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Control Mode of Mine Ventilation System and Its Implementation Based on Monitoring Data and Safety Information

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Abstract: Based on the full monitoring of mine ventilation system by a safety surveillance control system, the feedback control is applied to design a hierarchical control model. It mean that the total mine air volume is controlled by a main fan power supply module converter, the roadway area is controlled by an electric ventilation door, and the air volume of workplaces is controlled by the air register installed at the end of compressed air duct. The control of whole ventilation system is implemented using intelligent modular design. Through the communication interface, the parameters of the air speed and pressure of each laneway and air point for the ventilation system are collected, and the environmental safety status parameter is also considered, to adjust the effective air volume in production, and to optimize the structure and air volume of the ventilation system in the changing conditions of environmental security. The control strategy is divided into a dynamic adjustment scheme for the production safety state, and a manual-intervened adjustment program in the conditions of prediction deviation of safety state with the change of environment security. Through the ventilation data provided by the adjustment scheme, the intelligent module controls the ventilator, the electric ventilation door and the wind regulator in the outlet of air-supply duct to achieve the effect of both major and fine adjustment. Thus, the air quantity is always maintained in the range of safe level.

Introduction

As an important measure to ensure the safety production of mine, protect the life safety of underground workers, and prevent and control the accidents of underground, the control of mine ventilation system has an overall impact on the safety of mine ventilation [1] .The mine ventilation system not only should has a well-structured ventilation network and a well-matched ventilation facilities, but also should contains ventilation structures for guiding, isolating and regulating air volume, to ensure that the airflow is oriented and quantified in accordance with requirement [2] .The causes for the occurrence and expansion of major disasters in the mines have an closely related to mine ventilation structures [3] . For example, the reason for the occurrence of a coal mine fire accident in the Dafoshi coal mine of Binchang mining group in 2012 was that the unreasonable mining methods and techniques led to small quantity ventilation structures in the inlet air section, and most ventilation structures were located in the return air section. During the production process, due to the inadequate maintenance and management for ventilation structures, air penetrate directly into the return airway through gaps in the ventilation structure, the goaf zone or the surface subsidence area, which resulted in a large amount of air leakage in the return air system, caused

underground air turbulence and the further expansion of fire smoke. Therefore, the installation of reasonable and well-maintained ventilation structures can effectively control the air flow during the accident or disaster period, reduce air leakage and improve the reliability, stability and resilience of ventilation systems. For example, the blast door must be installed at the outlet of the main ventilator to prevent the expansion of gas explosion accidents; When a fire occurs in the intake shaft, it is necessary to take the anti-wind or close the wellhead fire door.

For many years, the adjustment and control problems of mine ventilation have attracted the attention of ventilation experts. Many research results of mine air conditioning and control technology have been applied to production, which has played a positive role in the safety production of mine. However, due to the complex and changeable conditions of mine and mining technology, there are many air flow control problems in the process of mine ventilation [4], such as air leakage, airflow short circuit, air flow circulation and no air blind area, etc, which seriously affect the stability of the ventilation system. On the basis of the theoretical models of nonlinear control, ejected air flow, neural network control, mining air curtain barriers and fuzzy control, numerous experts [5] ~ [8] have studied and developed many mine ventilation regulation and control techniques, such as technology and equipment of mine leakage risk control system, mining air curtain technology, expert system control technology, controllable circulating ventilation technology and automatic control technology of mine shaft ventilation. However, these control model and technology of ventilation systems have neglected the structure of mine ventilation system and the characteristics of air volume distribution. Therefore, in light of the structure of mine ventilation system and the characteristics of air volume distribution, we have proposed a hierarchical control model of mine ventilation system based on the full monitor of mine ventilation system by safety surveillance control system.

Air volume distribution characteristics and control principles of mine ventilation system

In mine ventilation system, air flow is composed of a oriented loop system in the form of its bifurcation and confluence. The flow of air in the system roadway is along oriented loop system thanks to the pressure difference in the two end of the roadway. In order to directly reflect the connection relationship between roadways, and the relationship between bifurcation and confluence, the roadway is simplified as a oriented line section, and the intersection point is simplified as a node. So the finite set V of the node element and the finite set E of the branch element constitute a oriented graph G= (V, E). The schematic diagram of the oriented path is shown in figure. 1.

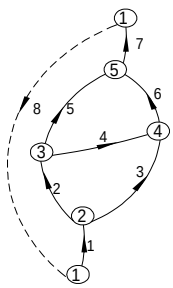


Figure.1 Diagram of oriented circuit path

For most of Chinese mine adopts extraction ventilation method, according to the layout system of mine roadway and the layout of mining area, in terms of air volume distribution, the air flow is under the law of wind balance, wind pressure balance and resistance, which makes the air flow from high energy to low energy. The main air volume of mine is mainly distributed in the intake shaft

and return shaf; Secondly, the working face, tunneling working surface and electrical and mechanical cavern are arranged within mining section, and the total air volume that enters into mining area flows through the rail roadway, haulage roadway and return air alleys; Finally, the air volume of various wind sites is small, and its spatial distribution is more dispersed. This air distribution characteristics and ventilation system structure is the basis of the control, which determines the mine air volume should be controled by different levels.

According to the characteristics of air volume grading distribution, a hierarchical automatically-adjusted control model is built based on Programmable Logic Controller (PLC). When the system is in operation, the corresponding deviation is obtained by comparing the parameters of environmental quality and ventilation that are collected via real-time monitor through the communication interface, with the safety setting values of each parameter such as gas concentration, wind speed and pressure in different roadways and in the wind location. Guided by the deviation from normal automatic correction principle of control theory, the deviation of the state parameters of the wind location is adjusted and modified online, and the adjustment scheme of ventilation parameters is put forward. Finally, automatically output the state parameters of the adjustment program to each intelligent module that controls the ventilator, the electric damper, and the draught regulator in the outlet of air-supply duct, then according to the on-demand supply principle of the wind site, realizing the effect of both major and fine adjustment, which will realize intelligent control of mine ventilation system. The schematic diagram of the control principle is shown in figure 2, the schematic diagram of the algorithm program of feedback control is shown in figure 3.

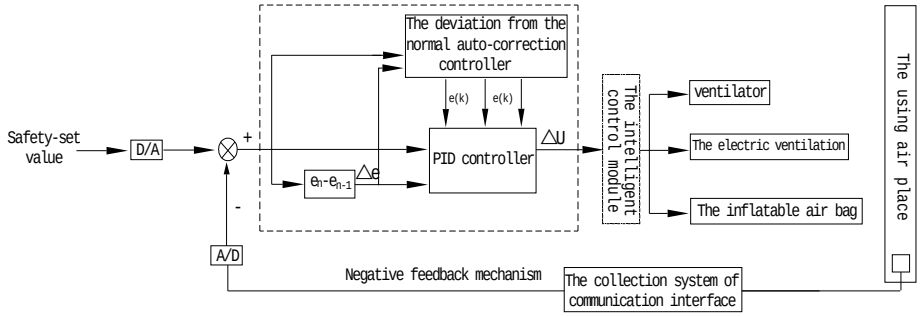


Figure.2 Diagram of control principle

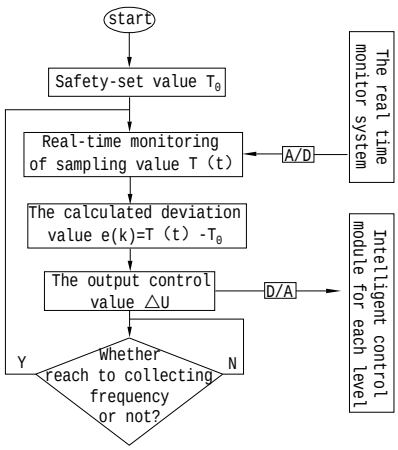


Figure.3 Diagram of the algorithm program of feedback control

Air volume control criteria of underground roadway

In the mine excavation project, due to the changes of the mining conditions and ventilation

system management, the resistance of airway, the network structure and the air volume required for each site are real-timely and dynamically changed with the propulsion and replacement of the working surface, which needs the mine air volume to be adjustd timely[9]. Considering the nonlinear, multi-interference and multi-coupling characteristics of the mine ventilation system, and there are some uncertainty factors such as the time-varying parameters, so the accurate modeling calculation cannot be realized[10]. Based on the analysis of the nonlinear control, the neural network control and the fuzzy control that active in the current control areas, this paper puts forward following control criterion of the underground roadway air volume:

(1) According to the regulations of Chinese《Coal Mine Safety Regulations》, comprehensively considered the ventilation requirements, mine exploitation modes and roadway layouts in different periods during the whole mining years, and in light of the methods of mine ventilation design and mine air quantity verification, the air volume in the underground mining face, the driving working face, the chamber and other roadway must be actively distributed to meet the basic requirement for the safety production. Based on the requirement of air volume for each site, all the ventilation roadways have the matched air volume that is known as the effective air volume of underground roadways.

(2) In the normal mining and exploitation of the mine, no matter in the wind location or ventilation roadway, when the actual air volume is deviated from its effective air volume, it would pose a safety risk. Therefore, it is necessary to automatically correct the deviation in time. Because the air volume distribution characteristics of mine ventilation system presents the hierarchical classification characteristics, determining the local or small amount of air conditioning should be orderly adjusted along a oriented path.

(3) The occurance of gas outburst, fire and other disaster would change the environment security status of mine. The volume control measure of anti-air, closure, etc in the ventilation system should be implemented sometimes for timely, effective control of airflow in the disaster period. Due to the uncertainty of disaster environment, and human's inaccessible to underground to adjust the ventilation equipment, the system must be automatically switched to the manual adjustment mode in order to prevent the disaster from uncontrollably expanding and greatly improve the safety factor of mine ventilation system.

Air flow control strategy of underground ventilation roadway

The air volume adjustment of ventilation system is a systematic engineering. In the case of air volume control, the subsystems of the system should be adjusted gradually, systematically and coherently based on the systematic principles. According to the different conditions of air volume of air supply, return air and air-using area in the ventilation system, it is divided into three levels of total mine air volume control, mining area air volume control and working face air volume control. Aimed at the three level characteristics of mine air volume control, a hierarchical control model for mine ventilation system has been built using the principle of intelligent modular design. The total mine air volume is controlled by a main fan power supply module converter, the roadway's airflow of mining area is controlled by an electric ventilation door, and the air volume of air-using area is controlled by the air register installed at the end of compressed air duct.

Main air volume control strategy of mine

The main air volume of mine refers to the air volume of main inlet and return air shaft. The main ventilator's working condition is automatically adjusted by using frequency control technology, realizing intelligent adjustment and control for the main air volume and air pressure of

mine. In terms of concrete implementation, to meet the air volume required for underground operation, the frequency control system in main fan power supply module is used to control the main fan frequency conversion operation, and automatically adjust the speed of the ventilator on a large scale to make it operate under the optimum condition. When need to reduce the air volume, the synchronous speed can be changed by reducing the stator supply frequency of the motor, which can realize the main fan speed decrease; Conversely, when need to increase the air volume, it can be realized by increasing the motor stator supply frequency. Using the frequency converter to drive the operation of the main ventilator not only can realize the soft start of the ventilator and the stepless smooth speed regulation but also can greatly reduce the energy consumption of the fan and save energy[11].The schematic diagram of the main air volume control of mine is shown in figure 4.

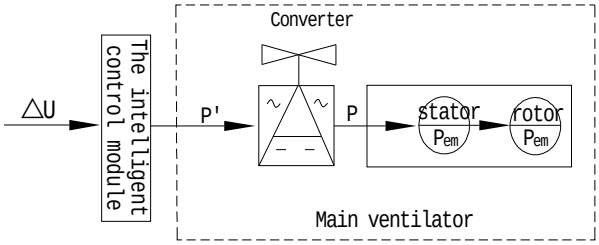
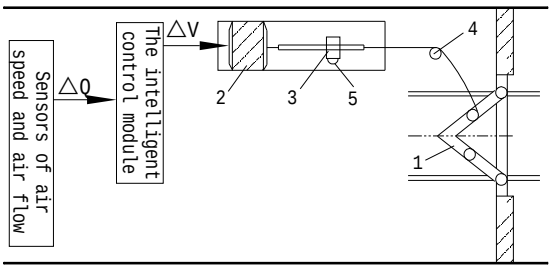


Figure.4 Diagram of the main air volume control of mine

Main air volume control strategy of mining area main roadways

The main air volume adjustment of mining area main roadways adopts the no-pressure damper installed at the mining area main return air alleys. The device adopts electric mode to adjust the opening angle of the damper, and then controls the main air volume of mining area. In terms of concrete implementation, a real-time monitoring and acquisition of roadway air volume is carried out by using the air volume and air speed sensor installed at the top of the roadway where air is stable in front of the no-pressure damper; Using infrared remote sensing technology and pneumatic technology to control the damper opening and closing linearly; Using displacement sensor to monitor the piston rod expansion of oil cylinder that adjust the opening angle of the damper, the results are also given to the intelligent control module, then the intelligent module control electric damper opening and closing linearly, drive cylinder piston rod to scale, which will automatically realize the no oscillating micro-adjustment of the damper's opening angle , until the air volume of mining area meet the pre-set security deviation range. This method not only can realize the rapid anti-risk control system during disasters, but also can effectively solve the air leakage of traditional damper and the frequent collision. The schematic diagram of the main air volume control of mining area main roadways is shown in figure 5.



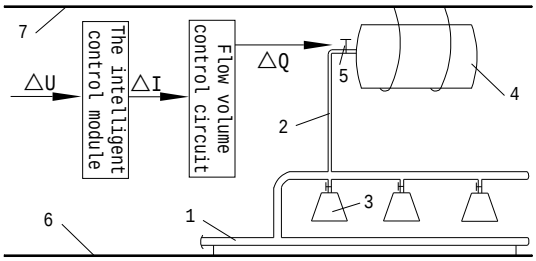
1. Door leaf 2. Electric motor 3. Slider 4. Leading sheave 5. Displacement sensor

Figure.5 Diagram of the main air volume control of mining area main roadways

Air volume control strategy of heading

Firstly, the inflatable air bags are suspended in the air return side of heading. According to the regulations of Chinese《Coal Mine Safety Regulations》, all mines must be equipped with a separate

set of mine compressed air self-rescue system. Next, the compressed air piping line is connected with the inflatable air bags through a branch pipe. If you need to reduce the air volume of working face, turn on the control valve to inflate the inflatable airbag, which can increase the air resistance of roadway and reduce the ventilation volume. Conversely, if we need to increase the air volume of working place, turn on the valve of the compressed air piping line that is located in the air return side of working face. The schematic diagram of the main air volume control of heading is shown in figure 6.



1. Pressure air pipe line 2. Compressed air self-rescue device branch 3. Protecting band
4. The inflatable airbag 5. reducing valve 6. Roadway floor 7. Roadway roof
Figure.6 Diagram of the main air volume control of heading

Development of ventilation system control technology

At present, the ventilation system of mine in China mostly adopt decentralized and independent automatic equipment, which is difficult to realize real-time monitoring, centralized dispatching and management. Meanwhile, due to lack of self-diagnosis ability and remote-control function, it is not conducive to the safe and stable operation of mine ventilation system. Therefore, by constructing a reasonable control model of mine ventilation system and combining the intelligent control technology with the configuration software and the touch screen technology applied in the coal mine ventilation system can realize intelligent monitoring, fault diagnosis and early warning, report output, remote control and interactive man-machine dialogue function , which can make the mine ventilation system and the safety production management continuously improve, and this technique will be the trend of future development.

The realization of ventilation system control technology requires mines to be equipped with the security monitoring and controlling system with remote control function at least. The system needs to integrate the main ventilator, the electric damper and the inflatable airbag control device in the outlet of air-supply duct through automatic control technology, to realize the real-time collection of related parameters that could reflect the environmental quality and ventilation status such as gas and dust concentration, roadway temperature and humidity, air pressure and air pressure etc. Furthermore, these parameters will be synchronously transmitted to the master control system for online fault diagnosis and warning. Then, according to the feedback control for guidance and relying on the hierarchical control model of mine ventilation system, the control strategies and adjustment plans are put forward. Finally, using the microcomputer process perform remote control intelligent module to quickly realize the dynamic adjustment of the effective air volume in production and the ventilation system structure and air volume adjustment in the circumstance of environmental security change. The architecture diagram of the implements of the control system is shown in figure 7.

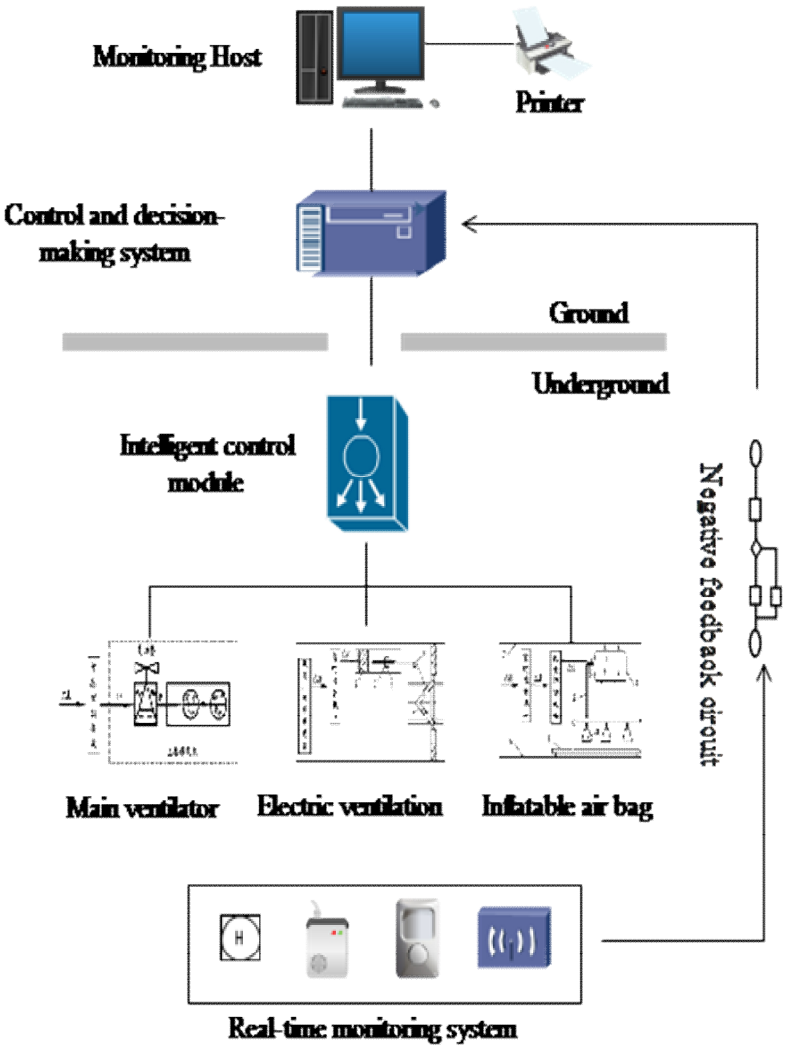


Figure.**7** Architecture diagram of the implements of the control system

Conclusions

Aimed at the ventilation status of coal mines in China, a hierarchical control model of mine ventilation system has been built using intelligent modular design concept based on the ventilation system structure and air volume distribution characteristics of the extraction ventilation. Under the conditions of the full monitor of mine ventilation system by safety surveillance control system, we have put forward that airflow control technology, configuration software and touch screen technology are applied to hierarchical control model to realize the dynamic adjustment scheme in the production safety state, and the manual-intervened adjustment program in the conditions of prediction deviation of safety state with the change of environment security. The implementation of model effectively improves the effective air volume rate and the air distribution quality of mine, and reduces the operational expenses of ventilation system in order to scientifically control and adjust the overall conditions of ventilation system.

References

[1] Xu G, Jong E C, Luxbacher K D, et al. Effective utilization of tracer gas in characterization of underground mine ventilation networks. Process Safety & Environmental Protection 99, 1-10

(2016).
[2] ZHANG Guo-shu. Science of Ventilation safety. 2nd edn. China University of Mining and Technology Press, Xuzhou (2000).
[3] WANG H N, PENG B , PENG J l , et al. Analysis of commonly existing ventilation problems and the optimal approach to deal with them in large-size mines. Journal of Safety and Environment 14(3), 24-27(2014).
[4] Wang H N. Cavern type airflow control technology of mine. Journal of Chong qing University 35(5), 126-131(2012).
[5] Hu Y, Koroleva O I, Krstić M. Nonlinear control of mine ventilation networks ☆. Systems & Control Letters 49(4), 239-254. (2003).
[6] Turchenko, Iryna, V. Kochan, and A. Sachenko. In: Neural-based Control of Mine Ventilation Networks. Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, 2007. Idaacs 2007. CONFERENCE 2007, pp. 219-224 . IEEE Workshop on, IEEE (2008).
[7] Fu H, Sun s s, Xu Z L, et al.Application of the information fusion method in mine air supplying systen based on fuzzy neural network. Journal of China Coal Society 32(2), 264-267.(2006).
[8] Wang P, Zhu K, Zhou Y, et al. Research and Application of Controlled Circulating Ventilation in Deep Mining ☆. Procedia Engineering 84(4), 758-763 (2014).
[9] SONG Z Y, LI X C, QI W Y, et al. An Approach for Quantificational Determination of Mine Ventilation Stability. China Safety Science Journal 21(9), 119-124 (2011).
[10] Du X H, Niu S, Wang X M, et al. Study on the Modeling of Main Mine Ventilator Based on Artificial Intelligence. Applied Mechanics & Materials 130-134, 3526-3530 (2011).
[11] ZHAO Z J, ZHU B.Application of variably frequency variably voltage in highway tunnel ventilation control. Journal of Chang'an University (Natural Science Edition) 26(4), 71-74(2006).