Design of Products in Electrical Fire Monitoring System for EMC Performance

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Abstract. This paper introduces components and functions of electrical fire monitoring system, and electromagnetic compatibility (EMC) tests and technical requirements in the product standards. And from the aspect of design of products, this paper puts forward some suggestions about hardware and software to improve the immunity to EMC interference, to ensure the EMC performance of products could meet the requirements of standards.

Components and Technical Requirements of the System

Electrical fire monitoring system is mainly composed of electrical fire monitoring equipment and various types of electrical fire monitoring detectors, and this subsystem as an important part of automatic fire alarm system, plays an important role for the protection of safety of power supple system, and prevention of electrical fire accidents in buildings. Electrical fire monitoring equipment as information display and control processing unit of the subsystem, is mainly used for receiving the working status signals of detectors, displaying alarm information, and uploading all kinds of information of the subsystem to the automatic fire alarm system. And electrical fire monitoring detectors are divided into different categories based on different types of physical parameters for fire monitoring, such as residual current, temperature, fault arcing and pyrolysis particle. As the sampling and detection units of the monitoring subsystems, the monitoring detectors is mainly used for measuring all kinds of physical quantities related to electrical fire of power lines, and sending measuring and sampling information to monitoring equipments or other terminal equipments in real time.

In order to guarantee the quality and performance of all kinds of products in the electrical fire monitoring system, the national standardization organization for fire products has revised the original standard of electrical fire products, and in 2014, the new version of series standards, GB 14287-2014<Electrical fire monitoring system>, has been issued, and every part of the series standards involves a type of electrical fire products in the monitoring system, which rules specific technical requirements for various performance of products. GB 14287 serial standards have ruled the EMC performance of every kind of fire products in the subsystem, which are applied in the fire control center and power distribution network. And according to different electromagnetic interference occurred in application places there are several EMC tests in the standards, which can test the inhibition ability of products to electromagnetic interference signals coupling from space and external interface to the internal circuit. According to the standards, it specified that products should maintain normal working state under the different types of electromagnetic interference conditions, without any abnormal situation such as system failure, false alarm, restart, display, communications failure and so on. Therefore product manufacturers, when developing new products even at the initial stage should pay attention to the design of the internal circuit and software program, and selection of hardware components, to guarantee products pass the type tests of standards.
EMC Tests in Standards and Design for EMC Performance

The Electromagnetic compatibility tests in GB 14287 standards mainly refer to IEC 61000-4 serial standards, which are basic standards of EMC tests for general electronic products. The EMC tests are shown in Table 1. It is recommended that manufacturers should adopt corresponding coping strategies to different tests, and finally form a comprehensive product design scheme. The article below will introduce every EMC test and present some design suggestions of hardware according to the characteristics of the electromagnetic interference.

Table 1. EMC and voltage fluctuation tests.

| Test item                                      | Standard Number | Type of products |        |
|-----------------------------------------------|-----------------|------------------|--------|
| Electrostatic discharge immunity test         | IEC 61000-4-2   | Monitoring       | √      |
|                                               |                 | Detectors        | √      |
| Electrical fast transient/burst immunity test | IEC 61000-4-4   | √                 | √      |
| Surge immunity test                           | IEC 61000-4-5   | √                 | √      |
| Radiated, radio-frequency, electromagnetic field immunity test | IEC 61000-4-3 | √                 | √      |
| Immunity test to conducted disturbances, induced by radio-frequency fields | IEC 61000-4-6 | √                 | √      |
| Power frequency magnetic field immunity test  | IEC 61000-4-8   | √                 |        |
| Voltage dips, short interruptions and voltage variations immunity tests | IEC 61000-4-11 | √                 | √      |
| Voltage fluctuation test                      | IEC 61000-4-11  | √                 | √      |

- a latest edition of the standard is adopted;
- b ‘√’ means the test is apply to this type of products;
- c power frequency magnetic field immunity test is only apply to residual current detectors.

Electrostatic Discharge Immunity Test (ESD)

Electrostatic discharge immunity test (ESD) is mainly adopted to prove the working reliability of the product when electrostatic discharge from the users or adjacent objects occurs [1]. There are two main types of the interference of ESD: contact discharge and air discharge. The voltages of test specified in the standards are 6 KV for contact discharge occurred on conductive surface of products or nearby objects, and 8 KV for air discharge occurred on the insulation surface. In general, the contact discharge may not only interfere the internal circuits of product through the metal parts, but also the high-frequency interference signals generated by ESD may coupling into the circuit and affect working condition of products. Therefore, it is important to prevent interference current through metal contact such as the I/O ports into inside circuit. Generally it is suitable to adopt a couple of fast, low capacity diodes between power supple, I/O interfaces and ground, or to adopt TVS diode which can eliminate the large discharge current more effectively between these parts. If when TVS diode adopted, it is suggested to use one or more high-frequency bypass capacitors between the power and ground of the components which is easy to be damaged. Secondly, it should be avoided to produce large inductance at the part of power supply in the circuit, which can affect the filter circuit to eliminate the ESD pulse current.

A good grounding is also very important to the products with metal case. It is necessary to connect grounding of power, grounding of signals and the metal case together, to make sure there is only one ground in circuit of products. When the shell the product is composed of pieces of metal structures, they should be connected continuously for good grounding. For the high-frequency electromagnetic
interference signal generated by electrostatic discharge, it should be considered as a kind of radiated interference signals from radio frequency electromagnetic fields according to the contents of below.

**Electrical Fast Transient/Burst Immunity Test (EFT)**

Electrical fast transient/burst immunity test (EFT) is adopted to simulate repetitive electrical fast transients generated because of the switch contact gap insulation breakdown or contact bounce of transient when perceptual loads disconnected in power supply network [3]. Amplitudes of voltages of test levels in standards are 2KV to power supply and 1KV to I/O interfaces. Because the energy of interference signals is small and the signal frequency is stable, the EFT disturbance signal normally can not lead to permanent damage to the power supply and I/O interfaces. But EFT which injected from power of product or coupling through lines into the internal circuit can charge junction capacitance of the circuit. When capacitance is charged to a certain degree, it will be occurred that the control unit of circuit misoperate or trigger an error signal, which can lead to a failure state.

EFT is a kind of common-mode disturbance. To eliminate the disturbance signals from power source, it is suggested to use ferrite beads or common-mode inductor, which can effectively restrain disturbance pulse. For the I/O port of communication and sampling, it is also necessary to install a signal filter in order to prevent transient getting into the signal processing unit of the circuit. Meanwhile, for the design of PCB board, to minimize printing line, especially the length of the ground, can reduce impedance of the ground, and improve inhibition performance of the filter.

**Surge Immunity Test**

Surge immunity test simulates the impact disturbance when switching a large capacitor in power supply network, as well as transient overvoltage caused by the lightning [4]. The test method of surge is to inject impact interference into the power lines and other external connections of the Circuit through the coupling/decoupling network. The test levels of open-circuit voltage are 2KV (line to ground coupling) and 1KV (line to line coupling) for AC power lines, and 1KV (line to ground coupling) for other external lines of the circuit. The characteristic of surge is high impact energy, which can easily damage the components in circuit to breakdown. So it is very important to restrain the impact current. It is suggested to use varistor, Transient voltage suppressor (TVS), gas discharge tube and other special surge suppression device, and it is more effective to use there devices comprehensively.

To select surge suppression devices, the characteristics of devices should be understood firstly. The advantage of varistor is the high current capacity, but due to the clamping voltage is high, generally it is only adopted at DC power cord, and low frequency signal interfaces. And TVS has a good performance of clamping voltage, but can not withstand high current, and it is not fit for high-frequency communication lines. So it should be used with other higher power surge suppression devices together, as the second level of filter in circuit. Gas discharge tubes have a good capacity for current and the clamping voltage is low enough. But because the response time is longer which makes the suppression devices maintain high voltage for a long time in working state, it will decrease the service life of gas discharge tube. For AC power lines, a surge suppression network which is composed of gas discharge tube and varistor in series should be adopted. But sometimes when surge pulse passing through the suppression network, because of the long response time of gas discharge tubes, there will be a residual narrow pulse signal getting into the internal circuit. So actually for design of circuit, it is necessary to install a low pass filter behind the network to eliminate this narrow pulse. Besides that, to restrain the disturbance of surge, the circuit of products must have good grounding.

**Radio-frequency Electromagnetic Field, Conducted Disturbances and Power Frequency Magnetic Field Immunity Test**

The former two tests simulate the electromagnetic interference generated in space and coupling into the circuit through power or I/O signal lines when products in radiated electromagnetic field
Radio-frequency electromagnetic field is generally produced by signal transmitters, such as mobile phone. The frequencies of electromagnetic waves are respectively from 80MHz to 1000Hz in radio-frequency electromagnetic field immunity test, and from 150k to 80MHz in immunity test to conducted disturbances. The test equipment of the former one is radio-frequency antenna, which releases electromagnetic waves in microwave dark room. And the latter test is to inject interference signal into circuit of simples tested through a coupling/decoupling network. Power frequency magnetic field is generated by power supply network. When the network at normal working state, the magnetic field is stable with lower amplitude, but when some failure occurred in the network, there will be an instantaneous magnetic field generated with higher amplitude [6]. Both of the two kinds of magnetic fields with power frequency and sine waveform, can influence working state of detectors.

For products in electrical fire monitoring system, the internal circuits of monitoring equipments and detectors generally have both analog signal circuit and the A/D conversion circuit which are sensitive to electromagnetic interference. In order to obtain working status and the real-time sampling data of detectors, monitoring equipments and detectors will keep communication, and every component of the system also has internal clocks and microprocessor chips. So the following aspects should be considered to improve the immunity to interference of electromagnetic environment in the stage of design of product:

a) To reduce frequency of the internal clock appropriately, that will reduce the high frequency noise, and the clock line should be as short as possible;

b) The I/O signal lines should far away from the clock and the digital signal bus;

c) Each function part of the PCB board has independent partition with reasonable wiring. Analog signal partitions, digital signal partitions, relays, and large current switches should be separated from each other, and lines should not be too long. Signal lines do not form a loop to reduce the coupling of electromagnetic interference;

d) Having good grounding is necessary for circuits. If the circuits have multiple grounding points, these points should eventually come back together, which means the single point grounding;

e) To install metal shields over the sensitive circuits.

**Voltage Dips, Short Interruptions Tests and Voltage Fluctuation Test**

These tests are adopted to simulate the voltage sag or interruption because of fault or sudden increase of load in power supply network, and Voltage fluctuation or persistent drop caused by changes of load or long power lines [7]. These tests are used for the testing of ac power supply products. The test levels are separately 40% rated voltage and duration of 10 cycles of sine wave for voltage dip, zero voltage and duration of 1 cycle of sine wave for short interruption, and from 85% to 110% rated voltage for voltage fluctuation test. The former two tests are transient ones, and the latter one is a continuous test as the change of test voltage.

The standards specified that the sample should keep normal working state during the test. For products with backup battery, such as monitoring equipments, even if the waves of test voltage could affect the sample, due to transient testing time is short, to adopt some filtering method in software can keep the working state stable. But for detectors which have no backup battery inside, there could be some fault phenomenon happened, such as restart of program or failure on display part. It is suggested to use a larger capacitor at the entrance of the power supply to ensure the stability of the input voltage. For monitoring equipments, it is recommended to install switching power supply or isolation transformer as the voltage stabilizer for internal circuit. For detectors, it is suggested to use power management chips at the power supply part with a filter network which can improve the stability of the power supply.

**Design of Software for EMC Performance**

The ideal software program is also effective to improve the EMC performance of products. According to actual requirement of application, the standards specified response time of all kinds of events in electrical fire monitoring system, such as alarms and failures of detectors. The shortest
requirement is that the system’s response time to fire alarm shall not be greater than 30 seconds. Relative to the requirement for reliability of system, the requirements for response time is obviously easy to realize. This gives designers of products chance to balance the two aspects.

For processing program of the I/O data, such as for measuring and communication, it should be considered to add same anti-jamming processing program. For calculating program, to add some filtering algorithm to the program could effectively reduce the chance of false alarms. For display parts of products, such as LCD screens and LED lights, it is suggested to refresh the display regularly to avoid error display content. Besides that, it is necessary to add a watchdog command in the main program, so that the timer in program can reset the microprocessor to make it recover from a internal fault or a state of suspended animation timely.

**Conclusion**

When developing products, designers should be fully familiar with technical requirements of standards, and improve the EMC performance of products from two aspects of hardware and software. Only if to guarantee the reliability of products in EMC interference environment, the electrical fire monitoring system can ensure the safety of power supply of buildings.

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