Research Of EMC Immunity In Mine Switches*

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Abstract: According to serious environment in the coal mine, the safety monitoring system of communication equipment (KJJ137 Switch Of Intrinsically safe flame-proof in mine) susceptible to surge, the group of pulse, and the problem of various kinds of electromagnetic interference on the switches EMC research. The study mainly from the power supply isolation and anti-interference, output signal safety barrier, the whole machine technology research aspects such as antistatic treatment. Experiments show that KJJ137 switches through the power surge immunity experiment, the output signal of pulse noise immunity, electrostatic immunity experiment machine. Various EMC experiment achieves level 4 standard, beyond the coal mine safety regulations require all kinds of interference rejection level 3 standards, make KJJ137 Switch Of Intrinsically safe flame-proof in mine, suitable for all kinds of bad environment of coal mine, ensures the mine safety monitoring system is right.

1. Introduction

With the national attention to safety in coal mines and the continuous improvement in comprehensive automation in coal mine industry, large-scale boring machine, belt control equipment, water pumps, video equipment, downhole high-voltage transformer equipment are widely used in coal mines\cite{1}, and various electromagnetic interference in coal mines is more and more serious. Safety monitoring system is essential in coal mine production safety. KJJ137 Flameproof and Intrinsically Safe Switch for Mine (hereinafter referred to as “the switch”) is the information transmission equipment in the safety monitoring system. The normal communication of the switch directly affects the normal operation of the safety monitoring system and the safety in coal mines. Therefore, the switch’s function of anti-electromagnetic interference becomes an important research task.

Electro Magnetic Compatibility\cite{2} (EMC) refers to the ability of the equipment or system to operate in accordance with requirements and not produce intolerable electromagnetic interference to any equipment in its electromagnetic environment. Therefore, there are requirements in two aspects: on the one hand, the electromagnetic interference generated by the switch to the environment in normal operation cannot exceed a certain limit value, on the other hand, the switch has a certain degree of immunity to electromagnetic interference in the environment, that is, electromagnetic sensitivity. The EMC anti-interference design of switches used in coal mines mainly includes three aspects. Firstly, power isolation and anti-interference design; secondly, anti-surge and group pulse design in communication interface; thirdly, static electricity anti surge design in the whole equipment.
2. Power isolation and anti-interference design
The switch is used in coal mines, and the connected equipment is intrinsically safe. Therefore, the reliable components of the switch must meet the requirements of the national standard, GB3836.4-83, and the reliable device of the switch is the transformer. According to Article 6.1 of GB3836.4-83, use Type R isolation transformer[3], and its input side adopts transformer tap mode. The Type R isolation transformer is characterized by small magnetic flux leakage and low temperature rise. It has small volume, light weight and makes no noise.

2.1 Points for attention in transformer design
The primary and secondary winding of the transformer are distributed on different columns of the iron core; the secondary winding is distributed inside and outside, and the grounding shield (made of copper foil) is added between the winding to improve the insulation measures, and the shielding layer and iron core are connected with the grounding wire; The input/output leads of the transformer must meet the designed resistance standards on temperature and voltage. The primary input leads must be high-voltage wires, and blown fuses with corresponding specification must be added to the leads. The rated working voltage of the leads should not be less than the maximum input voltage, and the insulation withstanding voltage of the leads should not be less than 4 KV; In normal tests, the insulation resistance of the transformer’s primary winding and secondary winding shall be over 50 MΩ, so is that between secondary windings, and between secondary winding and iron core and shielding layer. It shall withstand a power frequency voltage withstanding test for 1 minute, with the voltage of 4 KV. And in the test, there should not be spark, flashover and breakdown phenomena, and the leakage current shall not be over 1 mA; The insulation resistance of the transformer’s primary winding to iron core and shielding layer shall be over 50 MΩ, and it shall withstand a power-frequency voltage withstanding test for 1 minute, with the voltage of 4 KV. And in the test, there should not be spark, flashover and breakdown phenomena, and the leakage current shall not be over 0.5 mA; The structural diagram of the transformer is shown in Fig. 1.

Fig. 1 Structural diagram of the transformer

2.2 Anti-surge and group pulse design in input power
The AC power input end of the switch is designed with a filter circuit[4] to suppress the influence of high-frequency signals, variable-frequency signals and common-mode and differential-mode signals on the power supply. The power filter circuit is shown in Fig. 2. The filter circuit is composed of C1 (safety capacitor) and R1. The differential-mode inductor, L1, eliminates the influence of differential-mode interference on the power supply; C3 and C2 are safety capacitors (withstanding voltage value is 4KV) which cooperate with the inductors, L2 and L3, to eliminate the influence of common-mode interference on the power supply circuit.
3. Anti-surge and group pulse design in communication interface
The communication interface of downhole switch is composed of optical signal output interface, Ethernet electrical signal output interface and bus output interface. The luminous power of the optical output signal is as small as milliwatt level, so no safety circuit is designed for it.

3.1 Anti-surge and group pulse design in Ethernet output interface
The output signal of RJ45 is intrinsically safe signal, and the output signal should be isolated from the equipment shell and non-intrinsically safe terminal. The network data transformer is used in the circuit design. The transformer adopts double iron cores, and the iron cores are grounded. The primary side and the secondary side support isolation of 1500VAC. The structural diagram of data transformer is shown in Fig. 3.

The output signal voltage of network RJ45 is 3.3VDC. Two bidirectional TVS are designed for safety barrier circuit\(^5\)[6], and the fuse is 0.2A/2Ω. Choose the current-limiting resistance to be 2.2Ω ± 1%. A gas discharge tube, UN2E8-2500L, is designed between the line and the ground. The power of current-limiting resistor is \(W_R\).

\[
W_R \geq I_{\text{MAX}}^2 \times R \times (1+0.01) \times 1.5 \\
\geq (1\times1.7) \times (1\times1.7) \times R \times (1+0.01) \times 1.5 \\
\geq (0.2\times1.7) \times (0.2\times1.7) \times 2.2 \times (1+0.01) \times 1.5 \\
\geq 0.385 \text{ (W) }
\]

Choose the power of the current-limiting resistor to be 0.5W. The diagram of the safety barrier circuit is shown in Fig. 4.
3.2 Anti surge and group pulse design in bus output interface
When the interference signal enters the RS485 bus, high voltage will generate on the RS485BOUT/RS485AOUT line. Due to the slow-down effect of inductance, the high voltage signal causes the discharge tube to start and begin to discharge the high voltage to the ground. After discharging part of the high voltage through the discharge tube, part of the residual voltage enters inside of the bus through the inductance. This residual voltage causes the TVS to act, generating a large current, which triggers the TBU to act \cite{7}. TBU disconnects the communication line to prevent more residual voltage from entering. The residual voltage entering the bus becomes slow after being hindered by the inductive resistor, and then is released by the internal grounding device in the user end to achieve the purpose of safety protection. The diagram of bus safety barrier circuit is shown in Fig. 5.

4. Static electricity anti surge design in the whole equipment
The shell is made of metal materials, and the output interface is made with the form of horn mouth, so as to avoid the direct exposure of all circuit output interfaces. The distance between each circuit board and the metal part of the shell is more than 50 mm. The grounding electrode is added to the shell near the main board to realize anti-static interference.

5. Test
5.1 Isolation and voltage withstanding test
According to the national standard, a complete isolation and voltage withstanding test is carried out on the switch. The data of the isolation and voltage withstanding test are shown in Tab. 1.

| Test site                              | Power frequency withstand voltage |
|----------------------------------------|----------------------------------|
| Non-intrinsically safe end and shell   | 3000                             |
| Non-intrinsically safe side and intrinsically safe side | 3000                             |
| Intrinsically safe end and shell       | 1500                             |
5.2 Test on EMC
In May 2016, the notice of the State Administration of Coal Mine Safety on printing and distributing technical scheme for upgrading and transformation of coal mine safety monitoring system indicated that: the safety monitoring system and equipment both adopt EMC anti-interference design and must pass level-3 electrostatic immunity test, with the evaluation grade of A; and pass level-2 group pulse immunity test, with the evaluation grade of A; and pass power supply and signal port level-2 surge immunity test, with the evaluation level of B. KJJ137 Flameproof and Intrinsically Safe Switch for Mine has been tested in the laboratory. The data in the EMC immunity test are shown in Tab. 2.

| No. | Test name                  | Test equipment model | Output voltage | Coupling method/Coupling mode | Test phase | Test time | Test result                                      |
|-----|----------------------------|----------------------|----------------|-------------------------------|------------|----------|------------------------------------------------|
| 1   | Power surge test           | SUG61005DG           | ±4KV           | L-N-PE                        | asynchronous start | 40s       | ±4KV, L-N, L-PE, N-PE test, in line with A evaluation |
| 2   | Signal surge experiment    | SUG61005DG           | ±2KV           | 2Ω                            |             | 5s       | ±2KV, Repeat the test 5 times, in line with B evaluation |
| 3   | Power group pulse test     | EF61004BG            | ±4KV           | OUT-1/O                       |             | 60s      | ±4KV, Test 2 cycles, in line with A evaluation     |
| 4   | Signal burst test          | EF61004BG            | ±2KV           | OUT-1/O                       |             | 60s      | ±2KV, Test 2 cycles, in line with A evaluation     |
| 5   | Static test                | ESD61002AG           | ±8KV           | Contact discharge              | 0.05s      | 1000     | The accessible part of the equipment, tested for 2 cycles, conforms to the A evaluation |

Since the probe value of the laboratory oscilloscope is 2KV, there is no waveform test for power surge. The waveform test diagram of ± 4KV signal surge test is shown in Fig. 6. It can be seen from the waveform diagram that the residual voltage value is about 70V and the duration is about 1us in the ±4KV test.

![Fig. 6 Waveform test diagram of ± 4KV signal surge test](image)

6. Conclusion
KJJ137 Flameproof and Intrinsically Safe Switch for Mine is a mature product. After upgrading the safety monitoring system, corresponding EMC design changes are made. The modified switch has
passed the EMC anti-interference test: level-4 electrostatic immunity test, the evaluation level is A; level-4 group pulse immunity test, the evaluation level is A; power supply and signal port level-3 surge immunity test, the evaluation level is B. The above indicators fully meet the upgrade indexes of safety monitoring system, which makes the switch more suitable for use in coal mines and further improves its stability.

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