Energy-efficiency measures of oil and gas industry building using optimum conditions of faltering heating

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Abstract. Nowadays the problem of use of energy resources is the most relevant. The actions directed to increase in energy efficiency of use of energy resources at the mining utilities should be developed and introduce to solve this problem. The refusal of the systems of the centralized heat supply and transition to the decentralized systems is offered as the solution of an objective. In the centralized systems, development of warmth is carried out in separate sources. The giving of the heating agent in the systems of heat consumption is taken place through thermal networks. Thermal networks have the considerable extent and diameters at the same time. They are also equipped with thermal points, pump stations, automatic equipment and a control system.

1. Introduction
The system of heat supply is called decentralized one if it does not have the developed thermal networks and the source of warmth is located directly near the objects consuming warmth. This system is widespread at the utilities of a mining complex, for example, in administrative and household complexes [1, 2, 3] of working personnel on mines and trade platforms.

Now there are technical solutions of implementation of autonomous [4] heat supply of an object: classical – using of autonomous boiler houses, modern – using of solar energy as a warmth source and using of low-potential energy of soil, water and other.

Today there is a set of measures for decrease in energy consumption by buildings. This measures concern both constructions and engineering networks. One of the most effective measures for economy of heat energy is implementation of the faltering heating mode [5]. It allows saving resources and simplifying the structure.

The purpose of research is the definition of actual heat economy using the mode of faltering heating during all heating season for administrative and household rooms of trade platforms.

2. Faltering heating concept
The faltering heating mode is provided for economy of thermal energy introduction into an object. The mode of faltering heating consists in the following: in time off work– at night or in holidays when the office building is not operated. Beside, the required temperature must be ensured by the time of using the room.

Such system allows not only saving thermal energy and demanding small financial expenses concerning other energy saving actions [6, 7, 8].
At the same time, the task is set: to operate so the mode of heating of the building that the expense of thermal energy was minimum and internal temperature at the beginning and at the end of the non-working period corresponded to rated value. This task was considered in [9, 10, 11].

The simplified heat exchange model based on the discrete one-dimensional equations of heat conductivity was used in this article. The model describes evolution of temperatures on surfaces of enclosing structures and internal partitions and temperatures of internal air indoors. The operating parameter of model is heating system power. Functional of $I(W)$ from the power of $W(t)$ of a heating system was applied during regulation. Functional represents the sum of two non-negative parts composed to assessment of efficiency of heating (1):

$$I(W) = E(W) + \gamma (\Delta T_k(W))^2.$$ (1)

3. Methodology of the calculation method increasing efficiency of buildings due to faltering heating

This methodology was solved based on the mathematical models. The description of this model of thermal mode of the building for the optimum control algorithm for the non-working period was developed. The developed algorithm ensures the required temperatures of internal air at the minimum flow of thermal energy. Mathematical models were considered in [10, 12, 13].

The thermal mode of the building [11, 14, 15], strictly speaking, as object of management is an object with the distributed parameters therefore the problem about optimum control for this representation of an object was solved.

The analysis of literature [16, 17, 18] shows that the mathematical description of the thermal mode of the building can be well submitted as follows (2)-(7):

$$\frac{\partial t(x, \tau)}{\partial \tau} = a \frac{\partial^2 t(x, \tau)}{\partial x^2}, 0 < x < L, \tau > 0;$$ (2)

$$t(x, 0) = t^0(x), 0 \leq x \leq L;$$ (3)

$$-\lambda \frac{\partial t(0, \tau)}{\partial x} = \alpha_a [t_a(\tau) - t(0, \tau)] \tau > 0;$$ (4)

$$-\lambda \frac{\partial t(L, \tau)}{\partial x} = \alpha_i [t(L, \tau) - t_i(\tau)] \tau > 0;$$ (5)

$$c_a m_a \frac{dt_a(\tau)}{d\tau} = u(\tau) - \alpha_a F_{cm}[t_a(\tau) - t(0, \tau)] - k_{ok} F_{ok}[t_a(\tau) - t_i(\tau)], \tau > 0;$$ (6)

$$t_a(0) = t_a^0(x),$$ (7)

$t(x, \tau), t(0, \tau), t(L, \tau)$ – temperature respectively in a point with coordinate $x$ on thickness of an external wall, on an internal surface and on an external surface of an external wall of the building in time point $\tau$; $\lambda$ – coefficient of heat conductivity of material of an external wall; $\alpha_a, \alpha_i$ – thermolysis coefficient respectively for internal and external surfaces of a wall; $t_a(0), t_a(\tau)$ – temperature of internal air in initial timepoint and timepoint $\tau$ respectively; $t_i(\tau)$ – temperature of external air in timepoint $\tau$; $u(\tau)$ – management, heating system power in timepoint $\tau$; $c_a, m_a$ – the specific heat and mass of internal air in the building respectively; $a$ – thermal diffusivity; $F_{cm}, F_{ok}$ – respectively, the area of the exterior walls of the building and windows; $k_{ok}$ – window heat transfer coefficient.

On a set of admissible decisions, the functionality the $I$ was found. The first component $I$ was defined defines proximity of reference and final temperature of internal air, and the second was defined an expense of thermal energy (8):
\[ I = \left[ \tau_k \left( t_a(\tau) - t_0^k \right) \right] ^2 + \beta \int_0 ^{\tau_k} G[u(\tau)]d\tau, \quad (8) \]

\( \tau_k \) – the set period; \( G \) – the function estimating the current expense of warmth the building on heating; \( \beta \) – some weight coefficient.

The conditions of optimality are presented by the following ratios: for a formulation of conditions of optimality [19, 20, 21], function is entered (9):

\[ H = \psi_0(\tau)u(\tau) - \beta G[u(\tau)], \quad (9) \]

\( \psi_0(\tau) \) satisfies to the following system of the equations (10)-(11):

\[ -c_m a_m \frac{d\psi_0(\tau)}{d\tau} + (\alpha_a F_{cm} + k_{ok} F_{ok})\psi_0(\tau) - \frac{a a_m}{\lambda \psi_0(0, \tau)} = 0; \quad (10) \]

\[ \frac{d\psi(x, \tau)}{d\tau} + a \frac{d^2\psi(x, \tau)}{dx^2} = 0; \quad (11) \]

with entry conditions (12)-(13):

\[ c_m a_m \psi_0(\tau) = -2[t_a(\tau) - t_0^k]; \quad (12) \]

\[ \psi_0(0, \tau) = 0. \quad (13) \]

Boundary conditions for function \( \psi(x, \tau) \) were set in a look (14)-(15):

\[ a \frac{\alpha_m}{\lambda} \psi_0(0, \tau) - a \frac{\partial \psi(0, \tau)}{\partial x} - \alpha_a F_{cm} \psi_0(0, \tau) = 0; \quad (14) \]

\[ -\lambda \frac{\partial \psi(L, \tau)}{\partial x} = a_n \psi(L, \tau). \quad (15) \]

4. Scientific novelty of research

Efficiency of the following control algorithms was estimated by the received results.

Figure 1 shows scheme of efficiency of control algorithms.

\[ \text{Figure 1. Scheme of efficiency of control algorithms: } Q_{\text{max}} \text{ – maximum power of a system; } Q_{\text{min}} \text{ – minimum power of a system; } \text{IV mode – connection to thermal networks; III mode – with the stabilizing regulator; II – internal temperature comes to the border of } 12 \, ^\circ C; \text{ I – during the I period of time the power of a heating system is equal to the maximum (established) value, and during the II period – minimum [9]} \]

Figure 1 presents an analysis and comparisons of the 4 modes. The intensive warming up of the building is carried out only on the final site of time off (mode II). This mode was established
5. Calculation method of faltering heating
Thus, the application of the faltering heating mode in buildings with an autonomous source of warmth is expedient. On the other hand, the connection of them to the central thermal networks is irrational. This is due to the fact that building is connected to thermal networks and the central regulation of warmth on a source is made and the necessary power for a building warming up is function of temperature of external air. The energy from the central thermal networks is spent for compensation of the current heat losses of the building. A warming up of the building, or rising temperature of internal air in the building, does not happen because of lack of a stock of warmth.

6. Conclusion
In the research, the method of increase in energy efficiency of use of energy resources and energy saving actions is analyzed.

This task was solved on the basis of the mathematical models describing the thermal mode of the building. The optimum control algorithm of the thermal mode of the building during the non-working period was developed. It provides the required temperatures of internal air at the minimum flow of thermal energy [21, 22].

The application of the mode of faltering heating in buildings with an autonomous source of warmth is expedient. Their connection to the central thermal networks is irrational.

For object model with the distributed parameters the optimality conditions are defined. They are formulated in the form of the principle of a maximum. The general view of optimum control is established.

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