Applicability of information technologies in energy conservation

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Abstract. The article describes the computational complex designed for large-scale mathematical modeling and optimization of intra-quarter thermal regimes heating networks. Developed software allows to manage all users of thermal energy and carry out its accounting. On its basis, a strictly analytical system of targeted budget subsidies to individual consumers of thermal energy can be built, taking into account the social norms of housing, the estimated and actual power of heating devices, the location of the apartment in the house and the state of its enclosing structures. The article concludes about the effectiveness of the proposed mathematical modeling method in the organization and effective management of ensuring energy saving in the design of heating networks.

The information and analytical heat supply system is a set of software tools for storing all the necessary information about the elements of the structure of heat supply systems, powerful tools for entering and correction the graphic and parametric data, as well as for the operational manage of hydraulic and thermal calculations of operating modes and heating networks improvement.

The locality power supply system is a structure consisting of three levels:

- first level - a network of main heat pipelines between heat sources and central heating points (CHP);
- second level - a network of communal heating networks between the central heating station and buildings and structures that are consumers of thermal energy;
- third level - heating networks inside buildings and structures.

The heat supply system consists of the complex hierarchical structure with all inherent characteristics such as nonlinearity, anti-intuitiveness, interdependence, variability, etc. Due to the constant development of the heat supply system (the growth of the connected load on boiler houses and central heating stations due to new participants, the ramification and length of heating networks, etc.), the interconnections between its various levels and subsystems are increasing [1]. Since the various levels of the central heating system are interdependent, the decisions on its functioning taken for each subsystem separately are not optimal for the system as a whole.
Therefore, it is impossible to significantly reduce the volume of thermal energy usage unless system analysis and mathematical modeling of the urban heat supply system is conducted as well as the analysis of the processes and algorithms to optimize system parameters such as heat sources, heat energy users etc. are implemented.

The system can be used as an information and analytical base when reforming housing and communal services in the organizations responsible for the heat economy operations in district administrations and housing departments [2]. This system can put under control all users of thermal energy and carry out its accounting according to the conservation laws. The system consists of seven basic subsystems. The first subsystem is a scheme of main pipelines.

The second subsystem is a diagram of communal heat pipelines with the following characteristics: parameters of the coolant at the input-output of the central heating station; places of insertions and branches; geometrical and thermophysical parameters of linear sections of pipelines: length, height difference, diameter, wall thickness, steel grade, parameters of multilayer insulation, burial depth, burial method; parameters of the coolant at the entrance and exit of the building [3].

The third subsystem is a schema of heating networks inside buildings with the following characteristics: parameters of the coolant at the entrance and exit of the building; the number of risers, the number and type of batteries on each riser; geometric and thermophysical parameters of linear sections of pipelines: length, height difference, diameter, wall thickness, steel grade, insulation parameters [4]. The fourth subsystem represents characteristics of the rooms: name; floor; the area of the enclosing walls; window area; number of glazing layers; orientation to the cardinal points; type of enclosing surfaces; characteristics of the enclosing surfaces.

The fifth subsystem is a database of heat consumers: consumption by different rooms; consumption by different buildings; consumption across the complex of buildings.

The sixth subsystem is the reference information database, which consists of the following sections: subscriber inputs, elevators; fixtures, thermal insulation; enclosing structure; heating devices, pipes; soils; heat consumption.

The seventh subsystem is a functional block of mathematical models. Requirements for the software package are prompt access to each subsystem and to the structural element of the subsystem; the ability to adjust each structural element of the system; database scaling; the ability to link characteristics and input data in each of the blocks with mathematical models of thermal calculations [5].

Set of work required for the functioning of the software package: collection of information on the operating modes of the central heating station; collection and refinement of the initial technical documentation on the characteristics of heating mains, schemes for their laying, building structures and schemes for their heat supply; collection of information about heating systems of buildings, characteristics of elevator units, heating devices, dimensions of enclosing structures; creation of electronic albums of heating networks of central heating stations, heating networks inside buildings and electronic albums of building layouts; creation of a database of various sections digital information of heating networks; creation of the digital information database of about the characteristics of buildings; creation of a digital information database for calculating heat loss of buildings; creation of a digital information database for calculating the heat loss of individual rooms [6].

The created software-computing complex is intended for carrying out large-scale mathematical modeling and optimization of thermal regimes of intra-quarter heating networks. The created software makes it possible to put under control all consumers of thermal energy and carry out its accounting in compliance with conservation laws [7]. On its basis, a strictly analytical system of targeted budget subsidies to individual consumers of thermal energy can be built, taking into account the social norms of housing, the calculated and actual power of heating devices, the location of the apartment in the house and the state of its enclosing structures.

The software and computing complex is a necessary element of a more general information and analytical system aimed at mathematical modeling and feasibility study of various options for implementing the reform of housing and communal services in terms of energy saving of buildings.
practical operation of this system creates the necessary economic mechanism for consistently improving the quality of enclosing structures in order to improve their heat-shielding properties [8].

The main capabilities of the software and computing complex:

- processing of graphic and digital information about the state of observable objects and accounting;
- complex analytical data processing, analysis of the actual and standard state of the heating network various elements;
- calculation of hydraulic and thermal loads of buildings;
- calculation of costs on sections of the pipelines for a given state of valves and pumping stations;
- calculation of the distribution of temperature, coolant pressure in heating network pipelines, construction of a piezometric graph;
- calculation of heat losses of intra-quarter heating networks, the structure of heat losses of buildings and individual rooms;
- calculation of the room temperature based on the system of heat balance formula;
- design of buildings thermal protection and calculation of thermal energy possible savings;
- calculation of emergency modes, including when connecting or disconnecting consumers, branches and individual sections of the network;
- optimization of the users elevator nodes in order to minimize the deviation of the actual room air temperature from the calculated value;
- optimization of the heating network parameters and configuration, including diameters of pipelines, locations and parameters of pumping and throttling stations in order to minimize the reduced costs, consisting of the costs of construction, reconstruction of a heating network, pumping or throttling stations, costs of electricity spent on pumping the coolant and costs of heat losses [9];
- modeling of processes of non-stationary thermal regime of buildings;
- calculation and design of window systems;
- optimal design of boiler houses, central and individual heating points.

The practical operation of this system will make it possible to develop the necessary economic mechanism for consistently improving the quality of the walling, in order to improve their heat-shielding properties. It will also make it possible to develop a feasibility study for various options for implementing the reform of housing and communal services from energy saving point of view. To implement the proposed economic mechanism, it is necessary to revise the payment scheme for consumers for thermal energy.

Let us denote by $R_0$ the heat losses of any apartment for a certain period, which are due to the objectively existing or desired quality of the enclosing structures, and through $\Delta R$ additional heat losses associated with the absence of a certain set of insulation measures. Then $R=R_0+\Delta R$ will represent the total heat loss of the apartment. By means of $Q$, we denote the total arrival of heat into the apartment through heating devices, and by $Q_0$ the arrival of heat into the apartment through heating devices, which would compensate for heat losses $R_0$. Obviously $Q=Q_0+\Delta Q+\Delta Q_d$, where $\Delta Q$ – is the additional heat input required to compensate for the additional heat consumption $\Delta R$, and $\Delta Q_d$ – the imbalance of heating devices. This value can be either more or less than zero. By the way, with a positive value $\Delta Q_d$, the heat inflow is vented into the atmosphere through open vents or balcony doors.

It is impossible to keep heat payment at the same level for all categories of the population. However, it would not be entirely correct to raise the payment for heat energy in standard situations, when there are reserves for significant savings in heat resources. The new formula for paying for heat energy should also contain mechanisms for its saving. One of the possible payment algorithms for heat energy can be an algorithm defined by the following formula (1):
The calculation of the optimization of the model heating network parameters showed that the optimal way of laying pipelines is underground. So, if you lay a heating network with optimal diameters by the underground method of laying pipelines, then its reduced costs will be less than the costs of the existing heating network by 27%. Cost reduction is achieved by almost halving the cost of heat losses with slight increase construction and electricity costs. It should be noted that in this case, the calculations were carried out when insulating pipelines with "standard" heat-insulating materials. As a result of the use of modern technologies of thermal insulation, for example, insulation with polyurethane foam, the calculation showed that the optimal diameters remained the same as when using "standard" insulation, and the optimal method of laying pipelines is predominantly aboveground, which made it possible to reduce the costs of building a heating main. In this case, the savings are already 53%.

The calculation of the optimization in configuration and parameters of the heating network showed that the reduced costs of the new heating network will be less than the costs of the existing one by 56%.

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\[ P_h = \left[ R_0 \left( \frac{a^h}{100} \right) CS + \Delta Q \right] CS + R_0 (S - S_h) \left( 1 + \frac{b_0}{100} \right) \] (1)

Where \( R' \) – is the calculated desired value of the heat losses of the apartment, referred to the unit of its area (or volume); \( a^h \) – a new coefficient of budget subsidies, determined in such a way that in standard situations the cost of heating does not increase; \( S_h \) – the social norm of the apartment's housing, to which budget subsidies are applied; \( \Delta Q \) and \( \Delta Q' \) – additional heat inflow, which compensates for additional heat consumption \( R' \) and heat imbalance in the apartment, respectively, per unit area (or volume); \( b_0 \) – standard overhead costs of heat losses on the supply lines.
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