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Design and application of electrical fire monitoring system in mining industry

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ABSTRACT

To protect mining areas from electrical fire, it is very important to install electrical fire monitoring system to ensure safety in development of mineral resources and for buildings. In this paper, design for electrical fire monitoring and detection system with optional sensor modules has been proposed. In addition, necessity and suitability of electrical fire monitoring and detection system with optional sensor modules in mining areas have been reviewed. The designed electrical fire monitoring and detection system suitable for work environment of mining industry is composed by host-computer monitoring software and slave-computer detectors. Monitoring detectors are manufactured by using embedded technology. External shells deployed have superior enclosure performances and explosion-proof properties. It is easy to install and maintain the system. In general, the system has reached, or even exceeded standards specified in national standards for performances and appearances of such devices. Test results show application of electrical fire monitoring and detection system can effectively enhance monitoring intensity over the mining areas and provide reliable guarantee to ensure orderly development of mineral resources and to protect physical and property safety of citizens in these areas.

1. Introduction

Development and utilization of mineral resources are key components of economic and social development in China [1]. But development of mineral resources may involve adverse work environment and complex geological conditions, which are susceptible to fire hazards. For example, coal-mine fire can be considered as a common mine safety accident [2–5]. Fire in Baijigou coal mine of Ningxia province in the year 2003 is the largest underground fire ever happened in China in recent years. The fire is characterized by strong methane explosions. Though administration departments for development of mineral resources increased investments for detection devices for hazardous gases, various mine accidents and fire involving carbon monoxide poisoning, gas explosion, carbon dioxide suffocation and other mishaps remain a big challenge for resource development [6]. With comprehensive reviews for various mine accidents in China, it is determined that detection of explosive and toxic gases is the key for accident prevention. In addition, fast transmission of data is also a problem that requires urgent attentions.

To provide operators in mining zones with safe work environment and living conditions under special conditions related to development of mineral resources, it is absolutely necessary to deploy electrical fire monitoring system equipped with detectors for flammable, explosive and toxic gases [7]. Such electrical fire monitoring systems include predominantly aftercurrent protection devices. Products involving current-operated aftercurrent circuit breaker have been developed many years ago, but development of such products accelerated in recent years globally [8]. CBS-4/CBS-4C aftercurrent electrical fire monitor can display aftercurrent, trip and delay time simultaneously in real time. With monitors and transformers inter-connected, the monitor is capable of remote, local or automatic reset and self-checking; linkage with other fire-fighting facilities; audible and/or visible alarm and display of aftercurrent and corresponding codes of circuits at the time of tripping; DIN guide rail or disc (optional) installation; RS485 interface, MODBUS communication protocol function (optional) model; limited range of tripping values, generally at approximately 40 A. In China, majority of aftercurrent protection devices are of current-activating type. Zhejiang Sentai Electrical Apparatus Co., Ltd. produces STFL1 series electrical fire monitoring detectors for power-supply systems in high-rise buildings, public places, residential buildings and sites for storage of hazardous materials [8]. These

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detectors are characterized by intelligent control, fire alarm, linkage with fire-fighting network, remote monitoring, multiple control interfaces, leakage protection, multi-function Liquid Crystal Display (LCD), true self checking, super-low power consumption, wider working voltages and high reliability [9–12]. All these detectors shall be used together with monitoring systems.

Previously, these detection and alarm systems contain insufficient detection circuits with majority of currents used for detection are high currents. These detectors have low sensitivity for detection of low currents. With low degrees of integration, these detectors are big in size, which may make them hard to install. In addition, these detectors have low levels for explosion protection and without suitable sensor modules to cope with specific conditions in mining areas. With consideration to actual conditions in mining areas, a brand new aftercurrent monitoring and detection system with optional detection modules and desirable explosion-proof performances have been developed. Through optimal combination of electric, electronics, computer, network and software techniques, real-time monitoring and network management over leakage, overloading, short circuit, over-voltage, under-voltage, temperature rise, flammable & explosion gases and other operational conditions can be performed for power distribution circuits and electric devices. With field data uploaded to host-computer through wired or wireless network, remote monitoring, controlling and automatic recording of relevant data can be achieved in the central control room. With maximum detection circuits of up to 256, detection accuracy and sensitivity can be enhanced significantly. In addition, intelligent control can be performed over even large areas covered by the monitoring and detection system [13].

2. Analysis for system design requirements

The electrical fire monitoring system with optional detector modules is composed by host-computer system monitoring software and slave-computer electrical fire monitoring detector. Through network communication, detectors can be controlled centrally by the host-computer. The host-computer system monitoring software may provide monitoring interface for real-time display, remote operation and other functions. The slave-computer may serve as the electrical fire detector for detection of three-phase voltages, three-phase currents, leakage currents, temperature rise and detection of flammable, explosive and toxic gases. Whenever the detected parameters exceeded pre-set threshold range, these detectors may trigger alarms and initialize corresponding trip actions promptly.

3. Functional requirements and interface design of the host-computer

3.1. Analysis of functional requirements

The host-computer system monitoring software may provide remote monitoring and operation interfaces, through which users may browse real-time monitoring data, search or modify parameters related to monitoring threshold for monitoring points. In addition, users may control trip and other operations of detectors remotely. Periodically, the system may record real-time data and alarm records of all monitoring units. All historical records for monitoring and relevant alarm records can be reviewed and printed whenever necessary.

3.2. Setup of parameters

Setup of upper limits for threshold parameters in system monitoring software: rated heat current (A), rated current (A); power-distribution circuits and leakage current, over-voltage, under-voltage, temperatures of electric devices, together with concentrations of flammable, explosive and toxic gases [14–16]. To facilitate parameter calculation and setup, relevant calculation methods have been generated at the time of software programming. System operation time and alarm records can be displayed simultaneously with host-computer alarm window and slave-computer LCD screen. Through entering password in the software remote-operation window, operations engaging in monitoring operations may setup threshold parameters of monitoring points or perform emergency trip and other important operations remotely.

3.3. Interface design

Software interface of the host-computer may display two major sections: the first one is real-time conditions of different front-end points; the second one is records related to latest warnings, alarms, trip and other events of all such points. The points with the latest alarms can be displayed on topmost of the record window. Furthermore, current communication conditions (such as normal, tripped, abnormal communication, and emergency trip), natural of alarms (such as overheating, over pressuring, high concentrations of flammable, explosive or toxic gases) can also be displayed; Pop ups for alarms or trips can be removed manually upon proper elimination of relevant abnormal conditions. Simple design of the interface may minimize requirements for understanding and operation of users to facilitate operation and review in later stages. In this way, the system may function as the black boxes for air planes.

4. Application requirements and design of the slave-computer monitoring detector

4.1. Compositions of the monitoring detector

Composed by zero-sequence current transformer, single-chip microcomputer system and the circuit breaker, the slave-computer monitoring detector can be installed on site. With the single-chip microcomputer system as the core for the monitoring system, the monitoring detector can satisfy requirements related to detection and control of parameters in mining areas and residential areas. See Fig. 1 for components of the system [17,18].

4.2. Configuration of major hardware

To enhance detection sensitivity, custom-made current transformer and zero-sequence current transformer can be used. Also

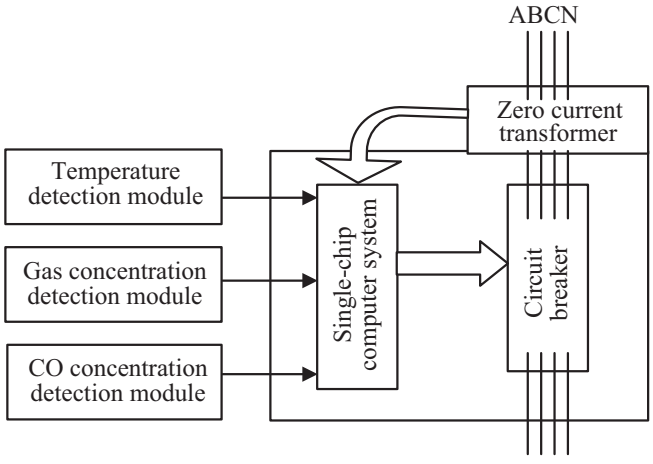

Fig. 1. Components of the electrical fire monitoring detector.