Research on Underground Remote Control Detonation System

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Abstract: In order to meet the technical requirements for unmanned mining of underground metal mines and overcome the key technologies of unmanned blasting, a wireless network-based underground remote control detonation system was studied. The research content includes the software and hardware of the underground and surface initiation control unit and the initiation control process, the communication realization method of the underground and surface initiation control terminal, the remote wireless initiation network security encryption technology, and the system security design. Under the premise of ensuring safety, the requirements of underground remote control blasting are realized, which is of great significance to the development of underground unmanned blasting technology.

1. Introduction

Many important metal mineral resources in China are obtained through underground mining. After decades of mining, many underground mines have gradually entered the stage of deep mining. The underground, especially the deep operating environment, poses a great challenge to safe mining, so in the future, intelligent unmanned continuous mining technology will be an important development direction for underground mining technology. With the development of communication technology, metal mine underground mining automation, intelligent equipment and continuous mining and ore transportation technology have been rapidly developed. Underground unmanned blasting technology is one of the key technologies to realize unmanned mining in metal mines. However, the underground blasting still uses the on-site detonation method. The wireless detonation system that can be applied to underground unmanned mining has no mature technical products that can be applied. Underground unmanned blasting has become one of the urgent problems to be solved in the realization of underground unmanned mining technology\textsuperscript{[1]}.

This article studies the underground remote initiation system, including the system technology principle, the software and hardware of the underground and surface initiation control unit and the initiation control process, the communication realization method of the underground and surface initiation control terminal, the remote wireless initiation network security encryption technology and the system security design, etc. Realize remote underground detonation operations of metal mines on the surface, provide technical support for the development of underground unmanned blasting technology and improve the intrinsic safety of underground mining blasting operations.
2. System composition and technical principles

The underground remote initiation system based on wireless network includes surface initiation control unit, underground field control terminal (including embedded communication unit, initiation control unit and detonator, etc.), and the initiation process is controlled by the combined use of surface initiation control unit and underground field control terminal to perform remote wireless control [2]. The underground field control terminal adopts embedded hardware control technology, and the single-chip microcomputer is used as the main controller [3]. The surface initiation control unit communicates with the underground communication unit through optical fiber cables, underground wireless networks and point-to-point radio frequency signal transmission. The communication unit and the initiation control unit are integrated. The initiation control unit and the electronic detonator control the self-check and initiation of each detonator through wired communication. The security of the system is guaranteed by the wireless network security encryption technology during the operation of the entire system. The technical schematic diagram of the system is as follows:

The working principle and process of the wireless remote control detonation system: the detonation control unit is set at the surface command end far away from the blasting source. When the blasting starts, it performs encryption verification with the on-site control end, sends out the established wireless remote control instructions, and receives feedback from the on-site end. Response signal: The underground field control terminal receives the wireless remote control command, and after checking and confirming that it is correct, it controls the detonation of the detonator according to the command and generates a feedback signal. Based on the basic components of electronic detonator initiation, the initiation system has functions such as signal transmission, data protection, parameter processing, etc., which can realize electronic detonator remote registration and recognition, remote postponement parameter setting, initiation network self-inspection and self-inspection [4].
3. Surface initiation control unit

The research of surface initiation control unit is mainly divided into three parts: initiation control software, surface initiation control cabinet and safety design.

3.1 Initiation control software

The surface initiation control software adopts C# technology of NET platform and MVC architecture design. The main functions are three aspects: blasting control (underground device communication, controlling the blasting process, verifying and recording the identity of the blasting personnel), blasting monitoring (detonator registration, detonator monitoring, detonator verification), blasting statistics (blasting information feedback, blasting history statistics).

The blasting control module realizes communication with the underground control terminal and controls the work of the underground control terminal. Its communication method adopts SOCKET long connection communication, self-defined communication protocol, encrypted transmission of communication data, and regular update of encryption keys. Both login system and detonation operations require the identification of the detonator (encryption lock, password, biometric identity).

The blasting monitoring module realizes the registration of all detonators; it verifies whether the batch and model of the detonators meet the requirements; it is necessary to monitor the detonator's condition before detonation, and the detonator can be detonated normally when its condition is normal.

The blasting statistics module records data for each blasting, and provides query and filter functions for blasting historical data.

3.2 Surface control cabinet

The design of the surface control cabinet mainly includes three aspects: the internal and external layout of the control cabinet; the identification module of the control cabinet; the physical buttons of the control cabinet.

3.3 Security design

In order to ensure the safety of the entire system and process, the safety of the surface initiation control unit needs to be designed from two aspects: hardware and software.

The hardware research mainly includes two parts: encryption lock and biometric technology. The encryption lock is an intelligent tool with software protection function for software developers. It includes a hardware installed on the parallel port or USB port of the computer, and a set of interface software and tool software suitable for various languages. The encryption lock is based on hardware protection technology, and its purpose is to verify the identity of the system operator through the protection of software and data. Biometrics technology is the close integration of computers with high-tech methods such as optics, acoustics, biosensors, and biostatistics principles, using the human body’s inherent physiological characteristics (such as fingerprints, faces, iris, etc.) and behavior characteristics (such as handwriting, Voice, gait, etc.) for personal identification. At present, the more mature technologies are fingerprint recognition, iris recognition, etc. The application of biometric technology further confirms the identity information of operators. This system adopts a dual verification technical scheme combining USB shield and fingerprint to ensure safety.

In terms of software, the communication method between the surface control unit and the underground control unit adopts Socket long connection and self-defined communication protocol. Communication data adopts software encryption (DES, 3DES, AES, etc.), and the key is randomly updated on a regular basis to ensure the security of communication. The working flow chart of the surface detonation control unit detonation control software is as follows:
4. Underground field control terminal

4.1 Signal communication receiving unit
The receiving unit is composed of amplifier circuit, analog signal processing circuit, synchronous signal extraction circuit, MCU control circuit and digital signal instruction circuit. The main function of the receiving unit is to receive, demodulate and decode signals. The command is input to the detonation controller in the form of signal.

4.2 Underground detonation control unit
The underground initiation control unit adopts an embedded software system. After establishing a reliable connection with the surface control terminal, it sends a request to the surface control terminal and confirms each other's identity, receives a temporary communication key, and encrypts and feedbacks the on-site networking situation to the surface control terminal; received After the surface control terminal encrypts the instructions, the temporary key is used to decrypt the instructions. After confirming that the instructions are complete and valid, the networking and initiation instructions are executed, and the blasting situation is finally fed back to the surface to complete the remote control initiation process [5]. The working flow chart of the underground initiation control terminal is as follows:

Fig.2 Surface initiation control software workflow
5. Security encryption technology of wireless initiating network

Security encryption technology mainly includes three parts: key management and distribution technology based on asymmetric encryption algorithm and digital signature technology, data encryption transmission technology based on symmetric encryption algorithm, and data anti-tampering technology based on information summary [6]. The security encryption work flow chart and technical roadmap of the wireless initiation network are shown in Figure 4.

Fig.3 Workflow Diagram of Underground Detonation Control Software
6. Conclusion

The underground remote initiation system based on wireless network is mainly composed of surface initiation control unit and underground field control unit. Through the combined use of surface initiation control unit and underground field control unit, remote wireless control of underground initiation process is carried out. According to the technical characteristics of the underground remote control detonation system, the detonation control workflow of the underground and surface units is strictly designed. The network security encryption technology scheme of the wireless detonation system ensures that the detonation command is not attacked and tampered, and the security of the system is guaranteed. The use of this system can change the current initiation method used in underground mines and provide technical support for the realization of unmanned underground mining.

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