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MODERN SCIENCE: CHALLENGES AND PROSPECTS

PROCEEDINGS OF II INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE
SEPTEMBER 24-26, 2026

LONDON
2026

MODERN SCIENCE: CHALLENGES AND PROSPECTS

Proceedings of II International Scientific and Practical Conference

London, United Kingdom

24-26 September 2026

London, United Kingdom

2026

UDC 001.1

The 2nd International scientific and practical conference “Modern science: challenges and prospects” (September 24-26, 2026) Cognum Publishing House, London, United Kingdom. 2026. 328 p.

ISBN 978-92-9472-198-3

The recommended citation for this publication is:
Ivanov I. Analysis of the phaunistic composition of Ukraine // Modern science: challenges and prospects. Proceedings of the 2nd International scientific and practical conference. Cognum Publishing House. London, United Kingdom. 2026. Pp. 21-27. URL: https://sci-conf.com.ua/ii-mizhnarodna-naukovo-praktichna-konferentsiya-modern-science-challenges-and-prospects-24-26-veresnya-2026-london-velikobritaniya-arhiv/.

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TECHNICAL SCIENCES

PHYSICAL AND MATHEMATICAL SCIENCES

УДК 614.8

STRUCTURE AND REQUIREMENTS FOR EARLY EMERGENCY DETECTION SYSTEMS

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Abstract: This study examines the design principles, structural features, and regulatory and technical requirements for modern automated early warning systems for emergencies (AEWS). The key components of the systems are analyzed, including primary measuring transducers (sensors), information processing units, communication channels, and actuators. Particular attention is paid to the criteria of reliability, response time, noise immunity, and survivability of the automation systems under man-made and natural threats. The current regulatory framework governing the design, installation, and operation of such systems at high-risk facilities is examined.

Keywords: Early detection automation, emergency, sensors, monitoring, technical requirements, reliability, high-risk facilities.

According to the theoretical principles outlined in [2], modern early detection automation is built on a modular principle, which ensures its flexibility and maintainability.

The basis of the system is a network of intelligent sensors. Unlike conventional fire alarms, early detection systems use:

Aspirating systems: continuously sample air through a network of tubes, followed by laser analysis for the presence of microparticles of pyrolysis products.

Gas analyzers: configured to detect pre-explosive concentrations (starting from the lower concentration limit of flame propagation), which allows for the prevention of an explosion even before an open flame appears [4].

An important design requirement is the use of ring loops. This ensures system operability even in the event of a single communication line failure. In accordance with the requirements of [1], cable lines must have a fire resistance class (e.g., FE180), which guarantees system operation for 180 minutes in a fire.

The central logic unit acts as the “brain” of the system. It is based on industrial controllers that perform:

Filtering of signals from interference (electromagnetic radiation, dust), comparison of the dynamics of parameter changes.

Based on the workshop [2], the following requirements for designing block diagrams should also be highlighted:

In large systems (e.g., in industrial giants), the system architecture must allow for the autonomous operation of individual nodes. If the central server fails, local controllers must continue to perform protection and alarm tasks within their zone.

Modern automation systems use digital signal processing (DSP). This allows distinguishing dust or steam from actual smoke, which is critical for performing early detection tasks without halting the production process.

The system must have a connection to the State Emergency Service’s Central Monitoring Station (CMS). According to [1], signal transmission must occur automatically without personnel intervention within no more than 30 seconds from the moment the alarm is confirmed.

Selecting a specific type of equipment is a key task in automation, since the speed of the entire system’s response to an emergency depends on the physical operating principle of the sensor.

In the theoretical foundations of automation, the structure of systems is typically interpreted as a multi-level network.

Primary measuring transducers (sensors): sensitive elements that convert physical quantities (smoke, flame, heat flux) into an electrical signal.

Communication lines: data transmission channels that must have high noise immunity and survivability in fire conditions.

Information processing devices (controllers): software-controlled logic devices that make decisions based on predefined algorithms.

Actuators: relays, valves, and actuators that exert a physical effect on process equipment.

According to [3], the control of safety systems is based on “OR” logic (maximizing detection, parallel connection) or “AND” logic (minimizing false alarms, serial connection). The reliability calculation method according to [3] determines the probability of failure-free operation Pt and the availability coefficient Kg, which allows for optimizing the system structure and implementing redundancy.

Requirements for automation systems are divided into national and industry-specific:

Continuous self-monitoring: the system must constantly check the integrity of its own components and signal any component failure.

Redundancy: Uninterruptible power supply units are mandatory, capable of sustaining system operation for at least 24 hours in standby mode and 3 hours in “Alarm” mode.

Protection against unauthorized access: The software must have access levels for personnel and service organizations to prevent accidental deactivation of protection.

These systems must meet strict technical requirements:

Reliability: The system must operate 24/7 without failure.

Resilience: The ability to function under emergency conditions (high temperatures, smoke) for a specified period of time.

Autonomy: The presence of a backup power supply that ensures the system continues to operate in the event of a power outage at the facility.

Response time: the time from when a sensor detects a hazard to the activation of the actuator must be minimal [2, 4].

Cybersecurity: protection of industrial control systems against unauthorized access and digital threats in accordance with international standards.

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