

# Design of a Safety Assessment System for Explosion-Proof Equipment in Coal Mines

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**Abstract.** Safety assessment is a crucial guarantee for the reliable operation of explosion-proof equipment in coal mines, as well as an important method for predicting the lifespan of such equipment. Based on an analysis of the safety production situation in coal mines and the significance of safety assessments for explosion-proof equipment, this paper proposes a relative wear method for safety assessment technology of switches used in explosion-proof equipment to enhance the safety of switches in coal mine explosion-proof equipment and provide a reference for the development of condition prediction technology for such equipment.

**Keywords:** Coal mine; Explosion-proof equipment; Wear method; Safety assessment.

## 1. Introduction

Coal accounts for over 90% of China's fossil energy resources, making it the most stable, economical, and self-sufficient energy source available. Although new energy sources such as natural gas, nuclear power, and wind energy are developing rapidly, coal's dominant position as an energy source will not change due to the characteristics of China's energy structure and its energy security strategy. Explosion-proof equipment in coal mines is vital for underground mining operations, gas extraction, transportation, drainage, and rescue efforts. The geological conditions in China's coal mining areas are complex, characterized by dark and humid environments with high levels of flammable and explosive gases and dust. Disasters such as gas explosions, rock bursts, fires, and water hazards occur frequently. Failures in explosion-proof equipment can lead to serious electromechanical accidents and gas explosions. Therefore, the safety of explosion-proof equipment is directly related to the smooth conduct of safe production activities in coal mines. The switches used in explosion-proof equipment include vacuum contactors, vacuum circuit breakers in Figure 1, isolating switches, and other components that connect and disconnect branch devices. In case of faults, these switches can instantaneously cut off faulty branches to provide protective functions.



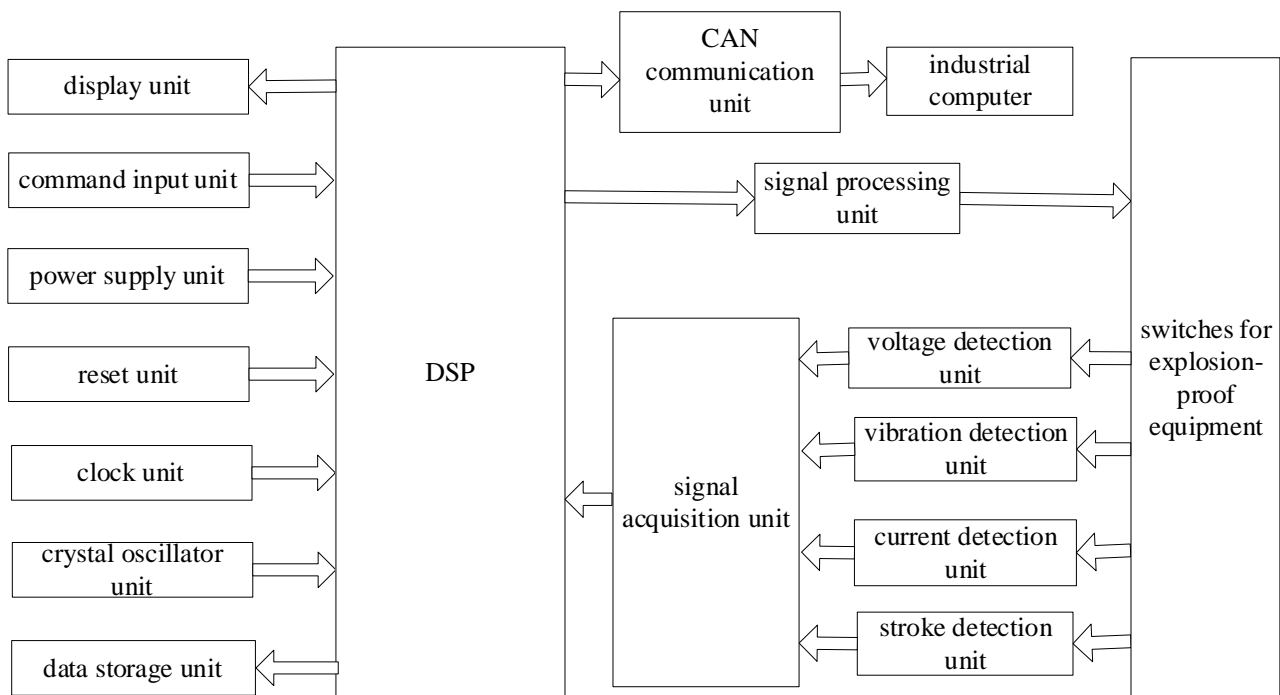
**Figure 1.** Vacuum circuit breaker for explosion-proof equipment in coal mine

Currently, safety management for switches in explosion-proof equipment primarily relies on regular maintenance and fault repairs, which somewhat ensures their safe operation. With the continuous advancement of intelligent mining technologies in China, there has been a significant

increase in both the types and quantities of electrical equipment used underground, especially with developments in intelligent and unmanned technologies which raises higher demands for the safety of underground power supply systems and switch devices. The operational status of these switches is directly related to the successful execution of safe production activities underground. Existing safety assurance technologies for switches in explosion-proof equipment can no longer meet the rapid development needs of coal mines; therefore, conducting research on safety assessment technologies for these switches is highly significant.

## 2. Safety Assessment Method

The safety assessment of switches in explosion-proof equipment for coal mines using the relative wear method primarily consists of a display unit, command input unit, power supply unit, reset unit, clock unit, crystal oscillator unit, DSP (Digital Signal Processor), signal conversion unit, switches for explosion-proof equipment, signal processing unit, current detection unit, signal acquisition unit, stroke detection unit, voltage detection unit, vibration detection unit, CAN communication unit, industrial computer, and data storage unit. In this system, the signal input terminal of the display unit is connected to the display signal output terminal of the DSP. The signal output terminal of the control unit is connected to the control signal input terminal of the DSP. The signal output terminals of the power supply unit, reset unit, clock unit, and crystal oscillator unit are connected to the corresponding terminals on the DSP for power supply connection, reset signal connection, clock signal input connection, and crystal oscillator signal input connection. The control signal output terminal of the DSP connects to the signal input terminal of the signal conversion unit. The output terminal of the signal conversion unit is linked to the control signal input terminal of the explosion-proof equipment switches. The current detection unit's testing terminal connects to the current testing point of the switches; similarly, the voltage detection unit's testing terminal connects to the voltage testing point. The vibration detection unit's testing terminal connects to the vibration signal testing point of the switches, while the stroke detection unit's testing terminal connects to the stroke signal testing point. The output terminals of the current detection unit, voltage detection unit, stroke detection unit, and vibration detection unit connect to the input terminals of the signal acquisition unit. The output terminal of the signal acquisition unit connects to the voltage, current, stroke, and vibration signal input terminals on the DSP. The communication signal port of the industrial computer is connected through a CAN communication unit to the communication port of the DSP. Lastly, the input terminal of the data storage unit connects to the storage signal output terminal of the DSP. The structure of the safety assessment system for switches in explosion-proof equipment using relative wear methods is illustrated in Figure 2.



**Figure 2.** The structure of the safety assessment system for switches in explosion-proof equipment using relative wear methods

The safety assessment technology for switches in explosion-proof equipment for coal mines using the relative wear method is based on the inverse relationship between contact wear and safety (Figure 3). Each interruption of current causes wear on the contacts, which is analyzed in conjunction with the stroke and vibration signals during the switching process of the explosion-proof equipment. The expected wear of the contacts in explosion-proof switches is characterized by the thermal energy generated from its electrical life cycles and rated current, with the calculation method as follows:

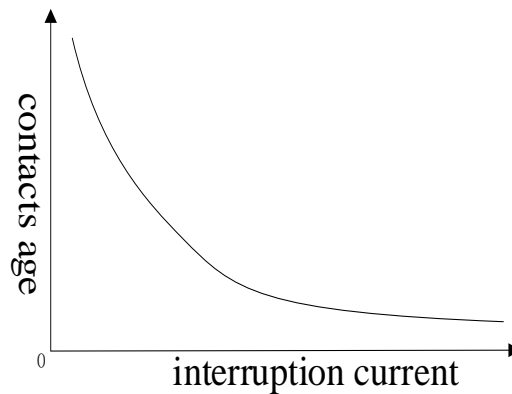
$$M_z = N \times I_e^2 \tag{1}$$

Where  $M_z$  represents the expected wear of the contacts in explosion-proof switches,  $N$  is the number of electrical life cycles, and  $I_e$  is the test current for electrical life.

The actual wear of the contacts in explosion-proof switches is calculated based on the number of interruptions and the interruption current, using the following formula:

$$M_s = T \times I_s^2 \tag{2}$$

Where  $M_s$  represents the actual wear of the contacts in explosion-proof switches,  $T$  is the number of interruptions, and  $I_s$  is the actual interruption current.



**Figure 3.** Breaking current and life curve of switch for explosion-proof equipment in coal mine

In the safety assessment process using the relative wear method for switches in explosion-proof equipment, two parameters, stroke and vibration, are introduced to identify safe operating conditions. Before putting an explosion-proof switch into operation, ten tests are conducted to measure stroke and vibration signals, from which expected values are calculated as follows:

$$L = \frac{L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L_8 + L_9 + L_{10}}{10} \quad (3)$$

Where L denotes the expected stroke of the explosion-proof switch, and  $L_1, L_2, L_3, L_4, L_5, L_6, L_7, L_8, L_9, L_{10}$  are actual measured stroke data.

$$A = \frac{A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 + A_9 + A_{10}}{10} \quad (4)$$

Where A indicates the expected vibration level of the explosion-proof switch, and  $A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9, A_{10}$  are actual measured vibration data.

Due to factors such as accumulated tolerances during operation and measurement accuracy from both stroke detection and vibration detection units, there may be some deviations in these two parameters. Therefore, during the safety assessment process using relative wear methods for switches in explosion-proof equipment, safety value ranges for stroke and vibration are set between 0.85 to 1.1 times their expected values. When either parameter exceeds this safety value range, a warning is triggered to indicate that maintenance should be performed on the explosion-proof switch.

### 3. Conclusion

Intelligentization and high reliability are the key development directions for explosion-proof equipment in coal mines. By utilizing the inverse relationship between the lifespan of switches in explosion-proof equipment and the number of current interruptions, a safety assessment system for such equipment has been designed. The introduction of stroke detection and vibration detection has enhanced the reliability of the system, thereby improving the safety of explosion-proof equipment in coal mines and ensuring a secure environment for safe production activities.

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