Research on Short Time Withstand Current Electrodynamic Analysis and Inspection Technology of Mine High Voltage Distribution Device

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Abstract. In this paper, combined with the situation of coal mine safety production in China, the use environment and mechanical interlocking function of mining high-voltage distribution equipment are introduced in detail, the short-circuit fault hazards and the working principle of short-circuit protection are analyzed, and the technical requirements for short-time withstand current capability test are put forward in combination with industry standards. The short-time withstand current capability test system of mining high-voltage distribution equipment is designed, and the working principle of Roche coil current transformer is studied.

Keywords: Mine use, High voltage distribution equipment, Short-term resistance to current, System design, Roche coil.

1. Introduction
In recent years, under the guidance of national safety production policy, scientific and technological progress and other comprehensive factors, China's coal mine safety production forms have improved year by year, and the total number of accidents and the death rate per million tons have shown a downward trend. However, the hidden dangers of accidents that threaten the safety of underground production cannot be completely eradicated in a short time, and the situation of coal mine safety production is still not optimistic. With the increase of underground mining depth and the development of comprehensive mechanized mining technology, the types and quantities of underground electromechanical equipment are increasing, and electromechanical accidents have become one of the important accidents threatening underground safety production. At the same time, electromechanical accidents can also cause secondary accidents such as gas explosion and transportation. It has become a hot research topic in the field of coal mine safety to carry out research on safety characteristics and safety performance detection technology of electromechanical equipment and improve the safety and reliability of underground electromechanical equipment.
2. Mine high voltage power distribution device

Mine high-voltage power distribution device is suitable for the environment with explosive mixture gas such as methane and coal dust in coal mine and its surrounding medium. It is generally used in central substation or distribution room in coal mining area of coal mine in three-phase power network with 50Hz AC, 6kV or 10kV voltage and 50 A ~ 630A current and ungrounded neutral point, and is used as power receiving, feeding, contacting and controlling high-voltage motor and transformer. The mine high-voltage power distribution device has the functions of overload, short circuit, voltage loss, overvoltage, leakage, insulation monitoring, etc., and can realize remote closing and remote opening through communication lines. The operating environment of mine high-voltage power distribution device is no more than 1000m above sea level, the ambient temperature is -5℃ ~ +40℃, the relative humidity is no more than 95% (25℃), and there is no severe impact, vibration and dripping water. Mine high-voltage power distribution equipment has interlocking function in mechanical structure, and the front of explosion-proof housing is a quick-opening structure, with an observation window and an illuminating lamp for opening and closing the isolating switch. Mine high-voltage distribution equipment has interlocking function. When the isolating bolt is in the closing position, the door cannot be opened; when the circuit breaker is in the closing position, the isolating bolt cannot be opened or closed. The physical objects of mining high-voltage distribution equipment are shown in Figure 1.

![Figure 1. High-voltage power distribution device for mining.](image)

3. Rated short-time withstand current capability

3.1. Short circuit protection

Over-current protection is one of the three major protections for coal mine electrical equipment. Over-current means that the current flowing through mine high-voltage distribution equipment exceeds its rated value. There are many causes of over-current in coal mine, such as short circuit, overload and single-phase operation of motor. Long-term over-current operation of mining high-voltage distribution equipment will lead to excessive temperature rise, resulting in damage to insulation structure and even serious accidents. Therefore, mining high-voltage distribution equipment must have over-current protection function. Overcurrent protection generally includes short-circuit protection and overload protection, but short-circuit protection is the main form of overcurrent protection. Short circuit protection means that the protector monitors the working current of mine high-voltage power distribution device in real time. If it is greater than the setting multiple of rated current (set according to the actual demand), the protector sends action signal to drive the mining high-voltage power distribution device to stop working, so as to avoid safety production accidents. The action time of protector is usually set as millisecond action according to the working condition demand. At the same time, it is required that the mining high-voltage distribution device must be able to withstand the current impact within the short-circuit protection action time, without contact fusion welding, mechanical deformation and other faults that damage the mining high-voltage power distribution device, and even cause other safety production accidents.
3.2. Analysis of short circuit fault condition
When short-circuit fault occurs in mine high-voltage distribution equipment, the short-circuit current exceeds the rated current of the line many times, and may reach tens of thousands to hundreds of thousands of amperes. The huge electrodynamic effect and thermal effect produced by short-circuit current will cause conductor deformation, insulation damage, electrical components damage, and even cause fire, gas explosion and other accidents. In order to improve the reliability and safety of mining high-voltage distribution equipment, the national standards and industry standards stipulate that short-time withstand current capability test must be carried out during product type test. The rated short-time withstand current capability test is to check whether the internal devices and terminals of the mining high-voltage distribution equipment have the capability to withstand large current when the output end of the equipment is short-circuited during operation. The main difference between rated short-time withstand current capability test and short-circuit switching-on and switching-off capability test is that there is no need to cut off the test line by mining high-voltage distribution equipment, but other equipment is artificially controlled to cut off the power supply.

When the short-circuit fault current passes through the mining high-voltage distribution equipment, it will produce electrodynamic effect and thermal effect, which will act on the mining high-voltage distribution equipment at the same time, and the destructive effects of these two effects on the mining high-voltage distribution device are interrelated. The repulsive force produced by the electrodynamic effect between the dynamic and static contacts of the circuit breaker in the mine high-voltage distribution device increases the contact resistance of the contacts, thus increasing the heating and thermal effect of the contacts. Thermal effect acts on the current-carrying parts of mining high-voltage distribution equipment, which reduces its mechanical strength, thus reducing its ability to withstand electromotive force.

When short-circuit fault occurs in mine high-voltage distribution equipment, the short-circuit current passes through the contact point of the moving and static contacts, and the current line will shrink near the contact surface, which will cause the electromotive force between the contacts under the action of their own magnetic field. If the current line is regarded as an element current-carrying conductor, the electromotive force of each element conductor is perpendicular to the current line, and the electromotive force is decomposed into horizontal and vertical directions. Because the current lines are symmetrically distributed in the horizontal direction, the horizontal components cancel each other out. The two force components in the vertical direction of the contact surface are in opposite directions, and the interaction between them constitutes the electric repulsion force between the contacts. The electric repulsion between contacts of mining high-voltage distribution equipment is proportional to the square of contact current. When the short-circuit fault current passes through the contacts, the short-circuit current of several thousand amperes will produce great electric repulsion between contacts. When the electric repulsion force is greater than the contact pressure, the contacts will be separated and an arc will be generated. The high temperature action of the arc will cause serious burning loss or welding of the contacts, and even lead to the damage of the mine high-voltage distribution device and the occurrence of coal mine safety production accidents.

3.3. Test requirements for short-time withstand current capability
In the short-time withstand current capability test of mining high-voltage distribution equipment, except for the different peak currents in the first cycle of each phase, if the maximum peak current in the first cycle occurs in the middle phase or the side phase (either side phase), the comprehensive electromotive force generated by the current is different. When the maximum peak current of the first cycle appears in the intermediate phase, the maximum electric force will be generated on the pole of the high-voltage distribution device, and the electric force is much larger than that when the maximum peak current appears on the side phase in the first cycle. Therefore, the short-time withstand current test adopts the mode of phase selection and closing, and the maximum peak current is respectively added to each phase of the mining high-voltage distribution device for examination in turn. After the test, the contacts of mine high-voltage distribution device shall not be fused, the mechanical parts and
insulating parts shall be free from damage and deformation, and the normal operation mode shall be able to reliably open and close.

The test of rated short-time withstand current capacity should be carried out on intact high-voltage distribution equipment for mining, and the tightening torque of screws on terminals should meet the national standards and product requirements. The mine high-voltage distribution equipment shall be connected completely according to the normal use conditions, and the no-load operation shall be carried out several times before the test.

4. Experimental system design

Mechanical standard JB/T 8739-2015 "Flameproof High Voltage Distribution Equipment for Mine" stipulates that rated short-time withstand current test is a test item that must be carried out in type test, and specific requirements are made for technical requirements and test methods according to equipment current grade. The test transformer, protection cabinet and current regulating device constitute a short-circuit fault current circuit for short-time withstand current capability test of mining high-voltage distribution equipment, and the current signal collected by Rogowski coil current transformer in the test process is fed back to the industrial computer after passing through the data acquisition system. The current control of short-term withstand current capability test is carried out through console control button and option switch. The voltage transformer tests the system voltage and feeds back to the instrument on the console for voltage data display. The protection cabinet has the function of overload, short circuit and other fault protection to realize the fault detection and protection of the whole test system. The structure diagram of short-time withstand current test system for mining high-voltage distribution device is shown in Figure 2.

![Figure 2](image-url)

**Figure 2.** The structure of the short-term withstand current capability test system for mine high-voltage power distribution devices.

The maximum current of the short-time withstand current capability test system of mine high-voltage distribution equipment reaches several hundred thousand, and the conventional current transformer can't measure large current, so Roche coil current transformer is used to test the system current. Rogowski coil current transformer is made according to ampere's loop law and electromagnetic induction law. It is an annular coil wound evenly on non-ferromagnetic material, without hysteresis effect and magnetic saturation phenomenon, and its phase error is almost zero. The output signal of Rogowski coil current transformer is the differential of current to time. The current signal can be restored by integrating the output signal. The measurement range is from Ma to WAN. The working environment temperature of Rogowski coil current transformer is between -20°C and +50°C, and the test current frequency is between 45Hz and 70Hz. The Rogowski coil current transformer is shown in Figure 3.
5. Conclusions
In order to assess the short-time current tolerance of mining high-voltage distribution equipment under short-circuit fault, a short-time current tolerance test system was designed, which realized the short-time current tolerance test of mining high-voltage distribution equipment, improved the safety and stability of mining high-voltage distribution equipment, and provided a technical verification platform for the detection and inspection technology of mining electrical equipment.

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