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Research on Dynamic Online Monitoring and Early Warning System for Mine Ventilation

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Abstract

Coal mines in China primarily rely on manual methods for mine ventilation monitoring, which demands significant time, labor, and resources while offering low data real-time performance. An online ventilation network monitoring and early warning analysis software is developed. By integrating underground ventilation monitoring sensors, the system enables dynamic calculations of the ventilation network based on real-time underground changes. It provides clear and intuitive dynamic displays of airflow, wind speed, and other parameters in various tunnels on the ventilation system diagram. Additionally, it supports dynamic analysis of ventilation system reliability in underground tunnels, online monitoring of ventilation anomalies, and alarm functions. This system serves as a scientific management tool and advanced technological solution for mine ventilation safety management and safe production.

Keywords

Mine Ventilation; Online Monitoring; Early Warning System; GIS.

1. Introduction

The mine ventilation system constitutes a critical component of mine safety production [1-3]. The design, operation, and management of ventilation systems directly impact both the safety of mining operations and economic performance [4,5]. An effective mine ventilation system must fulfill two crucial functions: First, it should efficiently deliver adequate fresh air to all underground work areas while maintaining proper temperature and humidity levels, ensuring both miner safety and improved working conditions. Second, during emergencies, the system must promptly regulate airflow direction and volume while coordinating with other safety measures to contain incidents and prevent escalation [6-10]. Maintaining stable and reliable ventilation operations is fundamental to mine safety [11]. Through modern information technologies, we can achieve digital and visual management of ventilation systems. This includes real-time monitoring of key parameters like airflow volume and gas concentration at major ventilation points, along with dynamic simulation analysis of the ventilation network. The system provides immediate alerts upon detecting potential hazards, thereby offering crucial technical support for ensuring ventilation reliability in underground mining operations.

2. System Analysis

For a long time, mine ventilation safety technicians have accumulated rich experience in the prevention and control of various disasters, but they are still not out of the qualitative analysis stage, and the control decision-making and disaster rescue in complex ventilation system are still very difficult work. Whether the mine ventilation system is reasonable or not has an

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important and long-term impact on mine safety production. In view of the complex mine ventilation system, how to ensure the air volume and air flow stability of the mine ventilation system, optimize various regulating facilities, reduce mine ventilation power consumption, make the whole mine ventilation system work in the best area, and realize the dynamic monitoring and real-time control of the mine ventilation system plays an important role in restraining mine disasters and maintaining safe production.

According to the application characteristics, the following analysis is made:

(1) System "integration"

The system needs to integrate the ventilation system spatial data, ventilation attribute data and ventilation resistance parameter data into the same database, which reflects the comprehensive management of mine ventilation information data. In terms of data storage, in order to achieve the goal of integration, it is necessary to unify the data storage standards and the exchange standards between heterogeneous data.

(2) System "intellectualization"

Drawing the ventilation system diagram with a good user interface, and automatically generating the topological relationship of the ventilation network. It provides a variety of ventilation resistance parameter values, which is suitable for automatic calculation of various parameter measurement methods. After the ventilation network is solved, the wind resistance value of the fixed air volume branch can be automatically calculated.

(3) System security and configurability

After the system is completed, only when it operates stably, reliably and safely can it give full play to its social and economic benefits. At the same time, it needs to be easy to maintain to reduce costs. Security and configurability are issues to be considered.

Ventilation system is an important part of mine production, and there are many factors that affect the mine ventilation system, which are restrictive and random. In order to ensure the normal operation of the ventilation system, it must be designed and managed scientifically. At present, there are some common problems in mine ventilation operation, such as heavy measurement work, high actual operation cost, lag of feedback information data, low efficiency and accuracy of ventilation system, difficulty in realizing partial or overall controllability and visualization of the system, etc. In order to do a good job in the technical management of the mine ventilation system, further improve the underground working conditions, ensure safe production, improve the safety and economic benefits of the mine, and timely master the actual working conditions of the mine ventilator and the actual operation of the ventilation system, the basic parameters of the mine ventilation system were measured and analyzed, and the problems existing in the ventilation system and the methods and ways to optimize the ventilation system were found out through the development of the system software.

3. Overall System Architecture Design

3.1. System Design Ideas

(1) Strengthen information management and utilization to provide reliable basis for decision making

The system will establish a unified data standard coding system, and carry out unified configuration and management of various basic data and applications in the design process. On the one hand, it can realize the rapid association and application of these data, and on the other hand, it is more conducive to strengthening data management and utilization.

(2) Open data structure design, constantly adapting to the changes and development of various standards

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The openness of data structure design enables the system to continuously adapt to the changes and development of various standards. It may take a long time to wait for all relevant standards to be issued. Therefore, we need to develop a standard coding system that meets the actual needs based on the existing national standards and industry standards. Through the open data structure design, the standard coding system used by the system can be continuously revised, expanded and upgraded in a very simple way, and constantly adapt to the development and changes of various standards.

(3) Establish a self maintenance, flexible adjustment and continuous improvement tool software system

The system enables the system administrator to complete the daily maintenance and continuous expansion of the system and data through simple interface operation without coding and understanding the detailed structure of the system. Without relying on the development unit, the system administrator can maintain or add personnel roles, tool plug-ins, data access rules, data inspection rules and other contents at any time to self expand and improve the business and data of the system.

3.2. Software System Architecture

In line with the principle of advanced, practical and flexible, the whole system is designed based on the mature c/s network computing mode. The system can choose SQL Server 2005 large database as the network data source on the server side, or use access database as the local data source on the client side. The whole system uses Microsoft Visual C \ Net development, application tools to complete the development.

COM technology is used to realize the object-oriented design and development of the system, and MapObjects related controls are used to complete the functions of the GIS part, so as to ensure the high efficiency and stability of the system. The system architecture is shown in Figure 1.

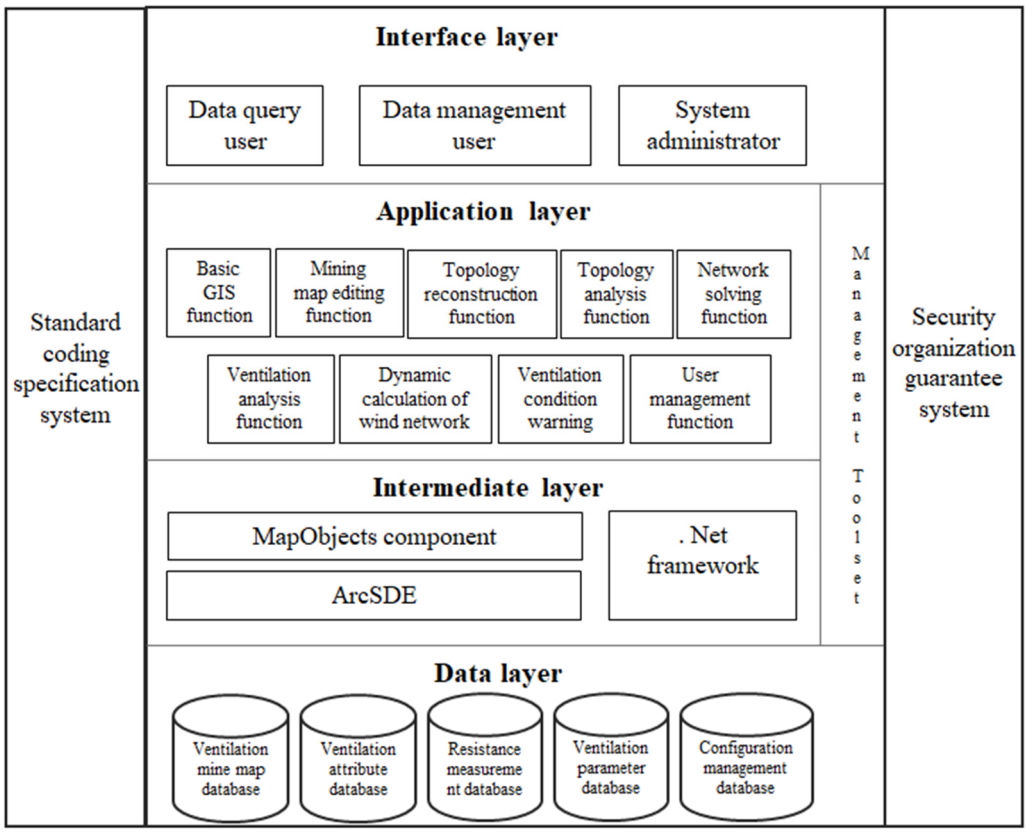

Figure 1. System architecture diagram

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On the whole, the ventilation network online monitoring system is based on computer hardware and network communication platform, guaranteed by specifications, standards, information institutions and security system, based on data and supported by MapObjects.

4. Software Function Development

(1) Ventilation system diagram editing function

Basic GIS functions: zoom in, zoom out, pan, full image, previous view, next view, add reference layers, layer management, display range settings, selection, refresh, and other functions. Map editing functions: creating new tunnels, adding nodes, adding tunnel annotations, air doors, seals, air bridges, main fans, local fans, etc., generating double line tunnels, node masking, intersection masking, and other functions. Map auxiliary feature editing: Add and edit auxiliary map features such as text, lines, frames, and names. The software interface is shown in Figure 2.

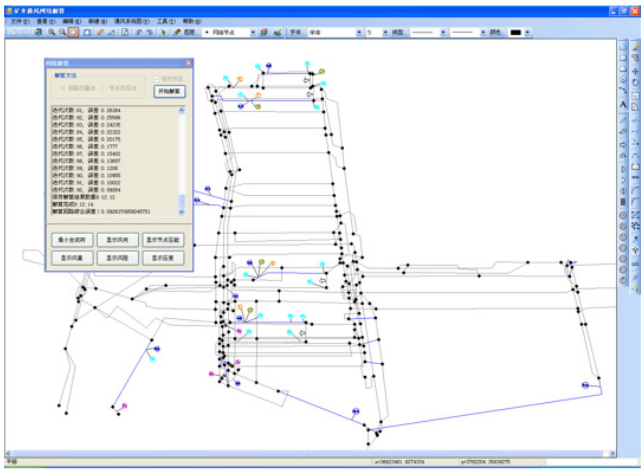

Figure 2. Ventilation system diagram editing function interface

(2) Ventilation network calculation function

Data checking function: tunnel attribute data check, fan attribute data check, air door attribute data check. And the completeness and consistency of spatial and attribute data of each element will be checked. Wind resistance calculation: calculate the wind resistance of the tunnel based on the hundred meter wind resistance, resistance coefficient, and resistance law, and calculate the wind resistance of the air door based on the test pressure difference and wind window area. Network calculation: natural wind pressure calculation, fan characteristic simulation, minimum tree generation, loop generation, loop air volume balance.

(3) Ventilation online monitoring function

Real time sensor value display: CH_4, CO, O_2. The real-time values of sensors such as wind speed and pressure can be viewed by clicking on the corresponding working face, roadway, etc., to view the numerical curve of the sensors associated with them within 30 minutes. Dynamic network solution: According to the set solution interval time, automatically calculate the air volume and pressure of other tunnels based on the real-time air volume and pressure situation of the tunnel, and provide the convergence of the solution in the form of a curve. Ventilation warning function: Using dynamic calculation results and relevant warning rules, it provides warnings on the ventilation safety situation of tunnels and working faces. The software interface is shown in Figure 3.

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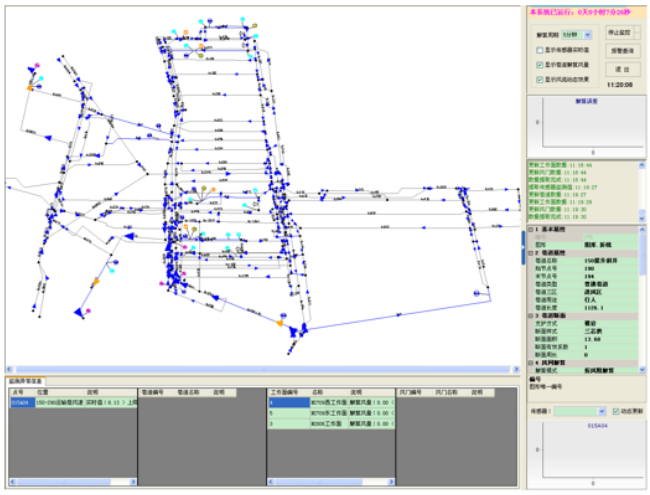

Figure 3. Ventilation online monitoring function interface

5. Conclusion

By installing relevant ventilation monitoring sensors underground and transmitting the monitored information to the ground monitoring center through a comprehensive monitoring system, combined with the developed ventilation network online monitoring and early warning analysis software, the ventilation network can perform dynamic calculation based on real-time changes underground, and display the air volume, wind speed, etc. of each roadway clearly and intuitively on the ventilation system diagram, which facilitates ventilation management personnel to understand the ventilation situation of each roadway underground in real time. At the same time, dynamic analysis of the reliability of underground tunnel ventilation system, early warning of ventilation safety status in mining face, online monitoring and alarm of ventilation abnormalities have been achieved, providing scientific management tools and advanced technological means for mine ventilation safety management and safety production.

Acknowledgments

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References

[1] Wei Lianjiang, Mu Xingwang, Tang Lin, et al. Research Progress and Prospects of Mine Ventilation System Abnormality Diagnosis[J/OL]. China Mining Magazine,1-9[2025-04-20].

[2] Liu Qingrun, Yin Qiangqiang, Zheng Kai. Current Status Analysis and Development Trends of Mine Ventilation Systems[J]. China Nonferrous Metals, 2024,(S2):288-290.

[3] Yang Jia'en, Rong Xiaobin. Research on Automatic Control of Mine Ventilation Systems[J]. China New Technologies and Products, 2024,(11):37-39.

[4] Liu Simin. Design and Application of Mine Ventilation Monitoring System[J]. Mechanical Management and Development, 2021,36(08):231-232+315.

[5] Ma Tengfei. Application of Key Technologies in Mine Ventilation Safety Monitoring and Control System[J]. Inner Mongolia Coal Economy, 2021,(01):115-116.

[6] Jiang Heguo, Cui Shuwen, Tan Pengcheng, et al. Comprehensive Evaluation Index System and Method for Mine Ventilation Systems[J]. Mining Safety & Environmental Protection, 2024,51 (02): 25-32+39.

ISSN: 2688-8645

[7] Wu Shuyi. Design and Application of Mine Ventilation Monitoring System[J]. Energy Technology and Management, 2020,45(06):161-163.

[8] Shao Hanbing. Design of Operation Monitoring and Alarm System for Mine Ventilation System[J]. Mechanical Engineering & Automation, 2023,(01):170-171+174.

[9] Shao Liangshan, Zhang Jiaqi, Yu Baocai, et al. Extension Evaluation of Mine Ventilation System Reliability Based on TF-Entropy Weight Method[J]. Journal of Safety Science and Technology, 2022,18(04):106-112.

[10] Ren Zihui, Chen Zepeng, Wu Xinzhong, et al. Research on Health Evaluation of Mine Ventilation Systems[J]. Industry and Mine Automation, 2021,47(09):70-76.

[11] Jin Yi, Sheng Jiquan, Zhao Wanxu, et al. Research on Influence of Atmospheric Pressure Changes on Mine Ventilation Systems[J]. Safety in Coal Mines, 2020,51(01):191-195.