and the wind speed of the 2900 section of the central air shaft. A schematic diagram of the associated wind speed sensors is shown in Figure 1.

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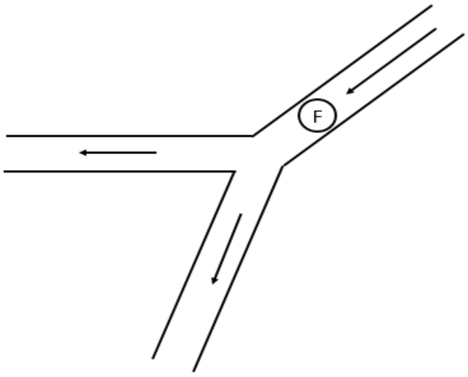

Figure 1 Arrangement of wind speed sensors in key ventilation lanes

4.2.2. Installation of wind pressure sensors

At present, some wind pressure sensors are installed in Yuka No.1 mine, and according to the needs of online monitoring and dynamic solving of wind network, 4 additional wind pressure sensors are installed. The wind pressure sensors are located at: 2960 yard air door, 1177 working face joint alley air door, 1272 return air chute bypass air door, 2900 central air shaft ventilation contact alley air door, a total of 4 additional units. The wind pressure sensors are installed on the fresh airflow side of the dampers, and are connected to the dirty air side of the dampers using silicone tubes. Specifically in the important inlet and return airway contact lane air door installation wind pressure sensor layout shown in Figure 2, wind pressure sensor can monitor the whole mine or local area ventilation resistance changes, for the disaster situation to take emergency measures to provide data support.

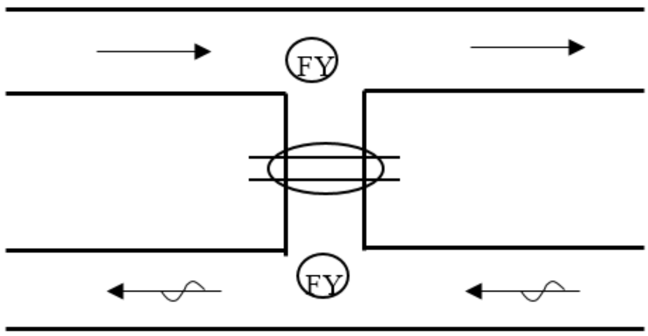

Figure 2 Arrangement of sensor for monitoring the differential pressure of dampers in the key inlet and return airway.

4.2.3. New Instrument Configuration for Ventilation Detection

According to the daily requirements of mine wind measurement, Yuka No.1 mine is equipped with CFD15 electronic high-precision anemometer for coal mines, which facilitates the daily work of mine wind measurement and improves the accuracy of the measurement data.The instrument has the advantages of low start-up wind speed (less than 0.01m/s), large range (0.1~15m/s), high resolution (0.01m/s), and high accuracy (±2%), etc. One set of equipment meets the determination of wind speed under all conditions (low, medium, and high speeds) in underground.

4.3. Construction of system software for Yuka No. 1 Mine

Ventilation system map editing is equipped with basic GIS functions, map editing functions, map auxiliary element editing and other functions. At the same time, after ventilation network solving and transformation simulation, it can have the ability of data checking, wind resistance calculation and network solving.

Ventilation online monitoring has, sensor real-time value display, dynamic network solving:, ventilation warning function.

4.4. Ventilation online monitoring system field application analysis

4.4.1. Network solving simulation application effect

Based on the ventilation report measured in the month, by adjusting the wind resistance of the ventilation facilities, it realizes the wind distribution according to the demand and ensures that the air volume of the air-using place meets the demand.

Taking 1177 coal face roadways as an example, according to the wind measurement results and the ventilation network solution results of Yuka No.1 mine in late July 2022, the comparison is shown in Table 1. The error between the solution results and the actual wind volume is controlled within 10%, which can meet the needs of daily ventilation management of Yuka No.1 mine.

Table1: Comparison of actual wind measurement and interpretation results.

Name of working face	Name of the roadway	Actual air volume(m^3/min)	Solve for airflow (m^3/min)	resolution error (%)
1177 working face	1177 transportation roadway	1151	1199	4.17%
	1177 return air roadway	1178	1199	1.78%

4.4.2. Simulation effect of disaster avoidance route

In order to demonstrate the timely formulation of the disaster avoidance route after the disaster, the simulation is carried out by taking the belt fire in W2706 transportation lane as an example. Assuming that the fire occurs 20m near the working face, the personnel avoiding the disaster take the new shaft as the final escape exit, and the ground node of the new shaft is numbered as 910.The simulation function of the avoidance route mainly includes two aspects, one is the scope of the disaster gas after the disaster occurs, which facilitates the personnel to take the necessary protective measures and evacuate within the scope; and the other is the function of the avoidance route, which is the evacuation route for the personnel based on the place where the disaster occurs. The second is the function of disaster avoidance route formulation, which is the evacuation route based on the disaster location.

Through the simulation of the disaster avoidance route in case of fire in the W2706 transportation lane, a reasonable disaster avoidance route is derived, and through manual verification, the disaster avoidance route and the range of influence of the disaster gas in case of fire are in line with the real situation of the ventilation system of the No.1 mine in Yuka, which provides an effective means of disaster prevention and mitigation, and accident rescue.

5. Summary

(1) Yuka No.1 mine adopts advanced CFD15 coal mine electronic anemometer, CPD120 mine intrinsically safe wind pressure meter and other instruments to carry out refined determination of ventilation parameters of key underground roadways, which improves the accuracy of determination of ventilation resistance parameters of the mine, and provides a reference basis and basic data for the reinforcement of the management of the ventilation system of the mine and the network solving.

(2) The mine ventilation online monitoring and analysis early warning platform can realize the simulation of mine wind flow self-allocation, online monitoring of ventilation parameters, and automatic solving of the whole mine wind network, which makes it easy for ventilation management personnel to understand the ventilation situation of each underground roadway in real time; at the same time, it can realize the early warning of the situation of using wind in the roadway, and the ventilation and safety of the working face through the early warning mechanism of the ventilation parameters.

(3) Through on-site application and continuous improvement of the mine ventilation online monitoring and analysis and early warning platform, the difference between the solution result of the ventilation network online monitoring and analysis system and the actual air volume is basically within 10%, and the system accurately monitors and solves the calculation of the ventilation network air volume. At the same time, the system simulates underground disaster and accident points, determines the scope of disaster after the occurrence of the disaster in order to facilitate the planning of reasonable personnel evacuation routes, and provides a decision-making basis for the mine to rapidly take effective emergency treatment measures.

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