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Development of A Mathematical Model for Substantiating the Energy Efficiency of a Heating-Cooling Device

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Abstract: This article considers the methodology for achieving efficiency by replacing the existing device scheme in the heating and cooling system of buildings with a new proposed structure scheme. In this case, using the created mathematical expression, its characteristics are obtained using the Matlab program and its validation is checked, and based on them, the device operation algorithm is created and the structural scheme of the device is developed.

Keywords: System, function, scheme, Laplace transform, validation, characteristic, matlab.

Introduction:

The issues of energy efficiency of microclimate systems in socially important buildings in the world are currently considered one of the most urgent tasks of science and practice, and such research is of great importance from the point of view of energy saving. Because systems for optimizing human life include energy-intensive subsystems such as heating, ventilation, air conditioning, cold and hot water supply, etc. The total final (useful) consumption of electricity worldwide (179 countries) for 2020-2021 was 2.3734 billion kWh. By 2020, total useful consumption had increased by 5.5% compared to 1992. The largest increase in electricity consumption in 2021 compared to 1992 was in Asia and Oceania - up to 5.1 times. Currently, "50-55% of electricity consumption is spent on heating and cooling buildings." Particular attention is paid to minimizing energy costs for existing facilities of these subsystems, as well as making optimal decisions when designing them.

A number of studies are being conducted around the world to introduce energy-saving devices into the heating and cooling systems of buildings, to manage them using environmentally friendly and modern devices, and to avoid using traditional electricity supplies as much as possible. Based on this, one of the urgent tasks is to increase the energy efficiency of economic sectors and the social sphere in the heating and cooling systems of buildings, to widely introduce energy-saving technologies and renewable energy sources.

Therefore, job creation and rational use of resources can help reduce some of the social costs. Our country is well positioned to take advantage of these opportunities..

Based on this, a number of decisions and decrees are being adopted and tasks are being set in our country to implement a number of changes in this regard. Taking into account these tasks, one of the important issues is the production of new devices for the heating and cooling system of socially important buildings using solar energy, the creation of improved resource-saving technologies, the optimization of energy saving issues in heating and cooling buildings, and thereby increasing energy and economic efficiency.

METHODOLOGY

Development of the device scheme. Before developing the device scheme, we need to consider the scheme of the existing heating and cooling device [1]. In Figure 1, we can see that the complexity of the existing device circuit and its high energy consumption due to the location of high-power elements in it, and in turn, when the energy consumption increases, it can cause overloading of the transformers. In addition, its compressor unit is installed outside the room where the device is installed, which causes it to emit loud noise and damage the external facade of the building.

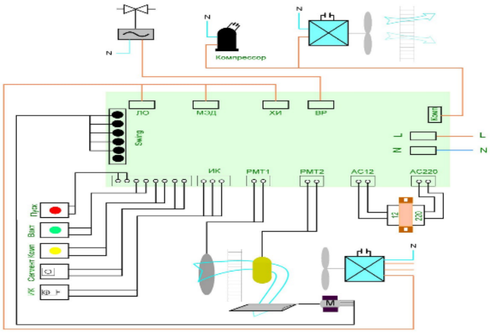

Figure 1: Structural diagram of the existing device

The above-mentioned principles served as the basis for developing an energy-saving and efficient device scheme in the power system. Due to the low-power elements in the device and the use of a Peltier element for cooling, there is no external block and high energy consumption in it [2]. In turn, the energy-efficient device prevents overloading of transformers during periods of high consumption.

The device's power supply converts the signal from the network into 12 V, which is necessary for the cooling system to operate, and 220 V, which is necessary for the heating system to operate.

The control board is one of the main components of the device, which controls the device's on-off, temperature control, switching of the heating and cooling system, and the signals from the remote control element. It also regulates and controls the device when it reaches the desired temperature limit based on the signal from the thermostat [3].

It can also be said that the device itself, depending on the changes in its functions, i.e., temperature changes or mode changes, displays them through the segment in which the device is installed.

Figure 2 shows the structural diagram of the device.

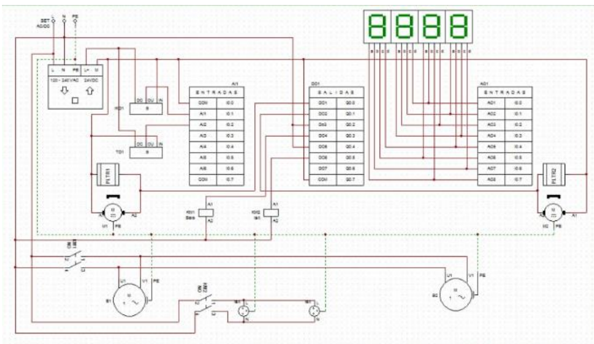

Figure 2: Structural diagram of the proposed device

In heating and cooling systems, two different temperatures are set for the device to ensure meteorological conditions in the room, that is, in the cooling mode of the device, when the set value of the room temperature "t_1" is less than or equal to the operating temperature of the device "t_0", the device remains in a stable state. Similarly, in the heating mode, when the set value of the room temperature "t_1" is greater than or equal to the operating temperature of the device "t_0", the device returns to a stable state. This is done by correctly directing the signal from the temperature sensor of the control board to the switch that regulates the device modes.

The circuit shown in Figure 1 is a program written on the Arduino C++ software on the mainboard for the device to operate, and it is the main element that regulates and controls all modes of the device.

Developing the device transfer function. Based on the time-related relationships between power and energy of the system, we express the transfer function as follows:

$$P_3(t) = \frac{k_{inv.f.i.k} P_0 t_0 + P_4 t_4 + k_{ak.f.i.k} P_2 t_2 - P_1 t_1}{t_3} \qquad (1)$$

Using the Laplace transform:

By taking the Laplace transform of the time function, we express the transfer function as follows:

$$P_3(s) = \frac{k_{inv.f.i.k}P_0(s)+P_4(s)+k_{ak.f.i.k}P_2(s)-P_1(s)}{t_3(s)} \quad (2)$$

Final transfer function:

The transfer function is the basic mathematical model for controlling power distribution and energy efficiency in an energy-efficient system of the “Climat control” device:

$$G(s) = \frac{P_3(s)}{P_0(s),P_4(s),P_2(s),P_1(s)} = \frac{k_{inv.f.i.k}+k_{ak.f.i.k}-1}{t_3(s)} \quad (3)$$

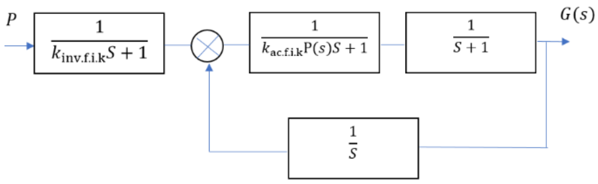

Figure 3: Transmission function

According to international statistics, primary fuel energy sources are decreasing today. This requires the use of renewable energy sources, while the issues of saving existing energy sources, their rational use, and the introduction of energy-saving technologies are relevant today. In particular, the use of renewable energy sources is of great importance in the use of energy-saving devices in the heating and cooling systems of socially important buildings. In addition, the use of autonomous energy sources in the implementation of such technologies will reduce the observed overloads, voltage asymmetry and non-sinusoidality, reactive power deficiency and a number of other abnormal modes in the power system.

One of the main criteria in building design is to accurately calculate the capacity of the heating and cooling systems of socially important buildings, the amount of electricity consumed during maximum and minimum load times (for the coldest and hottest times of the year).

This section discusses the improvement of the mathematical expression of modern automatic room climate control devices to achieve energy savings and thereby energy efficiency by using renewable energy sources (solar energy) rather than traditional electricity sources for the electricity they consume.

The mathematical expression of the working scheme of the improved "Climat control" device proposed above was based on the law of conservation of energy, the photoelectric effect, thermodynamic processes, heat exchange processes, electrostatic and electrodynamic laws.

We use solar energy as our primary energy source, but the power received during the day and the power received throughout the year are variable, that is, it is not possible to obtain constant power. Therefore, when obtaining electricity from solar energy, we calculate the power obtained using a solar photovoltaic panel based on the following conditions.

a) The intensity of the sun is assumed to be constant throughout each season. (Spring: $ye_0 = 1330\ Vt/m^2$; Summer: $ye_0 = 1380\ Vt/m^2$; Winter: $ye_0 = 1320\ Vt/m^2$; Autumn: $ye_0 = 1350\ Vt/m^2$;) [47].

$$e_0 = \int_0^{\omega} e_1(1)dx = const; \qquad [Vt/m^2] \quad (4)$$

Where, ω — angular velocity

ye_1 — instantaneous value of the solar constant

b) The average operating time of a solar photovoltaic panel is assumed to be the same for each season.

s) Solar photovoltaic panel statically clamped [86].

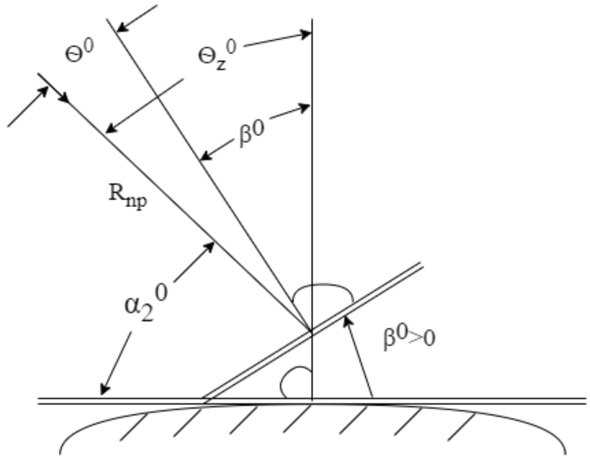

Figure 4: Static positioning of solar photovoltaic panels

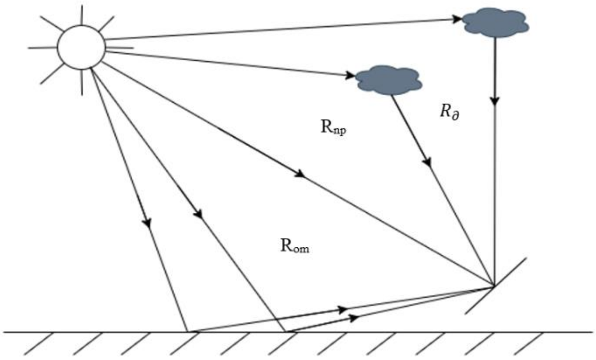

Figure 5: Sunlight falling on a solar photovoltaic panel

The active power generated by a solar photovoltaic panel during the day is generally as follows:

$$P_0 = \int_{t_1}^{t_2} P_t dt; \ [Vt] \qquad (5)$$

Where, t_1 – start time; t_2 – end time; P_t – instantaneous value of power over time

If we take into account the change in the angle of incidence of the sun on the photovoltaic panel during the day, and express the power in terms of the solar constant and the surface area of the photovoltaic panel, we obtain the following expression.

$$P_t = e_0 S \int_0^t \sin(\omega t) dt; \ [Vt] \qquad (6)$$

Where, S – solar photovoltaic panel surfacing surface, $\omega = \frac{2\pi}{T_f}$;

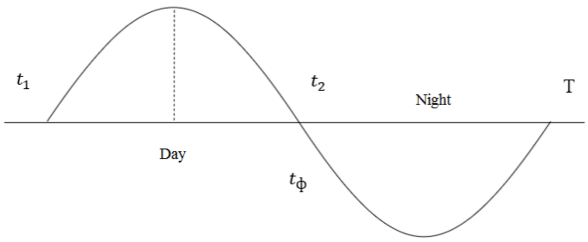

Figure 6: Active power graph used from the grid and solar photovoltaic panels during the day (not taking into account sudden changes in weather)

$$T_f = t_1 - t_2;$$

T_f- solar panel daily operating time.

Let's consider the power distribution according to the following principle diagram.

Since the power management inverter does not store power or energy, we can write the following relationship:

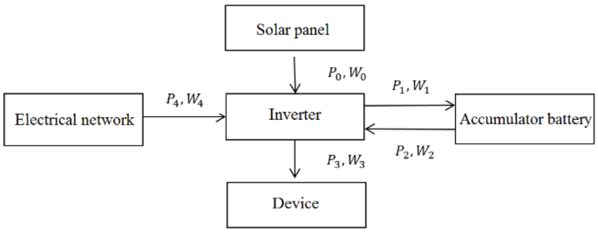

Figure 7: Schematic diagram for selecting the power of a solar panel for a device

1) Considering the inverter F.I.K, then according to the above principle diagram, we can write the following relationships in terms of power and energy flows.

$$k_{f.i.k}(P_0 + P_2 + P_4) - (P_3 + P_1) = 0; \quad (7)$$

Where, $k_{f.i.k}$ – inverter efficiency; R_0 – the active power generated by the solar panel; P_1 – active power flowing from the inverter to the battery; P_2 – active power output from the battery; P_3 – active power output from the inverter to the device; P_4 – active power entering the inverter from the power grid.

If we calculate the active power coming out of the inverter here, it looks like this.

$$P_3 = k_{f.i.k}(P_0 + P_4 + P_2) - P_1; \text{ [Vt]} \quad (7.1)$$

$$k_{f.i.k}(W_0 + W_2 + W_4) - (W_3 + W_1) = 0; \quad (8)$$

Where, W_0 – energy generated by the solar panel; W_1 – energy flowing from the inverter to the battery; W_2 – energy released from the battery; W_3 – energy flowing from the inverter to the device; W_4 – energy entering the inverter from the electrical grid.

2) The battery can store maximum energy depending on its capacity, and for long-term operation, this energy is not fully used, that is, it has a minimum value. Accordingly, the device can use the energy between the minimum value and the maximum value.

$$W_2 = W_{2min} \div W_{2max}; \text{ [kVt} \cdot \text{hour]} \quad (9)$$

Where, W_{2min} – the minimum usable energy of the battery; W_{2max} – maximum usable energy of the battery.

According to condition 2, we can write the same relationship for power.

$$P_2 = P_{2min} \div P_{2max}; \text{ [Vt]} \quad (10)$$

Where, R_{2min} – minimum usable active capacity of the battery; R_{2max} – maximum usable active capacity of the battery

If we calculate the energy consumed by the device from expression (2.8), we get the following expression:

$$W_3 = k_{f.i.k}(W_0 + W_4 + W_2) - W_1; \text{ [kVt} \cdot \text{hour]} \quad (11)$$

$$P = \frac{W}{t}; \text{ [Vt]} \quad (12)$$

According to expressions (2.11) and (2.12) and the above 3 conditions, we obtain the equation of the device power dependence on time depending on the device operating time:

$$P_3' t_3' = k_{f.i.k}(P_0 t_0 + P_4 t_4 + P_{2min} t_{2min}) - P_1 t_1 \text{ [Vt]} \quad (13)$$

Where, t_0 – The actual power generated by the solar panel is operating time.

t_1 – Active power output from the inverter to the battery operating time; t_{2min} – minimum time of active power output from the battery; t_3 – Active power output from the inverter to the device operating time; t_4 – The operating time of the active power entering the inverter from the power grid.

$$P_3'' t_3'' = k_{f.i.k}(P_0 t_0 + P_4 t_4 + P_{2max} t_{2max}) - P_1 t_1 \text{[Vt]} \quad (14)$$

Where, t_0' –the operating time of the active power generated by the solar panel according to condition 3; t_1' –The operating time of the active power output from the inverter to the battery according to condition 3; t_{2max}' –Maximum time of active power output from the battery according to 3 condition; t_3' –The operating time of the active power output from the inverter to the device according to 3 condition; t_4' –The operating time of the active power entering the inverter from the power grid according to 3 condition.

If we take into account the F.I.K of the battery, then equations (2.13) and (2.14) take the following form:

$$P_3 = (k_{inv.f.i.k}(P_0 t_0 + P_4 t_4 + k_{ak.fik} P_{2min} t_{2min}) - P_1 t_1)/t_3 \text{ [Vt]} \quad (15)$$

$$P_3' = (k_{inv.f.i.k}(P_0 t_0' + P_4 t_4' + k_{ak.fik} P_{2max} t_{2max}') - P_1 t_1')/t_3' \text{[Vt]} \quad (16)$$

Where, $k_{inv.f.i.k}$ – the inverter efficiency coefficient (taken to be equal to $k_{f.i.k}$); $k_{ak.f.i.k}$ – accumulator efficiency.

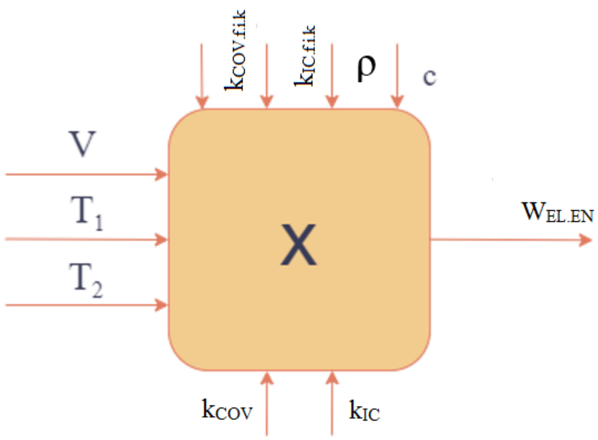

Figure 8: Input and output quantities when obtaining a mathematical representation of the proposed device

When the heating system is turned on, the power consumed by the device becomes equal to the heating power. All the elements necessary for heating start working. Therefore, the following relationship is valid:

$$R_{heat.0} = R_3; \text{ [Vt]} \quad (17)$$

However, since the heating system consists of several elements, some of the power is wasted in the circuit of these elements. We can determine this by the following expression.

$$R_{heat} = k_{ic} R_{heat.0}; \quad \text{[Vt]} \quad (18)$$

Where, k_{ic} – power loss coefficient in the heating system.

In turn, since power and energy are related through time, energy is also wasted, and the energy spent on heating per unit time is defined by the following expression based on the law of conservation of energy.

$$W_{heat} = R_{heat} t_{ic}; \ [kVt \cdot soat] \quad (19)$$

Where, t_{ic} – heating time.

The energy obtained for heating is introduced into the room using convection, and the required amount of heat is needed to reach the set temperature.

$$Q_0 = W_{heat} n; \ [\text{J}] \quad (20)$$

Where, n – the required portion of heat, which characterizes the time taken for heating in this case. According to the heat balance equation, we derive the following expression.

$$Q_{heat.eff} = k_{heat.f.i.k} Q_0 = cm(T_2 - T_1); \ [\text{J}] \quad (21)$$

Where, m – mass; $k_{heat.f.i.k}$ – heating efficiency; T_1 – outside temperature; T_2 – required temperature; s – the specific heat capacity of air, which is related to the parameters of the room volume and air density as follows.

$$m = \rho \cdot a \cdot b \cdot h \ ; \ [\text{kg}] \quad (21.1)$$

Where, ρ – air density; $a \ and \ b$ – room sides; h – room height.

Taking into account expressions (2.21) and (2.21.1), we calculate the amount of useful heat used for heating as follows.

$$Q_{heat.eff} = c\rho abh(T_2 - T_1); \ [\text{J}] \quad (22)$$

If $P_0 = P_a, \rho = 1.29 \ kg/m^3$;

$$W_{el.en} = R_3 t_{is}; \ [kVt \cdot hour] \quad 23)$$

Using expression (2.17), the electrical power is found by the following expression:

$$W_{el.en} = R_{heat.0} t_{ic}; \qquad [kVt \cdot hour] \quad (24)$$

Using expression (2.18), we can reduce the electrical energy to the following expression.

$$W_{el.en} = \frac{R_{heat}}{k_{ic}} t_{ic}; \ [kVt \cdot hour] \quad (25)$$

Using expressions (2.19) and (2.20), we define the electrical power in the following form.

$$W_{el.en} = \frac{W_{isit}}{t_{is} k_{is}} t_{is} = \frac{Q_0}{k_{is}}; \ [\text{kJ}] \quad (26)$$

Using expressions (2.21) and (2.22), we express the electrical power through the following expression.

$$W_{el.en} = \frac{Q_{heat.eff}}{k_{heat.f.i.k}k_{ic}} = \frac{c\rho abh(T_2 - T_1)}{k_{heat.f.i.k}k_{ic}}; \text{[kJ]} \qquad (27)$$

So we define electrical energy by the following expression.

$$W_{el.en} = \frac{c\rho abh(T_2 - T_1)}{k_{heat.f.i.k}k_{ic}}; \text{[kJ]} \qquad (28)$$

When the cooling system starts, the power consumed by the device becomes equal to the cooling capacity. All the elements necessary for cooling start working. Therefore, the following relationship is valid.

$$R_{cool.0} = P_3'; \text{[Vt]} \qquad (29)$$

However, since the cooling system consists of several elements, some of the power is wasted in the chain of these elements. We can determine this by the following expression.

$$R_{sov} = k_{sov}R_{sov.0}; \text{[Vt]} \qquad (30)$$

Where, k_{cool} – power dissipation coefficient in the cooling system.

In turn, since power and energy are related through time, energy is also wasted, and the energy lost per unit time for cooling is defined by the following expression based on the law of conservation of energy.

$$W_{cool} = R_{cool}t_{cool}; [kVt \cdot hour] \qquad (31)$$

Where, t_{cool} – cooling time.

The energy obtained for cooling is introduced into the room using convection and the required amount of heat is needed to reach the set temperature.

$$Q_0 = W_{cool}n; \text{[J]} \qquad (32)$$

Where, n – the required portion of cold, which characterizes the time taken for cooling in this case. According to this balance equation, we derive the following expression.

$$Q_{cool.eff} = k_{cool.f.i.k}Q_0 = cm(T_1 - T_2); \text{[J]} \qquad (33)$$

Where, m – mass; $k_{cool.f.i.k}$ – cooling efficiency; T_1 – outside temperature; T_2 – required temperature; s – the specific heat capacity of air, which is related to the parameters of the room volume and air density as follows.

Taking into account expressions (2.33) and (2.21.1), we calculate the amount of useful cold used for cooling as follows.

$$Q_{cool.eff} = c\rho abh(T_1 - T_2); \text{[J]} \qquad (34)$$

If $P_0 = P_a$, $\rho = 1.29\ kg/m^3$; s- specific heat capacity of air;

$$W_{el.en} = R_3 t_{cool};\ [kVt \cdot hour] \quad (35)$$

Using expression (2.29), the electric power is found by the following expression.

$$W_{el.en} = R_{cool.0} t_{cool};\ [kVt \cdot hour] \quad (36)$$

Using expression (2.30), we can reduce the electrical power to the following expression.

$$W_{el.en} = \frac{R_{cool}}{k_{cool}} t_{cool};\ [kVt \cdot hour] \quad (37)$$

Using expressions (2.31) and (2.32), we define the electrical power in the following form.

$$W_{el.en} = \frac{W_{cool}}{t_{cool} k_{cool}} t_{cool} = \frac{Q_0}{k_{cool}};\ [\text{kJ}] \quad (38)$$

Using expressions (2.33) and (2.34), we express the electric energy by the following expression.

$$W_{el.en} = \frac{Q_{cool.eff}}{k_{cool.f.i.k} k_{cool}} = \frac{c\rho abh(T_1 - T_2)}{k_{cool.f.i.k} k_{cool}};\quad [\text{kJ}] \quad (39)$$

Thus, we determine the amount of electricity consumed using the following expression.

$$W_{el.en} = \frac{c\rho abh(T_1 - T_2)}{k_{cool.f.i.k} k_{cool}}:\ [\text{kJ}] \quad (40)$$

Using the law of conservation of energy, the photoelectric effect, and heat exchange processes, the equation for the dependence of the device’s power on time, taking into account the operating time of the device and the F.I.K of the accumulator, was obtained [6], a mathematical expression that allows determining the electrical energy consumed by the device in accordance with the dimensions of the room.

RESULTS

Obtaining the characteristics and validation of the electrical energy consumed by the device. When determining the electrical energy consumption of a device’s heating and cooling system, we use the following expression to obtain its characteristics using the values from experimental research results [5].

$$W_{el.en} = \frac{c\rho abh(T_1 - T_2)}{k_{cool.f.i.k} k_{cool}};\quad [\text{kJ}] \quad (41)$$

Based on the above, we obtain the characteristic "Energy consumption in cooling mode according to room size changes" by entering the following values, based on the results of experimental studies.

Then, we obtain the characteristic of the electrical energy consumed by the device during the initialization of the $\rho -$ 1,29; $a \cdot b -$ 16 m^2÷ 40 m^2; $h -$ 2,7 m; s –1,0; $k_{cool.f.i.k} -$ 0,65; $T_1 -$ 25 S ÷ 35 S; $T_2 -$ 15 S; $k_{sov} -$ 0,5 values in the MATLAB program.

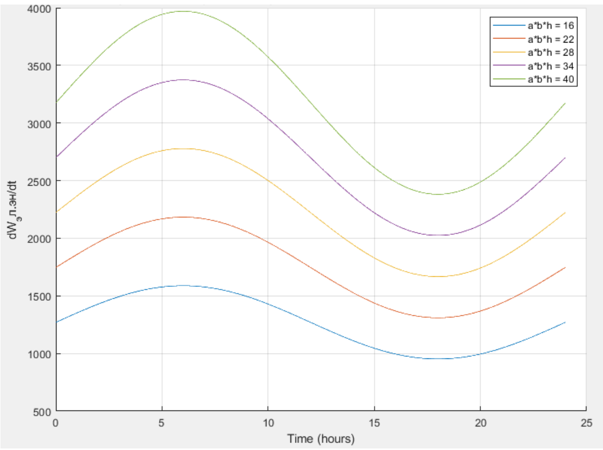

Figure 9: Energy consumption in cooling mode according to room size variation

In the same view, by entering the following values, we obtain the characteristic "Energy consumption in heating mode according to the change in room dimensions".

Then, we obtain the characteristic of the electrical energy consumed by the device during the initialization of the $\rho -$ 1,29; $a \cdot b -$ 16 m^2÷ 40 m^2; $h -$ 2,7 m; $s -$1,0; $k_{sov.f.i.k}$ – 0,65; $T_1 -$ 0 S ÷ 10 S; $T_2 -$ 25 S; k_{sov} – 0,5 values in the MATLAB program.

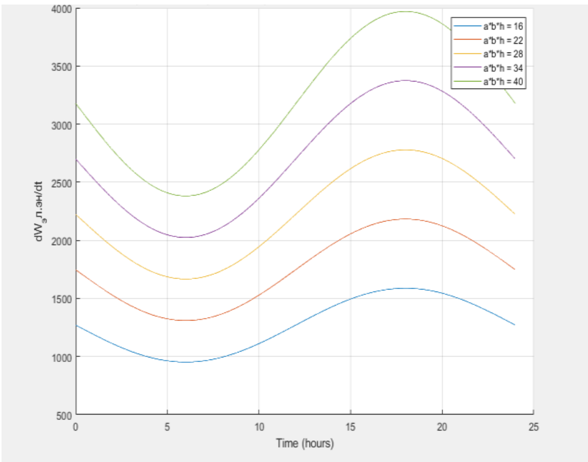

Figure 10: Energy consumption in heating mode according to room size changes

Confirming the reliability, accuracy, and correctness of the results obtained is called validation, in which the results are evaluated for their authenticity before being used.

Main stages of the result validation process:

Verification of results, Testing and evaluation, Expert opinion, Statistical analysis, Testing in real conditions, Importance of result validation, Increasing reliability, Identifying errors, Creating a basis for acceptance.

For example, if you are studying the effectiveness of a model as part of a scientific study, the validation process is necessary to determine how the results of that model work in real-world conditions.

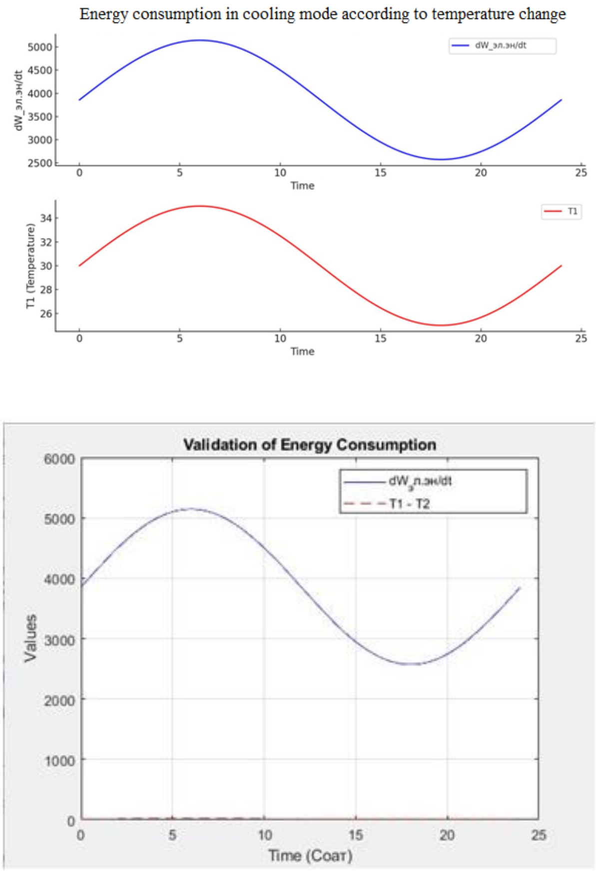

Figure 11: Energy consumption in cooling mode according to room size variation

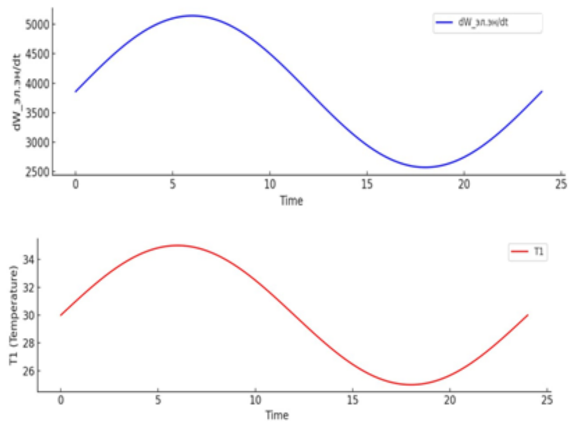

Figure 12: Energy consumption in heating mode according to room size changes

The graphs in Figures 11 and 12 show the validation results for temperature and energy consumption evaluation. Their descriptions are given below:

1. In the top graphs: $dW_{el.en}/dt -$ heating and cooling energy consumption is expressed.

The vertical axes show the values of $dW_{el.en}/dt$ (watt-hours), the amounts of energy required for cooling and heating.

The horizontal arrows indicate the time it took in hours.

The analysis shows that energy consumption has a sinusoidal variation. Maximum values are observed in the middle of the day. Minimum values occur in the evening and morning, which is of course directly related to temperature changes.

2. In the graphs below: $T_1 -$ expressed as outdoor temperature.

The vertical axis shows the ambient temperature T_1, measured at C.

The horizontal arrows indicate the time it took in hours.

The analysis shows that T_1 varies sinusoidally, with maximum values observed during the day, which increases energy consumption. Minimum values are observed at dawn and at night, which reduces the need for cooling or heating depending on its temperature change.

Validation results:

The energy consumption graph values will have positive values only when the conditions $T_1>T_2$ or $T_2>T_1$ are met. This is confirmed by validation.

If $T_1>T_2$, energy consumption is directed towards cooling, or vice versa, if $T_2>T_1$, then energy consumption is directed towards heating.

So the conclusion from the graph is that:

Validation is working successfully because values are generated only in accordance with physical laws.

As you can see from the graphs, energy consumption is calculated only under necessary conditions. This allows you to increase the efficiency of the system.

Development of a device operating algorithm. When developing the device's operating algorithm, the necessary quantities were initially selected and through them the active power generated by the solar photovoltaic panel and the active power supplied to the device were determined. Then, by entering the necessary conditions, it was possible to determine the power consumed by the device in heating and cooling and the electricity consumed.

- Start: Start the device's processing algorithm.

- P_{2min} — minimum usable active capacity of the battery; P_{2max} — maximum usable active capacity of the battery; P_4 — active power from the power grid; ye_0 — solar intensity; S — solar photovoltaic panel surfacing surface; $k_{inver.f.i.k}$ — inverter efficiency; $k_{accum.f.i.k}$ — accumulator efficiency; k_{ic} — power loss coefficient in the heating system; $k_{heat.f.i.k}$ — heating efficiency; $k_{cool.f.i.k}$ — cooling efficiency; k_{cool} — power dissipation coefficient in the cooling system; t_0 — The actual power generated by the solar panel is operating time; t_1 — Active power output from the inverter to the battery operating time; t_{2min} — minimum time of active power output from the battery; t_3 — Active power output from the inverter to the device operating time; t_4 — The operating time of the active power entering the inverter from the power grid; T_1 — outside temperature; T_2 — required temperature; ρ — air density; a — room length; b— room side; h — room height; c— specific heat capacity of air.

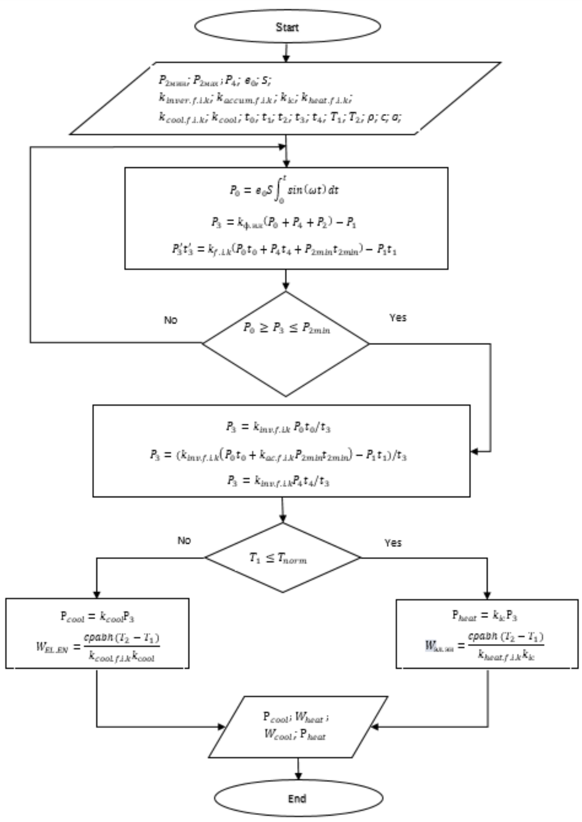

Figure 13: Device operation algorithm

- After the above parameters are entered, the total active power generated, taking into account the change in the angle of incidence of sunlight on the solar photovoltaic panel during the day, is calculated from expression (3). The solar photovoltaic panel is directly connected to the inverter, and the active power output from the inverter is calculated from expression (4.1). If the battery supplies active power to the device in the minimum operating mode, then the active power supplied to the device is calculated from expression (10).

After the given expressions are calculated, the algorithm moves to the next step and the following conditions are introduced:

$$P_3 = k_{inv.f.i.k} \cdot P_0 \cdot t_0 / t_3; \quad (42)$$

If the power of the solar photovoltaic panel is less than or equal to the power consumed, that is, $P_0 \leq P_3$, then the algorithm assumes the "no" condition and proceeds to the next stage, where the following condition is introduced:

If the power consumed by the device is greater than

$$P_3 = (k_{inv.f.i.k}(P_0 t_0 + k_{ak.fik} P_{2min} t_{2min}) - P_1 t_1)/t_3; \quad (43)$$

If the power consumed by the device is less than or equal to the battery capacity or the power of the solar photovoltaic panel is less than or equal to zero, that

$$P_3 = k_{inv.f.i.k} P_4 t_4 / t_3; \quad (44)$$

Once the power consumption of the device is determined based on the above conditions, the algorithm moves to the next step and the following conditions are introduced:

$$R_{heat} = k_{ic} R_3; \quad (45)$$

$$W_{el.en} = \frac{c\rho abh(T_2 - T_1)}{k_{heat.f.i.k} k_{ic}}; \quad (46)$$

If the external temperature is not lower than the temperature specified in GOST 30494-2011, then the algorithm accepts the "no" condition and proceeds to the next stage, where the following condition is introduced.

If the external temperature is equal to the temperature specified in GOST 30494-2011, i.e.

$$R_{cool} = k_{cool} R_3; \quad (47)$$

$$W_{el.en} = \frac{c\rho abh(T_2 - T_1)}{k_{cool.f.i.k} k_{cool}}; \quad (48)$$

The energy consumed in heating and cooling, as well as the electricity consumed, are displayed as a result of the conditions and calculated expressions provided in the algorithm.

End: The device processing algorithm ends.

CONCLUSIONS

1. An energy-efficient structural scheme of the device was developed based on changing the internal elements of the heating and cooling system, and a mathematical model was developed using the Matlab

If the power of the solar photovoltaic panel is greater than or equal to the power consumed, that is, $P_0 \geq P_3$, then the algorithm accepts the condition "x" and calculates the following expression:

or equal to the battery capacity or the power of the solar photovoltaic panel is greater than or equal to zero, that is, $P_3 \geq P_2 min$ and $P_0 \geq 0$, then the algorithm accepts the condition "yes" and the following expression is calculated:

is, $P_3 \leq P_2 min$ and $P_0 \leq 0$, then the algorithm assumes the "no" condition and the following expression is calculated:

If the external temperature is lower than the temperature specified in GOST 30494-2011, i.e. $T_1 < T_{norm}$, then the algorithm assumes the condition "yes" and calculates the following expressions:

$T1 = T_{norm}$, then the algorithm accepts the condition "yes" and the device switches to the standby mode.

If the external temperature is not equal to the temperature specified in GOST 30494-2011, that is, $T_1 < T_{norm}$, then the algorithm accepts the "no" condition and the following expressions are calculated:

program that allows determining the electrical energy consumed by the device, taking into account the room dimensions and external temperature;

2. A structural diagram of the device was developed. As a result, a prototype of the device was developed based on the diagram.

3. A mathematical model was developed using Matlab software to determine the electrical energy consumption of the device, taking into account the room dimensions and external temperature. As a

result, it was possible to compare the results of theoretical and experimental studies.

4. An algorithm for operating an innovative device that controls room temperature at set values in heating and cooling buildings of social importance was developed. As a result, based on this algorithm, moderate climate control was created in the room where the device is installed.

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