Design of the Test System for the Ability to Withstand the Overload Current of the Low Voltage Control Equipment Applied in Coal Mines

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Abstract. On the basis of the development prospect of energy industry and the safety production situation of coal mine, the composition structure and working principle of low-voltage control equipment applied in coal mines were analyzed, and the electric power and thermal effect theory of low-voltage control equipment applied in coal mine were studied, and the design scheme of overload resistance test system was put forward, meanwhile, the flameproof electromagnetic starter for coal mines was tested according to the coal industry standard. The test results show that the design of the overload tolerance is reasonable.

Key words: Coal Mine; Low Voltage Control Equipment; Overload Current Tolerance; System Design.

1. Introduction

Coal mine is the principal part of energy production and consumption in China. In recent years, although solar energy, nuclear energy, water energy and biomass energy technologies continue to develop, the principal position of coal will not change in the short term. In 2019, China's total coal output was 3.85 billion tons, with a year-on-year increase of 4.8 billion tons. China's total energy consumption amount was 4.86 billion tons of standard coal, with a 1% increase in coal consumption, accounting for 57% of the total energy consumption. In the ‘13th five-year’ plan for the development of coal industry, the National Development and Reform Commission as well as the National Energy Administration pointed out that by 2020 the proportion of non-fossil energy consumption is about 15%, and the proportion of natural gas consumption is approximately 10%, and the proportion of coal consumption is around 58%.

With the continuous progress of comprehensive mechanized coal mining technology and coal mine disaster management technology vigorously promoted in China, the situation of coal mine safety production has been improved year by year, and the total number of accidents and the death rate of one million tons have been declining, and the death rate in million-ton level coal mines in 2019 is 0.083, decreasing by 10.8%. However, the safety production environment of coal mine is complex, as the mining intensity and depth are increasing, and the underground power supply lines are increasing, the
power grid voltage is fluctuating greatly as well, meanwhile, the combustible gas content is high, dark
and humid environment and other factors are combined, resulting in the fact that underground safety
production situation is still severe. Coal mine low-voltage control equipment is an important equipment
of underground power system, which plays a dual role of control and protection in underground power
grid. Therefore, it is of singular significance to study the testing technology of the ability of coal mine
low-voltage

2. Coal mine low pressure control equipment
The low-voltage control equipment in coal mine mainly includes mine flameproof electromagnetic
starter, mine flameproof multi circuit combined switch, mine flameproof tunneling machine control box,
mine flameproof iron remover electric control box. The mine flameproof electromagnetic starter is
shown in Fig. 1. The low-voltage control equipment of coal mine is used in the mine with explosive gas
(methane) and coal dust, in the line with AC 50Hz voltage of 1140V, 660V and 380V three-phase central
point ungrounded, the local control or remote control three-phase asynchronous motor start, stop and
fault protection can be realized, and the reversing can be carried out during shutdown. The electrical
structure of low-voltage control equipment in coal mine is usually composed of isolation reversing
switch, low-voltage AC contactor, control transformer, electronic protector, transformer, display screen,
control button, etc. The isolation reversing switch plays the role of power isolation, no-load reversing
and breaking fault current when the low-voltage current contactor fails to operate. The low-voltage AC
contactor receives the signal of electronic protector to connect or cut off the branch circuit, and at the
same time cut off the branch current in case of short circuit, overload and other faults. The electronic
protector is the core of the whole low-voltage control equipment in the coal mine, which is used to
receive the signal of control button, transformer signal and other signals, controlling the start and stop
of the low-voltage control equipment in the coal mine, and comparing with the safety parameters, with
the function of protection and display after faults.

Figure 1. Mining flameproof electromagnetic starter

3. Ability to withstand overload current
The ability to withstand the overload current is an essential test item in the type test of low-voltage
control equipment in coal mines, which is used to assess its ability to withstand the electric power and
thermal effect formed by the large current in a short time without damage in case of short-circuit fault
and overload fault (without breaking the line). When the coal mine low-voltage control equipment
controls the coal mine flameproof motor (cage type) to start directly, the starting current is large,
generally more than 6 times of the rated working current, and the current returns to the rated value after
normal operation. When short circuit fault occurs in the operation of low-voltage control equipment in
coal mine, the protector needs to act quickly and cut off the fault branch within a few seconds or milliseconds. The coal mine low-voltage control equipment used to control and protect the motor shall be able to withstand the electric power and thermal effect caused by the large current in a short time.

As there is a magnetic field around the conductor with current, and the current carrying conductor in the magnetic field is subject to the action of mechanical force, the force generated by the presence of current in the conductor is usually called the electric force between conductors. The schematic diagram of electric power between conductors is shown in Fig. 2. When the current passes through the contact point of the contact, due to the contraction of the current line near the contact surface, the electric power will be generated between the contacts. The force generated by the contact current under the action of its own magnetic field is usually called the electric power of the contact. The repulsion force produced by the electrodynamic effect between the moving contact and the static contact of the low-voltage AC contactor used in the low-voltage control equipment of the coal mine increases the contact resistance, thus increasing the heating of the moving contact.

![Figure 2. Schematic diagram of electric power between conductors](image)

4. Test system design
The national standard GB 14048.4-2010 "low voltage switchgear and control equipment - Part 4-1: contactors and motor starters" and the coal industry standard MT/T 111-2011 "mine explosion-proof low voltage AC vacuum electromagnetic starters" clearly stipulate the test conditions, technical requirements and test methods for withstand overload current capacity. The simulation method is applied to test the ability of coal mine low-voltage control equipment to withstand overload current. The large current generating device composed of voltage regulating power supply and multi magnetic circuit transformer provides the simulation test current for the test line. The equipment of different current levels is tested by adjusting the test current output. The test system for the capacity of coal mine low-voltage control equipment to withstand overload current mainly consists of large current generating device, current transformer, voltage transformer, time relay, operation platform, display unit, etc., and the system structure diagram is shown in Fig. 3.

![Figure 3. Mining test system structure for the capacity of low-voltage control equipment to withstand overload current](image)
4.1. Current transformer
The current is the main parameter of the test system of the ability to withstand the overload current of the low-voltage control equipment in the coal mine, and its measurement accuracy is directly related to the accuracy and reliability of the system. The high-precision Hall current transformer is selected to test the current. The core of the current transformer is made of high permeability soft magnetic material, which is heat-treated for high temperature protection. The primary and secondary coils are wrapped with high-strength polyester enameled wire, and wrapped with low absorption insulating material. The surface of the coil is covered with paint, and the lead end conducting rod has enough contact area to ensure stable performance, safe and reliable operation. The maximum range of current transformer is 10000A (with multiple ranges for selection), and the test accuracy is class 0.2, and the operating environment temperature is -5 ~ +40 °C, and the working frequency is AC 50Hz. The current transformer is shown in Fig. 4.

![Current transformer](image1)

**Figure 4.** Current transformer

4.2. Operation platform
The operation platform is used to control the input and removal of the test circuit current, with the function of the circuit fault protection, as shown in Fig. 5. The input voltage of the operation console is 380V, and 380V voltage is output through the circuit breaker and AC contactor to provide working power for the voltage regulating power supply. The output signal of the auxiliary contact on the AC contactor on the operation platform is connected with the time relay to provide the electrical signal for the duration of the test current. The control button on the operation platform is connected with the control coil of the AC contactor to inform the button signal to control the start and stop of the whole test system.

![Operation platform](image2)

**Figure 5.** Operation platform
5. Overload current withstand capacity test

In order to verify the effectiveness of the designed test system, QBZ-200 / 1140 (660) mine flameproof electromagnetic starter is selected as the test object, and the circuit connection is conducted according to the requirements of national standards and industry standards. The working voltage of mine flameproof electromagnetic starter is 1140V and 660V, and the working current is 200A. According to the requirements of coal industry standard MT / T 111-2011 "mine explosion-proof low voltage AC vacuum electromagnetic starter", the test current of overload current withstand capacity is 1600 A, and the power on time is 10s. The input voltage as well as the input voltage of the voltage regulating power supply is 380V, and the output current of the test circuit as well as the output current of the high current generator is 1600A. The range of current transformer is 2000 A.

Several times of no-load operation of mine flameproof electromagnetic starter before inspection, and the start and stop functions were normal. The short-circuit protection and overload protection functions of the electronic protector of the mine flameproof electromagnetic starter are closed. If the protector does not have the short-circuit protection and overload protection closing functions, the setting parameters of the protector need to increase until the overload current withstand test and inspection are not affected. The current output of the test bench was controlled about 1600A and the current duration is about 10s, which proves the rationality of the experimental system design.

6. Conclusion

In order to check the ability of low-voltage control equipment in coal mine to bear electric power and thermal effect in case of faults, a test system for the ability to withstand overload current was designed. Through the test and inspection of mine flameproof electromagnetic starter, the rationality and effectiveness of the design scheme of the system were proved, which provides a test and verification platform for the development of detection and inspection technology of mine electrical equipment.

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