SECURE INFRASTRUCTURE DISPATCHING AND AUTOMATION OF ENGINEERING SYSTEMS AT HEALTHCARE FACILITIES

DOI: 10.36724/2072-8735-2025-19-6-60-68

Manuscript received 21 April 2025;
Accepted 18 May 2025

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Keywords: *SCADA system, healthcare institutions, APCS, information security, cyberattacks*

The widespread connection of medical infrastructure to networks carries risks. Insufficiently protected Automated Process Control and Dispatching Systems may be vulnerable to cyberattacks. Automation of engineering systems in hospitals allows maintaining optimal conditions for the treatment and stay of patients, ensuring the continuity of vital services of the healthcare facility. This emphasizes the need to develop a secure infrastructure for dispatching and automation of engineering systems of medical facilities. The article describes a project of a secure infrastructure for dispatching and automation of engineering systems at healthcare facilities. The architecture of the proposed SCADA system has been developed and a secure network for dispatching engineering systems of the selected facility has been designed (including the selection of the necessary equipment and software). Testing of the SCADA system functionality is described, including verification of compliance with information security requirements for healthcare institutions, and the results are analyzed. The developed system can be expanded by connecting new subsystems of the engineering infrastructure (for example, a water supply system, access control, etc.), thereby creating a single platform for managing the entire life support complex of a medical institution. A promising direction is the integration of analytics technologies for equipment diagnostics: analysis of big data collected by the SCADA system will allow you to anticipate possible failures and plan preventive maintenance even before failures occur.

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Для цитирования:
Кудряшова А.Ю. Анализ критериев для выбора векторного канала или матрицы ортогонального предварительного кодирования в системах связи с мультиплексированием // T-Comm: Телекоммуникации и транспорт. 2025. Том 19. №6. С. 60-68.

For citation:
A.Y. Kudriashova, "Secure infrastructure dispatching and automation of engineering systems at healthcare facilities," *T-Comm*, 2025, vol. 19, no. 6, pp. 60-68.

1 Introduction

Automation of engineering systems in hospitals – such as climate control, power supply, heating – allows maintaining optimal conditions for the treatment and stay of patients, ensuring the continuity of vital services of the healthcare facility.

However, the widespread connection of medical infrastructure to networks also carries risks: insufficiently protected APCS (Automated Process Control and Dispatching Systems) may be vulnerable to cyberattacks. This emphasizes the need to develop a secure infrastructure for dispatching and automation of engineering systems of medical facilities.

This study is aimed at solving the urgent problem of digitalization of healthcare infrastructure and is aimed at forming a sustainable, scalable and secure automated control and dispatching system for technological processes using modern information technologies. The results of this study can be used to develop an automated control and dispatching system for technological processes in the context of large healthcare facilities [1-4].

2 Design of the architecture of the control and dispatching system

This project provides for dispatching of the facility using a dispatching panel that collects data from various devices and apparatus. The information is displayed on an automated workstation with the installed MasterScada SCADA software.

The central automated workplace of the dispatching system operator is installed in the control room and includes a personal computer, 2 monitors.

The automated workplace has software products developed in the MasterScada environment, where information on the state of the building's engineering systems is displayed.

All data on the system's operation in the form of numbers and graphs are stored in the automated workplace's memory, which allows, in the event of emergency situations, to determine the cause of their occurrence.

An automated workplace is installed in the control room, which serves to display information on the state of the elevators (state of the elevator shaft doors, control of the elevator control cabinet door, control of safety circuits) from the elevators.

The panel is located in the server room. The panel collects data from the elevator equipment, from cabinets (via Modbus RTU), from the VRF system controller, from the contacts of the machine status, from electricity meters, as well as water disposal equipment [5].

All collected information is displayed on the dispatching automated workplace, and the collected information from the elevators is transmitted to the elevator automated workplaces.

Signals are sent to the automatic fire-fighting equipment by addressable relay modules (disabling general ventilation in case of fire, controlling independent tripping devices for disabling air conditioning systems and thermal curtains in case of fire.

The structural diagram of the ACS is shown in Fig. 1.

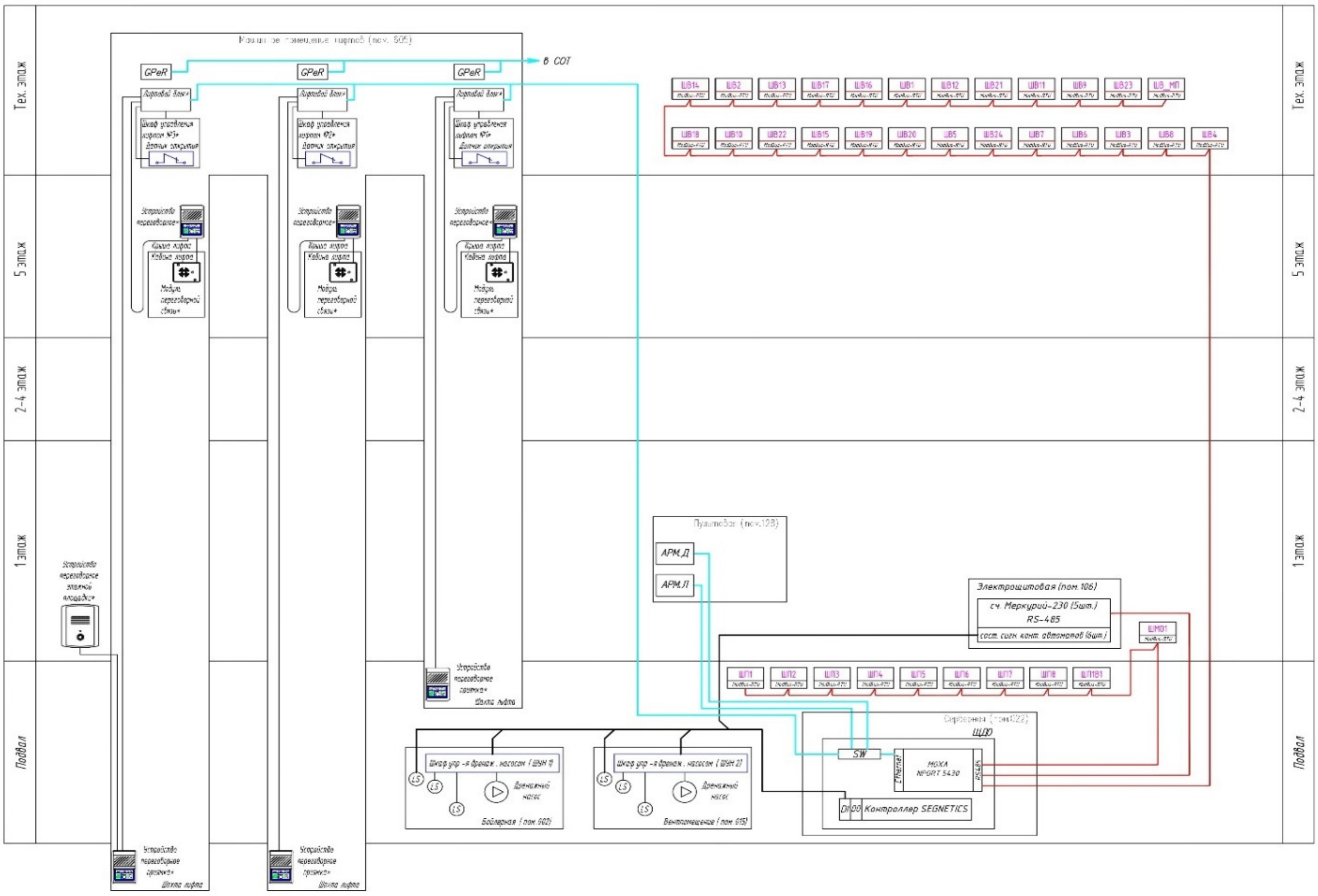

Fig. 1. Structural diagram of dispatching

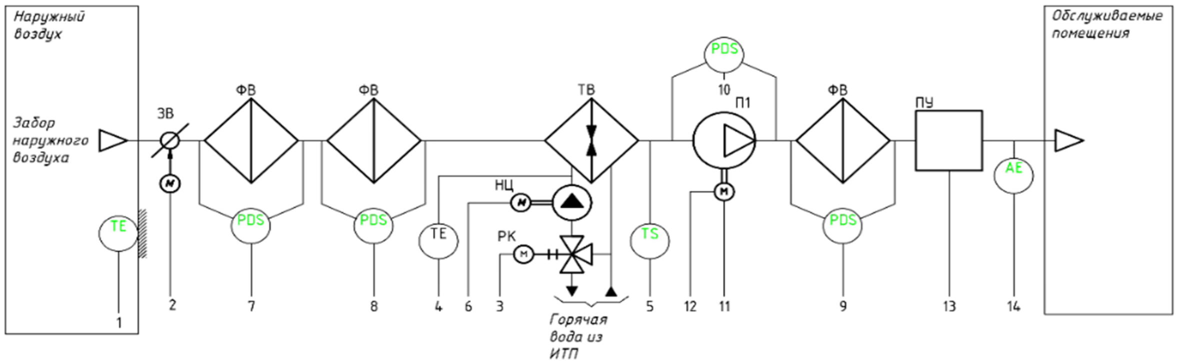

Fig. 2. Structural diagram of the control of supply general exchange ventilation

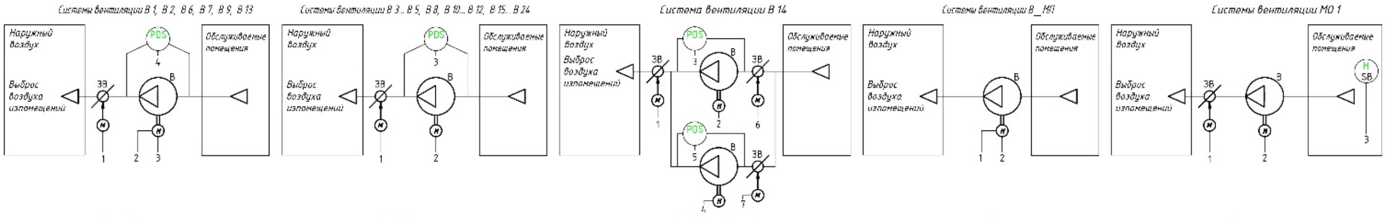

Fig. 3. Structural of the control system for exhaust general exchange ventilation

Automatic supply ventilation systems allow changing the system operation algorithm depending on climatic conditions (winter/summer mode).

Fan speed is controlled using frequency converters and speed controllers. Start/stop of the frequency converter of fan motors is carried out by a discrete signal from the control cabinet, the operating frequency is determined during equipment setup and saved as a parameter of the frequency converter.

The supply and exhaust system servicing the premises has an air recirculation mode. The recirculation mode is switched on and off by the system control cabinet by opening and closing the corresponding air dampers.

Partial redundancy of the exhaust system is provided. If the main fan fails, the backup fan is automatically switched on and an emergency signal is sent to the dispatching system.

When a "Fire" signal is received from the fire alarm system, the freeze protection circuits of the water heaters remain energized.

The automation schemes of ventilation systems are shown in Fig. 3 and 4.

The smoke protection system is designed to turn on, control and monitor the smoke ventilation system in terms of smoke removal. A smoke removal system is provided to ensure the evacuation of people in the event of a fire in the building.

The structural diagram of the fire-fighting automation is shown in Fig. 4.

The complex of technical means for automating fire protection systems of a building provides for centralized and automatic shutdown of general ventilation systems when fire alarms are triggered and activation of fire protection systems.

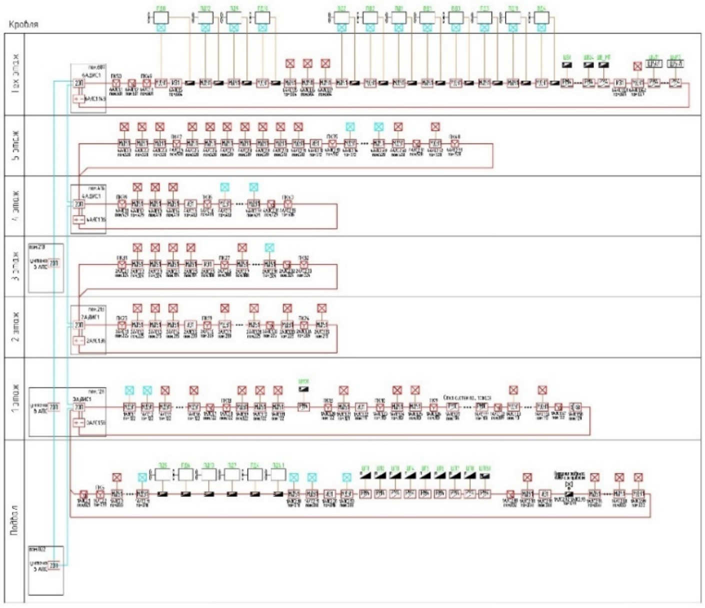

Fig. 4. Structural diagram of fire-fighting automation

To ensure the required microclimate for the premises of the complex, the project provides for air conditioning. The structural diagram of the air conditioning is shown in Figure 5.

The control of the internal units is carried out using wired remote controls installed in the immediate vicinity of the corresponding internal unit (local control), as well as centrally from a controller installed in the control room, and also remotely from the dispatching workstation via a web server (remotely and automatically).

The building also has three elevators, all of which have a dispatching system. Elevator No. 3 is designed to transport fire brigades.

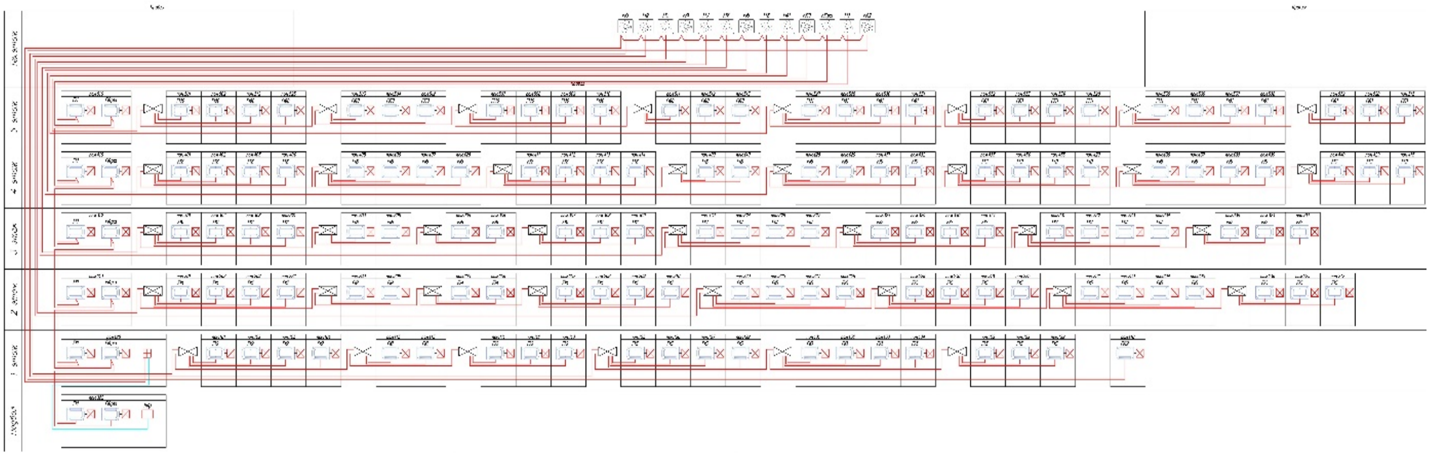

Fig. 5. Structural diagram of air conditioning

The basic connection diagram of the elevator equipment is shown in Fig. 6.

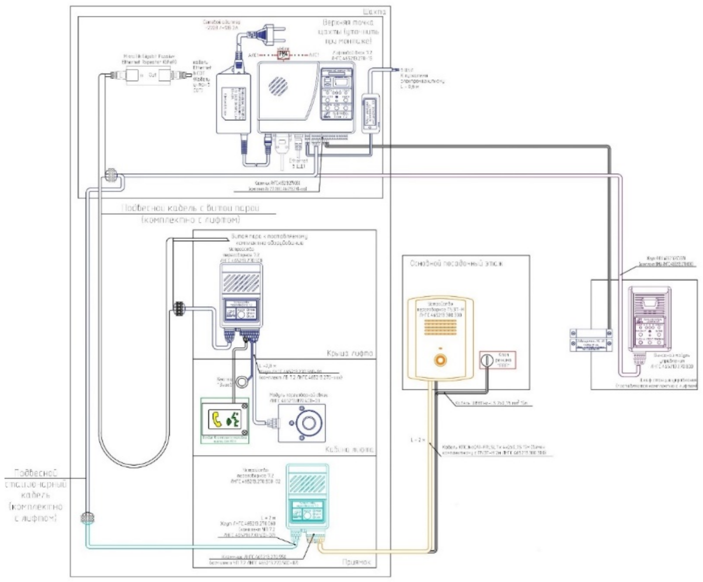

Fig. 6. Schematic diagram of the connection of elevator equipment

The elevator communication system as part of the control complex provides intercom between the elevator cabin and the main landing floor, as well as with the elevator roof and pit.

3 Development of SCADA system

The development of a SCADA system is one of the stages in the creation of an automated control and dispatching system for engineering systems of a healthcare facility. The goal of this stage is to implement a software tool that provides visualization, control and management of all subsystems of the facility within the framework of the previously developed architecture.

The development process is based on the integration of the software level with the physical components of the system – control cabinets, sensors, actuators and controllers. The Master-SCADA system, which provides support for industrial protocols, was chosen as a platform for building SCADA.

The main page interface is designed as a structured graphic page, where all implemented engineering subsystems are presented as interactive buttons with captions and visual grouping. This approach ensures intuitive and fast navigation between sections, without the need to search through nested menus (Fig. 7).

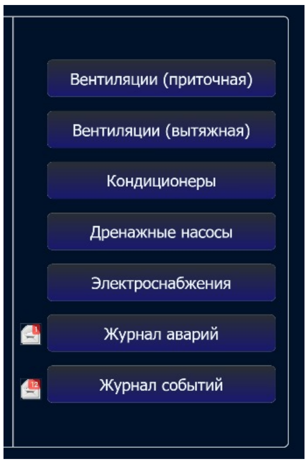

Fig. 7. Main page of the SCADA system

The first in the hierarchy of the system is the supply ventilation. The interface is implemented in two levels of mnemonic diagrams. The mnemonic diagrams provide the operator managing the technological process with a graphical interface for visual dynamic display of the technological process and issuing control actions using virtual controls.

The first (Fig. 8) is an overview, where all supply units are displayed, each with its own status indication, including the current supply temperature, operating status and a visual fan icon.

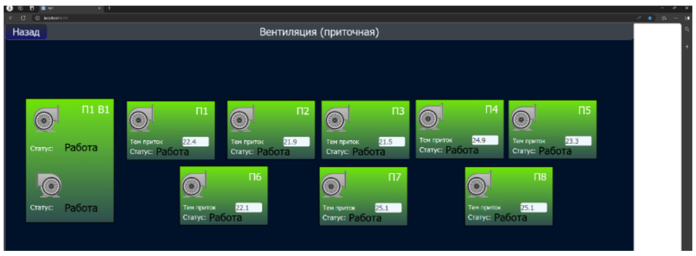

Fig. 8. General interface of the supply ventilation system

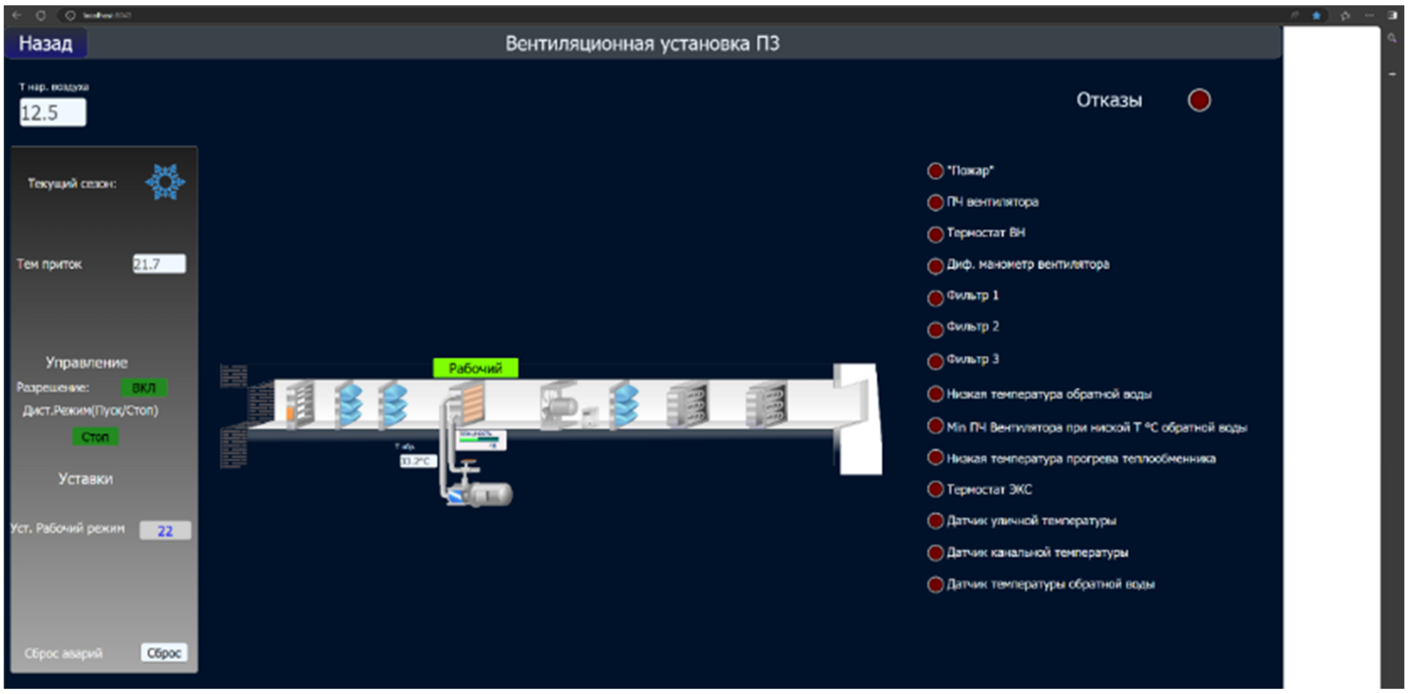

Fig. 9. Detailed interface of the ventilation supply system

The second (Fig. 9) is a detailed mnemonic diagram of a specific unit, made with a full graphical drawing of all key components: heaters, filters, silencers, dampers, recirculation lines, temperature sensors and drives.

On the left side is a control unit with the ability to turn on/stop the unit, select the season (winter/summer), set temperature settings, activate the remote mode and reset alarms. The right side displays a failure panel with up to 15 possible malfunctions: from thermostat activation and filter clogging to frequency converter failures, overheating and freezing of heat exchangers.

All information comes from control cabinets via the RS-485 interface (Modbus RTU), is updated at a frequency of 1-2 seconds and archived in a log.The next section is the exhaust ventilation, presented by a generalized mnemonic diagram for 24 units (Fig. 10).

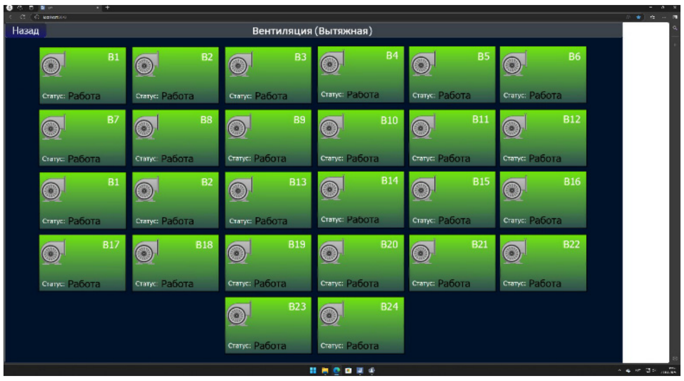

Fig. 10. General interface of the exhaust ventilation system

Each block contains the name of the fan, its current state (operation/stop) and a visual indicator. The visualization is organized as a flat matrix, where green means normal operation, and yellow and red (implemented as needed) signal malfunctions.

This approach allows you to quickly assess the status of the entire exhaust group without having to go to each unit. All events, including starts, stops and accidents, are automatically logged and available for analysis.

The third in order is the air conditioning subsystem, based on monitoring VRF systems. Visualization is based on architectural floor plans (Fig. 11).

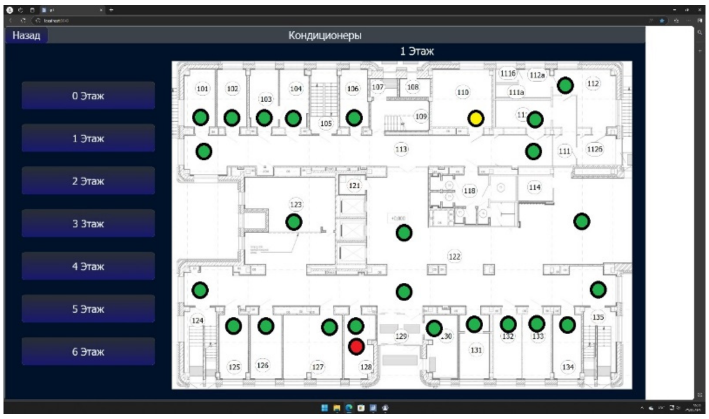

Fig. 11. Air conditioning system interface

The operator can select any floor (0–6) using the vertical menu, after which the floor plan displays the indoor units of the air conditioners as colored circles. Green color corresponds to normal operation, yellow signals a warning (for example, temperature deviation or filter contamination), and red signals an accident (sensor error, overheating, failure to communicate with the outdoor unit, etc.).

This arrangement of units strictly corresponds to the layout of the premises, which significantly simplifies diagnostics. Air conditioners are connected via Modbus RTU gateways, providing two-way data transfer: from operating modes and temperature to error codes. The information is updated at a high frequency and is available for archiving and unloading [6].

The fourth system is drainage pumps responsible for water drainage in process rooms. The mnemonic diagram (Fig. 12) shows six pumps, each with its own status block and location signature.

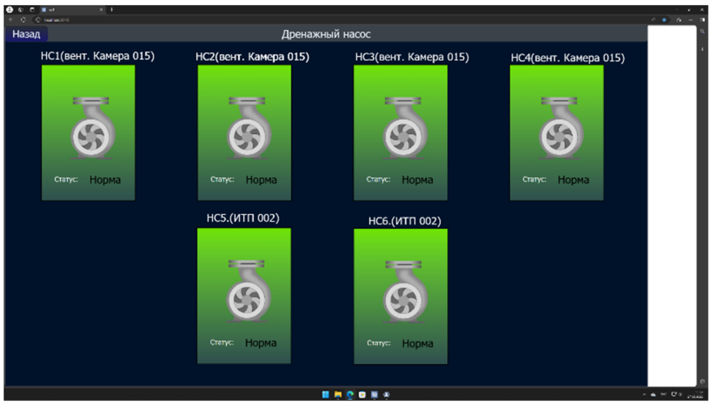

Fig. 12. Drainage systems interface

The pumps are shown with a visual icon, the color indication shows the current state: "Normal" - green, in case of a malfunction - yellow or red indication is possible.

The system receives signals from level sensors, dry-running protection, motor thermal protection and overload. All alarms are sent to SCADA and reflected in the alarm log with recording of the time and signal source.

The drainage system is critical for the smooth operation of the building and prevention of flooding.

Next comes the power supply, divided into monitoring the status of circuit breakers (Fig. 13) and electricity metering (Fig. 14). The mnemonic diagram shows the circuit breakers, each of which has a color indication of the status (on, off, failure). Nearby are four blocks of meters, each with the ability to open a detailed page with current parameters: active/reactive/apparent power, currents, voltages, angles between phases, frequency.

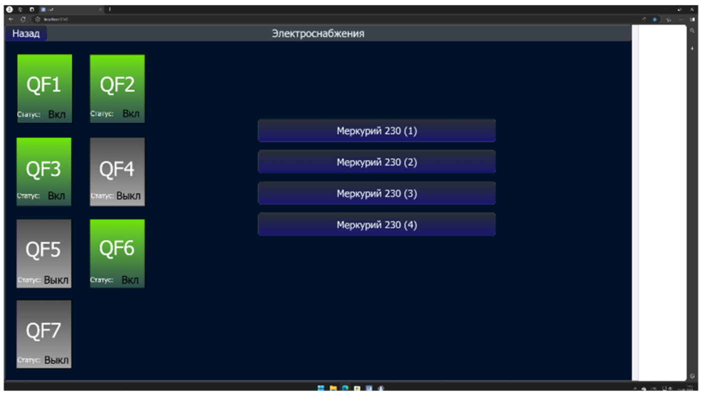

Fig. 13. Circuit breaker status monitoring interface

Such data allows you to assess the quality of power supply, phase imbalance and overloads. The meters are integrated via Modbus RTU and are polled cyclically, with data saved in the archive. All information can be used to build a load profile and control the power supply of critical areas.

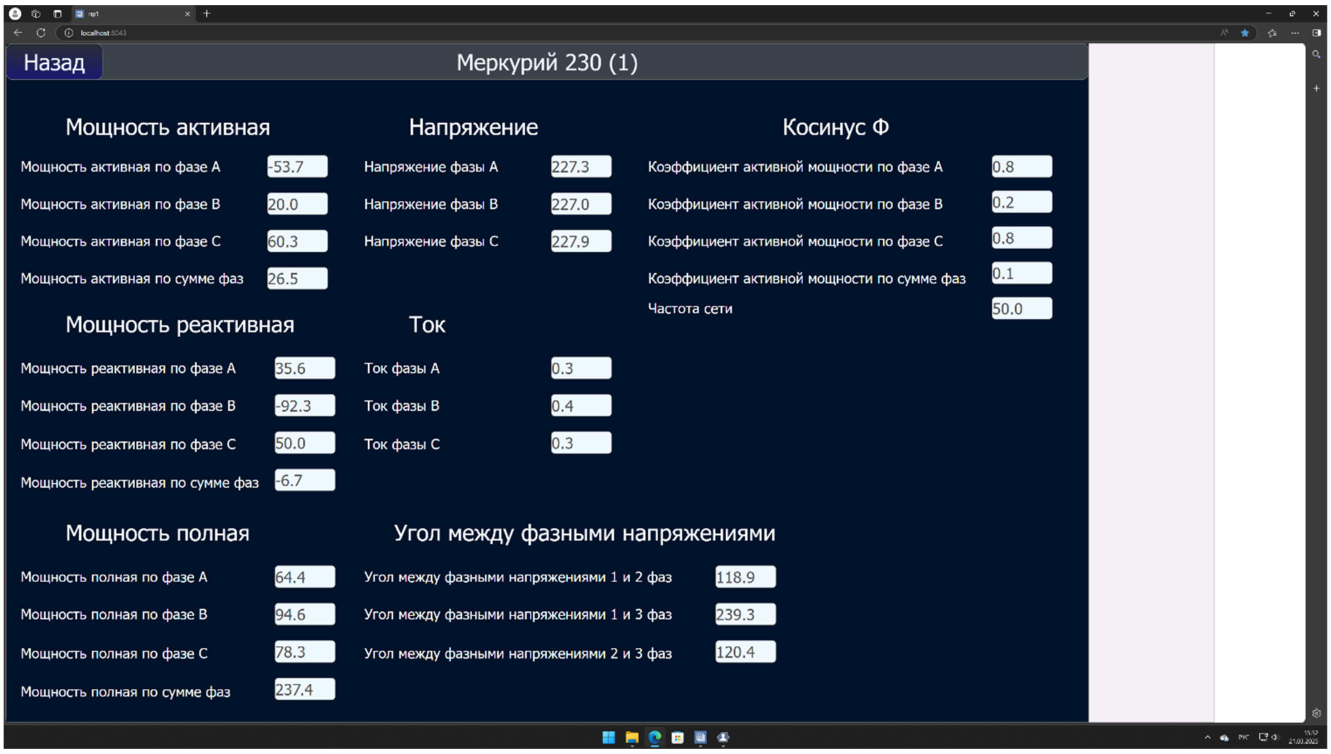

Fig. 14. Circuit breaker information interface

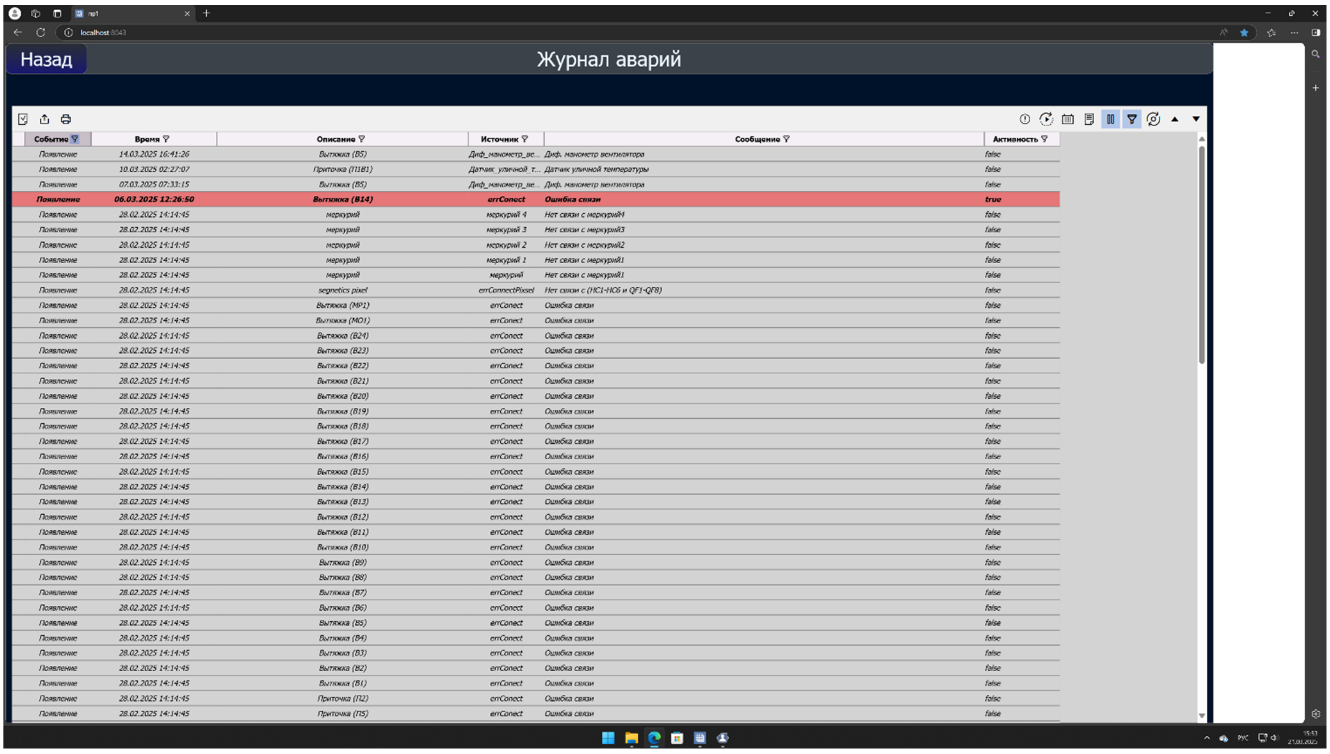

Fig. 15. Crash log interface

The sixth interface element is the alarm log, which aggregates all critical events with reference to source, time and description. The interface includes a table structure with filters by date, device and activity (Fig. 15).

All events are received automatically from SCADA subsystems and are displayed with color indication - active alarms are highlighted in red, inactive ones - in gray. The operator can view the history of failures, reset alarms after troubleshooting and generate reports by category. The alarm log allows you to accurately track the technical condition of equipment and is an important element of operational analysis.

The panel ends with an event log that records all user actions and automatic transitions between modes (Fig. 16). The following are recorded: switching on/off of installations, changing settings, timer triggering, switching seasons, and changing device statuses.

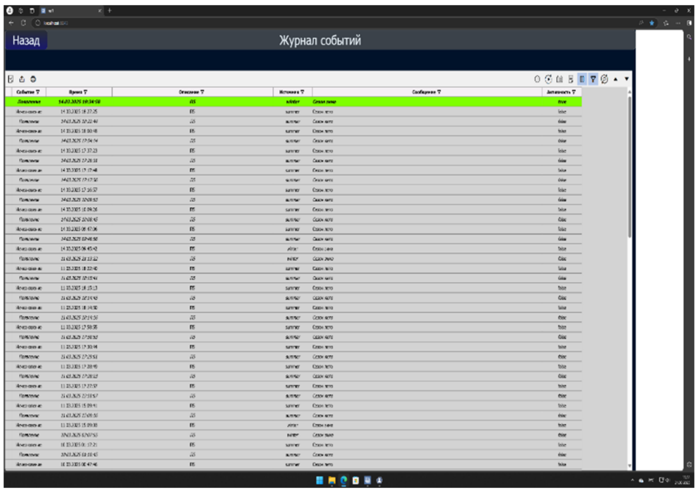

Fig. 16. Event log interface

The table contains the date, time, source, and text of the event, which allows you to quickly restore the chronology of actions and events at the facility. This is critical when analyzing incidents, especially in an environment with multiple interconnected engineering systems.

Additionally, beyond the central panel, the SCADA system includes elevator equipment dispatching, implemented in the SmartHouse Client software shell (Fig. 17). The interface displays elevator shafts, elevator number, current cabin position, direction of travel, call status from the floor and from the cabin, as well as the general equipment status.

Fig. 17. Elevator equipment dispatching interface

The display is built on a vertical principle: each cabin is accompanied by numerical and graphic indicators, including the number of floors and a loading icon. The system is integrated with the equipment through specialized elevator equipment controllers, which allows displaying both standard actions and emergency conditions, including communication failure or protection activation. All events are recorded in the log, ensuring control of vertical transport.

4 Testing and integration of the developed SCADA system

To ensure practical security, the developed system is integrated with special certified security tools. The facility's network is equipped with industrial security gateways ViPNet Coordinator IG, which are designed to organize secure communication channels (VPN) and prevent unauthorized access to the industrial network.

In addition, the built-in solution ViPNet SIES (Secure Industrial Embedded Solution) is used to protect information in the APCS.Additionally, the SCADA system uses a local USB hardware protection key (hardware security key), which prevents unauthorized launch or modification of the project.

The role-based access model (RBAC), required for any secure APCS, is implemented. Integrity control is also configured in the security parameters - SCADA checks the integrity of its software and project at startup, which identifies attempts to make unauthorized changes to system files [7].

To test the system operation in an emergency, an emergency mode was simulated - a situation requiring automatic activation of security and emergency notification systems. As such a scenario, the commission chose a simulated fire affecting the ventilation and smoke removal systems, since this is one of the key security modes for a healthcare facility. When the conditional fire alarm signal was triggered, the SCADA system executed the embedded emergency response algorithm [8].

General ventilation units and air conditioners were automatically switched off to prevent the spread of smoke throughout the premises. At the same time, the smoke protection system was automatically launched: special smoke removal fans turned on at maximum capacity, ensuring the extraction of smoke from the corridors and premises in accordance with the smoke ventilation design plan. The fire dampers in the air ducts were checked - the system issued commands to close or open them depending on the required scenario (cutting off the inflow and organizing the smoke exhaust path), and the control interface reflected their current states (the status "Open" for smoke exhaust ducts and "Closed" for the rest) [9-10].

In addition to the fire scenario, other possible emergency situations were also simulated. These included disconnecting the main power supply of the ventilation equipment (with a check of the startup of backup power supplies and maintaining the operability of the server dispatching equipment) and the failure of one of the sensors or drives.

These tests showed that the system as a whole is resistant to individual failures: when the power is disconnected, the main functionality is maintained due to the backup UPS, and if an individual element of the automation fails, the SCADA system promptly signals the operator about this. Thus, the tests confirmed that even in emergency situations the system continues to perform its functions, ensuring the safety and informing of personnel [11-13].

5 Conclusion

The created dispatching system allows the operator to receive up-to-date data on the equipment status, promptly respond to abnormal situations (emergency signals, parameter deviations), and keep an event log for subsequent analysis. Based on the testing results, the developed solution was confirmed to comply with key information security requirements, which is especially important for medical organizations with increased requirements for information protection and infrastructure reliability.

The practical significance of the work is that the proposed solution is directly aimed at improving the efficiency and safety of managing the engineering systems of a healthcare facility. The implementation of the developed SCADA system at a real medical facility ensures higher reliability of the infrastructure: the risk of equipment failures is reduced due to constant monitoring, timely detection and troubleshooting is ensured, and resource consumption (electricity, heat) is optimized due to precise regulation.

Centralized dispatching facilitates the work of the hospital's engineering and technical personnel, allowing them to make informed decisions faster when managing life support systems.

The results obtained and the created system can be used in the future for replication to other healthcare facilities. This means that the approaches and solutions implemented in the project are applicable for equipping similar smart hospitals and clinics that require modern automation systems. Thus, the project has practical significance: it provides a ready-made methodology and a prototype of a system that can be adapted to the needs of different medical institutions, increasing the overall level of digitalization and security of the industry [14-15].

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I would like to express my gratitude for assistance in the research to the leading engineer of the State Budgetary Institution "Directorate for Development of Healthcare Institutions", M.S. Pronyakin.

БЕЗОПАСНАЯ ДИСПЕТЧЕРИЗАЦИЯ ИНФРАСТРУКТУРЫ И АВТОМАТИЗАЦИЯ ИНЖЕНЕРНЫХ СИСТЕМ В УЧРЕЖДЕНИЯХ ЗДРАВООХРАНЕНИЯ

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Аннотация

В статье описан проект защищенной инфраструктуры диспетчеризации и автоматизации инженерных систем учреждений здравоохранения. Разработана архитектура предлагаемой SCADA-системы и спроектирована защищенная сеть диспетчеризации инженерных систем выбранного объекта (включая подбор необходимого оборудования и программного обеспечения). Описано тестирование функциональности SCADA-системы, в том числе проверка соответствия требованиям информационной безопасности учреждений здравоохранения, и проанализированы полученные результаты. Разработанная система может быть расширена за счет подключения новых подсистем инженерной инфраструктуры (например, системы водоснабжения, контроля доступа и т. д.), тем самым создав единую платформу управления всем комплексом жизнеобеспечения медицинского учреждения. Перспективным направлением является интеграция технологий аналитики для диагностики оборудования: анализ больших данных, собираемых SCADA-системой, позволит предвидеть возможные сбои и планировать профилактические работы еще до их возникновения.

Ключевые слова: *SCADA-система, учреждения здравоохранения, АСУ ТП, информационная безопасность, кибератаки*

Благодарность: *Выражаю благодарность за помощь в проведении исследований ведущему инженеру ГБУ "Дирекции Развития Учреждений Здравоохранения" М.С. Пронякину.*

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