Design of a Data Fusion System for Short-Circuit Testing of High-Voltage Distribution Devices in Mining

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Abstract. Mining is a crucial foundation for the rapid development of the national economy and an important guarantee for national energy security. Based on an analysis of the safety production situation in mines, this paper introduces the origin, development, and application fields of multi-data fusion technology. It discusses the characteristics of parallel, serial, serial-parallel hybrid, and networked data fusion structures and designs a data fusion structure for short-circuit testing of high-voltage vacuum distribution devices used in mining. This design serves as a reference for the development of short-circuit testing systems for high-voltage vacuum distribution devices in mines.

Keywords: eCAN bus, coal mine; starter, communication system.

1. Introduction

Mineral resources are vital non-renewable natural resources and serve as fundamental materials for national economic construction. The degree to which these resources are secured directly impacts the long-term stable development of the national economy and national security. China is one of the few countries in the world with a complete variety of mineral resources and abundant reserves. Statistics indicate that over 90% of China's energy, more than 80% of its industrial raw materials, and over 70% of agricultural production materials come from mineral resources. Safety production in mines is critical to safeguarding people's lives and property, as well as to ensuring economic development and social stability; thus, it is a top priority in safety production.

The mining industry faces severe challenges due to poor safety production conditions, numerous geological disaster hazards, and continuous occurrences of serious accidents, which severely restricts the development of China's mining industry towards deep, high-intensity, large-scale operations. In recent years, with continuous advancements in mechanization, automation, and intelligent technologies, the safety production situation in mines has gradually improved; however, both the total number of accidents and fatalities have increased. However, constrained by the complex environment and geological conditions of mine production, mine safety work remains the focus of China's safety work. High-voltage distribution devices used in mining are essential equipment within mine distribution systems, playing dual roles in control and protection within the mining power grid. Short-circuit protection is a critical inspection item during type testing of high-voltage distribution devices used in mines; it serves as a key parameter for evaluating protective device performance under fault conditions.

2. Multi-Data Fusion Technology

The research on multi-data fusion technology began in the 1970s, with its earliest applications found in the military domain. Multi-sensor data fusion was proposed in the 1970s, and military applications served as the foundation for this technology's inception. Starting from the mid to late 20th century, rapid advancements in microelectronics, networking technologies, computing, and sensors led to significant changes in the fundamental characteristics of warfare worldwide. This paved the way for modern warfare models primarily centered around network-centric and information

warfare. In this context, both the number and types of sensors have been continuously increasing, thereby enhancing detection capabilities across time, frequency, and spatial domains. From around the 1970s onwards, multi-sensor data fusion technology garnered significant attention globally, culminating in a surge of research activity post-1990s. Military forces from various countries, major academic institutions, and numerous large corporations established laboratories to conduct research and testing on information fusion theories and algorithms. They developed information fusion systems and evaluated fusion algorithms. The application of data fusion technology has progressively expanded beyond military domains to various fields including energy, aerospace, automotive industries, and machine tools.

3. High-Pressure Power Distribution Devices for Mining

Mining high-pressure vacuum power distribution devices are suitable for environments such as underground coal mines where explosive gases (methane mixtures) may be present. These devices provide protection for three-phase AC power supply systems with a rated frequency of 50Hz, a rated voltage of 10kV or 6kV, and rated currents up to 630A that do not have their neutral points directly grounded. They safeguard against overloads, short circuits, ground faults (leakage), insulation monitoring issues, over-voltage, under-voltage, and three-phase imbalances; they can also be used for direct starting of high-voltage motors. As illustrated in Figure 1, mining high-pressure vacuum power distribution devices offer reliable and sensitive protection with high measurement accuracy. They feature a Chinese menu-based human-machine interface and include communication ports that enable networking between protective devices. These devices can display real-time equipment parameters, operational statuses, fault information, and more.

Figure 1. Mining high-pressure vacuum power distribution devices

4. Short-Circuit Test Data Fusion System

The data fusion system is designed to minimize the loss of information from all or individual sensors. From the perspective of the information flow between sensors and the fusion center, the structure of information fusion consists of four forms: parallel, serial, series-parallel hybrid, and networked. In a serial multi-sensor data fusion method, the information from two sensors is first fused together. The result of this fusion is then combined with data collected from another sensor, continuing this process sequentially until all sensor data has been fully integrated. When using a serial structure for fusion, each individual sensor not only has the capability to receive and process information but also possesses data fusion functionality. The data processed by each sensor is closely related to the output format of the preceding sensor. Ultimately, the last sensor synthesizes all output information from its preceding sensors, resulting in a conclusion for the serial structure fusion system.

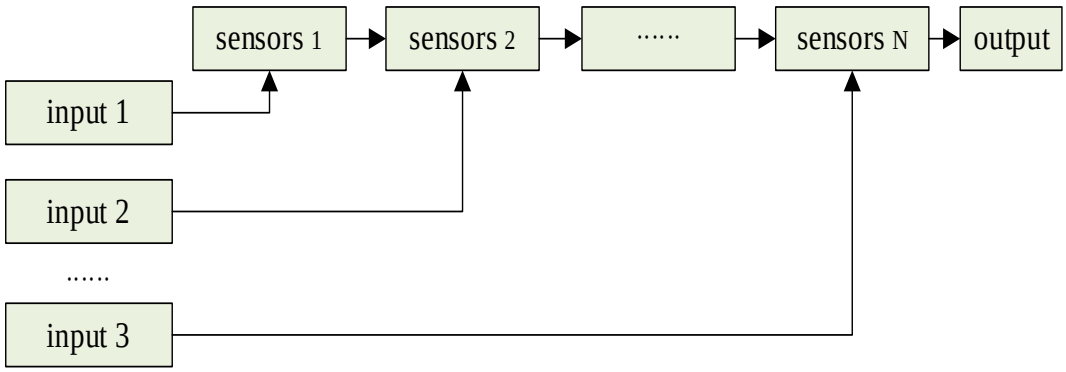

Figure 2. Parallel structure of data fusion

In contrast, parallel multi-sensor data fusion involves inputting the outputs from all sensors into the fusion center simultaneously. Each sensor operates independently, and the fusion processing center employs appropriate methods to comprehensively handle various types of data, ultimately producing a fused output result. Therefore, in parallel fusion scenarios, there is no mutual influence among the outputs of all sensors. The hybrid series-parallel structure combines both serial and parallel forms; it can either perform series integration followed by parallel integration or vice versa. The networked sensor information fusion structure is more complex, where each sub-data fusion center acts as a node within a network. Its inputs may include outputs from other nodes as well as direct sensor data streams. The final output can serve not only as an output for a specific fusion center but also for multiple centers, with conclusions derived from the combination of all outputs.

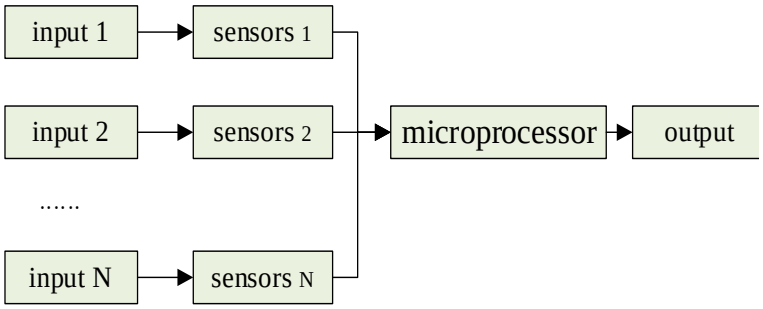

Figure 3 Parallel Structure of Data Fusion

For short-circuit testing of high-voltage vacuum distribution devices used in mining, signals that need to be collected include input voltage of the test system, input current of the test system, output voltage of the test system, environmental temperature, environmental humidity, and atmospheric pressure. Based on an analysis of different types of data fusion structures and considering the requirements for short-circuit testing of high-voltage vacuum distribution devices used in mining, a parallel structure has been adopted for this purpose. This is illustrated in Figure 4.

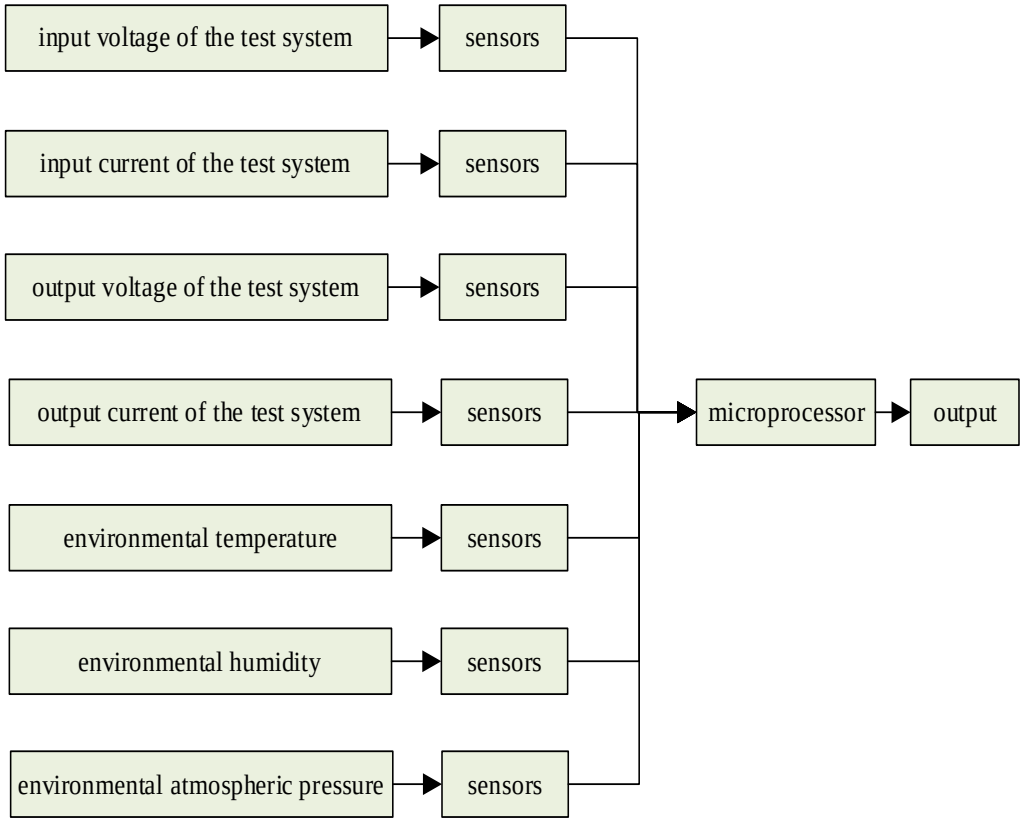

Figure 4. Data fusion structure of short-circuit test of mine high-voltage vacuum power distribution device

5. Conclusion

High-pressure power distribution devices used in mining serve a dual role of control and protection within the mining power grid. Short-circuit testing is a crucial method for validating the protective functions of these high-voltage distribution devices. Based on multi-data fusion technology, a parallel data fusion structure for short-circuit testing has been designed, enabling the integration of short-circuit test data for high-voltage vacuum distribution devices used in mining. This approach enhances the accuracy and reliability of data processing.

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