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New technologies for the creation of an automatic security and fire alarm system

M.Yu. Egorov[1]* and *E.L.* Ryzhova[1]

[1] Emperor Alexander I St. Petersburg State Transport University, 190031 Saint Petersburg, Russia

Abstract. The object of this study is the analysis of the latest domestic and foreign technologies for the creation of automatic fire alarm systems. The subject of the study is the fire protection system of the laboratory building of the University. The purpose of the study is to design a demonstration stand for an automatic fire alarm and fire extinguishing system in the laboratory building of the University based on the analysis of the latest domestic and foreign research. The theoretical and methodological basis for the analysis of Russian and foreign technologies in fire alarm systems were legislative acts, regulatory documents, and other sources on the topic of the work. A study has been carried out on the development of a demonstration stand of an automatic fire alarm system in modern conditions using statistical data and scientific publications of recent years. In the work, the structural and schematic diagrams of the stand for demonstrating the operation of automatic fire alarm systems are designed, the rationale for choosing the base of the main elements of the alarm system is given, the characteristics of the elements and their reliability indicators are calculated.

1 Introduction

Recently, there has been interest in automatic fire alarm systems (ASPS). In recent years, more and more advanced technical means of automatic fire extinguishing have appeared. These innovations are characterized by simplicity, reliability and optimal price-quality ratio, which makes them very attractive for wide application. Consequently, the number of facilities implementing these technologies is growing. However, despite these achievements, numerous methodological problems in this area remain unresolved. Although the normative documents contain definitions aimed at achieving a common understanding, a unified approach to addressing these issues has yet to be developed.

A fire prevention system is a set of organizational measures aimed at eliminating the conditions for the occurrence of fires established by Federal Law and aimed at preventing danger and harm because of a fire. According to the Technical Regulations on Fire Safety Requirements No.123-FZ, Chapter 12, Article 45, any automatic fire extinguishing system must ensure the required reliability of operation [1]. It is evident that the reliability of the functioning of ASPS is paramount in ensuring the normative value of fire risk. The issue of reliability has become increasingly critical, particularly considering the recent spate of

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[*] Corresponding author: mikhail.yu.egorov@gmail.com

natural and man-made disasters worldwide. These catastrophic events not only result in significant loss of life but also disrupt the essential functions and infrastructure of entire cities for extended periods [2].

Due to such accidents, ASPS may be inoperable, since their water and energy supply depends on the infrastructure of the protected facility. Conversely, ASPS can be designed to operate autonomously for a certain period, while maintaining functionality independently of external power supplies and control systems.

Due to the lack of scientifically based approaches to the use of ASPS, their development is slowing down. To summarize, the use of an automatic fire alarm system requires increased reliability and reduced risks [3-12].

One of the fundamental requirements for fire alarm systems is "reliability." This encompasses not only the accurate and timely detection of fire at its initial stage but also the minimization of false alarms, which can undermine operators' confidence in the security system. ASPS are prevalent, operating on a binary logic where alarm sensors exist in two states: "norm" and "fire." The alarm is activated when the monitored parameter of the configured sensor surpasses a predefined threshold. Consequently, determining the optimal trigger threshold value presents a significant challenge, as it must balance sensitivity to real fires with resistance to false alarms.

The purpose of this study is to present an analysis of existing automatic fire alarm systems and to search for promising areas of automatic fire extinguishing. This analysis considers the degree of reliability, identifies current scientific and technical challenges, and reviews the contributions of manufacturers and researchers in this field. Furthermore, the study aims to propose solutions to the identified problems, thereby advancing the effectiveness and dependability of fire extinguishing technologies.

Automated fire extinguishing control systems are also used in higher educational institutions (universities). It follows that the development of a modern ASPS demonstration stand is necessary. The university will allow you to present the work of the latest fire extinguishing systems.

An analysis of works on fire safety technologies and fire alarm systems has shown that works on this topic were written both recently and more than 10 years ago. New articles allow specialists of design and installation and service organizations to understand the requirements of current regulatory documents. Early works explain the requirements in these documents.

The basis for fire prevention is the organization of fire safety, and the Russian Federation has adopted regulatory legal acts in the field of fire safety. The legislation on fire safety is based on 17 of the Constitution of the Russian Federation and includes the Federal Law "On Fire Safety", adopted federal laws, as well as laws and acts of the subjects of the Russian Federation regulating fire safety issues. According to the federal law "On Fire Safety", the purpose of creating a fire safety system for an object of protection is to prevent fire, ensure the safety of people and protect property in case of fire [13].

The designated problem of creating an automatic fire alarm system is considered by the authors of the work [14], which contains issues of organizing the protection of objects using technical means and security systems. It presents an analysis of access control and management systems, and video surveillance within the framework of the overall security system structure. Information is provided on modern technical means of security, encompassing fire alarm systems, their classification, technical characteristics, and typical applications within integrated security systems. Additionally, the features of their installation and operation are discussed. The requirements outlined in regulatory and guidance documents for the design, installation, and operation of this technical equipment are detailed, with particular emphasis on fire safety issues.

The article [15] also addresses the challenges associated with the development of modern Russian technologies in security and fire alarm systems. It outlines the evolution of security systems in the context of global automation and their integration into unified automated control systems. The article reviews the prospects of using artificial intelligence (AI) in security systems to identify complex situations that are difficult to classify using conventional monitoring data. The potential for employing fire alarm systems based on AI principles, particularly neural networks, is evaluated. This includes the construction of neural networks and logic systems based on combinatorics. Additionally, the article describes the development of a mathematical model to accurately signal the transition of the system to the "fire" state. It addresses the challenge of correctly setting the threshold for triggering these signal generation systems and discusses the minimization of false alarms through the introduction of an additional channel that captures initial information about the state of the object in the optical range. Also, the article presents a study on the reliability of the characteristics of gas fire detectors as claimed by manufacturers. This study aims to determine the feasibility of using these detectors as primary elements in fire alarm systems based on neural network principles.

A number of problems are addressed in the book [16] regarding the design and application of fire extinguishing installations. It reflects on the directions of development in automatic fire extinguishing, presenting the legal, regulatory, and scientific-technical challenges faced by manufacturers and researchers in this field.

The research of the authors of works [17, 18] in the field of fire alarm systems has shown that at present the problem of technical operation of fire automation systems is becoming increasingly important. The problem is also relevant due to the fact that about 13% of the ASPS installed at the facilities are inoperable. This is due to the following reasons:

- imperfection of regulatory documents establishing norms and rules for the design, installation and operation of automatic fire alarm and fire extinguishing systems, as well as requirements for the equipment of systems;
- errors in the design of automatic fire alarm and fire extinguishing systems;
- insufficiently high quality of work performed by enterprises engaged in the production and supply of automatic fire alarm systems, as well as companies engaged in installation, commissioning and maintenance of systems [17].

By working on the above issues, it is possible to improve the quality of ASPS work. The automatic fire extinguishing system has long been highly integrated and comprehensively solves the safety of equipment and personnel in protected areas. However, it is worth noting that any fire protection system will not function effectively without a fire alarm system. This is a set of technical devices, thanks to which it is possible to quickly determine the moment of ignition. Fire alarm is one of the components of a complex fire extinguishing system, which provides necessary information to such systems as notification, fire extinguishing, access control, smoke extraction and others [18].

Thus, a study of the literature has shown that fire safety technologies and fire alarm systems are an integral part of ensuring safety in various facilities, ranging from homes and offices to industrial complexes. The latest technologies open up opportunities to prevent fires and minimize damage.

2 Materials and methods of research

2.1 Theoretical foundations of the development of an automatic fire alarm system of an educational institution

Fire alarm systems are an element of fire safety. A fire alarm system is a set of technical means for fire detection, processing, transmitting fire alerts in a given form, special information and issuing commands to turn on automatic fire extinguishing systems and turn on smoke protection systems, technological and engineering equipment, as well as other fire protection devices.

2.1.1 Analysis of existing fire alarm systems in educational institutions

An assessment of fire risks shows that in such premises as a sports hall or an assembly hall, the probability of an open fire increases. Therefore, it is preferable to control the space according to two parameters-the release of smoke and fire. Moreover, the latter can occur without heavy smoke. In this case, it is not enough to use only smoke detectors – you need a fire detection device.

According to statistics, it is in educational institutions that the percentage of arson among the total number of fires is very high. Special control is required in chemistry, physics, biology classrooms and utility rooms where flammable substances are stored. Detectors installed in a school or boarding school should respond to such fires with lightning speed.

The optimal solution for the organization of automatic fire alarm systems in educational institutions is a rational combination of smoke detectors and open fire detection sensors. Only in this case will the scheme be effective and prevent potential victims.

Let's analyze the features of fire alarm systems in conditions of increasing complexity.

The most common type of automatic fire protection systems is threshold fire alarm systems (burglar alarm). Fire detectors react to electromagnetic radiation from a flame or smoldering fire, thereby preventing the development of a fire.

A threshold-type fire alarm system (unaddressed) is often used to protect small objects. It is impossible to determine the location of the triggered detector, since only the number of the circuit to which it is connected is triggered. If one of the detectors from the common circuit is triggered, a common alarm will be generated, since this system uses a fixed sensitivity sensor. When an alarm occurs, one or more sensors close the circuit, a current of several milliamps passes through it, which causes an alarm in the controller. No more than 20 separate devices can be connected to each circuit, since the system transmits only alarming information throughout the entire circuit.

The only advantage of unaddressed systems is their low cost. These systems are built using conventional electronic components typically designed for ordinary consumer goods.

The key difference between addressable and threshold fire alarm systems lies in their communication algorithms with the fire detection and control device. In threshold systems, the receiving and control device continuously waits for a signal from the fire detector indicating a change in its state. In contrast, addressable systems periodically poll the connected fire detectors to ascertain their status. This type of alarm is designed for medium and large security facilities. In this system, appropriate detectors are used to analyze the state of the environment. In addition, an information exchange protocol is formed in the cycle.

Now, the best is an addressable analog fire alarm system. It is a telemetry system equipped with sensors (detectors) that can transmit measured parameters on request in continuous mode. The addressable analog system not only has the advantages of past systems, but also has additional advantages, and also differs greatly from previous systems in terms of data processing.

2.1.2 Selection of the optimal means of automation of the fire alarm system

In order to develop a properly functioning system, the following have been investigated:

1. patents for inventions and patents for utility models of educational and laboratory stands;
2. Interfaces and protocols used in modern fire protection systems;
3. installation of communication between reception and control devices and fire detectors in well-known fire protection systems.

The array of patent documents selected in the database of the Federal Institute of Industrial Property (FIPS) with a search depth of 10 years makes up patent documents for fire extinguishing system stands [19]:

1. Research laboratory stand for automatic fire alarm systems and emergency management of engineering systems of buildings.
2. A stand for the study of gorenje processes and fire extinguishing.
3. Training stand for technical means of fire alarm and automation.
4. Test and demonstration stand for automatic fire alarm installation

Stands numbered 3 and 4 were selected for the study.

Training stands for technical means of fire alarm and automation refer to educational equipment and can be used for practical training of maintenance and duty personnel to work with fire automation equipment. The disadvantages of these devices are that they do not provide staff training in the skills of working with reception and control devices. Also, there is no possibility for personnel to make managerial decisions in the operation of fire automation during training (manual start of fire extinguishing, installation and removal of fire loops from protection).

Test and demonstration stands of automatic fire alarm systems include a light and sound alarm system, a reception and control security and fire device, a two-wire communication line, optoelectronic addressable analog detectors, a manual detector and a backup power source.

The technical advantage of using these stands is the ability to connect third-party dispatch and access control systems to it, and when using stands for personnel training, it is possible to simulate various equipment failures [20].

At the same time, the stands have disadvantages, the essence of which is the use of heterogeneous interface devices, controllers, sensors, between which a low data transfer rate is provided. In addition, the stands do not provide algorithms for controlling the ability to connect dispatch systems and access control systems from third-party manufacturers. Also, the stands do not allow staff to be trained to simulate various equipment failures.

In addition, an analysis of the activities of the Profi company, which specializes in the development and manufacture of high-tech equipment, reveals their significant contributions to educational and laboratory stands. Notably, the company produces the laboratory stands "Electrical Installation and Adjustment of Fire Alarm Systems" ENPS-01 and "Electrical Installation and Adjustment of Fire Safety Systems" ENPS-SPB-01. The advantage of these developments is that the stands incorporate elements of both address-threshold and address-analog fire alarm systems, providing a comprehensive educational tool for understanding and managing different fire alarm technologies.

The advantage of the laboratory stand "Automatic gas fire extinguishing system", manual desktop version, ASP-G-01-NR is the presence of a USB/RS-485 interface converter. And for the same stand in the desktop computer version of ASP-G-01-NK and the laboratory stand "Fire safety control and maintenance systems", the presence of a USB / RS-485 interface converter and the ability to control processes using a laptop is the advantage of this development.

The disadvantages of all the similar laboratory stands described above are the lack of programmable logic controllers (PLCs), which means that it is impossible to make changes to the operation of the stand and subsequent modernization, as well as the extremely high cost of these developments [21].

In the European patent database ESPACENET PATENT SEARCH, "fire alarm stand" was chosen as the subject of research. When selecting patent documents for this automatic fire alarm system, the principle of operation of the development and the scope of its possible application were taken into account [22]:

1. Stand-alone wireless fire alarm and system including the same.

2. Stand-alone type photoelectric smoke detection fire detection alarm device.
3. Electric fire and combustible gas alarm control ware teaching experiment platform.
4. Additional function expandable fire detection.
5. Wireless automatic fire alarm device based on Internet of Things technology.
6. Combined fire alarm system using stand-alone fire alarm visible light camera.

Patent documents were selected for analysis in the ESPACENET PATENT SEARCH database:

Stands 4, 5 and 6 were selected for the study.

The disadvantage of the 4th patent is that this device is not a full-fledged stand.

Among the disadvantages of the 5th invention, it can be noted that fire extinguishing begins only after sending a message to the operator on a smartphone and at a temperature above 78 degrees Celsius, and there is no repetition of the extinguishing cycle when the fire resumes or incomplete extinguishing.

Stand 6 includes a fire detection sensor, a signal processing unit, a visible light camera that photographs the area where a short-range fire alarm is installed, an image analysis unit, an image and data storage unit, as well as a short-range communication unit.

In the database of the United States Patent and Trademark Office United States Patent and Trademark Office (USPTO) with search depth over the past 10 years, fire alarm systems have been selected as research objects, when choosing patent documents for which the principle of operation of the development and the areas of their possible application were also taken into account. The array of selected patent documents in the USPTO database consists of 2 patent documents for fire alarm systems:

1. System and method for emergency communication in a TCP/IP based redundant fire panel network.
2. Master slave wireless fire alarm and mass notification system.

The TCP/IP-based emergency communication system and method in the backup fire panel operates on a TCP/IP interface over a ring network topology. The advantage of this system is that there is an emergency interface (a separate communication channel) between the panel processor and the panel transceiver.

The wireless fire alarm system includes wireless repeaters for alarm notification to the subordinate devices of the control panel, an active charger, and a battery. The system provides wireless message sending (checksum method).

Thus, during the patent search over the past 10 years, twelve similar stands have been identified in three patent databases. Five educational and laboratory stands produced by Profi were also found. An analysis of the advantages and disadvantages of the ASPS used has shown that there are significant gaps in research and development

2.2 Formation of the stages of development of a demonstration stand for an automatic fire alarm system of an educational institution

2.2.1 Formation of the terms of reference

The fire protection system stand, constructed from a metal housing, includes a control controller, a remote I/O module, a multi-channel addressable fire alarm, a power source, an optoelectronic smoke detector, an alarm siren, a light annunciator, a smoke extractor fan, a powder extinguishing module and an electric door lock drive.

The novelty of the stand under development is the ability to start and stop extinguishing using a GSM module via SMS with a frequency range of 850/900/1800/1900 MHz. To work successfully with the GSM module, it is necessary initially.

To protect the system from intruders, the start and stop of extinguishing will be carried out from a single address specified in the parameters of AT commands. The system is designed to detect a fire at a controlled facility and eliminate a fire.

Synchronization takes place over the RS-485 interface using the ModBus TCP/IP protocol.

The demonstration stand of the automatic fire alarm system has technical and operational requirements:

1. The frame of the stand must be assembled from durable metals.
2. The operator's automated workplace must interact with the fire protection system network via a controlled Ethernet port using the IP communication protocol with full command and control capability.
3. Communication with SCADA INFINITY must take place over the Ethernet channel. The complex must have support for programming languages: FBD, ST and CFC.
4. The stand should be able to connect different types of fire detectors.
5. The stand must have power supplies for 220V AC and 12–24V DC and at least 4 discrete and 2 analog operating outputs.
6. Maintenance should be carried out every 6 months.

For SCADA INFINITY components to work (without taking into account OS requirements), it is recommended:

- Processor — Intel Pentium IV 3 GHz;
- the amount of RAM is at least 512 MB. For projects with more than 20,000 signals — at least 1024 MB;
- 2 network cards that provide operation in a 100-megabit network. It is recommended to use a guaranteed power supply that ensures the operation of the server for at least 15 minutes with fully charged batteries (in case of power failure with fully charged batteries).

2.2.2 Formation of technical, design, working, and executive documentation

Calculation of the signal amplifier from the photodiode output

Consider the circuit for generating the supply voltage in Figure 1:

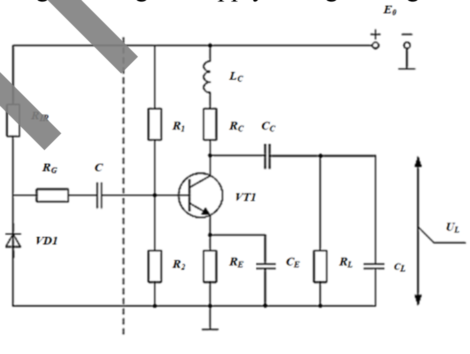

Fig. 1. Equivalent circuit of a photodiode signal amplifier,

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As an active element, let's take the KT357B transistor.

Input impedance and output capacitance of the cascade:

$$R_{IN} = (\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_{INV}})^{-1}$$

$$C_{OUT} \approx \frac{1}{2\pi \cdot f_T \cdot R_E} + C_C(1+K)$$

where: f_T - the boundary frequency of the transistor,
$R_E = \frac{0{,}026}{I_C} = 14{,}188$ Om - emitter resistance,
C_C - collector capacity.

$$R_{IN} = 649.762\ Om$$

Cascade output capacity:

$$C_{OUT} \approx 37.39\ \text{pF}$$

The amplitude of the input signal U_{amIN}:

$$U_{amIN} = \frac{U_L}{K} = 0.15\ \text{mV}$$

The amount of permissible distortion in the low-frequency region is distributed, taking into account the element base allowed for use, between the parameters of the transition circuit and parameters of the emitter circuit. In this case

$$\boldsymbol{K_{LE} = \sqrt{K_L} = 0.922}$$

Then

$$\boldsymbol{C_C = \frac{1}{2\pi \cdot f_L \cdot (R_C + R_L) \cdot \sqrt{\frac{1}{{K_{LE}}^2} - 1}} = 4.165 \cdot 10^{-8}\ F}$$

According to the table of denominations:

$$\boldsymbol{C_C = 4.3 \cdot 10^{-8}\ F = 43\ \text{nF}}$$

Emitter capacity:

$$\boldsymbol{C_E = \frac{1}{2\pi \cdot f_L \cdot R_E}\sqrt{\frac{(1 + S_E R_E)^2 - \frac{1}{{K_{LE}}^2}}{\frac{1}{{K_{LE}}^2} - 1}}}$$

where:

$$\boldsymbol{R_G^{/} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_G}\right)^{-1} = 193.548\ \text{Om}}$$

- equivalent resistance of the signal generator

$$\boldsymbol{S_E = \frac{1 + h_{21e}}{R_{INV} + R_G^{/}} = 0.05}$$

- the steepness of the emitter current characteristic.
Then

$$\boldsymbol{C_E = 3.241 \cdot 10^{-4}\ F}$$

The resulting value

$$\boldsymbol{C_E = 3.3 \cdot 10^{-4}\ F = 330\ \text{mcF}}$$

Calculation of the reflected signal amplifier

Partial software correction of the signal level of the measuring transducers on the MC is possible. Let's draw the amplifier circuit (Fig. 2).

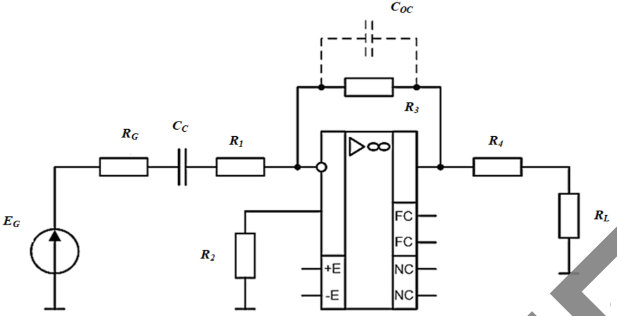

Fig. 2. Equivalent circuit of the reflected signal amplifier

The calculation begins with determining the resistance of the protection resistor:

$$\boldsymbol{R_4 = \frac{U^{+}_{out\,max}}{I_{out\,max}} = 2.67 \cdot 10^3\ \mathrm{Om}}$$

where $U^{+}_{out\ max}$ - is the maximum amplitude of the output signal;

$I_{out\ max}$ - maximum constant output current.

We accept the resistance of the protection resistor in accordance with GOST: R_4=3kOm.

The validity of the above expression can be explained using the amplitude characteristic of the operational amplifier (OP AMP) shown in Fig. 3.

Calculate the resistance of the resistor R_3. In this R_3case, two R_3circumstances should be taken into account. Firstly, the resistance should not shunt the load, and secondly, it is desirable to choose a resistance, possibly of a smaller value, in order to ensure minimal phase distortion in the feedback circuit (OS). They often choose $R_3 = (20{\ldots}40)R_4$.

In accordance with a number of E24 denominations, we select $R_3 = 120$ kOm.

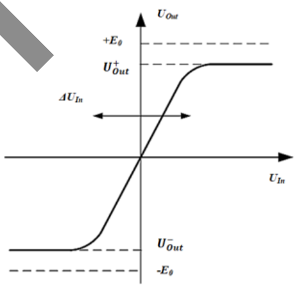

Fig. 3. Amplitude characteristic of the operational amplifier

Before calculating R_1, you should refer to two auxiliary formulas. The gain factor of the of the operational amplifier covered by the OOS K_{EF} is calculated using the formula:

$$K_{EF} = \frac{K_U}{1 + B \cdot K_U}$$

where K_U is the gain factor without the OOS, B is the transmission coefficient of the feedback circuit.

In this case

$$B = \frac{R_G + R_1}{R_G + R_1 + R_3}$$

Since they K_U , K_{EF} are set by the condition, it is necessary to calculate the value according to the first expression B :

$$B = \frac{K_U - K_{EF}}{K_U \cdot K_{EF}} = 1.62 \cdot 10^{-3}$$

According to the second expression

$$R_1 = \frac{B \cdot R_G + B \cdot R_3 - R_G}{1 - B} = 94.56 \text{ Om}$$

From the E24 series, select the nominal value: $R_1 = 100\ Om$.

In order not to unbalance the amplifier due to the small, but existing input currents, choose $R_2 = R_1$.

The input and output resistances are calculated using the formulas:

$$R_{In} = \left(\frac{R_3}{K_U}\right) + R_1 = 106 \text{ Om}$$

$$R_{Out} = \left(\frac{R_3}{B} \cdot K_U\right) + R4 = 6{,}7 \text{ kOm}$$

The input capacity of the operational amplifier itself (several picofarads) is negligible compared to the capacity introduced due to the parallel input of the OOS. The actual capacitive component of the OOS circuit is created due to the pass-through capacitance C_p of the resistor R_3 (is indicated by a dotted line).

Then the input capacity of the cascade:

$$C_{In} \approx C_p \cdot K_{EF}$$

where $C_p = 10\ pF$.

$$C_{In} = 6 \text{ nF}$$

The maximum amplitude of the input signal U_{amIN} depends only on the maximum amplitude of the output signal and the gain:

$$U_{amIN} = \frac{U^{+}_{out\ max}}{K_{EF}} = 1{,}3 \text{ mV}$$

Feedback depth:

$$F = \frac{K_U}{K_{EF}} = 33.3$$

Calculation of the overload protection circuit

The overload protection circuit of the compensating stabilizer is implemented on the elements $VT1$, $VT2$ and R_3, see Fig 4.

For calculation, we take the maximum protection trip current equal to 120% of the nominal value I_n:

$$I_{n\ max} = 1.2\ I_n = 3.6\ A$$

At a resistance R_3 voltage of 0,7 V, the transistor $VT2$ opens and the control transistor is shunted $VT1$.

$$R_3 = {}^{U_{be}}/_{I_{n\,max}} = 0.07\ \mathrm{Om}$$

A resistor of this value must be wired.

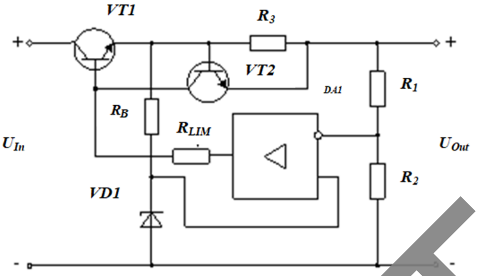

Fig. 4. Schematic diagram of a stabilizer with a current limiter

We calculated the maximum electrical power consumed by the detector, Table 1.

Table 1. Detector power calculation

Element type	Quantity	Power	Total power, W
Resistors 0,25	9	0.00066	0,006
Resistors 0,125	1	0.002	0,002
K157UD2	2	0.002	0,004
LED	1	0.004	0,004
MK STM32	1	0.012	0,012
Diodes	1	0.1	0,1
TOTAL			0.038

For signals from photodiodes, the range of measured values after analog-to-digital conversion with an 8-bit representation lies within 0-255. We defined the current value of the illumination levels as AS1 and AS2. For a converter measuring the intensity of the reflected signal, the current level value should lie within the range AS 2 = 0 to AS1.

During processing, it is necessary to pay attention to the fact that information about the current state of smoke in the controlled area is contained in relation $k = \frac{AS2}{AS1}$ to the levels of direct and reflected rays in the smoke chamber.

To utilize this phenomenon effectively, an adaptive threshold level should be applied to make decisions about the presence of smoke. This involves averaging the threshold level over a sufficiently long sample of intensity ratio values.

$$\text{threshold value}_n = \frac{\sum_{i=1}^{n+1} k(i)}{n},\ \text{threshold value}_{n+1} = \frac{\sum_{i=1}^{n+1} k(i)}{n+1},\ \text{threshold value}_{n+1} = \frac{(\text{threshold value}_n + k(n+1))}{2};$$

$$l(n) = |k(n) - \text{threshold value}_n|.$$

The decision on smoke is made based on the analysis of the difference function l, this avoids making an erroneous decision about a fire, based on the fact that the value of the threshold constant is obtained by processing a large number of previous values of the ratio.

Let's choose the number of counts used: $2^{20} = 1048576$

When the reference variable exceeds the value, the current threshold value is reset and the threshold variable is assigned the current value *k(i).*

The level corresponding to the temperature $t = 60°C$ is calculated using the formula:

$$AT1 = \frac{(t - t_0)}{\Delta t_{\max}} \cdot 2^8 = \frac{40}{80} \cdot 256 = 128$$

Therefore, the threshold must be set to 64.

3 The results of the study

The solution to the problem of comparative evaluation of the selected indicators is carried out experimentally to verify the accuracy of the declared technical characteristics. Initially, the declared characteristics of the sensors, as indicated in the accompanying technical documentation and available in open sources, were thoroughly studied.

3.1 Assessment of the reliability indicators of the ASPS stand

The purpose of the calculations is to determine the reliability indicators of the system, which can be presented to optimize system maintenance, used in calculating risks, and used as a justification for system modernization.

To assess the reliability of the stand in fire automation systems, a number of quantitative indicators are used:

- the probability of trouble-free operation;
- average time to failure;
- failure rate;
- average service life.

With all the variety of regulatory documentation for determining reliability indicators and requirements for them, existing documents related to fire automation systems are not enough. We considered the requirements of regulatory documents on the reliability indicators of each individual element of the automatic fire system equipment (Table 2).

Table 2. Requirements for each individual element of the system

Equipment reliability indicator	1st stage (release after pre-1995)	2nd stage (release after 2000)
Fire detectors, thermal		
Average time to failure, hours, not less:		
for maximum detectors (except dilatometric)	500 000	700 000
for maximum dilatometric	100 000	200 000
for differential and maximum differential	50 000	60 000
Smoke detectors, optical and gas		
Average time to failure, hours, not less:	50 000	60 000
for point detectors	70 000*	70 000*
for linear detectors	20 000	60 000
Flame detectors		
Average time to failure, hours, not less:	35 000	60 000
Fire control and reception devices		
Average time to failure, hours, not less:		
to the PPCP loop without addressing:		
small capacity	20 000; 30 000*	30 000
medium and large capacity	8 000; 10 000*	18 000
to the PPCP loop with addressingна	-	10 000
Central Monitoring Panel (Central Control Panel)		
Average time to failure for one channel, hours, at least:		
*- value at the consumer's request	5 000	7 500

The specifics of GOST sets requirements for the reliability of existing fire detector equipment and suggests further improvement of the standard, taking into account the development of technologies:

1. The average operating time of fire detectors in an emergency situation should be at least 60,000 hours.
2. Fire detectors should be designed for round-the-clock and continuous operation.
3. The average service life of a fire detector should be at least 10 years.

Requirements for the reliability of fire-fighting equipment.

Fire fighting equipment:

1. PPKP and PPU should be designed for round-the-clock continuous operation.
2. PPCP and PPU should be products suitable for restoration and maintenance.
3. Average recovery time, hours, no more than 6.
4. Average service life, years, no less than 10.

Requirements for the reliability of power supplies for fire-fighting equipment and equipment:

1. IE should be designed for round-the-clock continuous operation.
2. IE must be a recoverable and usable product.
3. The average service life of IE should be at least 10 years.

The process of determining the reliability indicators of ASPS can be divided into two stages:

1. The test stage.
2. The forecasting stage.

3.1.1 Initial data for determining the reliability indicators of ASPS (Table 3).

Table 3. Information about the system equipment

Equipment name	Quantity	Operating time for failure, hour	Failure status
Smoke spot detector	8	60 000*	Recovering
The detector is manual	2	60 000*	Recovering
The device is a fireman	1	20 000*	Recovering
The light alarm	1	30 000*	Recovering
The sound alarm	1	60 000*	Recovering
*- The conditional values of the indicators are given			

The initial data includes information about the time before the failure of the main equipment of the system, data on equipment maintenance, information about the architecture of the system. Information about the time to failure comes from the official information letter of the equipment manufacturer (equipment passport).

3.1.2 Methodology for calculating the reliability indicators of the ASPS

Based on the set goals, we choose a simplified calculation method for the stage of operation of the system. The main reliability indicators are calculated in accordance with GOST.

Compilation of a computational model.

Determining the maintenance scheme in accordance with the functional purpose of the system. In this case, the automatic fire alarm system has two target circuits:

1. Automatic fire alarm circuit.
2. The scheme of the fire alarm system and evacuation control.

The zones covered by one fire detector, depending on the height of the protected area, are shown in Table 13.3 SP 5.13130.2009. When calculating coverage areas, it will also not be superfluous to take into account the radius of coverage of the detector. Thus, it turns out that the only case of serial connection of detectors is the "corridor" in the room due to its relatively complex configuration (there are some areas that are not captured by only one detector in the room).

Calculation of the main reliability indicators.

In accordance with the methodology described in the regulatory documents, the failure rate of each element is determined - this is the value of the reverse failure time:

$$\lambda = 1/T_0$$

For smoke detectors:

$$\lambda_{SD} = 1{,}67 \cdot 10^{-5}\ 1/\ ch$$

For manual detectors:

$$\lambda_{MD} = 1{,}67 \cdot 10^{-5}\ 1/\ ch$$

For a fireman's device:

$$\lambda_{FD} = 5 \cdot 10^{-5}\ 1/\ ch$$

For the light detector:

$$\lambda_{LD} = 3{,}33 \cdot 10^{-5}\ 1/\ ch$$

For the sound sounder:

$$\lambda_{SD} = 1{,}67 \cdot 10^{-5}\ 1/\ ch$$

The failure rate of each circuit is determined. For the automatic fire alarm system (AFAS) circuit, the failure rate will be

$$\lambda_{AFAS} = 3 \cdot \frac{\lambda_{SD} \cdot \lambda_{SD}}{\lambda_{SD} + \lambda_{SD}} + 2 \cdot \lambda_{SD} + 2 \cdot \lambda_{MD} + \lambda_{FD}$$

$$\lambda_{AFAS} = 14{,}17 \cdot 10^{-5}\ 1/\ ch$$

Similarly, we calculate the failure rate for the warning and evacuation management systems (WEMS) circuit:

$$\lambda_{\mathrm{WEMS}} = \lambda_{LD} + \lambda_{SD} = 5 \cdot 10^{-5}\ 1/\ ch$$

The failure rate of the entire system will be determined by:

$$\lambda = \lambda_{\mathrm{WEMS}} + \lambda_{AFAS} = 19{,}17 \cdot 10^{-5}\ 1/\ ch$$

The average time to failure of the entire system is determined by the inverse formula:

$$\mathrm{T}_0 = \frac{1}{\lambda} = 5216{,}5\ h$$

Based on the average time to failure of the entire system, the probability of failure-free operation for a specified operating interval can be determined. The values of this interval are typically set at 1000 or 2000 hours. It is observed that the longer the specified interval, the lower the probability of maintaining uptime.

Calculation of the probability of system uptime for 2000 hours:

$$P(t) = exp(-2000/T_0) = 0.983$$

The probability of failure-free operation can also be calculated directly with the system modules. In this case, for a serial connection, the probability of trouble-free operation is determined

$$P_C = \prod_{i=1}^{n} P_i$$

and for a parallel connection

$$P_C = 1 - Q_C = 1 - \prod_{i=1}^{n} q_i = 1 - \prod_{i=1}^{n} (1 - P_i)$$

4 Analysis of the research results

We have determined the main reliability parameters of a small automatic fire alarm system and an evacuation warning and control system. For long-term cable communication lines, the following reliability indicators can be used:

- time to failure per 100 km of transmission line is not lower than T_0 = 34,375 hours;
- The readiness factor is not lower than K_g = 0, 99970.

For short lines, the introduction of an additional module «Cable communication line» will not affect the final result. But this type of communication is rarely used in fire-fighting automation systems.

Table 4 shows the correction factors for the failure rate depending on the operating conditions.

Table 4. Correction factors for calculating the failure rate depending on the operating conditions

Operating conditions of the equipment	From vibration	From shock load	The resulting coefficient
Laboratory	1.0	1.0	1.0
Station field	1.04	1.03	1.071
Camper trucks	1.35	1.08	1.458
Railway	1.4	1.1	1.54

The reliability of the software can also be taken into account in the calculation. In some methods, the following characteristics of software reliability are given, depending on the period of program development (Table 5).

Table 5. Software reliability indicators depending on the program development period

The period of program development	The intensity of program errors, 1/hour	Average operating time per software error, h	Average time to eliminate a failure, min
The initial period of complex debugging	0.07	15	12
Completion of complex debugging	0.02	50	8
The initial period of trial operation	8-10-3	125	6
Completion of trial operation	0.5-10-3	2 000	6

Using, in particular, reliability calculations, it is possible to estimate the probability of trouble-free operation of the fire automation system for subsequent use of the obtained value in calculating individual fire danger.

Thus, a schematic diagram was designed, on the basis of which an algorithm for the operation of the fire extinguishing system was developed. This algorithm was implemented in a software environment where emulation was performed and visualization of the system operation was created without connection to a programmable logic controller (PLC).

5 Conclusion

Thus, the analysis of the main features of existing automated fire alarm systems was carried out in the work.

As a result of the analysis of the existing fire alarm systems, their advantages and disadvantages were revealed. The implemented system functions were divided into implemented hardware and software. It was decided to select the base of elements and implement the elements of the system, and their nominal value was calculated.

A schematic diagram of the demonstration stand of an automated fire alarm system has been developed, and its software has been described. The proposed measures can be used in the practical application of the developed system.

Thus, the analysis of the obtained results allows us to draw the following conclusions:

1. A project has been developed for a stand demonstrating the operation of an automated fire alarm system.
2. The types of fire detectors were compared, and a patent review of the stand's analog systems was conducted.
3. The analysis of interfaces and protocols used in modern fire systems has been carried out. It has been revealed that the RS-485, Ethernet and RS-232 interfaces are most applicable in fire safety. This indicates their stability, reliability, and data transfer rate when a fire point is detected.
4. A schematic diagram has been developed, on the basis of which an algorithm for the operation of the fire extinguishing system has been proposed. This algorithm is implemented in the CodeSys software environment, where emulation was performed and visualization of the system operation was created without connection to a PLC.

Fire alarm systems enriched with the latest technologies are becoming a reliable ally in ensuring safety. From digital sensors and artificial intelligence to mobile applications and robots, these innovations are changing the landscape of fire safety, making it more efficient and accessible to a wide range of users.

Fire alarm systems enriched with the latest technologies are becoming a reliable ally in ensuring safety. From digital sensors and artificial intelligence to mobile applications and robots, these innovations are changing the landscape of fire safety, making it more efficient and accessible to a wide range of users. Today's technologies make it possible not only to detect and extinguish fires, but also to prevent their occurrence, which is an important step towards ensuring the safety of our society.

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