Evaluation of the effectiveness of the building heating control system

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Abstract. Currently, improving energy efficiency and introducing energy-saving technologies is a strategic task for all national economies. Improving the efficiency of buildings and reducing energy consumption in homes can lead to real reductions in resource consumption while ensuring the required level of living comfort. The use of different types of regulation of the building heating system allows the heat transfer of heating devices to be as close as possible to the current heat demand of the object in order to maintain the required internal temperature with a constant change in external conditions. The paper considers the following types of regulation: room-by-room regulation, regulation according to the temperature schedule of CHP and weather regulation. A calculation of each type of regulation was carried out and comparisons of room-by-room regulation with regulation according to the temperature schedule of CHP plants and with weather regulation were presented. As a result, the most effective option was proposed.

1. Introduction
Currently, improving energy efficiency and introducing energy-saving technologies is a strategic task for all national economies. Improving the efficiency of buildings and reducing energy consumption in homes can lead to real reductions in resource consumption while ensuring the required level of living comfort. Today, the population of different levels invests money, paying for the heat losses of the building, and this is taking into account the fact that the cost of energy resources in Russia is increasingly approaching world prices. There are a large number of different options for technical solutions to reduce the loss of resources in residential buildings while ensuring comfortable living conditions, which, ultimately, should lead to a decrease in housing maintenance costs. Prospects for the development of centralized heat supply systems are discussed in detail in articles [1-3].

The use of different types of regulation of the building heating system allows the heat transfer of heating devices to be as close as possible to the current heat demand of the object in order to maintain the required internal temperature with a constant change in external conditions. Of the most common in practice and in the literature, three types of regulation can be distinguished: regulation according to the temperature schedule of a thermal power plant (CHP), room-by-room regulation and weather regulation. Features of the use of weather regulation in heating systems of buildings are considered in articles [4-7].
2. Materials and methods

The object of the research is a hostel located at the Republic of Mari El, Yoshkar-Ola. The hostel is an eight-storey apartment building with 750 beds and an area of 6641.2 m². Year of construction of the building – 2016.

The heat supply system is supplied with a heat carrier - water with parameters 95 - 70° C. The heating system is vertical one-pipe with the upper supply of the heat carrier. Piping routing - top. Heating devices - bimetallic radiators. The pipes are steel. A control valve is installed on the supply pipeline. Heating pipelines and heating devices are laid openly.

Heat supply to the hostel in the city of Yoshkar-Ola is provided from the city networks of the Municipal Unitary Enterprise "Yoshkar-Ola CHP-1".

The object is connected according to a dependent scheme with an open water intake for hot water supply.

Figure 1 shows dorm floor plan [8].

The design temperature of the internal air $t_{in}$, °C for the living room of a public building in Yoshkar-Ola is 22 oC. The design temperature of the outside air (the outside air temperature of the coldest five-day period with a probability of 0.92 for the city of Yoshkar-Ola) is taken $t_{out} = −33°C$. The duration of the heating period (with an average daily outside air temperature of no more than 8° C) is taken for the city of Yoshkar-Ola $z_{ht} = 215$ days.

Within the framework of the simulation, the calculation of the room-by-room regulation was made.

Room-by-room regulation is carried out with the help of thermostats, which are designed to automatically regulate the flow rate of the coolant with a temperature of up to 110° C and a working pressure of up to 1.0 MPa inclusively through radiators of heating systems of buildings and structures of any purpose. The use of thermostats allows to automatically maintain the air temperature in the premises at a given level with an accuracy of 1°C. The thermostat consists of a thermostatic head and a
valve [9]. Thus, room-by-room control with the use of thermostats on heating devices allows to ensure full compliance with the heat losses of the room and the heat gains from the heating devices.

Calculation of heat gains from heating devices with room-by-room control was carried out according to the following formulas to determine heat losses in rooms.

Heat losses through walls in a room

\[ Q_{wall} = F_{wall} \times k_{wall} \times (t_{in} - t_{out}) \times n, \text{ Вт}, \]

where

- \( F_{wall} \) is the area of the wall without a window, m\(^2\);
- \( k_{wall} \) – wall heat transfer coefficient;
- \( t_{in} \) – indoor air temperature;
- \( t_{out} \) – outdoor air temperature;
- \( n \) - coefficient taking into account the cardinal points.

Heat losses through windows in the room

\[ Q_{win} = F_{win} \times k_{win} \times (t_{in} - t_{out}) \times n, \text{ Вт}, \]

where

- \( F_{win} \) – window area, m\(^2\);
- \( k_{win} \) – window heat transfer coefficient.

Total heat loss of the room, equal to heat gain from heating devices with room-by-room control

\[ Q_{room} = Q_{wall} + Q_{win}, \text{ Вт}, \]

The calculation of heat inputs from heating devices during heating according to the temperature schedule of a thermal electric central (CHP) was carried out under the condition of constant thermal characteristics of heating devices and a change in the temperature of the coolant in them. The temperature schedule is approved annually by the CHP and in accordance with this schedule, the temperature supplied to the heating system is controlled.

The heat transfer coefficient of heating devices was calculated using the formula:

\[ \alpha = \frac{Q_{HL}}{(t_{HS} - t_{in})}, \text{ Вт/К}, \]

where

- \( Q_{HL} \) is the heat loss of the enclosing structures, W;
- \( t_{HS} \) is the average maximum temperature in the heating system, which was the schedule of the CHP.

Heat input from heating devices when operating according to the temperature schedule of the CHP

\[ Q_{temp.gr.} = \alpha \times (t_{av} - t_{in}), \text{ Вт/К}, \]

where

- \( \alpha \) is the heat transfer coefficient of radiators, W / K;
- \( t_{av} \) is the average temperature in the supply pipeline of the building heating system according to the temperature schedule of the CHP.

For weather regulation, outdoor sensors are installed on the outer walls of the building (usually north, north-east or north-west). In accordance with the measured street temperature, the electronic controller calculates the corresponding temperature of the coolant, which enters the heating devices. The dormitory has an ECL Comfort 200 electronic controller with a Danfoss P30 control card [10].

To calculate the heat transfer of radiators by weather regulation according to the settings of the regulator, a temperature graph with a weather regulator was built. Then the temperature in the supply pipe of the dormitory heating system was determined for each floor.

Heat gain from heaters during weather control operation

\[ Q_{weath.} = \alpha \times (t_{floor} - t_{in}), \text{ Вт/К}, \]

where \( t_{floor} \) is the temperature in the heating system on the floor with weather regulation, °C.

Based on the presented formulas, a mathematical model of Microsoft Excel was developed with the built-in macro-Visual basic for application. Within the framework of the model, the parameters of heat consumption were determined for each room of the building. For each type of regulation, a daily simulation of work was performed for the period from September 15, 2018 to April 30, 2019. Weather
data were taken from the weather archive at the meteorological station in the city of Yoshkar-Ola [11].
The total annual heat consumption of the building was also determined for each type of simulation.

3. Results and discussion
Based on the simulation results with a step of 3 hours for the period September 15, 2018 to April 30, 2019, the values of daily heat gain from heating devices were obtained at varying outdoor temperatures for each room in the building. The simulation was carried out for the types of regulation discussed above. Figure 2 shows graphs of daily heat gains for room-by-room regulation, regulation according to the temperature schedule of CHP and weather regulation. The abscissa axis in the graph represents the number of the simulation step since the beginning of the heating season. Within the framework of the simulation, 1824 steps were performed, which corresponds to a period of 228 days.

![Graphs of daily heat gains for different regulation types](image)

**Figure 2.** Heat gains with room-by-room regulation, regulation according to the temperature schedule of CHP and weather regulation for the heating season 2018-2019.

The total heat consumption of the building for the heating season of 2018-2019 with room-by-room regulation amounted to 3915 GJ, with regulation according to the temperature schedule of CHP - 5768.5 GJ, with weather regulation - 5189.3 GJ.
The economy of room-by-room regulation in comparison with regulation by CHP is clearly visible in figure 3. The main disadvantage of regulation by the temperature schedule of CHP is visible, which consists in overheating at high outdoor temperatures at the beginning and at the end of the heating period. The total savings of the building when using room-by-room control compared to control according to the temperature schedule of a CHP plant for the heating season 2018-2019 amounted to 1,853.5 GJ or 32.13%.

The savings of room-by-room regulation versus weather regulation is clearly seen in figure 5. The total building savings when using room-by-room regulation versus weather regulation for the 2018-2019 heating season amounted to 1274.3 GJ or 24.55%.
4. Conclusions
Based on the simulation results, it has been established that the most effective type of regulation is room-by-room regulation. The use of room-by-room control allows you to save up to 32.13% of the annual consumption of heat energy for heating a building. Weather regulation saves up to 10% of the annual consumption of thermal energy for heating the building. At the same time, the most uneconomical among the considered types of regulation turned out to be regulation according to the temperature schedule of CHP plants.

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