The Design and Implementation of Coal Mine Monitoring System Based on Internet of Things

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Abstract

China is rich in coal resources and has cheap labor, but the backwardness of mining technology and the lack of management seriously affected the sustainable development of the coal industry. Internet of Things, whose management and control is very convenient, is to realize the connection between objects and objects, objects and people, objects and network. This paper introduces Internet of Things technology to the development of coal mining and monitoring system, and makes design from the aspects of hardware and software. The system improves the production efficiency, safety and reliability.

Keywords: Internet of Things, Coal System, Automation

1. Introduction

Along with the application of information technology in coal mine production, the future developing direction of coal mining system is systematic, automation and diversity. Coal system is a huge and complicated system, whose components are mutual influence and mutual restriction. In face of such a large complicated system, it requires us to have a rapid and accurate understanding of the operation condition of coal mine system and the characteristics of each part and make accurate decisions to give full play to the system ability and efficiency, complete and unify system, and coal mine automation system is thus generated[1~3]. Real-time mine surveying, GPS real-time navigation and remote control, GIS management and aid decision making and 3DGM application have appeared internationally. Some large opencast mines have realized generating deposit models and making mine mining plans in the office, with mining equipments connected, a complete dynamic management and remote control command system has been formed. In addition, artificial intelligence technology such as neural network, fuzzy logic, adaptive pattern recognition and genetic algorithm, GPS technology, radio frequency identification technology, global optimization method and remote sensing technology have been applied in many research areas such as intelligent geological exploration survey, intelligent mining, intelligent mine design, planning and control and mine disasters remote sensing prediction, etc[4~7].

Coal mine informationization system is a combination of comprehensive technologies such as computer technology, automatic control, communications, information technology and modern management technology and so on. It controls and manages the enterprise production process control, operation and management as a whole, and provides the overall solution, in order to realize the optimization of enterprise operation and control, and improve the status of production, safety level, and the accident hazard prediction and production business management level, so as to improve the core competitiveness of the enterprise [8].

In recent years, with more attentions and implementation to the coal mine safety production measures from country, many coal mines installed underground personnel positioning system, equipment check point system and wireless communication system, etc.. But some universal problems exist: one is simple system function. Systems isolate from one another in production and safety management, which makes efficiency maximization can't be achieved, the cooperative function between the systems is hard to play, and the systems can’t harmonize well with the actual production and safety management of the enterprise, as a result, system became "isolated island" and even became a decoration or "visited project"; The second problem is system is still not perfect or has blank, such as locomotive positioning system, equipment positioning system, the powder transportation and management system in the mine, etc.; The third problem is the present system still does not have the function of disaster recovery and emergency communication.
The appearance of “Internet of Things” concept broke the traditional thought. The ideas before is always setting the physical infrastructure and information infrastructure apart. To the coal mine safety production, in the "Internet of Things" era, gas, CO and other kinds of sensors, cable, electrical machinery equipment, steel-reinforced concrete and so on, all of these will integrated with chip and broadband for unified infrastructure. Based on “Internet of Things” network, more real-time collaborative management and control can be implemented to the people, machinery, equipment and infrastructure of the production system in complicated coal mine environment. "Internet of Things" is the third wave of world information industry after computer, internet and mobile communication network. It is "informationization new stage" of information technology renewal. As the bridge connecting physical world and virtual information world, "Internet of Things" is not only the natural extension of the communication network and advanced computing technology, but also the systematic and information product of the physical world based on exploring the nature of the physical world. The core idea of “Internet of Things” is to break through limitations of interaction between people and objects (or machines), enable the human resources to be liberated and management be more intelligent. Internet of Things is the deepening of information, and it is the new period of global information development promoting from the informatization to the intelligence. The application of it will infiltrate into every industry and every corner of social life, bearing the great mission of the country and public security and national economic lifeline.

2. Coal production situation

China is rich in coal resources and geological conditions are complicated. Most are still underground mined, key coal mines are basically gas, coal and gas outburst mine, and mostly low permeability coal seam. Coal occurrence condition is poor and mining depth is deep, the coal dust, flood, fire, and other serious problems trouble the development of the mining industry. Coal industry is not only an important pillar of the national energy, but a high-risk industry in China. In recent years, In recent years, with more attentions and implementation to the coal mine safety production measures from country, many coal mines installed underground personnel positioning system, equipment check point system and wireless communication system, etc.. But some universal problems exist:

(1) Narrow underground space, poor conditions, complex roadways, but concentrated many large scale equipments needed in power supply, ventilation, drainage, mining and so on.

(2) What coal mining need is mobile working environment, many large equipments need to be removed at any time along with the progress of the mining, but both the management and operation level of the mining enterprise are low, with low efficiency, equipment and material loss is quite serious.

(3) The coal mine locomotive used in the production of coal mines. The main method of coal mine locomotive positioning in China is cable communication mode. For rail locomotives, at present positioning relay plus cable communication way is used the most, but because of the restriction of technology, cost and field installation environment, positioning relay can't be installed a lot with high density, so the positioning can only be realized in a few key positions such as switches, stations, etc., while the accurate location can’t be achieved when the locomotives are on the way. For the locomotives on the ground or underground, there is no mature reliable positioning and management system.

(4) in the management and use of explosive, coal mining enterprises need to use large amounts of explosive in daily continued production, many malignant mine disasters are due to improper management and use of explosive. While the existing explosive management work in coal enterprise internal is still in a comparative primary registration state. There isn’t any corresponding management technology in the mine explosive carrier vehicle and underground explosion.

(5)Decrease the number of workers and increase efficiency is an important goal and means of coal enterprise to improve safety production management level. It put forward higher request for coal mine underground communication system security to realize decrease number of workers and increase efficiency in the mobile production environment with less workers and long distance underground roadway.

(6) Among coal mine safety rules, there are a large amount of procedures involving the collaborative operation between people, equipment, transportation tools and mining process, for the
implementation of regulations at present it’s mainly depending on the system and people's consciousness, lack of effective monitoring technology.

(7) When the accident takes place in coal mine underground, the communication between the ground and underground is not in time, so the ground staff can’t grasp the dynamic information about personnel distribution in the mine and their operation situation. Once the coal mine accidents take place, the rescue efficiency and safe rescue efficiency are low and search and rescue effect is poor. Therefore, the number of underground is unknown, trapped personnel position is not clear, the communication is not free are the problems needed to be resolved after disaster.

3. Introduction to Internet of Things

Internet of things is a kind of network which connects up everything with internet to make information exchange and communication according to contract agreement through information sensing devices such as the radio frequency identification (RFID), infrared sensors, global positioning system, laser scanner, etc, so as to realize intelligent identification, location, tracking, monitoring and management.

From the technical structure point of view, the internet of things can be divided into three layers: perception layer, network layer and application layer. Perception layer is composed of all sorts of sensors and sensor gateway, including perception terminals such as carbon dioxide concentration sensor, the temperature sensor, humidity sensor, two-dimension code labels, RFID tags and reader, camera, GPS and so on. The main function of perception layer is to identify the objects and collecting information. The network layer is responsible for the transmission and processing the information getting from the perception layer, while the application layer is the interface between internet of things and users. It combined with industry needs in order to realize intelligent application of internet of things.

(1) At present personnel positioning system, equipment checking system and gas monitoring system have been used in the coal mine, and these technologies proved that the bottom WSN, RFID radio frequency identification technology, WiFi radio frequency orientation, GPS positioning technology, network video technology have been applied very well in coal mine.

(2) Based on the two-dimension code, RFID radio frequency identification technology, WiFi radio frequency orientation, GPS positioning technology, network video technology and so on, through the wireless Ethernet and industrial Ethernet, personnel, equipment and network are linked to make information exchange and communication, in order to realize intelligent identification, location, monitoring, and to realize the synergy of operation and intelligent management innovation application between "people and people", "objects and objects" and "people and objects".

(3) It can be regarded as the innovative application core of the internet of things technology in safety production of coal enterprises to combine the object location and the people positioning, aided by communication system, and collaborated with production system, coordinate used in coal mine enterprises safe production management.

(4) The unified integrated integration can greatly improve the production efficiency. The system integration can improve the reuse rate of equipments, reduce material waste and control personnel subjective operation loss. At the same time it can make a good analysis to the enterprise benefit by integrating from coal mining, the purchase of equipment, equipment use and coal sales, providing a great convenience for top leaders to analyze the method of improving benefit.

Above 4 points show that internet of things can be solved effectively and used efficiently no matter from technology or from management. The particularity of the coal industry makes it necessary to go up to the new step of “Internet of Things”.

4. Coal monitoring system design

4.1. Overall structure

The overall structure of coal mine safety system based on the internet of things adopts hierarchical architecture; from down to up it can be divided into perception layer of internet of things, platform layer of internet of things, application layer of internet of things and application layer of coal mine.
The sensing layer of internet of things mainly completes the collection, processing and transmission of information. Using sensor, intelligent video, RFID technology, it collects all kinds of real-time information from various objects such as personnel, objects, scene and so on within coal mine sites. The information collected need to be melted step by step, so as to realize collaborative perception and cooperative control.

The platform layer of internet of things mainly realizes the management of network equipment, the conversion from network equipment level information to business information, the presentation of equipment information and business information. The platform effectively shields complexity and diversity of the bottom equipment and network, unified equipment management interface and information model. Using the modular construction mode The platform supports the application scenes from simple to complicate by means of component configuration, layout and the strategy scheduling.

Based on all kinds of components provided by platform of internet of things, the application layer of the internet of things organizes fine particle technical components into bigger size function module, and organizes for a specific internet of things application.

The application layer of coal mine is the materialization and specification of the overall application system architecture in this particular application scene of coal mine. Around the core content of "perception coal mine", combined with coal industry management status, identification and monitoring system can be refined out for personnel, equipment and environment. For function and technical realization, this kind of system can be made by the above function module of internet of things and application mapping.

The perception layer of internet of things mainly solves the problem of "feeling". The platform layer of internet of things mainly provides solutions to "know". The application layer of internet of things and application layer on the coal mine mainly solve the problem of "application" aspect. The above four aspects formed an organic, complete coal industry perception system structure.

![Figure 1. Based on the content networking coal perception system model](image)

4.2. Hardware Platform Construction

1) Set server, a kind of infrastructure used for application procedure development, deployment, maintenance and management.
2) Set I/O server, collect all information of production and safety in the whole coal mine, and provide it to each operator station of Ethernet, and then each workstation send control information to the whole coal mine subsystem from the server, through the industrial Ethernet corresponding node.

3) Set WEB server, responsible for WEB publishing, transfer the information to the local area network.

4) Set the database server: database server is responsible for the information storage of the whole coal mine safety and production; produce the real-time and historical database for management and data query and analysis.

5) Set location server, realize the mine personnel position information collection and position calculation.

6) Set 4 workstations, used for monitoring the various subsystems condition, equipment status and controlling of the operation of equipments.

7) Set engineer station, responsible for all the control system configuration and maintenance, the engineer station should be operated by the engineer who received special training.

8) Set hardware firewall, responsible for isolating monitoring network from local area network of the coal mine, in order to ensure the relative independence of monitoring network.

9) Set up the core industrial switches to realize the information interaction of the whole mine safety and production.

10) Configuration UPS power supply equipment with 30 kVA capacity, backup time not less than 4 hours.

Figure 2. Equipment Distribution of control center

4.3. Software platform construction

Software platform ensures that all coal mine safety production, personnel, equipment, management information and complicated heterogeneous information run in a unified network platform, and communicate and share in heterogeneous conditions, and make the different parts of the application system connected, coordinate and operate orderly, make independent monitoring system information sharing.

Function Structure
The main functions that software platform realize are: the unity of the heterogeneous data access interface, control command output interface, real-time data processing and storage, communication condition monitoring and alarm, real-time alarm and warning, data report and curve.
(1) Real-time data acquisition and processing. Fast storage of all kinds of safety production real-time data, personnel underground position information, the running state of the equipment information, environmental safety real-time information through the real-time database function.

(2) The access to heterogeneous system data. Design protocol conversion interface in accordance with the unified protocol specification for the coal mine existing various system. Using the existing system with OPC, ODBC interface functions, connect the data to real-time / historical database directly. For non standard interface system, converse according to the specified CVS protocol.

(3) Real-time data display.
Ø Safety production and equipment data: have basic information display function such as real duration, time, location and relevant equipment real-time working state, and have the related information query function.
Ø Personnel information: have the staff position, time real-time display function, have the staff complicated information query function.
Ø Environment perception data: with regional data real time duration, display function.

(4) Data on-line analysis. Based on the data analysis of data change trend within a period of time, forecast data development trend. Synthesize the continuous work and changing state of personnel, environment and equipment. Introduce intelligent information processing technology to predict health and work condition of personnel and equipment. Forecast environmental safety situation. According to all kinds of real-time data, perform early warning and alarm functions on regional information, personnel information, and equipment information.

(5) Data report function. According to users' needs, provide all kinds of complicated query, provide the related data query, screening and analysis function cross systems. Based on the production need, provide standard and unified data report print function; Support the report's EXCEL data export function.

(6) Curve function. According to the configuration principle, draw real-time and history curve.

(7) Intelligent data decision support. Derive data processing technologies like data warehouse, data mining and neural network. Intelligently search all kinds of data conforming to the special conditions in the complex data environment and use its inline relationship to proceed intelligent analysis testings, such as personnel positioning, equipment failure and environmental safety. Provide more objective and comprehensive technical support for high-level decision.

(8) Communication state real-time monitoring. Monitor multisystem’s data and communication state in the access process.

(9) Reserve standard open interface.

Software platform design

![Software platform model](image-url)
Software platform mainly consists of five components:

1) Data input interface. Standard OPC, ODBC realizes link up with the existing system; In addition formulate CVS input interface which meets the standards.

2) Data center. Include two parts: industrial historical database and business database Sql Server. Industrial historical database is primarily responsible for the compression processing of industrial control real-time data which can meet the standards.

3) Application system. In establishing a unified data center, construct application services in accord with different needs. Such as a number of application-oriented subsystem: production scheduling subsystem, GIS and VR subsystem, safety information management, disaster prevention and control, marketing management, material and equipment management, office automation, personnel information management, and system safety management.

4) Data output interface. Based on the feedback control demand of various monitoring system, provide standard output interface according to the standard protocol specification.

5) WEB SERVER. Provide WEB service function for the application system data display and control.

5. Experimental verification

In order to detect this paper design based on content networking technology coal monitoring the effectiveness of the system, through the simulation results to one with this design based on content networking technology coal monitoring system of a large coal company's operation situation analysis, through the finishing a period of the relevant data, can figure out the system operation efficiency as shown in figure 1 shows:

![Figure 4. The operation of the system efficiency](image)

Analysis chart 1, this paper design based on content networking coal monitoring system of the basic keep efficiency between 91% and 97%, in line with the provisions of the relevant requirements. In this paper the design of coal monitoring system can rapid detection and analysis of coal production information, to ensure the smooth progress of coal production.

In order to further verify the superiority of the system in this paper, the results of data statistics, through the quantitative data analysis in this paper the performance of the system level, detailed quantitative results in table 1 description.
Table 1. In this paper the monitoring system performance

<table>
<thead>
<tr>
<th>Monitoring time (s)</th>
<th>20</th>
<th>25</th>
<th>15</th>
<th>8</th>
<th>16</th>
<th>19</th>
<th>22</th>
<th>23</th>
<th>25</th>
<th>17</th>
<th>19</th>
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<th>15</th>
<th>19</th>
<th>23</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring error rate (%)</td>
<td>3.5</td>
<td>5</td>
<td>4.5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>6.5</td>
<td>4</td>
<td>3.8</td>
<td>9</td>
<td>3.8</td>
<td>4.5</td>
<td>6</td>
<td>5</td>
<td>4.5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Leakage monitoring rate (%)</td>
<td>6.5</td>
<td>6.8</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>9</td>
<td>7</td>
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<td>6.9</td>
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<td>7.6</td>
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Table 1 analysis, this paper system monitoring time is short in twenty s, and keep monitoring error rate between 3.5% and 7% meet the corresponding threshold requirements, and this system has low leakage detection rate. Finally the result demonstrates that the system can quickly and accurately to the corresponding coal production monitoring, and analysis and decision not provide reliable data basis, to ensure that the coal production and management system of high efficiency and stable operation.

6. Summary

Internet of Things technology platform is a safety management solution, which can build all kinds of sensor equipment and network integration and connect all kinds of equipments simply. In data transmission, Internet of Things technology platform uses the present network capacity and simplifies the complexity of communication equipment in a smart way.

Internet of Things technology is still in the initial stage in the application of mine safety production administration in China, and confronts many difficulties. But the application of information technology to safety production management is an inevitable trend. Its high efficiency, advanced and practical features will attract more and more attention and be widely used. By comprehensively promoting the application of informatization equipments, achieve mining enterprise integrated information networking, process control automation, security management informatization, production intensive efficiency. Realize the total integration of information and business and information sharing. These will promote the coal mines overall safety management level and enhance the sustainable development of coal industry in our country.

7. Acknowledgements

The authors were appreciated for the support from the ShanXi Science and technology Department in 2010 with the program number 20100322003 and the program name The coal sales safety control and management system based on electronic ticket

8. References