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RELIABILITY AND OPERATING ANALYSIS OF TRANSMISSION OF ALARM SIGNALS OF DISTRIBUTED FIRE SIGNALING SYSTEM

Analiza niezawodnościowo-eksploatacyjna transmisji sygnałów alarmowych rozproszonego systemu sygnalizacji pożarowej

Abstract: *The article presents basic issues regarding the operation process and analysis of the reliability of the fire alarm and transmission system in the distributed fire alarm system. Signals of fire and fault alarms generated from the fire alarm system (SSP) send fire monitoring. Fire monitoring consists of sending, with the confirmation, an automatic fire alarm and a fault signal to the appropriate alarm receiving centers (ACO). The reliability structure of the fire and fault alarm transmission system is presented. An analysis of reliability of independent SSP system information transmission paths was performed.*
Keywords: reliability structures, fire signalling system

Streszczenie: *W artykule przedstawiono podstawowe zagadnienia dotyczące procesu eksploatacji i analizy niezawodności systemu transmisji alarmów pożarowych i sygnałów uszkodzeniowych w rozproszonym systemie sygnalizacji pożarowej. Sygnały alarmów pożarowych oraz uszkodzeniowych generowane z systemu sygnalizacji pożarowej (SSP) przesyła monitoring pożarowy. Monitoring pożarowy polega na przesłaniu z potwierdzeniem, w sposób automatyczny alarmu pożarowego i sygnału uszkodzeniowego do odpowiednich alarmowych centrów odbiorczych (ACO). Przedstawiono strukturę niezawodnościową systemu przesyłania alarmów pożarowych i uszkodzeniowych. Przeprowadzono analizę niezawodności niezależnych torów przesyłania informacji o stanie systemu SSP.*
Słowa kluczowe: struktury niezawodnościowe, system sygnalizacji pożaru

1. Basic definitions related to fire prevention

According to § 31 of the Regulation of the Minister of Internal Affairs and Administration of 7th June 2010 on fire protection of buildings, other structures and areas (Journal of Laws no. 109, item 719) [11], the owner, the manager or the user as indicated in art. 5 of the Act of 24th August 1991 on fire prevention [1] should agree the method of signalling and alarm devices of the fire signalling system with a Fire Brigade site or with a site indicated by a Fire Brigade commander, with said Fire Brigade commander. Using the definition specified in the Regulation [11], a SSP is a system which includes signalling and alarming devices used in automatic detection and sending of fire-related information, as well as receivers of fire alarms and receivers of damage signals. Fire alarm signals and damage signals generated by the SSP are sent using the fire monitoring system. Fire monitoring includes automatic sending, with a receipt, of a fire alarm and of a damage signal to the relevant alarm receiving centres (ACO). The fire alarm should be sent without any human activity to a continuously manned site which dispatches Fire Brigade staff and resources, indicated by the relevant County (City) Commander, where the fire alarm receiving station (SOAP) is installed. Damage signals are automatically sent to the damage signal receiving station managed by the fire monitoring system operator.

Fire signalling system reliability is a key to cooperation with the transmitter and with fire signal transmission to the ACO. An example may be provided using data cited in the Fire Brigade report for 2017 in the Silesian Voivodeship [19]. According to this document, Fire Brigade units intervened a total of 69,219 times in the Silesian Voivodeship in 2017, including:

- 16,279 fires (15,783 small, 470 medium, 23 large, 3 very large fires),
- 46,330 local hazards (5,765 small, 39,894 local, 650 medium, 21 large hazards),
- 6,610 false alarms (248 malicious, 4,034 reported in good faith, 2,328 from fire monitoring).

In the context of this article, special attention should be paid to data indicating 2,328 false alarms from fire monitoring systems, out of the total of 6,610 of all reported false alarms, as represented graphically in fig. 1. In comparison, the share of false alarms from fire monitoring systems in the total number of false alarms in the same voivodeship was as follows [20], where the total number of all false alarms was 4,583, malicious alarms – 262, alarms reported in good faith – 2,688 and alarms from fire monitoring systems 1,633 (fig. 2). Taking the cited data into account it may be said that the share of 35% of false alarms from fire monitoring systems in the total number of all false alarms indicates the need to implement activities aimed at decreasing that number. False alarm generation is influenced by both the fire signalling systems and by the devices transmitting fire and damage alarms.

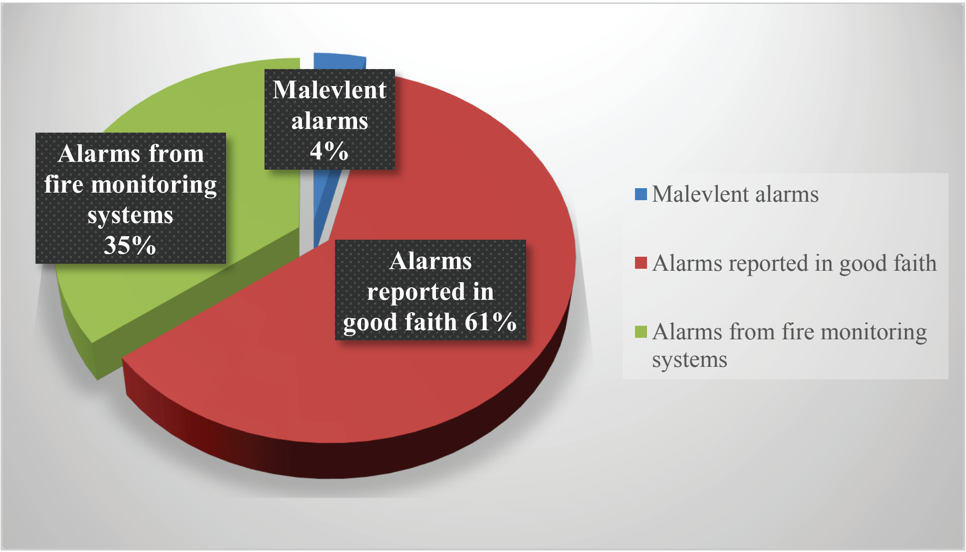

Fig. 1. The share of false alarms from fire monitoring systems in the total number of all false alarms in 2017 in the Silesian Voivodeship

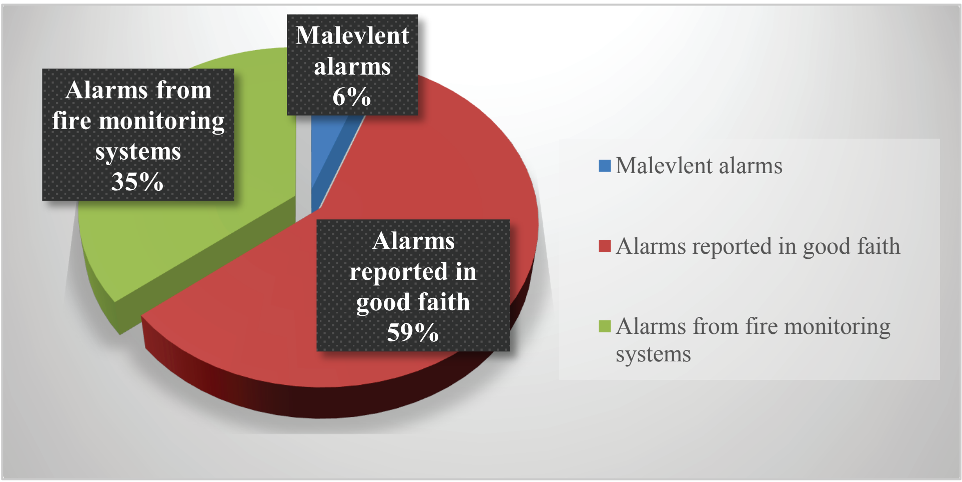

Fig. 2. The share of false alarms from fire monitoring systems in the total number of all false alarms in 2015 in the Silesian Voivodeship

2. Concentrated and distributed fire signalling systems

The use of a specific type of SSP systems depends on legal requirements relevant to such systems, the fire scenario which should be executed, legal requirements related to the protected site, the accepted scope of protection and functional requirements which should be met by the SSP installation. Single, open monitoring lines, also known as radial lines, non-addressed or addressed should monitor a fire area of up to 1,600 m^2 according to the requirements, whereas the maximum number of rooms protected by a single, open line is 10. Installation of up to 32 fire sensors or up to 10 manual fire signalling devices (ROP) is permitted within a single line (fig. 3). Such systems may be provided with outputs for connection of fire alarm transmitters and damage alarm transmitters (UTAPS).

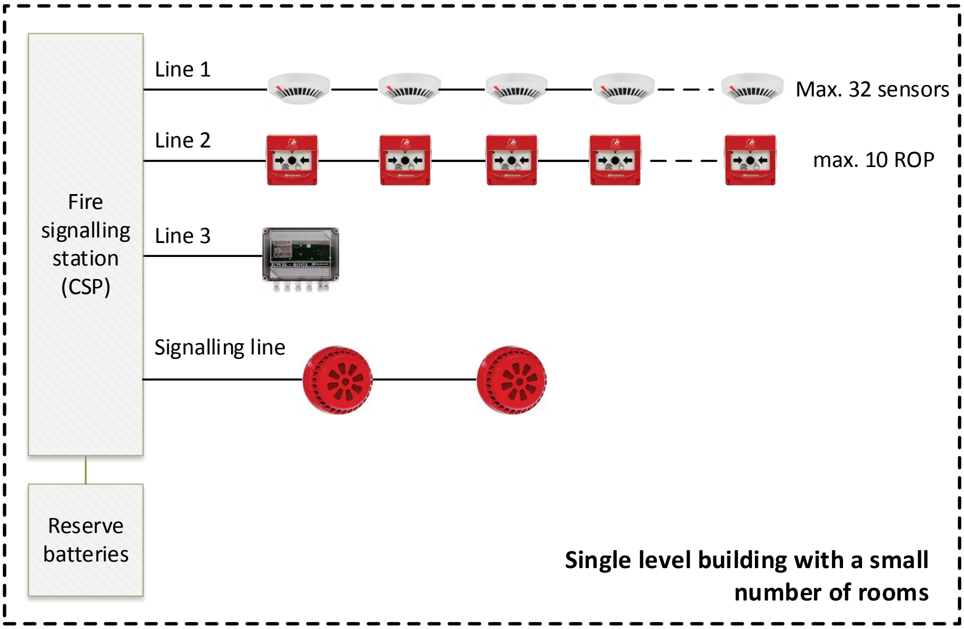

Fig. 3. Concentrated SSP with open monitoring lines, without a connection to a Fire Brigade notification system

SSP with loop-type, addressed monitoring lines are intended for larger sites, where the concentration of technical installations and the number of rooms exclude the option of system controlling using conventional control stations and open lines (fig. 4).

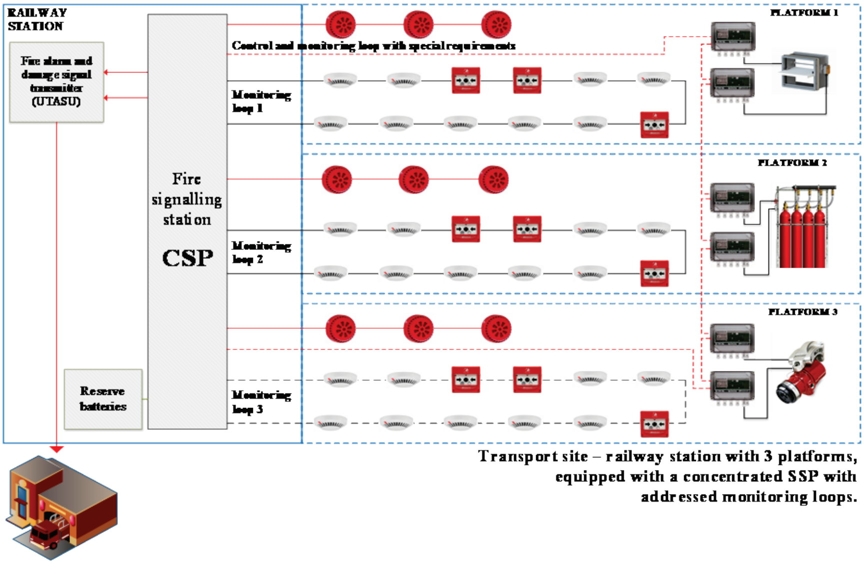

Fig. 4. Concentrated SSP with open, addressed monitoring lines at a railway station with three platforms

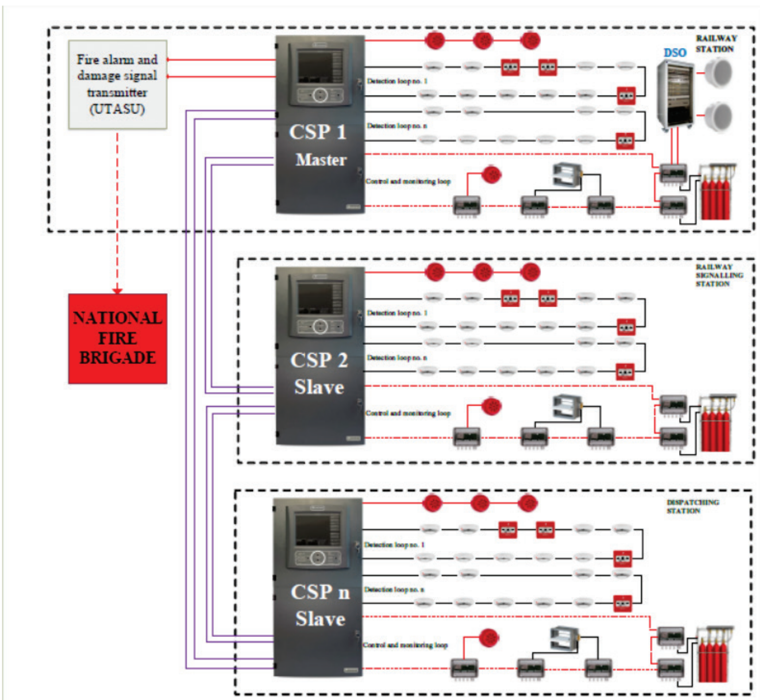

Fig. 5. A diagram presenting a distributed SSP at a vast site

Vast sites require monitoring provided by distributed SSP systems. A distributed SSP system includes a few or several CSPs, which individually monitor a separate building or an area and are connected within a network providing mutual communication and information transfer. A distributed system could also be designated as a network system or a distributed architecture system (fig. 5).

3. Analysis of signal flow in a fire alarm and damage signal transmission system

Fig. 6 presents a schematic representation of a fire alarm transmitting system structure, conforming to the framework organisational and technical requirements of the Chief Commander of National Fire Brigade. The first element of the fire alarm transmission system is a fire alarm and damage signal transmitter (UTASU), installed at the monitored site. The signal is sent from the UTASU via the transmission network, directly to the fire alarm receiving centre (COAP), or via an intermediate station of the system operator. Damage signals are sent directly to the system operator.

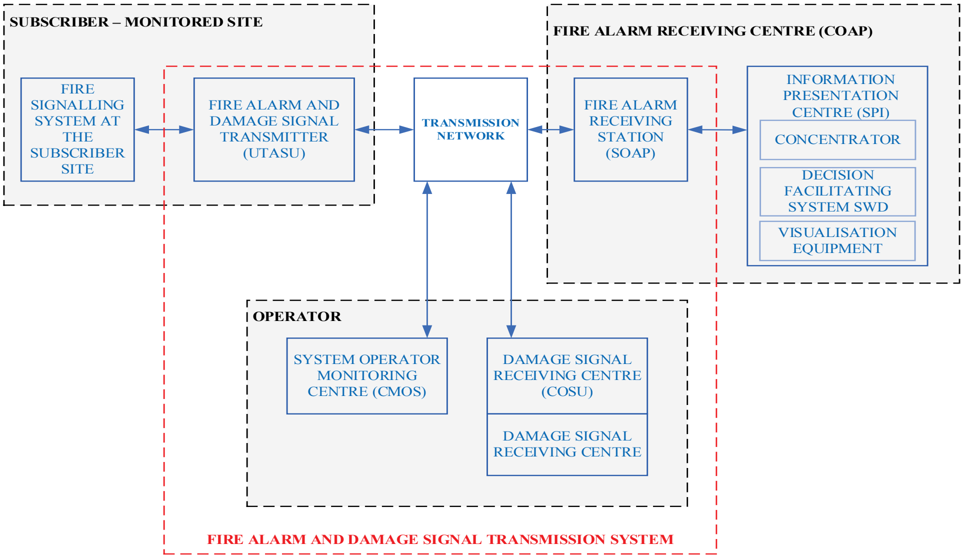

Fig. 6. Transmission diagram for fire alarms and damage signals (prepared on the basis of framework organisational and technical requirements of the Chief Commander of National Fire Brigade)

4. Reliability structure of fire alarm and damage signal transmission

The CSP fire signalling station at the monitored site is wired to the first element of the fire alarm transmission system, namely a fire alarm and damage signal transmitter (UTASU), installed at the monitored site, usually near CSP, in the same room. The signal is sent from the UTASU via the transmission network, directly to the fire alarm receiving centre (COAP), or via an intermediate station of the system operator. A graph presenting operation of the fire alarm and damage signal transmission system is presented in fig. 7.

Damage signals are sent directly to the system operator. If the system becomes damaged, the operator shall be obliged to inform the fire alarm receiving centre about a damage preventing a fire alarm to be sent from the monitored site. After the repair, the operator shall immediately notify the fire alarm receiving centre (COAP) that system functionality has been restored.

The system may be present in the following functional states [8, 9, 13, 15]:
$R_{O(t)}$ – probability function for the system in fully operational condition SPZ,
$Q_{ZB(t)}$ – probability function for the system in a safety hazard condition SZB,
$Q_{B(t)}$ – probability function for the system in a safety fault condition SB (fig. 7).

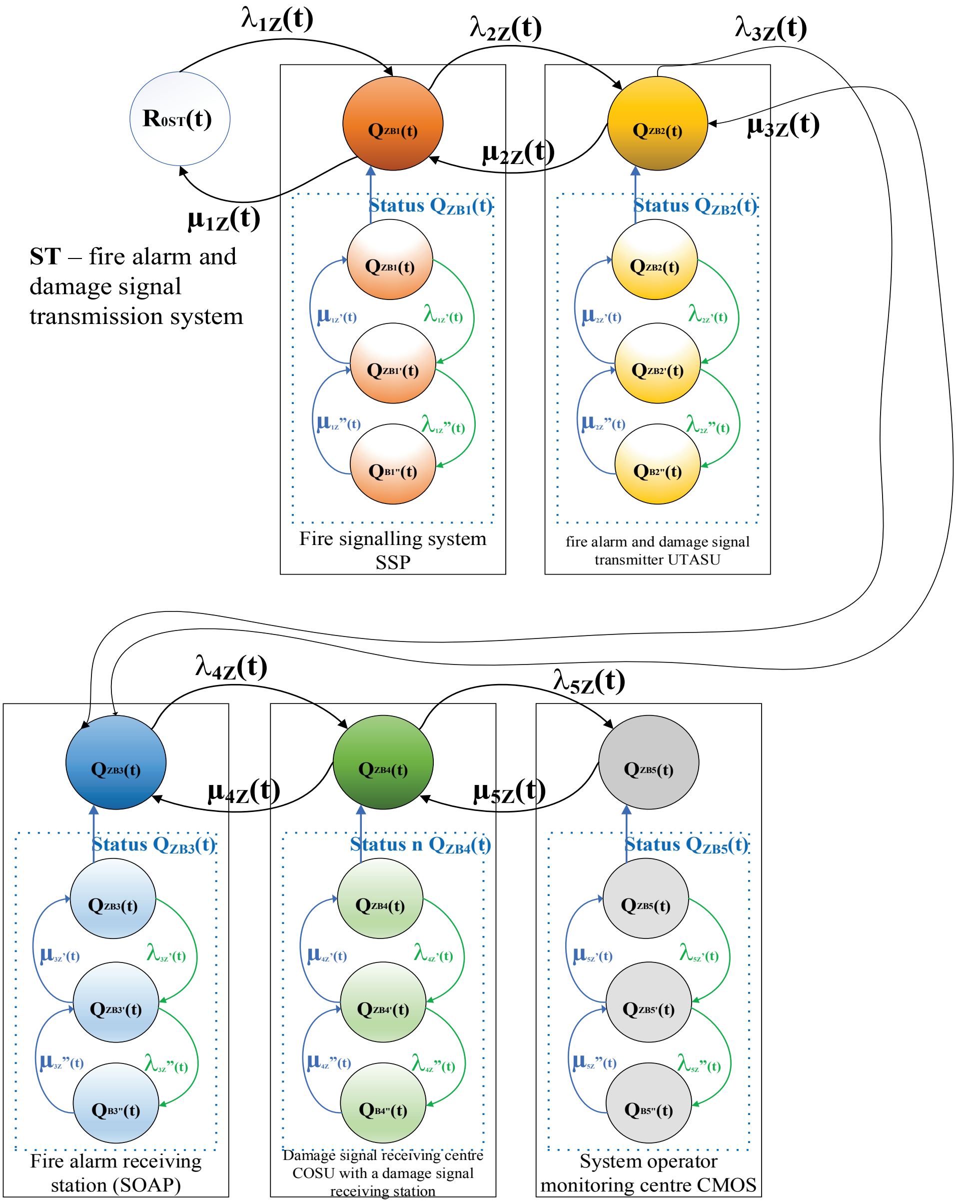

Fig. 7. Graph presenting operation of the fire alarm and damage signal transmission system

Fig. 7 key: $R_{OST}(t)$ – probability function for the system in fully operational condition S_{PZ}, $Q_{ZB1,2,3,4,5}(t)$ – probability function for the system in a safety hazard condition S_{ZB}, $Q_B(t)$ – probability function for the system in a safety fault condition

S_B, $\lambda_{1,2,3,4,5}$ – intensity of transitions between the fully functional condition S_{PZ} and the safety hazard condition S_{ZB}, $\mu_{1,2,3,4,5}$ – intensity of transitions between the safety hazard condition S_{ZB} to the fully operational condition S_{PZ}, $\lambda_{1\text{-}5z}$ – intensity of transitions from the safety hazard condition S_{ZB} to the safety fault condition S_B, $\mu_{1\text{-}5z}$ – intensity of transitions from the safety fault condition S_B to the safety hazard condition S_{ZB}.

5. Conclusions

A fire alarm and damage signal transmission system has a complex reliability structure of a mixed, parallel-serial type [2, 4, 5, 10, 12, 14, 17]. The transmission system includes a SSP system which may use various redundancies, e.g. Element redundancies – e.g. sensors, ROP; resistance redundancies – various cable routes and units, information redundancies – various methods used to send information to information presentation systems, etc. The objective behind the use of such technical solutions in SSP systems is to increase operational reliability of such systems in all functional conditions, e.g. monitoring, damage or alarming. Such systems also use the safe damage rule, applicable to alarm stations in particular [3, 4, 7, 9]. A single damage to the system does not result in a catastrophic damage. Fire alarm transmitters installed at the site monitored by a SSP system should be located in the same, fire-separated room, which significantly improves the transmission reliability of fire and damage signals. A fire alarm and damage signal transmission system should always be based on a wired connection and on a radio transmission system.

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