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# Construction of an Intelligent Management and Control Platform for Coal Mine Electromechanical Safety in the Context of Smart Mines

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**ABSTRACT**
With the in-depth advancement of smart mine construction, the intelligent transformation of coal mine electromechanical safety management and control has become an inevitable trend in the industry, as it serves as a core link ensuring the sustainability of mine production. Currently, coal mine electromechanical safety management and control face prominent issues such as fragmented data resources with difficulties in integration and sharing, outdated management models with low early warning and response efficiency, and unscientific maintenance systems with unreasonable resource allocation. These problems severely restrict the improvement of safety management efficiency. To address these challenges, this paper proposes a strategy for constructing an intelligent management and control platform for coal mine electromechanical safety under the background of smart mines: breaking resource barriers by building a collaborative architecture and a unified data system, enhancing early warning response and decision-making efficiency through the development of full-process intelligent management and control modules, and consolidating technical support by strengthening the construction of professional talent teams. The construction of this platform provides a full-cycle, intelligent management and control solution for coal mine electromechanical safety, helps transform and upgrade the mine safety management model, and promotes the high-quality development of smart mines.

**KEYWORDS**
Smart mine; Coal mine electromechanical safety; Intelligent management and control; Platform construction; Electromechanical equipment monitoring

## 1 Introduction

With the comprehensive advancement of smart mine construction, the automation and integration levels of coal mine electromechanical equipment have continuously improved, and their safety management and control have become a core proposition for ensuring mine production safety. Currently, traditional management and control models face practical dilemmas such as data fragmentation, delayed response, and inefficient maintenance, which are difficult to meet the safety management needs under complex working conditions. Constructing an intelligent management and control platform for coal mine electromechanical safety is a key path to solving existing problems and improving the accuracy and efficiency of safety management. Based on the technical background of smart mines and targeting the pain points of electromechanical safety management and control, this paper explores the core strategies for platform construction, providing practical references for the intelligent transformation of mine safety.

## 2 Prominent Problems in Current Coal Mine Electromechanical Safety Management and Control

### 2.1 Fragmented Data Resources and High Difficulty in Integration and Sharing

Most coal mines' electromechanical equipment is purchased from different manufacturers in different periods, resulting in a wide variety of equipment models and inconsistent communication protocols. Consequently, equipment operation data is scattered across multiple independent systems such as production, ventilation, and transportation, forming typical "data silos." For example, data from shearers in fully mechanized mining faces is managed by the excavation intelligent system, while data from main ventilators belongs to the ventilation monitoring system. These data not only differ in format and collection frequency but some systems also have data encryption restrictions, making unified integration and sharing difficult. To grasp the operational status of electromechanical equipment across the mine, managers need to frequently switch between multiple systems for queries, which not only increases workload but also prevents comprehensive analysis across equipment and links. This makes it difficult to identify risks in collaborative equipment operation, seriously affecting the integrity and effectiveness of safety management and control, and laying hidden data barrier risks for subsequent intelligent platform construction.

### 2.2 Outdated Management and Control Models and Low Early Warning Response Efficiency

Some coal mines, especially small and medium-sized ones, still adopt the traditional management and control model of "manual inspection + regular maintenance." The identification of equipment failures relies entirely on the experience of inspectors, which not only involves high labor intensity but also carries significant risks of inspection blind spots and human errors. This often leads to delayed fault detection and inaccurate judgment. Even if some coal mines have introduced basic monitoring systems, most remain at the level of data collection and simple display, lacking support from advanced intelligent algorithms such as machine learning and big data analysis. As a result, in-depth mining of equipment operation data is not possible, and potential fault risks such as abnormal temperature and excessive vibration are difficult to identify in advance. When equipment malfunctions occur suddenly, early warning signals need to be transmitted through multiple links including teams, districts, and mine dispatch centers, resulting in a long response chain and slow speed, which often leads to the escalation of failures. This not only affects production continuity but also may trigger safety accidents such as electromechanical injuries and gas leaks.

### 2.3 Unscientific Maintenance Systems and Unreasonable Resource Allocation

Current maintenance of coal mine electromechanical equipment mostly adopts a "one-size-fits-all" regular preventive maintenance model. Regardless of the actual operational status and usage frequency of the equipment, shutdown maintenance is performed strictly according to fixed cycles. This model has significant drawbacks: for equipment with stable operation and low wear, excessive maintenance increases maintenance costs and unplanned downtime, reducing production efficiency; for equipment operating under high load or showing slight abnormalities, timely handling may not be possible due to unexpired maintenance cycles, leading to sudden failures. Meanwhile, due to the lack of accurate analysis of equipment failure patterns and spare parts consumption data, spare parts inventory management is chaotic, often resulting in two types of problems: first, a large backlog of low-frequency spare parts, occupying the enterprise's working capital; second, insufficient reserves of key spare parts, making it impossible to replace them in a timely manner when equipment malfunctions occur, extending repair time and causing a dilemma of coexisting resource waste and production losses.

## 3 Construction Strategy of an Intelligent Management and Control Platform for Coal Mine Electromechanical Safety in the Context of Smart Mines

### 3.1 Build a Collaborative Architecture and Data System to Break Resource Barriers

Based on the special production scenarios of coal mines with high humidity, high dust, and strong electromagnetic interference, focusing on "data interconnection and efficient response," a three-level collaborative platform architecture of "cloud-edge-terminal" is constructed, while a standardized and integrated data system is established to jointly break long-standing data barriers and management and control silos. The "terminal" layer serves as the forefront of data collection. Vibration sensors, temperature sensors, and mine intrinsic safety data acquisition terminals with anti-interference capabilities are deployed at core components such as bearings and motors of key electromechanical equipment (e. g., shearers, scraper conveyors, main ventilators). Meanwhile, environmental monitoring equipment is installed at working faces and roadway intersections to collect real-time equipment operation parameters (e.g., rotational speed, current, oil pressure) and environmental data (e. g., gas concentration, dust concentration, humidity) with a sampling frequency accurate to the millisecond level, ensuring the comprehensiveness and real-time nature of data collection. The "edge" layer deploys edge computing nodes in underground chambers, equipped with lightweight AI algorithms for preprocessing such as noise reduction and screening of collected data, quickly filtering invalid data, extracting fault feature values, and directly triggering local shutdown or early warning instructions for urgent abnormalities such as motor overheating and bearing abnormal noise, avoiding the delay risk of data transmission to the cloud. The "cloud" layer builds a data center relying on the coal mine enterprise's private cloud, integrating preprocessed data uploaded from the "edge" layer across the mine, and conducting in-depth analysis using distributed computing technology. In the construction of the data system, in strict accordance with the "Intelligent Data Specification for Coal Mine Safety Production," unified standards for data collection scope, format, and transmission protocols are formulated, and multi-protocol conversion gateways are developed to solve the problem of inconsistent communication protocols of equipment from different manufacturers. Meanwhile, a centralized data middle platform and a full-process safety guarantee system are built, preventing data leakage and tampering risks through technologies such as encrypted data transmission, hierarchical access control, and operational behavior auditing. Ultimately, centralized storage, standardized management, and efficient cross-system sharing of electromechanical equipment data across the mine are realized, laying a solid data foundation for subsequent intelligent analysis and decision-making management and control.

### 3.2 Develop Full-Process Intelligent Modules to Improve Management and Control Efficiency

Centering on the full-process needs of electromechanical safety management and control (monitoring-early warning-maintenance-emergency response), a highly integrated matrix of intelligent functional modules is developed to achieve full-lifecycle refined management and control of equipment from procurement and warehousing to scrapping and renewal, completely breaking away from the limitations of traditional models. The real-time equipment monitoring module relies on digital twin technology, adopting KJJ127 mine intrinsic safety data collectors to build a 1:1 three-dimensional visualization model of the underground electromechanical system. Parameters such as shearer cutting unit vibration (accuracy ±0.1Hz), conveyor roller temperature (range -20~200℃), and ventilator air pressure (error ⩽1%) are accurately associated with model nodes. Managers can intuitively view dynamic data through a 4K central control screen and retrieve details such as equipment factory numbers and fault records in the past three months by clicking on model parts. Combined with VR equipment, immersive inspections of equipment operation scenarios within 100 meters are realized, eliminating visual blind spots of manual inspections. The intelligent early warning module introduces an optimized random forest algorithm (120 decision trees) and LSTM network (256 hidden layer neurons), building a prediction model based on 120,000 historical fault data over 5 years to accurately identify potential fault risks such as bearing wear (error ⩽0.02mm) and circuit aging. Early warnings are pushed at three levels: yellow warnings are synchronized to team leaders via a mine-specific APP, orange warnings are sent to district responsible persons through SMS and voice notifications, and red warnings trigger an acousto-optic alarm in the mine dispatch center (decibel ⩾85dB), ensuring zero-delay information transmission. The full-lifecycle maintenance module breaks the misunderstanding of "regular maintenance." By analyzing data such as equipment operation load (judging high load when the daily cumulative working time is ⩾16 hours) and wear rate, dynamic maintenance plans are generated. For example, the maintenance interval for fully mechanized mining equipment is shortened to 7 days, while that for auxiliary equipment is extended to 30 days. Linking with the spare parts management system, the ARIMA model is used to predict spare parts consumption, realizing "automatic reminders when stock is 20% below the safety level and early warning for cleaning when backlog exceeds 3 months," avoiding resource waste. The emergency disposal module pre-enters 12 types of standardized accident plans. When an equipment failure occurs suddenly, the system matches the optimal plan within 3 seconds, displaying the emergency process, contact information of responsible persons, and escape routes on a visual interface. It automatically dispatches real-time data such as emergency material inventory (e.g., hydraulic support seal ring reserves) and rescuers' real-time positioning, and links with the KXT127 mine broadcast to issue targeted instructions, achieving seamless connection of "plan push-resource dispatch-instruction transmission." The four modules are deeply interconnected through a data middle platform (adopting a Hadoop distributed architecture). Early warning hazards are automatically synchronized to the maintenance module to generate work orders, and fault escalation triggers the emergency module, forming a closed-loop management and control system that completely replaces traditional models and improves the accuracy and response efficiency of management and control.

### 3.3 Strengthen Talent Team Construction to Consolidate Technical Support

The efficient operation of the intelligent management and control platform relies on compound talents who are proficient in both coal mine electromechanical expertise and intelligent technologies. Therefore, it is necessary to build a three-dimensional talent training system of "internal training + external introduction + university-enterprise cooperation" to provide solid talent support for platform implementation. Internal training adopts a "hierarchical classification + practical empowerment" model. Special training on basic platform operations is carried out for frontline inspectors, simulating equipment fault scenarios through virtual simulation systems to improve their ability to identify and initially handle early warning information. For technical backbones, advanced training on intelligent algorithm application and data modeling is focused on, inviting engineers from technology enterprises to give on-site lectures to ensure they can independently complete platform parameter debugging and simple function optimization. A "mentor-apprentice" mechanism is established, where technical backbones are paired with senior employees to accelerate the inheritance of digital skills. External recruitment implements a "precision profiling + channel expansion" strategy. Talent profiles are formulated based on platform operation needs, clarifying core competencies such as mastery of coal mine electromechanical equipment principles, Python data analysis, and machine learning frameworks. Through channels such as coal industry special job fairs, high-end talent hunters, and intelligent technology forums, compound talents with more than 3 years of relevant experience are targeted to form a core technical team of 10-15 people responsible for daily maintenance and iterative upgrading of the platform. Deepen "university-enterprise cooperation + industry-university-research integration," co-establishing "smart mine talent training bases" with coal characteristic universities such as China University of Mining and Technology and Xi'an University of Science and Technology. Targeted scholarships are set up to attract students from related majors, and customized courses on "coal mine electromechanical intelligence" are offered, integrating platform practical operation content into the teaching system to achieve seamless connection between talent training and enterprise needs. Meanwhile, establish a technical cooperation alliance with technology enterprises such as Huawei and ZTE, introducing their advanced fault prediction algorithms and digital twin visualization technologies, and inviting experts to station in mines for guidance to promote the rapid landing and transformation of technological achievements in the platform. Establish a dual incentive mechanism of "material incentives + career development," issuing special technical allowances to talents mastering core technologies, and directly linking platform operation and maintenance performance with performance bonuses. Build a dual career development channel of "management + technology," allowing technical talents to be promoted to chief engineers through skill rating and enjoy the same salary and treatment as management personnel. Through comprehensive talent construction measures, a virtuous cycle of "talents supporting technology, technology empowering the platform, and the platform improving efficiency" is formed, providing sustained motivation for intelligent management and control.

## 4 Conclusion

The deepening of smart mine construction provides a key opportunity for the innovation of coal mine electromechanical safety management and control. However, current problems such as data fragmentation, outdated management and control models, and unscientific maintenance systems have become core bottlenecks restricting the safe and efficient production of mines. The three-in-one construction strategy proposed in this paper—constructing a collaborative architecture and data system, developing full-process intelligent modules, and building a talent team—provides a systematic solution to the above problems. The implementation of this intelligent management and control platform can not only break data barriers, improve early warning response efficiency and resource allocation rationality but also promote the transformation of coal mine electromechanical safety management from "passive response" to "proactive prediction" and from "experience-driven" to "data-driven." In the future, it is necessary to continuously optimize the platform's technical architecture and application scenario adaptability, strengthen industry-university-research collaborative innovation, and help smart mines achieve safe, efficient, and sustainable high-quality development.

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