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Selected issues of the probability of false alarms in electronic security systems used in building objects

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Abstract

The article presents selected issues concerning problems related to the probability of false alarms generated by electronic security systems (ESS) during technical monitoring states. ESSs are used in building objects. The authors of the article conducted a theoretical analysis regarding the causes of false signals in security systems, with particular attention to Fire Alarm Systems (FAS). FAS are the most important security systems that are responsible for fire safety in buildings and large areas – e.g. airports, railway stations, etc. FAS are responsible for the life and health of people using the objects, but also for property and the surrounding natural environment. In accordance with CPR Regulation No. 305 of March 9, 2011, of the European Union, FAS elements and devices are required to obtain certification and are treated as generally available construction materials.

Keywords: electronic security systems, false alarm, fire alarm system, fire safety, detector

1 INTRODUCTION

In building objects and so-called extensive grounds, which include airports, military units, railway stations and adjacent areas, etc., electronic security systems (ESS) are used to ensure an appropriate level of safety for people, the natural environment and the collected property. These systems are responsible for identifying and detecting security

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threats, both external and internal. This is always done in two separate zones due to the distance from the protected object (Wiśnios et al., 2024):

- far zone – on approaches, in protected extensive areas, use of so-called perimeter protection of building objects using, for example, closed-circuit television (CCTV) (Paś, Rosiński and Białek, 2021), (Paś and Klimczak, 2019), (Paś et al., 2022),
- local zone – as the use of specialized sensors and detectors to detect a threat directly in the surrounding space both externally and internally. Due to the different ways in which unwanted extortion associated with breaches in the security of objects and adjacent areas is affected, specialized ESSs are used that are responsible for supervised objects. Among them are:
  - Fire Alarm System (FAS) – detecting the hazard response associated with so-called fire characteristic quantities (FCQ), which can include e.g. smoke, temperature or flame (Sakellariou et al., 2020), (Urbieta et al., 2019), (Wu, H., Wu, D. and Zhao, 2019),
  - Voice Alarm System (VAS), designed to broadcast messages in building objects and supervised areas by FAS about the occurrence of a fire phenomenon (danger, alarm or evacuation),
  - Intrusion Signaling System and Assault (ISSA), responsible for detecting unauthorized entry into protected areas or spaces (Ziółkowski et al., 2022), (Białek, Wetoszka and Paś, 2019),
  - Closed-Circuit Television (CCTV) system currently used to identify, alarm and record threats in outdoor and indoor spaces (Paś, Rosiński and Białek, 2021), (Duer et al., 2021), (Dyduch, Paś and Rosiński, 2011),
  - Access Control System (ACS) used to supervise entry or exit in protected areas (Paś et al., 2022), (Ziółkowski et al., 2022), (Klimczak et al., 2023).

The above-mentioned ESSs have been presented according to their importance of use in the process of protecting objects or in a given space. No single universal ESS has been developed. In order to ensure an appropriate level of security using ESS, the presented systems are integrated using their various functionalities. One of the most important ESS that is directly responsible for health, life and accumulated property, including the natural environment, is FAS. It is supplemented by acoustic-optical signaling devices and sometimes by VAS (Klimczak and Paś, 2020), (Klimczak and Paś, 2019), (Krzykowska-Piotrowska et al., 2021). FAS are often used in combination in protected spaces with fixed extinguishing systems (FES) and gas extinguishing systems (GES). These two systems respond directly to an existing fire risk in the early stages of fire development, before the arrival of the State Fire Service (SFS), limiting the amount of damage.

In all ESSs, the issue of false alarms is a major concern. This is a particularly significant problem in FAS, where false alarms are caused by FCQs other than those that occur during a fire. The occurrence of false alarms in FAS may result in additional hazards caused, e.g. during an redundant evacuation. It is also tangible material damage such as the stopping of trains traffic, planes, etc. This signal always interferes with the normal functioning of the building objects and supervised areas (Stawowy et al., 2021a), (Stawowy et al., 2021b), (Rosiński et al., 2024). Special attention should be paid to these events by designers, supervisors of the exploitation process, installers, service technicians and also users of the objects. Technical Specification No. PKN-CEN/TS 54-14, which still does not have the status of a Polish standard, recommends always investigating the causes of false alarms and keeping records of such events – in the FAS there was a so-called event category assigned. The maximum number of false alarms allowed is one such alarm per 100 automatic detectors in the FAS, per year of usage in accordance with the applicable standards. However, such activities in the ESS should be carried out in order to continuously reduce the number of false alarms (Wiśnios et al., 2024), (Sakellariou et al., 2020). If, for example, the number of permissible false alarms (FA) is exceeded in an FAS, the pattern of events occurring should be established as a first step, i.e. the time, place, reaction of the fire alarm control panel (FACP) and the supervisors of the FAS exploitation process should be determined (Baek et al., 2021), (Milke et al., 2003), (Adib et al., 2017). Then visually inspect the scene of the incident and determine whether it is possible to reduce the number of FA signals by, for example, changing the type of detector, location, FAS control and management procedures, modifying the technical structure of the line or monitoring loop, etc. (Wu, H., Wu, D. and Zhao, 2019), (Muhammad et al., 2020), (Łukasiak, Rosiński and Wiśnios, 2021).

2 Probability of false alarms in the ESS - selected issues

The main operational task of the ESS is to ensure safety by obtaining reliable information on violations of security areas for ISSAs or exceedances of FCQ parameters for detectors in the building where the FAS is installed (Kubica et al., 2016), (Drzazga, Kołowrocki and Soszyńska-Budny, 2016). A change in a detector's technical state from supervision to alarm is an announcement of an alarm along with the location of the occurrence of this phenomenon to the Alarm Control Panel (ACP) or FACP. Always the ACP (FACP) identifies from the detector's alarm signal the room number, the number of the detector's line or loop, the time of the change of technical state from supervision to alarming (Mohapatra and Khilar, 2016), (Kwasiborska and Skorupski, 2021). All events occurring in the ESS are stored in the non-volatile memory which is always on Alarm Control Panel equipment. At the receiver input in the ACP (FACP), in addition to the useful signals, there are natural or artificial, intentional and unintentional interferences.

These disruptions can include:

- mechanical forcing’s (e.g. vibrations of the ground, walls, building partitions, etc.) which can affect the functioning of e.g. detectors;
- electromagnetic interference (EMI) conducted and radiated (intentional, unintentional – stationary and non-stationary), directly or indirectly affecting the receiver, lines, loops, antennas, etc. (Paś and Klimczak, 2019), (Krzykowska-Piotrowska et al., 2021), (Sodhro, Pirbhulal and de Albuquerque, 2019);
- forcing’s and variations in parameters of natural environmental – temperature, pressure, humidity or pollutions, including electromagnetic radiation (light) from the entire spectrum range;
- other types of interference that directly affect hazard detection processes are e.g. wind speed, forced (unforced) air flow in warehouses (air conditioning), sound level relevant to VAS.

ACP or FACP should make two decisions after receiving a signal from the detectors, which should be mutually exclusive (Paś, Rosiński and Białek, 2021), (Stawowy et al., 2021b), (Antosz et al., 2022):

- condition Q1 means that “there is a real threat in the protected area, building, space, etc.”, it is e.g. fire, intrusion, smoke;
- condition Q2 means there is no real threat in the protected area, a space that can be additionally supervised by a person. Occurring EMI causes a transition in the ESS from the SS state to the SA state (surveillance – alarm, etc.). As a result of interference, signal fluctuations in surveillance loops or transmission lines, two different decisions can be automatically assigned for each technical condition in the ESS (SS, SA) (Paś and Klimczak, 2019), (Urbieta et al., 2019), (Kołowrocki and Soszyńska-Budny, 2018), (Siergiejczyk, Paś and Rosiński, 2014):
  - decision Q_1^* is a decision about a real threat – fire, burglary;
  - decision Q_0^* is the decision that there is no danger in the object and the presence in the surrounding natural environment, e.g. interference.

The quality of threat detection in the ESS for condition Q_1 can be determined by the corresponding conditional probabilities described by the expression (1) or (2). It can be written as follows:

- probability of correct detection of the threat in the ESS. The maintenance staff or ACP (FACP) in ESS made correct decision, detected threat, performed correct action – expression (1)

$$\theta = P\left(\frac{Q_1^*}{Q_1}\right) \tag{1}$$

- probability of so-called false calm – the threat is present in the object, but there is a lack of response from the maintenance staff or ACP (FACP), assuming the correct functioning of the entire ESS – expression (2)

$$\bar{\bar{Q}} = P\left(\frac{Q_0^*}{Q_1}\right) \tag{2}$$

The decisions Q and $\bar{\bar{Q}}$ made by the maintenance staff or headquarters are mutually exclusive random events – equation (3).

$$Q + \bar{\bar{Q}} = 1 \tag{3}$$

The quality of the alarm announcement in the ESS with the practical absence of FA signals for all systems is determined by the conditional probabilities described by expressions 4 through 5:

– FA probability in ESS – e.g. FAS – expression (4)

$$H = P\left(\frac{Q_1^*}{Q_0}\right) \tag{4}$$

– probability of correct lack of announcement of fire alarm or intrusion into the object for ESS – expression (5)

$$\bar{\bar{H}} = P\left(\frac{Q_0^*}{Q_0}\right) \tag{5}$$

Events occurring in the ESS are mutually exclusive. The following condition, expressed by equation (6), then occurs:

$$H + \bar{\bar{H}} = 1 \tag{6}$$

Figure 1 shows the process of identifying threats.

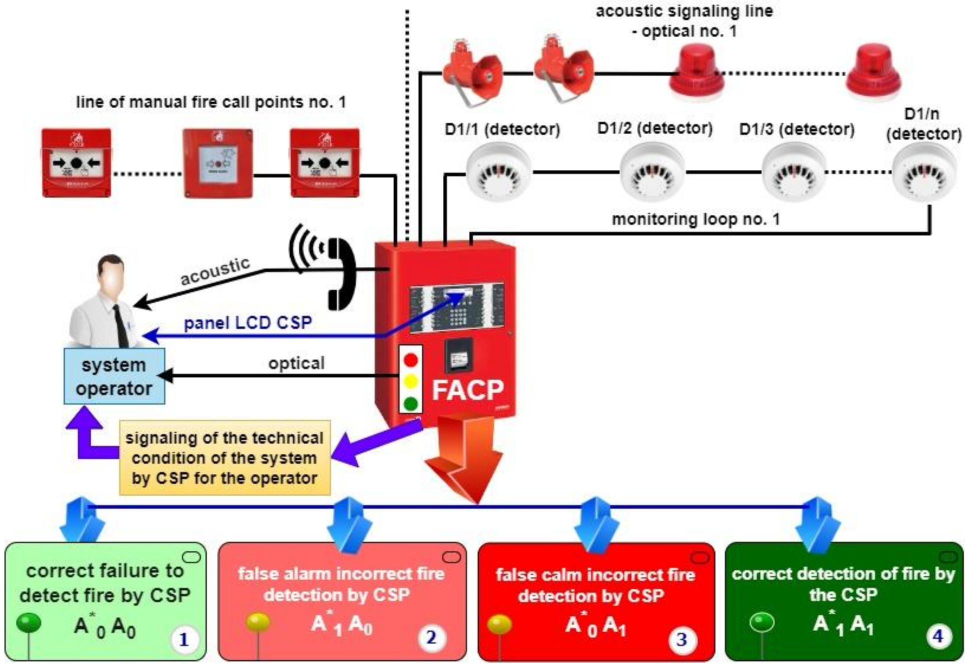

Figure 1. *Implementation of the identifying threats process in the ESS, possible a priori fire threats decisions related to the exploitation process*

For the case of detecting a fire threat as in Figure 1, we talk about the probability of the situation Pn, where n = 1,2,3,4. The sum of these events must always equal unity - as represented by expression (7)

$$P_1 + P_2 + P_3 + P_4 = P_1(A_0^*, A_0) + P_2(A_1^*, A_0) + P_3(A_0^*, A_1) + P_4(A_1^*, A_1) = 1 \tag{7}$$

3 Selected factors of natural environmental causing resulting in false alarm signals in FAS

In contemporary using FAS, there is an exploitation problem related to fire sensors, their susceptibility to detect FCQs and their changes, which are not related to the actual fire. This is approximately 80% of fire alarms generated by sensors in FAS, the so-called mono-detector ones. This is due to the physical processes and phenomena that occur, which often simulate the phenomenon of fire. Particularly when the FAS are connected to an alarm and damage signal transmission device (ADSTD) that has communication with the SFS, as well as fixed extinguishing systems, i.e. GES and FES, including the smoke ventilation system (SVS) or VAS – as shown in Figure 2.

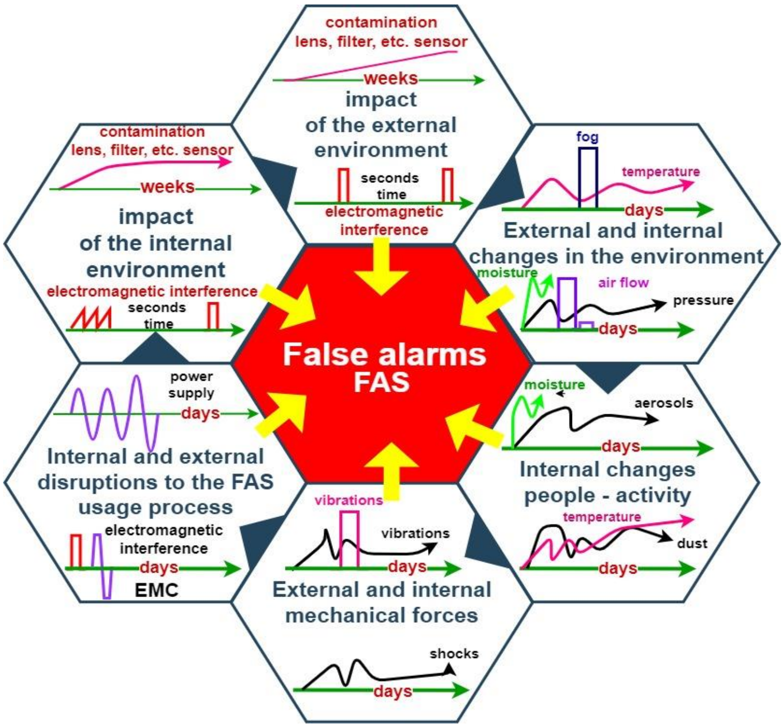

Figure 2. *Selected reasons for the occurrence of FA signals in FAS*

The right side of Figure 3 shows typical fires that can occur in protected objects and the course of their initial phases. In the case of burning cotton, there is a slow change in the parameters of the FCQ, it is a time interval of minutes – hours, but burning wood is the rate of change of parameters already counted in seconds/minutes. Exceeding the limiting FCQLP parameters corresponding in a given detector to a certain threshold exceedance (e.g., voltage) causes a change in the operating state, i.e., a transition from the supervision state to the alarm state and sending this signal to the FACP in FAS. Reducing in PFA value in FAS is also the use of advanced detectors that use neural networks to detect and analyze the magnitude of amplitude change, increment and fluctuation over a set period of time. These detectors respond to various FCQ quantities – such as temperature change, smoke, and their changes over a preset period of time.

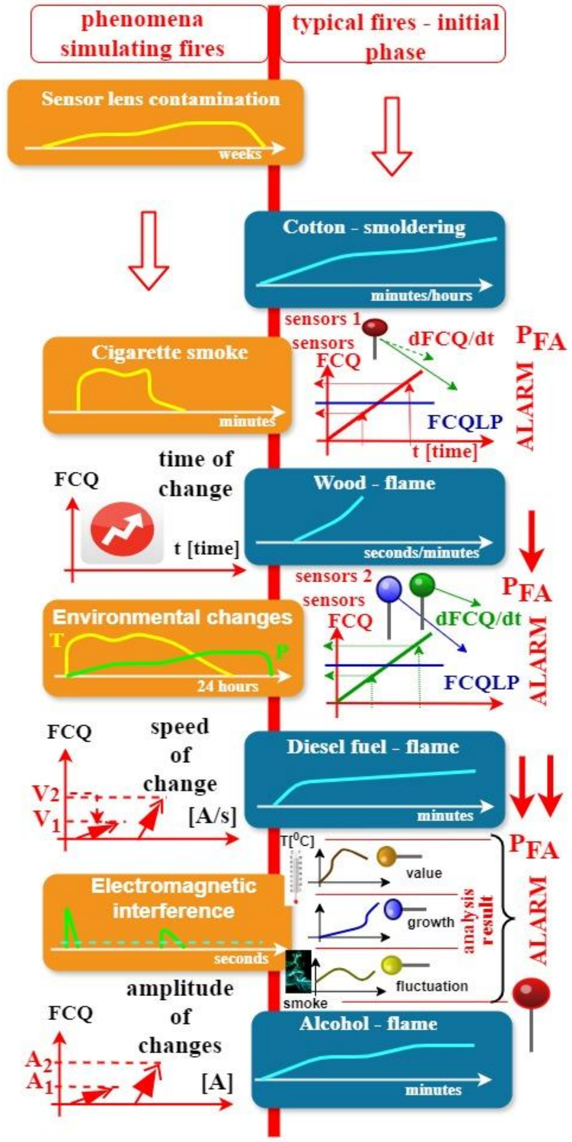

Figure 3. *Distinction FCQ for simulated and actual fire phenomena occurring indoors to reduce* P_{FA} *in supervised spaces by FAS, where:* dF_{CQ}/dt *– the rate of change of FCQ in a given time interval,* FCQ_{LP} *– constant limit value causing the alarm to be triggered in FAS,* P_{FA} *– probability of false alarms, dA/dt – the rate of change in the amplitude of physical signals, interfering with the FCQ over time, A – the amplitude of changes in the magnitude of FCQ, interference in a given time interval – e.g. seconds, minutes, etc.*

4 Selected issues and methods to reduce the probability of false alarm used in fire alarm systems

In order to reduce the value of the P_{FA} parameter in FAS, all available technical, organizational and combined both solutions should be used. The declaration of an alert in FAS is a large economic cost, associated with the announcement of evacuation by VAS, stopping traffic, the arrival of SFS services and cleanup work. There are measurable economic losses, but also image losses. Therefore, FAS manufacturers, designers, but also users should strive to minimize P_{FA} values. Using the solutions shown in Figure 4, you can contribute to changing the P_{FA}.

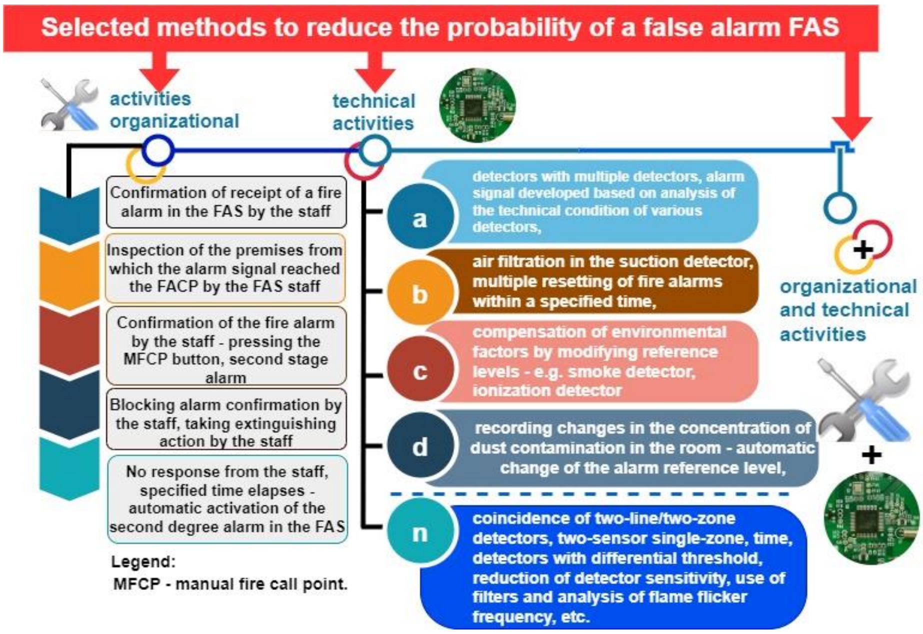

Figure 4. *Selected methods of reducing P_{FA} used in FAS*

Figure 5 shows a functional diagram of a redundant temperature detector in the “Tina” simulation programme using the OP1 operational amplifier and NTC thermistor. The reference voltage (detector trip threshold) is determined by the voltage divider R2 and R3. A change in the detector's technical status is indicated by an LED, with LED1 being green and LED2 being red. J1 are the detector supply voltage sources and J2 are the supply voltage sources for OP1. Figures 6a, 6b show a time simulation of the effect of changing the ambient temperature of the redundant detector for two classes, i.e. A1 and C. The duration of the computer simulation is 180 seconds. This means that the ambient temperature rise of the detector is 30°C/min. For a class A1 detector, the U_{wyj} value is constant and up to time t_{1a} = 108 s. The voltage U_{wyja} then increases to a value of approximately 11V for Δt_a = 18 s. The time for the system to change its response from supervision to alarm is equal to 18 second. For a class C redundant detector, the state change occurs for a time t_{1c} = 149 s. Then, in the detector circuit, the voltage U_{wyjc} reaches a value of approximately 12V at time Δt_c = 16 s.

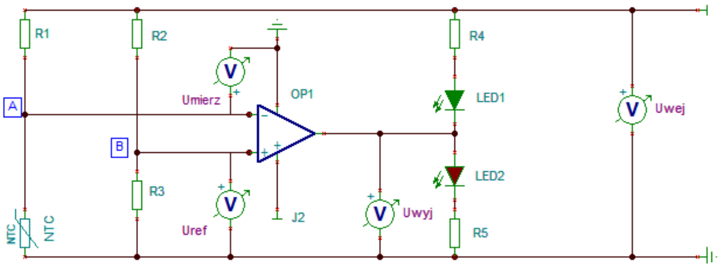

Figure 5. *Functional diagram of the redundant temperature detector*

The time for the system to change its response from supervision to alarm is 16 s for a class C detector. The switching times of the detectors for classes A and C are comparable. However, the switching time is t_{1a} = 108 s while t_{1c} = 149 seconds.

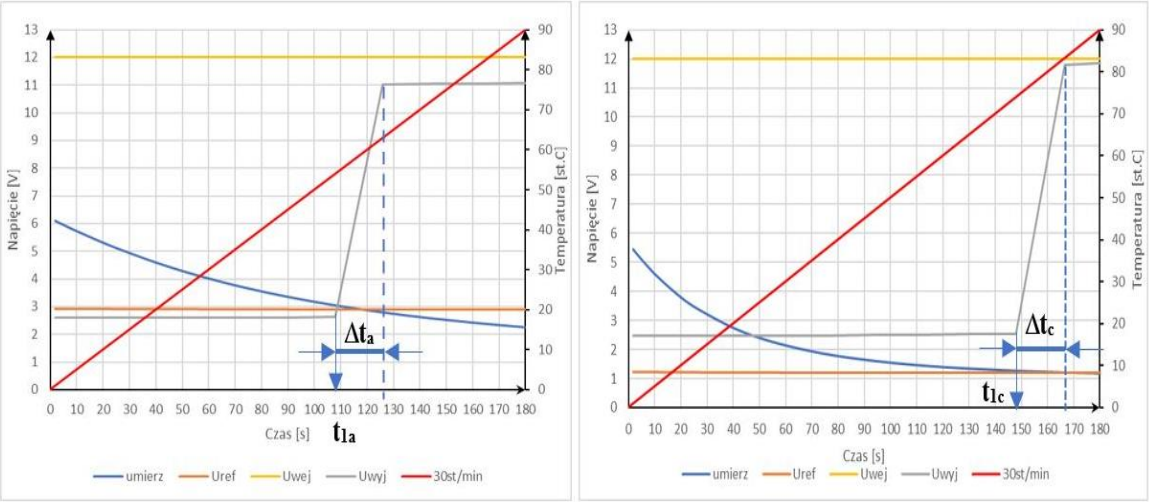

Figure 6 a, b. *Voltage graph for the class A1 and C redundant detector (room temperature rate of changes is 30 °C/min.)*

5 Conclusions

The likelihood of FA signals in the ESS is an issue of great importance, especially in FAS. Therefore, efforts should be made already at the design stage of the ESS to minimize this indicator using the various detector technologies available and also ACP (FACP). The analysis of this issue should also take into account the human factor, the operators and the service of these systems. An important issue that also contributes to minimizing this indicator is the continuous analysis of changes in the use of rooms or entire objects in the process of exploitation and the change of the type of detectors in lines and surveillance loops. This is the role of ESS exploiters, who should liaise with the designers of these systems on an ongoing basis and keep abreast of technical developments, construction of detectors and alarm control panels. The task of reducing PFA in the ESS is a continuous process over time. This is also the result of training and training alerts after the system in question has already been commissioned in the relevant building object.

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