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INTELLIGENT MANAGEMENT OF FIRE ALARM SENSOR NETWORKS IN RESIDENTIAL COMPLEXES AND ENHANCEMENT OF THEIR EFFICIENCY

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Abstract

This research is devoted to highlighting innovative methods for organizing fire safety in modern multi-apartment residential buildings. The article analyzes issues related to improving inter-device information exchange processes, implementing algorithms that filter external environmental noise, and increasing the reliability coefficient of the system. During the study, digital data transmission channels and the adaptive operating principles of sensors are substantiated.

Keywords

Building safety, intelligent sensors, data analysis, adaptive control, emergency monitoring, communication protocols, technical diagnostics, fire detection.

Today, the increasing complexity of urban infrastructure requires a fundamental reconsideration of safety strategies in residential areas. The rapid pace of urbanization, the growing number of multi-storey residential buildings, and the high population density are significantly increasing the demand for advanced safety systems. In particular, fire safety issues are becoming one of the most critical components of modern urban life. Automated systems used to monitor potential fire hazard points must not only be technically advanced but also capable of analytical thinking. This necessitates the development of systems that, unlike simple signaling devices, can perform in-depth data analysis, assess risk levels, and make independent decisions.

In many cases, the limited capabilities of traditional devices lead to misunderstandings or delays that pose a threat to human life. For example, conventional smoke detectors may interpret steam or cooking fumes in kitchens as fire, generating false alarms. Conversely, in some situations, real danger may exist, but the device responds too late due to insufficient sensitivity. Therefore, it is scientifically and practically important to redesign the architecture of early fire detection systems in residential sectors, equip them with self-analytical functions, and implement centralized control mechanisms.

Modern approaches show that safety systems should not be limited to mere alert functions. They must be capable of real-time monitoring, data storage, and subsequent analysis. At the same time, the integration of artificial intelligence and machine learning technologies enables systems to continuously improve their performance. Such systems learn from various situations over time and adapt to select the most optimal response for each case.

The foundation for improving fire alarm systems in residential facilities lies in fundamentally changing the methods by which detectors receive and process data. According to modern requirements, each control point must adapt to dynamic environmental changes. This means that sensors should independently adjust their sensitivity levels based on the specific characteristics of the room in which they are installed, such as kitchens, bedrooms, storage areas, or corridors. This adaptive approach significantly reduces false alarms and enhances overall system performance.

Moreover, modern detectors are distinguished by their ability to analyze multiple parameters simultaneously. For instance, they monitor not only smoke but also temperature, gas concentration, and even the composition of airborne particles. This multi-parameter monitoring system allows for more accurate detection of fire onset. As a result, the system makes decisions based on a comprehensive evaluation of several factors rather than relying on a single indicator, thereby significantly increasing reliability.

International experience with “smart sensors” demonstrates that it is not sufficient to simply transmit information to a central unit; it is more effective to perform initial data analysis directly at the sensor level. This approach is based on the principles of edge computing, where data is processed locally before being sent to a central server. This reduces the workload of the central controller and shortens response time in critical situations to milliseconds.

Ensuring the stability of wireless communication networks used in residential complexes is also an important issue. Signals can often weaken or be lost due to metal structures or thick concrete walls. Therefore, it is necessary to create and optimally place special repeater nodes. These nodes retransmit signals and ensure the stable operation of the entire system. In addition, the use of mesh topology in modern networks is highly beneficial, as each device connects with others to form a robust and unified network.

Centralized control platforms also play a crucial role in the development of fire safety systems. These platforms collect data from all sensors into a single center, enabling analysis and visualization. Dispatchers or responsible personnel can monitor the condition of every part of the building in real time and take prompt action when necessary. Furthermore, the system can automatically notify emergency services, illuminate evacuation routes, and perform other essential functions.

In modern urban environments, improving fire safety systems requires a comprehensive approach. The integration of technological innovations, artificial intelligence, adaptive sensors, and reliable communication networks plays a key role in this process. In the future, such systems are expected to evolve into integrated platforms capable not only of detecting fires but also of preventing them, predicting risks, and ensuring maximum protection of human life.

To extend the system’s service life and maintain a high level of readiness, the implementation of remote service elements is highly important and advisable. Such systems, developed based on modern technological approaches, not only detect malfunctions but also help prevent them. The system continuously scans the technical condition of each individual component, operating in a constant monitoring mode. Through this process, the performance indicators of sensors, transmission lines, power sources, and other components are monitored in real time.

If the level of dust accumulation in a sensor increases, it can directly affect its sensitivity. Dust particles accumulating on the sensor surface can interfere with its proper functioning, leading to false alarms or delayed responses. Therefore, the system detects such changes at an early stage and automatically sends notifications to maintenance services. Similarly, if the power source of sensors weakens, the system provides advance warnings, enabling technicians to perform timely maintenance, replace batteries, or clean the devices.

Another important advantage of remote service systems is the minimization of human-related errors. In traditional approaches, technical staff periodically inspect devices manually, which can result in some issues being overlooked. Automated monitoring operates continuously and detects even minor changes. As a result, the likelihood of unexpected failures is reduced to nearly zero, and the overall reliability of the system remains consistently high.

Additionally, such systems allow for data archiving and analysis, which helps further improve preventive measures in the future. For example, it becomes possible to identify areas where sensors become contaminated more frequently or determine which types of devices wear out faster. Based on this information, maintenance schedules can be optimized, leading to more efficient resource utilization and reduced operational costs.

Another key aspect is the integration of fire alarm systems with other engineering systems. In modern buildings, safety is ensured not by a single system but through the coordinated operation of multiple systems. In the improved model, once a fire is detected, the fire alarm system simultaneously sends signals to other systems, which begin operating in synchronization.

For example, as soon as a fire is detected, the smoke extraction system is automatically activated, and special valves are opened. This prevents smoke accumulation, facilitates breathing, and ensures safer evacuation. At the same time, elevators are automatically brought to the ground floor and temporarily disabled, as their use during emergencies can be dangerous.

Furthermore, intelligent evacuation signs are integrated with the system. These signs determine safe routes in real time and guide people to the nearest exits. If certain areas of the building are affected by fire or smoke, the system automatically suggests alternative routes. This prevents confusion and accelerates the evacuation process.

In addition, such integrated systems can directly communicate with emergency services. Once a fire is detected, the system automatically sends alerts to fire safety services, ensuring their rapid arrival at the scene. As a result, the spread of fire is prevented, and both material and human losses are minimized.

The integration of remote service systems and various engineering systems elevates the efficiency of fire alarm systems to a new level. This approach not only ensures continuous and reliable operation but also enables rapid and coordinated responses in emergency situations. Consequently, the level of protection for human life and property is significantly increased.

The development of fire alarm systems in residential facilities involves not only the installation of new devices but also a transformation in the logical model of their management. The interaction between sensors, data analysis through cloud technologies, and full integration with building management systems are integral components of the future smart city concept. These improvements not only enhance the safety of residents but also raise the efficiency of fire safety services to a new level.

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