Development of an automated house climate management system based on industrial controller

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Abstract. The task of increasing the safety, efficiency and environmental friendliness of the heating system is being solved, as well as improving the conditions for a person's permanent stay in the building. Building automation is the automatic, centralized control of heating, ventilation and air conditioning, lighting, access control, security systems, and other interconnected systems through a building management system or building automation system. This direction is especially relevant in industrial zones with poor ecology. In addition, in connection with the constant anthropogenic activity of man, high-amplitude temperature drops occur more and more often in periods unusual for them, and therefore it becomes more and more difficult to timely respond to such changes. Automation of the microclimate control process frees a person from the need to directly control mechanisms, which in turn saves him time and resources. The role of a person is reduced to setting the necessary parameters and providing the system with consumables. The purpose of this work is to create an automated climate control system, using and modernizing existing controls, based on an industrial controller.

1. Introduction

With the development of automation tools using microcomputer electronics, significant progress has been made in indoor climate control systems. Still, most of the systems were used in production, and not for the personal purposes of a specific person, due to the high price of equipment.

There is an interstate standard GOST 30494-2011, which establishes construction requirements for the microclimate of public and residential buildings [1]. This GOST defines the microclimate of a room as "the state of the internal environment of a room that affects a person." The indoor environment is mostly indoor air.

The first step towards the creation of any automated system is a preliminary survey of the facility. At this stage, specialists are acquainted with the automation object, carry out work to search for automation capabilities and assess the possibility of implementing the necessary tasks.

Many researchers solved this problem at the beginning of the 20th century. The first step in this direction was the creation of a room air conditioner, the ancestor of modern split systems, released by General Electric in 1929.

Therefore, in work [2], the author investigates ways of implementing climate control systems in an intelligent house. Provides positive aspects of solving the problem, as well as prerequisites for the development of these systems in Russia.
In [3], the authors propose to use the PID control algorithm to solve the temperature control problem. The abbreviation PID stands for "proportional", "integral", "differential". Each of these elements performs its own task and has its own specific effect on the functioning of the system.

2. Description of the development of an automated room climate control system

The design of the system takes place in a residential building with a total area of 81 m². There is a non-automated coal-fired water boiler and a heat pipeline. The heating system does not have a natural circulation of the heating medium, and therefore a water pump is integrated into it. Heat transfer occurs through the radiators of the batteries. Plastic windows are used to renew the air in the house. Due to the boiler room located in the house, fine ash particles penetrate into the rest of the house, which reduces the comfort and cleanliness of the whole house.

Table 1 shows the initial parameters of the building.

| Room       | Room size     | Number of heating radiators | Window size      | Number of windows | Door to room | Street door |
|------------|---------------|------------------------------|------------------|-------------------|--------------|-------------|
| Hall       | 4.5m x 5.5m   | 3                            | 1.6m x 1.4m      | 2                 | -            | -           |
| Room 1     | 3m x 3.7m     | 1                            | 1.6m x 1.4m      | 1                 | 1            | -           |
| Room 2     | 5.5m x 3.5m   | 3                            | 1.6m x 1.4m      | 2                 | -            | -           |
| Kitchen    | 3.5m x 3.5m   | 1                            | 1.6m x 1.4m      | 1                 | 1            | -           |
| Hallway    | 3m x 5.3m     | 2                            | 1.6m x 1.4m      | 1                 | -            | 2           |
| Boiler room | 1.5m x 3.7m  | -                            | 0.6m x 0.6m      | 1                 | 1            | -           |
| Restroom   | 1.5m x 3.7m   | -                            | -                | -                 | 2            | -           |
| Bathroom   | 1.5m x 3.7m   | 1                            | -                | -                 | 1            | -           |
| Corridor   | 4.5m x 1.8m   | -                            | 1.6m x 1.4m      | -                 | -            | -           |

The existing climate control system in the house is essentially a conventional heating system with no even the simplest local automation. The system includes a boiler designed for 12 kW of power. This boiler requires constant monitoring of its condition, adjusting the volume of air supplied to the furnace by changing the position of the damper (blower), due to which the temperature will be regulated throughout the house.

In the system, it is necessary to control the water level in the expansion barrel; if the water level falls below the minimum, airing of the heating system is possible, which will lead to a decrease in heat transfer by heating radiators. Due to the difficulty of maintaining the optimal boiler combustion mode manually, at which the maximum efficiency and minimum ash content, it is necessary to extinguish the boiler very often to clean it from unburned fuel residues in the furnace, which also wastes time and firewood for ignition. Also, on peak days in subzero temperatures, the boiler cannot warm up the house to a comfortable temperature of 18-25 and does not rise above 16-17 in the maximum performance mode.

To solve the problem of temperature control, it was decided to use the PID control algorithm. The abbreviation PID stands for "proportional", "integral", "differential". These three components describe the simplest elements of a PID controller. In this mode, the controller simply takes the deviation, multiplies it by a constant and outputs it as a control action. To simplify the PID control task, a PID controller was used.

The program in the controller is responsible for maintaining a certain temperature of the air (floor). The universal input of the PID regulator receives the air (floor) temperature from the climate zone sensors. The controller receives a signal from the sensor. The average temperature of the air (floor) in the zone is calculated and transmitted to the PID-controller via RS-485 in which the set temperature is compared with the given hysteresis with the current one. At the exit from the regulator, we get a unified signal that goes to the needle valve servo drive, which determines the degree of its opening (closing),
due to which the system reaches the steady state as quickly as possible. In addition, by transferring the measurement and control functions to the PID controller, the load on the controller is reduced, thereby increasing the system’s performance [4].

A Danfoss needle valve fitted with a REHAU actuator will be used to control the temperature of radiator batteries and underfloor heating.

The air quality control system is necessary to create a circulation of fresh air, cleaned of fine particles, remove dirty, toxic and disinfect the air mass in the event of circulation in a closed circle.

In connection with the need to install supply ventilation, the required arbitrariness was calculated. An automatic calculator of ventilation systems was used for the calculation [5]. Table 2 shows the initial data for calculating the ventilation system.

| Table 2. Initial data for calculating the ventilation system. |
| --- | --- |
| **Parameter** | **Value** |
| Main air duct | |
| Duct length | 8.5 m |
| Number of turns for 90 | 1 |
| Air flow rate | 4 m/c |
| Filter | Not less EU4 |
| Branches from the main duct | |
| Length of the longest branch | 4m |
| Number of turns for 90 | 0 |
| Air flow rate | 2 m/s |
| Zone No. 1 | |
| Maximum number of people | 4 |
| Room area, m² | 58.7 |
| Ceiling height, m | 2.8 |
| Zone No. 2 | |
| Maximum number of people | 2 |
| Room area, m² | 19.2 |
| Ceiling height, m | 2.8 |
| Zone No. 3 | |
| Maximum number of people | 2 |
| Room area, m² | 12.3 |
| Ceiling height, m | 2.8 |
| Zone No. 4 | |
| Maximum number of people | 4 |
| Room area, m² | 11.1 |
| Ceiling height, m | 2.8 |

Table 3 and 4 show the performance calculations and the recommended ventilation cross-sectional areas in each room and for the house as a whole, respectively.

| Table 3. The result of calculating the performance in each room separately. |
| --- | --- |
| **Parameter** | **Value** |
| Zone No. 1 | |
| Ventilation performance | 240 m³/h |
| Duct cross-sectional area | 333 cm² |
Zone No. 2
Ventilation performance 120 m³/h
Duct cross-sectional area 167 cm²

Zone No. 3
Ventilation performance 240 m³/h
Duct cross-sectional area 333 cm²

Zone No. 4
Ventilation performance 120 m³/h
Duct cross-sectional area 167 cm²

Table 4. Results of calculating the performance of the ventilation system.

| Parameter                              | Value  |
|----------------------------------------|--------|
| Overall performance                    | 720 m³/h |
| Cross-sectional area of the main duct  | 667 cm² |

According to the calculation results, for the simultaneous air circulation in four zones of the house, an air supply unit with a capacity of at least 720 m³ / h is required. Based on the calculation results, a CAUF 800 VIM air-handling unit with a capacity of 720 m³ / h and an installed EU 4 class air filter (G 4 in accordance with GOST R 51251-99) was selected.

To increase the speed of air regulation in the house, it was decided to use exhaust ventilation. The installation of this system in the bathroom, toilet, boiler room and kitchen is especially relevant. The system helps to remove excessively humid or polluted air from the house.

The signal about the air condition is sent to the controller, which compares the air humidity, the number of PM2.5 particles, if they go outside the set limits, the controller sends a signal to the air valve and after opening, and it turns on the fan. After the parameters are normalized, the controller gives a command to turn on the fan and close the air valve.

For this task, the following components were selected:

- Fan Vents TT100. This exhaust fan is resistant to highly humid air, has a quick-detachable main unit, which increases ease of maintenance without the need for partial dismantling of the system;
- AVC-210 series PM2.5 transducer provides accurate and reliable measurement of 2.5 particle content in the range of 0 to 600 mcg / m³, while it can accurately transmit data via RS485 interface in Modbus RTU protocol in real time;
- Airone IRIS 100 iris air damper for airflow regulation in ventilation ducts.

To maintain the optimum humidity set by the user, a humidifier must be installed. Among the humidifiers, the most efficient and economical ultrasonic humidifiers are, therefore CAREL UU02DD0000 was chosen. This humidifier assumes installation directly into the ventilation system, which simplifies the further distribution of humid air across zones.

Since plastic windows with the possibility of opening them have already been installed in the building, it is necessary to provide for the possibility of automatically closing or opening the window. This is necessary to eliminate the ineffective operation of the air conditioning system in the summer, if the window is not closed; the air conditioner will not start without user confirmation in manual mode and will automatically start only after closing the windows.

To realize the automatic opening of existing windows, it was decided to use the ST 450 aprimatik electric rod drive. This device allows you to open a window both in a vertical projection and in a horizontal one.

The climate control system in the house is the most important part of the hierarchy of the system, which is an intermediary that helps a person to interact with all mechanisms. Often, the development of
a control system takes a significant part of the time allotted for the development of a project, but SCADA systems have been developed to simplify this process.

SCADA (Supervisory Control and Data Acquisition) is a software package designed to develop or provide real-time operation of systems for collecting, processing, displaying and archiving information about a monitoring or control object [6-8].

The control system in the project will be built in the CODESYS SCADA system. CODESYS (Controller Development System) is a toolkit for industrial automation.

The basis of the CODESYS complex is the development environment for application programs for programmable logic controllers (PLCs).

The main control device will be the PLC210-03-CS processor module (controller). The controller is programmed in the CODESYS V3.5 SP14 Patch 3 environment. It is recommended to use a line of Mx210 modules with an Ethernet interface as input and output signal expansion modules.

The main communication interface of PLC210 is Ethernet. The controller has four Ethernet ports, three of which are combined into a managed switch. This allows the use of various network topologies, as well as the use of the controller as a gateway between the industrial network and the enterprise network [9-10].

To determine the air humidity, the FW04 sensor is used, which is designed to measure the relative humidity in residential and office premises. It has a full range of humidity variation, with an accuracy of + - 2%.

To determine the temperature, the RTM1-MODBUS-BD1 sensor is used with a built-in LCD display on which the temperature is displayed and a potentiometer for changing the temperature setting.

To control and monitor the system, the user uses the SP310-R touch control panel. This panel is designed to connect to the controller by means of Ethernet, RS-485, and RS-232 transmission of influences on the system introduced by the user and display all system parameters.

The main screen of the automated control system is the top link of the control hierarchy, from which you can move to any screen (figure 1).

![Figure 1. The main screen of the automated climate control system.](image)

The main screen contains:

- Table of alarms, where warnings, explanations about events occurring in the climate control system will be displayed.
- Indication of operation (on / off) of the main climate control devices.
- Display of the outdoor temperature from the outdoor temperature sensor installed at the weather station.
- Calendar (at the request of the customer).
• Clock.

On this screen (figure 2), the user can observe the graph of the air conditioner operation for the last 10 seconds, the condition of the air conditioner, the screen of messages about the operation and changes in the condition of the air conditioner at a certain time. From this screen, you can manually control the air conditioner; namely, set the air temperature setting throughout the house, the hysteresis value and return to the main control screen.

![Figure 2. The main screen of the automated climate control system.](image)

On this screen (figure 3), you can control the parameters of underfloor heating. The screen is divided into two parts: the floor control area in the bathroom and the floor control area in the hall, it contains information about the floor temperature, air temperature. The user has the ability to set the temperature from 10 to 20 degrees for the entire period and change its values for four periods.

![Figure 3. Air conditioner control screen.](image)
For further ease of use of the system and quick mastery of its functionality, a hierarchical menu layout was developed. On this diagram, you can specify the path of transition from the main menu to a specific submenu, which simplifies navigation through the system.

3. Conclusion
To solve the problem formulated in the work, an automated climate control system in a residential building, a heated floor control system in rooms, as well as an automated system for closing (opening) plastic double-glazed windows, with the ability to remotely open each of the windows, were developed.

A schematic description of the room climate control system is given.

In the future, this project will be implemented and its functionality will be expanded to a full-fledged smart home.

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