# Design of Test System for Arcing Time of Air-Type Switch for Explosion-Proof Electricity in Coal Mine

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**Abstract.** In order to improve the accuracy of testing the arcing time of air-type switch for explosion-proof electrical use in coal mine, this paper puts forward the testing technology of coexistence characteristics of voltage and current. On the basis of analyzing the leading position of coal industry in energy structure and the situation of coal mine safety production, this paper expounds the generation mechanism and the theory of arc suppression of air-type switch used in coal mine explosion-proof electricity, and designs a test system for the arcing time of air-type switch used in coal mine explosion-proof electricity, which can effectively test the arcing time.

**Keywords:** Coal Mine; Explosion-Proof Electrical; Air Type Switch; Arc Time.

## 1. Introduction

Coal is the main source of energy in China, but also a safe and reliable energy. Promote the revolution in energy production and consumption, to hold the important energy domestic production of self-sufficient strategic bottom line, effective protection of national energy security, is an inevitable requirement for the construction of an energy power. From the production point of view, China has formed a multi-wheel energy supply system driven by coal, oil, gas, nuclear, new energy and renewable energy, focusing on both improving the energy self-sufficiency rate and giving priority to the development of non-fossil energy. From the consumption point of view, China has established and improved the energy consumption intensity and the total amount of dual control degree, the energy-saving indicators into the ecological civilization, green development and other performance evaluation index system, to promote energy consumption structure to clean and low-carbon to accelerate the transformation.

In recent years, under the combined influence of factors such as intelligent mining and safety monitoring in coal mines, China's coal mine safety situation has improved year by year. In 2021, there were 91 accidents and 178 deaths in coal mines, down 26% and 21.9% respectively, and the coal mine death rate per million tons fell to 0.044, down 24% year on year. However, with the increase of coal mining intensity and depth, the underground production environment is intricate and complex, and the work of coal mine safety production is still severe. Electromechanical accidents have become one of the main accidents that endanger the safe production of coal mines, while the electric sparks generated by electromechanical accidents are also the main cause of gas explosions. Coal mine explosion-proof electrical, including underground power distribution equipment, electrical equipment, monitoring equipment, rescue equipment and other underground mechanical and electrical equipment, which play a pivotal role in the safe production of coal mines.

## 2. Coal Mine Explosion-Proof Electric Apparatus

Coal mine explosion-proof electrical apparatus means that the electrical equipment used in the explosive environment of the coal mine will take certain safety measures so that the electric sparks generated in its operation do not detonate the explosive mixture in the surrounding environment. In the design, production and inspection of coal mine explosion-proof electric apparatus, the

requirements of GB/T 3836 explosive environment series national standards must be followed. Explosion-proof electrical explosion-proof types in coal mines include explosion-proof type, intrinsic safety type, pouring and sealing type, etc., which are mainly used to prevent internal electric spark from igniting external explosive mixture. Air switch is the main isolation and fail-safe breaking component in coal mine explosion-proof electrical system, and it belongs to class C controlled item that can't be changed at will in safety standard management system. National standards and industry standards put forward clear requirements for the breaking capacity of air-type switches, generally breaking the rated working current at the rated working voltage. In the product type test of coal mine explosion-proof electric apparatus, the air-type switch must meet the technical requirements of breaking test. Arc time is an important index to measure the breaking performance of air-type switch.

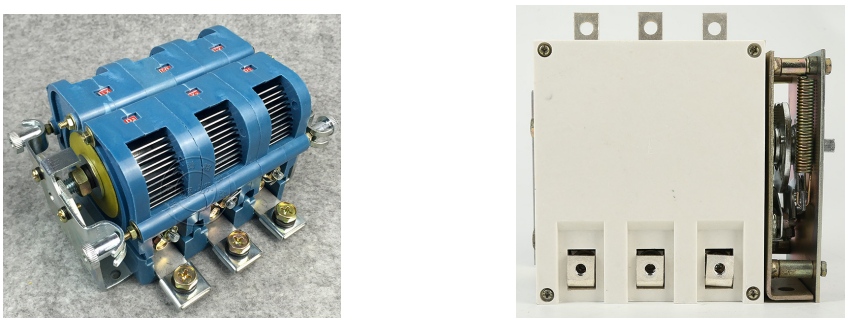


**Fig 1.** Physical drawing of air-type switch products for explosion-proof electricity in coal mine

## 3. Air-type Switch Arc Generation Mechanism

Under ideal conditions, that is, no external factors, and air temperature, humidity and other parameters are in the normal state of the gas (air) can be regarded as the ideal insulation medium. When a voltage is applied to the electrode for a certain time, no current flows through the gas in the insulation gap. When the electrode voltage is increased to a certain value, the gas between the electrodes will lose its insulating property, which will lead to a sharp increase in the current between the electrodes, and the gas will change from the insulating state to the conductive state. This process is called gas breakdown. When the discharge current increases to a certain value, the discharge channel will obviously become thinner, and the discharge channel will become brighter and brighter, and the voltage drop in the discharge gap will decrease, which indicates that the resistance of the discharge channel is getting smaller and smaller, while the conductance of the discharge channel is getting bigger and bigger. At this time, the discharge will enter the arc discharge process.

When the air-type switch for coal mine explosion-proof electricity breaks the current, the gap voltage and current of the fracture are much larger than the critical value of arc, and the existence of arc will affect the breaking characteristics and other performance indexes of the air-type switch for coal mine explosion-proof electricity. Testing the arcing time of air-type switch used in coal mine explosion-proof electricity is also an important index of pilotscale experiment and type test in the process of related product development. From the point of view of heating, the arc can be regarded as a purely resistive heating element, and its consumed electric power $P_{\mathrm{h}}$ can be expressed as:

$$P_{\mathrm{h}} = I_{\mathrm{h}} U_{\mathrm{h}} = I_{\mathrm{h}} \left( U_0 + U_{\mathrm{z}} \right) \tag{1}$$

Where $I_{\mathrm{h}}$ is the arc column current, $U_0$ is the sum of the voltage drops near the cathode and near the anode, and $U_{\mathrm{z}}$ is the arc column voltage drop.

The formula (1) shows that the arc consumption power $P_{\mathrm{h}}$ is the sum of the power consumed by the near cathode, near anode and arc column. The power loss of the arc will be transferred to the surrounding medium by heat dissipation, which will lead to the increase of the arc temperature. There are three ways of arc heat dissipation to surrounding media: conduction, convection and radiation. The total arc heat dissipation power $P_{\mathrm{s}}$ can be expressed as:

$$P_s = P_{cd} + P_{dl} + P_{fs} \tag{2}$$

In which, $P_{cd}$ is conduction heat dissipation power, $P_{dl}$ is convection heat dissipation power and $P_{fs}$ is radiation heat dissipation power.

If $P_h \rangle P_s$, then $W_Q$ gradually increases, the arc temperature tends to increase, and the diameter of arc column will expand, that is, the arc combustion tends to be hotter; If $P_h \langle P_s$, then $W_Q$ decreases gradually, the arc temperature decreases gradually, and the diameter area of arc column shrinks continuously, that is, the arc tends to go out; If $P_h = P_s$, then $W_Q$ remains unchanged, and the arc temperature and diameter remain unchanged, that is, the arc is in a stable combustion state.

Therefore, the essence of whether the air-type switch arc used in coal mine explosion-proof electricity can really extinguish is whether the arc gap can bear the effect of arc gap recovery voltage without arc reignition after the current crosses zero. After the AC arc current crosses zero, there are two interrelated physical processes in the arc gap: the dielectric strength recovery process and the arc gap voltage recovery process. If the recovery process of arc gap dielectric strength is faster than the recovery process of arc gap voltage, that is, the recovery strength of arc gap dielectric is always greater than the recovery voltage of arc gap at any moment, the arc will not reignite and go out. On the contrary, if the recovery voltage of the arc gap is higher than the dielectric recovery strength of the arc gap at a certain moment, the arc will reignite. The arc extinguishing conditions of air-type switch for explosion-proof electricity in coal mine are as follows:

$$u_{jf}(t) \rangle u_{hf}(t) \tag{3}$$

Where $u_{jf}(t)$ is the dielectric recovery strength of the arc gap and $u_{hf}(t)$ is the recovery voltage of the arc gap.

## 4. Arc Time Testing System

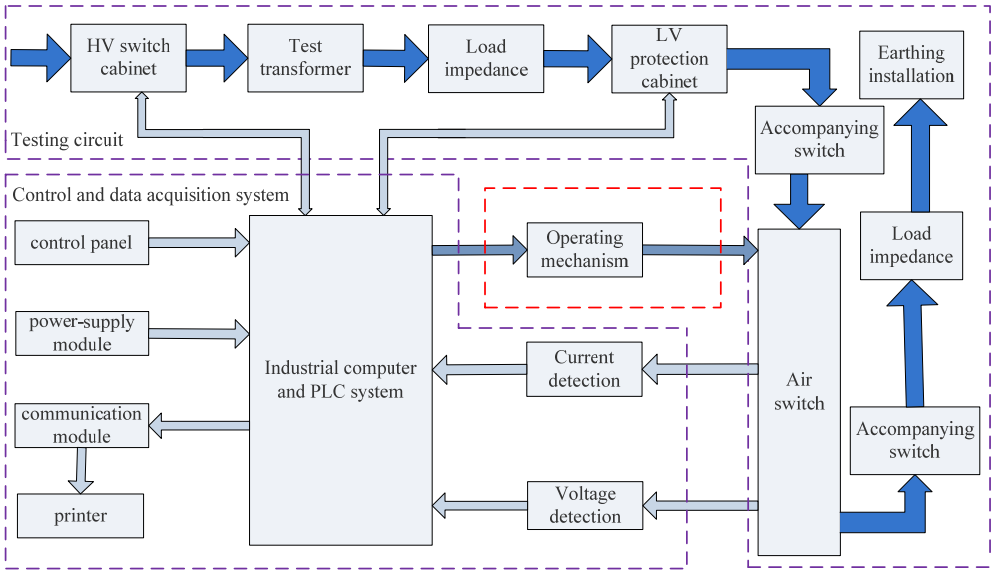



**Fig 2.** Structure diagram of arc time test system of air-type switch used in explosion-proof electricity of coal mine

The arc time test of air-type switch for explosion-proof electricity in coal mine belongs to the process of instantaneous operation and variable load. The external operating mechanism is used to provide driving force for the breaking process, so as to realize the effective control of the breaking process. According to the requirements in the test of connecting and breaking capacity in 8.3.3.5 of GB 14048.1-2012 Low-Voltage Switchgear and Control Equipment, a test system for the arcing time

of air-type switch for explosion-proof electricity in coal mine is designed, as shown in Figure 2. The test system for the arcing time of air-type switch used in coal mine explosion-proof electricity is divided into three parts: test circuit, control and data acquisition system and operating mechanism. The test circuit provides current for the test. The control and data acquisition system reasonably controls the whole test process, and realizes the acquisition, processing, display and storage of voltage and current data. The operating mechanism provides operating force for the breaking of air-type switch used in coal mine explosion-proof electricity.

The arc burning process of the air-type switch breaking test for explosion-proof electricity in coal mine occurs at the later stage of the test, and the voltage and current exist simultaneously in the arc burning process. The breaking test of air-type switch for explosion-proof electricity in coal mine uses the coexistence characteristics of voltage and current to test the arcing time. The relationship curve between breaking voltage and current of air-type switch for collecting explosion-proof electricity in coal mine is shown in Figure 3. It can be seen from Figure 3 that the voltage and current exist for about 11ms at the same time, and the arcing time of the air-type switch for explosion-proof electricity in coal mine is 11 ms.

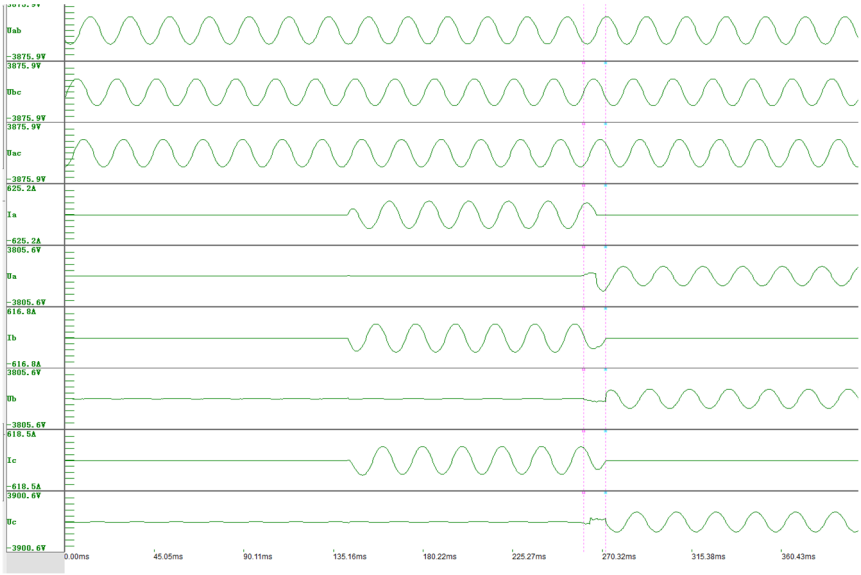



**Fig 3.** Curves of breaking voltage and current by air type switch for coal mine explosion-proof electric

## 5. Conclusion

In order to improve the reliability of arc time test of air-type switch for explosion-proof electricity in coal mine, We propose a technique for testing the arc-burning time based on the characteristics of coexistence of voltage and current, built a test system to test the arc-burning time of air-type switches for coal mine explosion-proof electrical use, which improved the testing accuracy of air-type switches for coal mine explosion-proof electrical use breaking test and promoted the sustainable and healthy development of coal mine explosion-proof electrical testing and inspection industry, set up a test system to test the arcing time of the air-type switch for coal mine explosion-proof electrical equipment, improve the test accuracy of the breaking test of the air-type switch for coal mine explosion-proof electrical equipment and promote the sustainable and healthy development of the coal mine explosion-proof electrical inspection industry.

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