CONCEPT OF A FIRE AND GAS SAFETY SYSTEM FOR ACCELERATORS

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Abstract

Today CERN's facilities are equipped with automatic smoke and gas detection systems. Upon smoke or gas leak detection, local safety actions are automatically performed and alarms indicating the location and type of danger are transmitted to the CERN Fire Brigade. The firefighters then size their intervention based on the information received. The increasing complexity, size and quantity of CERN installations drives safety systems to evolve in the direction of simplicity. Intuitive interfaces are required to cope with high turnover of firefighters, and the inherent multinational environment. Global overview of alarms and safety actions statuses are needed by firefighters to decide on the best strategy for intervention. In some emergency situations, it might be necessary to manually trigger remote actions. CERN is studying a new concept, inspired by French standards, where the detection and protection layers are separated and act independently, but provide a common interface. This paper presents an application of this concept for the SPS accelerator. Detection, fire-compartment and evacuation zones are presented, as well as the architecture of the detection and protection layers.

ALARMS SYSTEMS FOR DETECTION AND PROTECTION FUNCTIONS

CERN facilities include equipment with fire & gas related hazards for personnel and the environment. When risks exceed the acceptable level, as part of the mitigation measures, alarm systems are installed to perform 2 types of automatic functions (see Fig. 1):

- Detection functions: To detect a fire or gas leak hazard and trigger an alarm at CERN Fire Brigade for an immediate intervention
- Protection functions: To detect a fire or gas leak hazard and protect locally personnel and environment

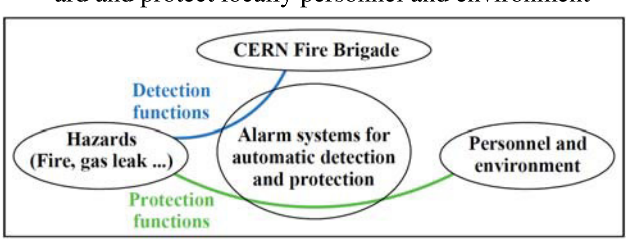

Figure 1: Two types of automatic functions in case of hazards: detection and protection.

Detection functions provide the CERN Fire Brigade with the exact location and the type of hazard detected. For example: “Fire detection, building 3525-S-0, sensor SFDEI-15951”, “Flammable gas leak detection, building 2870-R-010, sensor SGDGA-01657”. Protection functions must be performed automatically to protect personnel and environment as soon as possible, before the arrival of CERN Fire Brigade which at some distant points implies a substantial travel and response delay. Typical protection functions would be: “activation of evacuation sirens in case of smoke detection in the LHC machine tunnel”, “cut out of electro-valves in case of flammable gas leak detection in the ATLAS detector” or “compartmentation of building 513 (CERN data-center) in case of smoke detection”.

DESCRIPTION OF ALARM SYSTEMS FOR AUTOMATIC DETECTION AND PROTECTION FUNCTIONS

Alarm systems are categorized at CERN by type of hazard to detect, which are generally (see Ref. [1]):

- Fire detection systems: specific controllers connected to smoke sensors
- Gas leak detection systems: specific controllers connected to oxygen, flammable or toxic gas sensors
- Emergency evacuation systems: specific controllers connected to emergency evacuation break-the-glass devices

Many types of actuators are triggered by CERN’s alarm systems: sirens, flashing lights, luminous panels, fire doors, fire dampers, power switches, electro-valves, ventilation processes, etc… In a given installation, all actuators of a particular type are normally cabled to a unique category of alarm system controller to perform the corresponding protection functions. For example: fire doors are cabled to a fire detection controller, emergency evacuation sirens are cabled to an emergency evacuation controller.

In order to perform the protection functions of some installations, a given controller may have to trigger actuators cabled to a controller of another category or to a controller of the same category but in an adjacent building. For example in building 3170 (a flammable gas storage building), electro-valves for flammable gas distribution are cabled to the gas detection controller and can be activated either in case of flammable gas leak detection or in case of fire detection. The fire detection controller signal is then cabled to the gas leak detection controller and a part of the related fire protection function is performed by the gas leak detection system. In case of large installations with multiple risks which imply several interconnected alarm systems, the number of interconnections between controllers could be important (see. Fig. 2).

The last 10 years of operation have shown that the number of interconnections grows and therefore it can be difficult to manage:

- Difficulties in integrating new alarm systems or new protection functions in an existing architecture
- Difficulties in separating maintenance activities by category of alarm systems, by type of function or by location
- Difficulties for Fire Brigade in obtaining a quick overview of protection functions triggered

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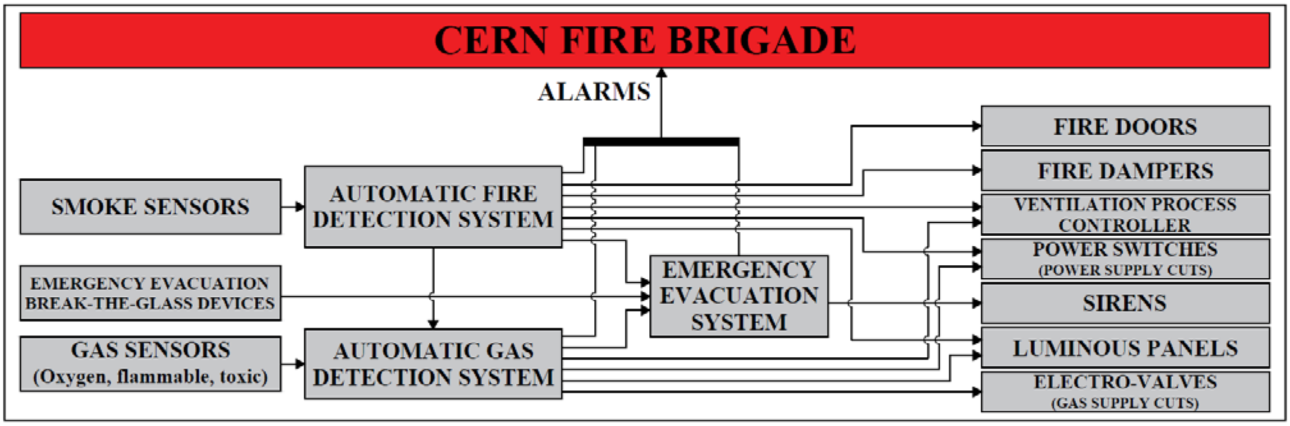

Figure 2: Current architecture - Interconnections generally existing between categories of alarm systems.

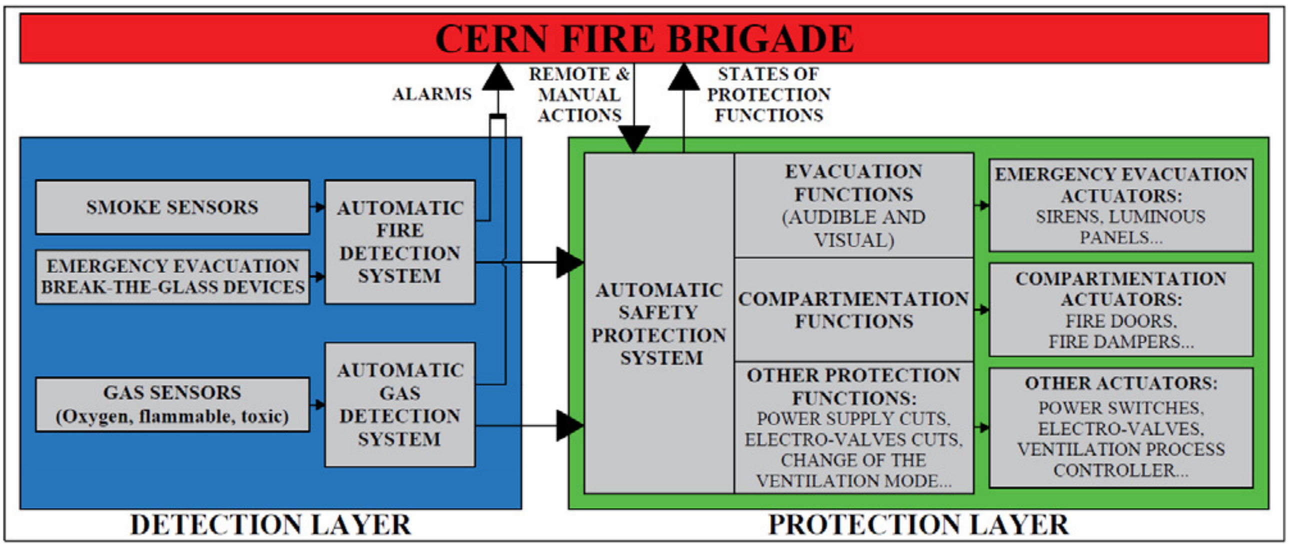

Figure 3: Conceptual architecture - Separation of alarm systems into 2 layers.

However, in the case of installations with infrequent changes and few interconnections between controllers, the current architecture is efficient. This suggests the existence of a complexity threshold above which it is relevant to choose a different type of architecture for alarm systems. In a given installation, this complexity threshold is difficult to quantify but could be evaluated upon several indicators:

- The number of detection and protection functions
- The quantities and categories of alarm system controllers interconnected
- The size of the installation and its potential evolution
- The response delay of CERN Fire Brigade

CONCEPT OF SEPARATION OF ALARM SYSTEMS INTO 2 LAYERS

The new architecture for alarm systems with a complexity level above the mentioned threshold has to be capable of evolving, easy to maintain and to operate. Inspired by French standards on fire safety, a new concept has been designed (see Ref. [2] to [10]). In this conceptual architecture, alarm systems are separated into 2 layers (see Fig. 3):

- 1st layer: the "detection layer", sub-divided into categories of alarm systems by the type of hazard being detected (Fire, Gas leak …). These alarm systems perform the detection functions and transmit the states of the detection zones to the second layer.
- 2nd layer: the "protection layer", with all actuators connected to one single system but sub-divided according to categories of protection functions: evacuation, compartmentation, electrical power cuts, electro-valves cuts, change of ventilation mode… This layer receives the states of the detection zones about hazards detected, to complete the protection functions.

With this architecture, a concept of detection and protection zones should be introduced:

- Detection zones: defined by category of alarm systems in the detection layer. For a given alarm system, any sensor in alarm in a detection zone will trigger the same protection functions. For example in building 104, if all smoke sensors trigger the same protection functions, the automatic fire detection zone will be the entire building.
- Protection zones: defined by category of protection function to trigger in the protection layer. A protection function of a category will trigger all actuators of its category included in the corresponding protection zone. For example in building 513, the actuators of the

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compartmentation category (fire doors and dampers) are all triggered in case of smoke detected, the compartmentation zone is then the entire building.

This zone definition must be decided at the beginning of the project, with its associated functional safety matrix. This definition will simplify the understanding and the programming of the system.

In comparison with the existing architecture of alarm systems, this conceptual architecture separated into 2 layers brings several improvements:

- Detection and protection layers are independent: one layer in failure doesn't affect the functions performed by the other
- All protection functions can be triggered by all alarm systems of the detection layer without modification of the cabling
- New alarm systems and new functions (detection and protection) can easily be added
- Alarm systems of the detection layer could be tested independently and without triggering the actuators (by checking the reception of the information on the controllers of the protection layer)
- When modifying a detection zone, there is no need to test the protection functions entirely but only to check that the information received by the controllers of the protection layer has not been modified
- If a protection function needs to be modified or added, there is no need to test the detection layer but only the protection layer
- By adding a human machine interface in the protection layer, new possibilities are granted to CERN Fire Brigade. The protection functions can be triggered remotely and a global overview of protection function states is provided. This allows firefighters to make informed decisions based on the field conditions. The remote triggering can also be useful in case of emergency phone calls from people in danger.

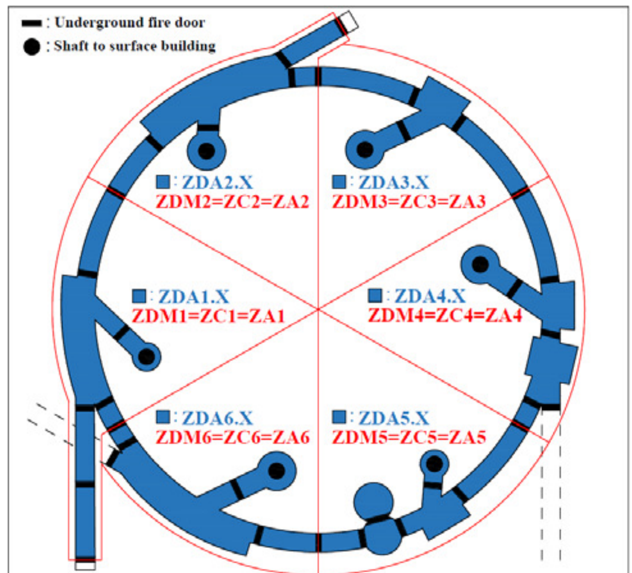
CONCEPT APPLICATION: FIRE SAFETY IN THE SPS MACHINE

The SPS machine, built in the 1970s, consists of a circular tunnel with a circumference of 6911 meters equipped with 6 vertical shafts on average 45 meters underground. The shafts are used both for the passage of general services and for access of personnel. Alarm systems are currently installed in the SPS machine to protect from fire related hazards. Given the increasing remanent radiation level in SPS tunnels and frequent improvements on the accelerator, alarm systems might evolve to perform additional detection and protection functions. For example: to integrate new hazards such as helium for cryogenic equipment.

As part of the future renovation of the SPS fire safety system, an architecture of alarm systems with separated detection and protection layers is currently under study. The SPS tunnel has been divided into safety zones with an associated safety matrix (see. Fig. 4 and Ref. [11], [12]):

- ZDA: Automatic Detection Zone: any smoke sensor of this zone triggers the same protection functions
- ZDM: Manual Detection Zone: any emergency evacuation break the glass device of this zone triggers the same protection functions
- ZC: Compartmentation Zone: corresponds to a protection function which triggers all compartmentation actuators of the zone
- ZA: Alarm Zone (for emergency evacuation): corresponds to a protection function which triggers all emergency evacuation actuators of the zone

The safety matrix has been defined as a compromise between personnel safety and machine operation needs. The impact of a spurious detection is then minimised.



	ZC1	ZC2	ZC3	ZC4	ZC5	ZC6	ZA1	ZA2	ZA3	ZA4	ZA5	ZA6
ZDM1 OR ZDA1.x	X						X	X				X
ZDM2 OR ZDA2.x		X					X	X	X			
ZDM3 OR ZDA3.x			X					X	X	X		
ZDM4 OR ZDA4.x				X					X	X	X	
ZDM5 OR ZDA5.x					X					X	X	X
ZDM6 OR ZDA6.x						X	X				X	X

Figure 4: SPS main tunnel (not to scale) - Underground safety zoning and main protection functions.

CONCLUSION

CERN experimental and accelerator facilities undergo a continuous evolution and upgrade process, and present different and changing hazards. An analysis based on installation parameters defines the level of complexity of alarm systems to be installed. Number of detection and protection functions, number of alarm systems interconnected, installation size, installation evolution, and CERN Fire Brigade response delay are key parameters. Above a certain threshold of complexity, a separation of alarm systems architecture into detection and protection layers becomes relevant and brings many improvements to maintenance teams and CERN Fire Brigade. Inspired by French standards, this paper brings a possible strategy for addressing these challenges. The new conceptual architecture of alarm systems is studied as part of the renovation of the SPS fire safety system. This architecture will also be proposed in future CERN's projects such as HL-LHC or FCC.

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