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OPTIMIZING THE RELIABILITY OF THE FIRE ALARM SYSTEM IN THE TAIWAN PHOTON SOURCE

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Abstract

The fire alarm system plays a critical role for the safety of building occupants. However, in the past two years from 2016 to 2017, occasionally false alarms at the Taiwan Photon Source (TPS) occurred. Results of more detailed observations indicated that radiation and/or electromagnetic interference (EMI) of the TPS accelerator disturb smoke detectors and signal line circuits (SLCs). Lead shielding covers, adjusting of the detector alarm verification time and a laser-based aspirating smoke detector were used to reduce the probability that fire alarms become activated to less than 0.5 times per year.

INTRODUCTION

A fire alarm system has been installed in the TPS including the automatic fire alarm, the manual alarm and the emergency broadcasting subsystems. Photoelectrical topical type smoke detectors are the major components of the automatic fire alarm subsystem and are installed for every 75 m^2 of effective room detecting areas, every 30 m of waking distance in aisles and passages or every 15 m of vertical distance in stairways. Photoelectrical separated type detectors are installed in the experimental hall of the TPS. The optical axis of a photoelectrical separated type detector is about 28 m and above the height more than 80% of the space between ceiling and floor plate. The distance between the optical axes of photoelectrical detectors is about 6.8 m.

A fire alarm control panel (FACP) was designed for the large-scale TPS automatic fire alarm subsystem. With seven SLCs, the FACP supports 918 intelligent addressable fire detectors and 661 monitor or control modules. A twisted-shielded pair of 1.25 mm² cable is used for each SLC wiring in a metal conduit and the maximum distance unsusceptible to electrical interference is about 1500 m [1]. The capacitance of any SLC wiring (both between conductors and from any conductor to earth) does not exceed 0.5 μF and the resistance is less than 50 Ω. The TPS automatic fire alarm subsystem diagram includes SLCs as indicated in Fig. 1. The maximum number of SLCs could be expanded to ten in each FACP.

When a fire alarm signal is detected or a manual fire alarm station is pulled, the following functions of the automatic fire alarm subsystem are activated:

- The alarm LED shall flash and a local piezo-electric signal in the FACP shall sound.
- The LCD display in the FACP and graphical interface control workstation shall include all information associated with the fire alarm situation, including the type of alarm point and its location within the protected premises.
- All system output programs shall be executed and associated system reactions (e.g. emergency broadcasting, smoke exhaust system, closing of fire doors…) shall be activated.

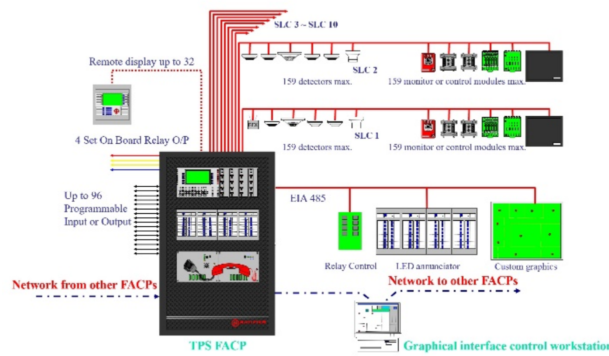

Figure 1: TPS automatic fire alarm subsystem diagram.

TPS FIRE ALARM SYSTEM OPERATION

System Description

The TPS building is divided into three zones: (1) experimental hall including beamline hutches, laboratories and utility area (zone A); (2) shielded tunnels containing linac, booster and storage ring (zone B); (3) the core area including control instrumentation areas (CIA), radio frequency (RF) modules, laboratories and utility area (zone C), as illustrated in Fig. 2.

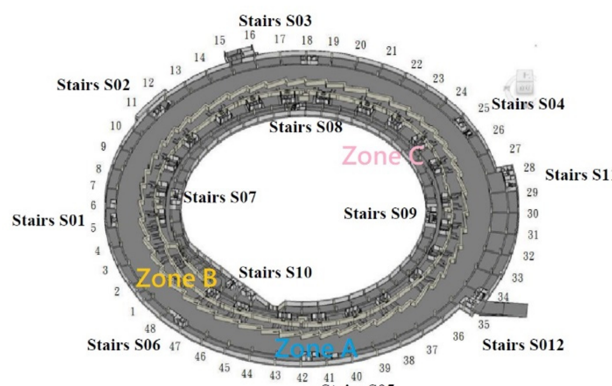

Figure 2: Perspective drawing for the first floor of the TPS [2].

The distribution of the SLCs for the TPS is listed in Table 1. The protection area of SLC 1 is just for office and stock regions, but we do not discuss those in this article.

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Table 1: SLCs Distribution of TPS

SLC	Zone A			Zone B	Zone C	
	1F	2F	3F	1F	1F	2F
SLC 2			V			
SLC 3	V			V	V	V
SLC 4		V				
SLC 5	V	V				
SLC 6				V	V	V
SLC 7				V	V	V

Prevention of False Alerts

To prevent false alerts from the TPS fire alarm system, three procedures are used:

- Detector sensitivity settings: To obtain early warning for incipient or potential fire conditions, the fire alarm system supports pre-alarm functions. Nine sensitivity levels from 0.5 to 2.35 % obs/ft are provided for pre-alarm and alarm detection. These levels can be set manually or can be changed automatically between day and night.
- Drift Compensation and Smoothing: This function allows the detector to retain its original ability to detect actual smoke and resist false alarms, even as dirt accumulates. Smoothing filters are also provided by software to remove transient noise signals, usually caused by electrical interference.
- Maintenance warnings: When the drift compensation for a detector reaches a certain level, the performance of the detector may be compromised, and warning signals are given. There are three warning levels: (1) low chamber value; (2) maintenance alert, indicative for dust accumulation that is near but below the allowed limit; (3) urgent maintenance, indicative of dust accumulation above the allowed limit.

Operation Phenomenon

The fire alarm system of the TPS was stable for sixteen months since December 2014 while the 3-GeV TPS was being commissioned. However, in March 2016 the fire alarm system became unstable while operating at a beam current of 300 mA or more. The 24 photoelectrical topical type smoke detectors mounted on SLC 3, 6 and 7 in the booster and storage ring tunnels (zone B) were prone to frequent failures. Analysing the abnormal information revealed several problems in the TPS FACP:

- Upon a single trouble warning signal, the FACP showed “no answer” from a failed smoke detector.
- When two trouble warnings appeared, the FACP showed both “no answer” from a failed smoke detector but a “dual address” from another detector in the same SLC. When the “no answer” smoke detector was replaced, the “dual address” warning disappeared.
- If the “no answer” smoke detector problem was not solved, a fire alarm signal may be triggered but would be bypassed by the pre-alarm step.

When the emergency response team arrived at the location originating the fire alarm, no smoke, no heat and no odour could be detected. The failing smoke detectors were tested by re-installing them in other normal operating SLC. Unfortunately, they turned out to be broken permanently. The regular lifetimes of photoelectrical topical smoke detectors installed in other buildings or other zones of the TPS were at least seven years, but in these cases, it was dramatically reduced to six months.

Smoke Detectors Failure Investigation

Visual inspection The broken smoke detectors were dismantled into parts and inspected visually. Dust/mist accumulation and trace of surge striking on printed circuit board were not discovered, as demonstrated in Fig. 3.

Figure 3: Visual inspection of failed smoke detectors.

SLCs inspection An oscilloscope of type Fluke 190-102 was used to diagnose the SLCs, providing signals as shown in Fig. 4.

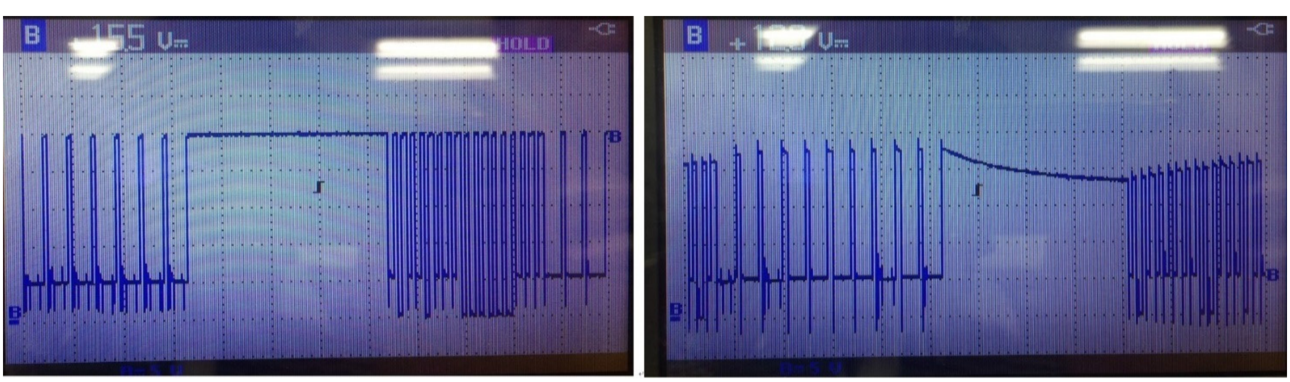

Figure 4: Signals on a normal SLC (left) and on a failing SLC with broken detector (right).

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Signals were measured on the SLC 3, 6 and 7 through tunnel of the TPS. In the normal case, the signal was almost a perfect rectangular wave. For a broken detector, spikes appeared in the signal peaks and the peaks dropped down (see Fig. 4).

Radiation evaluation Six thermo-luminescent dosimeters (TLDs) were utilized to record the radiation dose to smoke detectors installed in the TPS tunnel, as shown in Fig. 5. The TLDs were attached to the smoke detectors for a week and then analysed by a Harshaw TLD Model 6600 Plus Automated Reader Instrument. The total deep dose in these six TLDs were 2.41 to 4.33 Gy. A CERN report [3] has determined an upper dose limit to electronic components of 100 to 1000 Gy. This guideline implies that the exposure of the smoke detectors installed in the TPS tunnel would reach the upper dose limit in 20 to 45 weeks.

Figure 5: Detector installed in the TPS tunnel with a TLD.

IMPROVE RESULTS

A two mm thick lead shield around the smoke detectors and a porous plate at the bottom was installed to prevent noise induced by radiation or EMI, as shown in Fig. 6. A smoke detector tester was used to verify a sensing time of less than 30 seconds. Furthermore, the alarm verification time was adjusted from 0 to 5 seconds for the smoke detectors installed in the TPS tunnel and the probability for a false alert by the TPS fire alarm system was reduced to less than 0.5 times per year, even for a beam current of 500 mA.

Figure 6: Smoke detector with lead shielding.

Aspirating smoke detector with high sensitivity with laser-based detection chamber was employed at the outside of the TPS tunnel, as shown in Fig. 7. Air from the tunnel was drawn into the detection chamber through a network of air sampling pipes by an aspirator. The benefit to electronic components of this detector is no exposure to radiation and/or an EMI environment. The alarm sensitivity range of this laser-based detector was wide (i.e., 0.0091%–7.62% obs/ft) and can be used as an add-on to the fire alarm system in the TPS tunnel.

Figure 7: Aspirating smoke detector installed in the CIA room outside of the tunnel (left) and sampling pipes in the tunnel (right).

CONCLUSION

False fire alarms were frequently activated when the TPS accelerator operated at or above 300 mA. Both, radiation and/or EMI caused damage to smoke detectors in the tunnel. In order to reduce false fire alarms, lead shielding around smoke detectors, alarm verification time adjusted from 0 to 5 seconds and aspirating smoke detectors were implemented. The probability for false fire alarms were thus reduced to 0.5 times/yr.

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