

# Research on Leakage Protection Test Technology of Coal Mine Explosion-Proof Electric Appliances

Zhe Ju<sup>1, 2, 3</sup>, Hongkui Zhang<sup>1, 2, 3, \*</sup>

<sup>1</sup> CCTEG Shenyang Research Institute, Fushun, CO 110178, China

<sup>2</sup> State Key Laboratory of Coal Mine Safety Technology, Fushun, CO 110178, China

<sup>3</sup> Fushun CCTEG Inspection Center Co. Ltd, Fushun, CO 110178, China

\* Corresponding Author Email: 18940021505@126.com

**Abstract.** Leakage protection is an important project for the type testing and factory inspection of explosion-proof electrical equipment in coal mines, serving as a crucial indicator for assessing product safety. Based on an analysis of the current state of leakage protection testing technology for coal mine explosion-proof electrical equipment, a leakage protection testing system has been designed. This system details the processes for leakage lock testing and leakage unlock testing, providing a reference for the development of intelligent testing technology for coal mine explosion-proof electrical equipment.

**Keywords:** Coal mine, explosion-proof electrical equipment, PIC, leakage protection.

## 1. Introduction

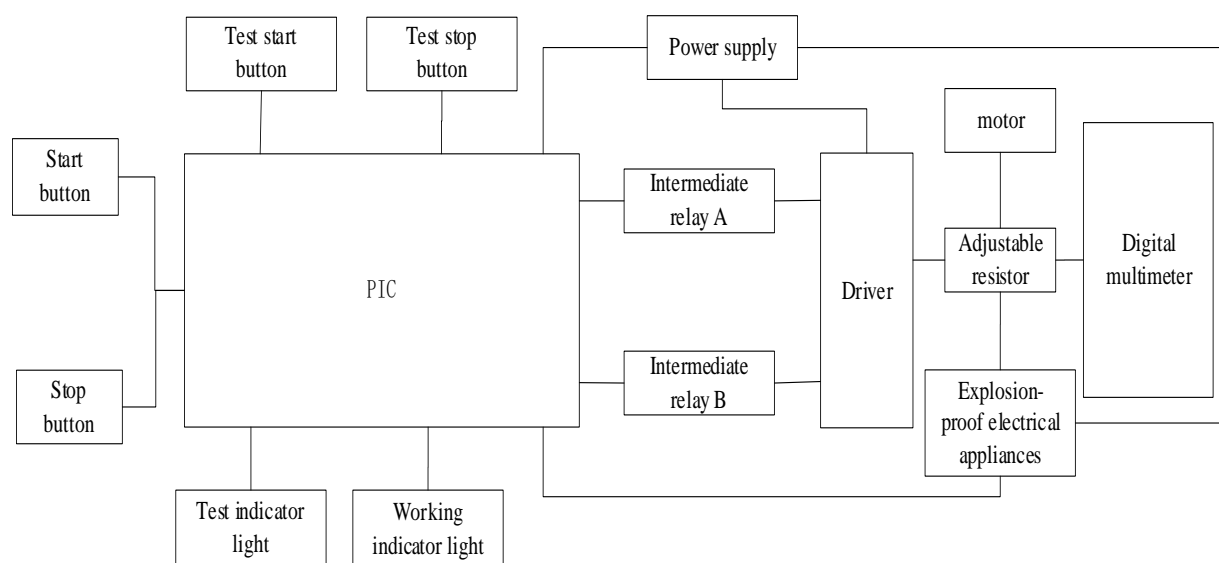
Coal mine explosion-proof electrical equipment refers to devices used in underground safety production, such as explosion-proof electromagnetic starters, explosion-proof control boxes, and explosion-proof lighting protection devices. These devices play a role in controlling and protecting electrical equipment within the underground power network. Long-term overload operation, insulation aging, mechanical damage, and voltage breakdown can lead to decreased insulation and increased leakage current in coal mine explosion-proof electrical equipment. This results in the outer casing of the equipment becoming live, posing a risk of electric shock to personnel who may come into direct contact with it or through conductive tools.

If leakage faults occur in the outer casing of coal mine explosion-proof electrical equipment and are not promptly addressed, they could endanger lives and even trigger explosions due to gas or coal dust. Leakage protection is one of the three main protections for coal mine equipment. The leakage protection test for the main circuit is a key component of type testing and factory inspection for coal mine explosion-proof electrical equipment. The performance of leakage locking and unlocking directly relates to the product quality of these devices. Currently, various inspection agencies and enterprises primarily use manually adjustable resistance boxes to conduct leakage protection tests on coal mine explosion-proof electrical equipment. This manual adjustment process requires operators to adjust resistance values manually, making it complex, time-consuming, and lacking in intelligence.

## 2. The leakage protection testing system

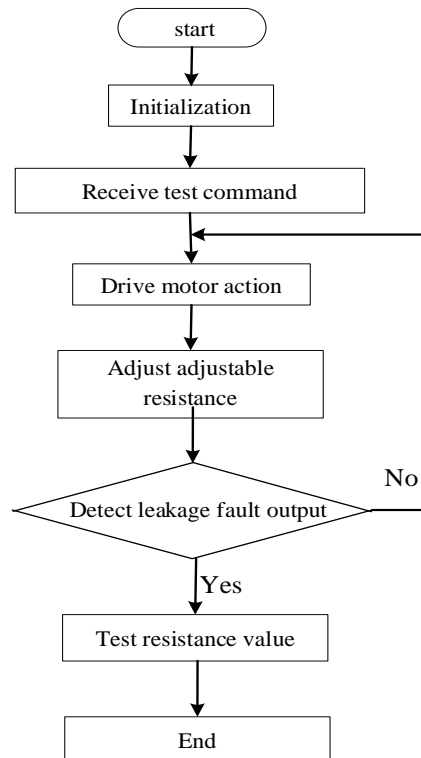
The leakage protection testing system for explosion-proof electrical equipment in coal mines includes a PIC controller, a start button, a stop button, a test start button, a test stop button, a test indicator light, a working indicator light, intermediate relay A, intermediate relay B, a driver, a DC motor, an adjustable resistor, and a digital multimeter. The PIC controller uses the PIC16F877A microcontroller. The start button, stop button, test start button, and test stop button are connected to the digital signal input terminals RC1, RC2, RC3, and RC4 of the PIC16F877A microcontroller respectively. The input terminals of the test indicator light and working indicator light are connected to the digital signal output terminals RC5 and RC6 of the PIC16F877A microcontroller respectively. The control terminals of intermediate relay A and intermediate relay B are connected to the digital

signal output terminals RB1 and RB2 of the PIC16F877A microcontroller. The output terminals of intermediate relay A and intermediate relay B are connected to the action signal input terminal and forward/reverse control signal input terminal of the driver respectively. The voltage output terminal of the driver is connected to the input terminal of the DC motor winding. The position signal output terminal of the driver is connected to the position signal input terminal of the DC motor. The spindle of the DC motor is mechanically connected to the resistance adjustment terminal of the adjustable resistor. Both ends of the adjustable resistor are connected to the testing terminals for leakage protection testing of explosion-proof electrical equipment in coal mines. The leakage fault output terminal of the explosion-proof electrical equipment is connected to the digital signal input terminal RB4 of the PIC16F877A microcontroller. Both ends of the adjustable resistor are also connected to two testing terminals of the digital multimeter. The structure of the leakage protection testing system for explosion-proof electrical equipment in coal mines is shown in Figure 1.



**Figure 1.** Structure of coal mine explosion-proof electrical leakage protection test system

The PIC controller (PIC16F877A microcontroller) is used to control the startup and shutdown of the leakage protection testing system for explosion-proof electrical equipment in coal mines while sending testing instructions to control the DC motor that drives the adjustable resistor for resistance adjustment. The start button is used to initiate the leakage protection testing system. The stop button is used to halt operations in this system. The test start button controls whether or not to conduct leakage protection tests in this system. The test stop button is used to stop leakage protection tests (in cases where there is a failure in locking or unlocking signals for leakage protection in main circuits). The test indicator light signals that a leakage protection test is being conducted. The working indicator light indicates whether the leakage protection testing system is operational. Intermediate relay A and intermediate relay B are used to feedback control commands from the PIC controller to the driver. The driver controls starting, stopping, and forward/reverse operations for the motor. The motor adjusts resistance values through the adjustable resistor. The adjustable resistor provides test resistance for leakage protection tests on explosion-proof electrical equipment. Finally, a digital multimeter measures resistance values during these tests. The workflow for conducting leakage protection tests on explosion-proof electrical equipment in coal mines is illustrated in Figure 2.



**Figure 2.** Flowchart of the main system programmer

The leakage protection testing for explosion-proof electrical equipment in coal mines consists of leakage locking tests and leakage unlocking tests. The process for the leakage locking test is as follows:

1. After pressing the start button to power on the leakage protection testing system for explosion-proof electrical equipment in coal mines. The working indicator light changes from off to green, while the test indicator light shows red.

2. The leakage protection test begin after pressing the test start button. And then the test indicator light changes from red to green.

3. The PIC controller activates intermediate relay A, sending action commands to the driver. At this point, intermediate relay B does not engage, and the driver controls the DC motor to adjust the resistance of the adjustable resistor from a higher to a lower value.

4. The testing terminal for leakage protection in explosion-proof electrical equipment detects the value of the adjustable resistor. When a leakage fault occurs in the explosion-proof electrical equipment, the leakage fault output terminal sends a feedback signal about the fault to the PIC controller.

5. The PIC controller ceases outputting control commands, disconnects intermediate relay A, stops voltage output from the driver, halts motor operation, and changes the test indicator light from green back to red.

6. The operator starts the digital multimeter to measure the locking resistance value during the leakage protection test.

7. Once the stop button is pressed, the coal mine explosion-proof electrical leakage protection test system will stop working.

During the leakage locking test process for explosion-proof electrical equipment in coal mines, intermediate relay A sends a forward signal to the DC motor, causing it to rotate forward and adjust the resistance of the adjustable resistor from low to high values. In contrast, during the main circuit's leakage unlocking test for explosion-proof electrical equipment, intermediate relay B sends a reverse signal to the motor while intermediate relay A controls it to rotate backward, adjusting the resistance of the adjustable resistor from high to low values.

The working process for leakage unlocking tests is similar to that of leakage locking tests and follows these steps:

1. The operator presses the start button to power on the leakage protection testing system for explosion-proof electrical equipment in coal mines. The working indicator light changes from off to green, while the test indicator light shows red.

2. After pressing the test start button, testing for leakage unlocking will begin. The test indicator light will change from red to green.

3. The PIC controller activates both intermediate relay B and intermediate relay A, sending action commands to the driver so that it can control DC motor operation and adjust resistance values of the adjustable resistor from a lower to a higher value.

4. The testing terminal of the explosion-proof electrical equipment's leakage protection system detects values of the adjustable resistor. When unlocking occurs in this equipment due to a leakage fault, its fault output terminal stops sending feedback signals about leaks back to the PIC controller.

5. The PIC controller ceases outputting control commands; both intermediate relays A and B disengage, stopping voltage output from the driver and halting DC motor operation while changing the test indicator light from green back to red.

6. The operator starts a digital multimeter to measure resistance values during unlocking tests for leakage protection in explosion-proof electrical equipment.

7. After pressing the stop button, the coal mine explosion-proof electrical leakage protection test system stops working.

### 3. Conclusion

Based on a PIC microcontroller design, a fully automated measurement technology has been developed for conducting leakage protection tests on explosion-proof electrical equipment in coal mines, replacing traditional manual testing techniques and achieving automated operations for these tests.

### References

- [1] R. A. Stoker, "Earth leakage protection schemes and relays," in Transactions of the South African Institute of Electrical Engineers, vol. 33, no. 3, pp. 53-72
- [2] L. Pazmandi, "Stator earth-leakage protection for large generators," in IEEE Transactions on Power Apparatus and Systems, vol. 94, no. 4, pp. 1436-1439
- [3] L. H. L. Badham, "'Neutral earthing and earth leakage protection'," in Transactions of the South African Institute of Electrical Engineers, vol. 31, no. 4, pp. 119-121
- [4] W. Wu and Y. Wu, "Preventing electrical hazards under grounding-fault condition by means of surface leakage protection," IECON 2015 - 41st Annual Conference of the IEEE Industrial Electronics Society, Yokohama, Japan, 2015, pp. 000197-000201
- [5] Wei Wu and Yuejia Wu, "Surface Leakage Protection - Next generation of electrocution protection technology," 2014 IEEE IAS Electrical Safety Workshop, San Diego, CA, USA, 2014, pp. 1-5
- [6] H. Cai, Z. Liu, R. Li and J. Chen, "Leakage protection device based on smart home," 2020 International Conference on Virtual Reality and Intelligent Systems (ICVRIS), Zhangjiajie, China, 2020, pp. 696-699
- [7] H. Mafi, R. Yared and L. Bentabet, "Smart Residual Current Circuit Breaker with Overcurrent protection," 2019 IEEE 2nd International Conference on Renewable Energy and Power Engineering (REPE), Toronto, ON, Canada, 2019, pp. 6-9
- [8] M. A. R. M. Fernando and V. Cooray, "Lightning surges at distribution transformer secondary," 2010 5th International Conference on Industrial and Information Systems, Mangalore, India, 2010, pp. 532-537