Method of calculation of power efficiency by optimization of work of heat supply systems

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Abstract. In this work results of mathematical modeling and results of the pilot studies conducted at the laboratory stand for the system of heat supply of Kazan, the development of power of the large cities directed to development of an integrated approach at a research of problems are integrated. By means of the program Zulu complex the mathematical model intended for optimization of work of power systems during their operation has been created. Results of the conducted researches have allowed to analyse influence of stage-by-stage introduction at consumers of automatic metering stations and weather regulation (AITP) on a hydraulic operating mode of system of heat supply for large municipal associations. In this work the main criteria are also considered, the algorithm and a method of calculation of power efficiency is developed by optimization of systems of municipal heat supply by introduction of the automated individual thermal points (AITP). The questions of influence of the made technical solutions on financial and economic and investment indicators are raised. The considered actions for energy resources saving are investigated for the purpose of reduction of volumes of consumption or more rational use of fuel and energy resources.

1. Introduction

Management of the systems of development, transportation and distribution of energy carriers is a basis of increase in power and economic efficiency of economic entities of the industry and the sphere of housing and communal services.

Realization of the having potential of energy saving requires complex interaction of elements of external and internal engineering systems on the way from a warmth source to the consumer. Economy of energy is reached due to optimization of a holiday of thermal energy, regulation of the hydraulic mode [1,2], introduction of the automated thermal points (AITP) which are a link of internal and external thermal networks [3].

The tool of the solution of the main problems which are available in concrete thermal network are the computer models giving the chance to define the hydraulic and thermal mode of system [4].

Modeling of the modes of a holiday of heat by means of the electronic scheme allows to analyze profitability of options of loading of the heating equipment from the point of view of minimization of costs of transfer of heat, specific fuel consumption on a holiday of thermal and electric energy taking into account opportunities of thermal network for transportation of the heat carrier.
Earlier authors have analysed influence of stage-by-stage introduction of automatic metering stations and regulation on the most remote from the central heat distribution station the consumers connected according to the elevator scheme [5].

Optimum consumption of thermal energy at respect for the required comfort in rooms of buildings is the main objective of energy saving in the sphere of municipal heat supply to which much attention is paid [6] today.

Comparison of result, the research (electronic modeling of operating modes and pilot studies) conducted in various ways is presented in the figure 1.

![Figure 1](image)

Figure 1 The required located pressure at CTP exit depending on stages of introduction of ITP

Apparently from the schedule, considerable influence on the hydraulic mode of system of heat supply, renders the level of equipment of consumers of the AITP system of 60%. At this value significant increase in the located pressure on an entrance to the considered contour, therefore, and increase in pressure in the giving pipeline is required. Increase in pressure of network water can lead to emergence of the emergency or transition hydraulic processes caused by fluctuation of pressure in the system of heat supply of the city in general [7]. It can't be allowed from the point of view of reliability of the operated systems of heat supply which is one of the major factors at implementation of the heatsupplying organizations and consumers of thermal energy [8].

The difference $\Delta H$ between the received values during an experiment and modeling in our opinion is explained by an error of devices.

The most optimum from the point of view of quality of heat supply and power overall performance of system is providing AITP more than 80% of consumers of total number. At the same time the set thermal and hydraulic mode in the system of heat supply remains, there is no disbalance of system and the required temperature condition directly at the consumer is exposed [9].

2. Goals and objectives

The method of calculation of energetic efficiency is developed for increase in energy saving taking into account step-by-step implementation in the systems of municipal heat supply of automated
metering stations and regulations of thermal energy and also for maintenance optimum, from the point of view of saving of energy resources, the hydraulic mode by optimization of systems of municipal heat supply by implementation of the automated personal thermal points (APTP) (further the Technique).

Use of this Technique allows to estimate technical and economic efficiency of the actions directed to saving and optimum use of energy resources.

The technique is developed for the closed systems of heat supply.

It can be applied as to quarterly calculation of systems of heat supply of the large cities, and to calculation of diagrams of heat supply of small settlements.

The purpose of development of the Technique is complex assessment of efficiency, the energy saving actions offered to implementation in natural and monetary value.

The main objectives by development of the Technique were:

- choice of criteria for evaluation of efficiency of execution of an energy saving action;
- development of an algorithm of calculation of criteria according to saving from implementation of energy saving actions in natural and value terms, based on a technical entity of the executed actions.

The main criteria in case of compilation of this technique selected indices of the expenditure of the heat carrier (network water), indices of change of a heat load of customers, in case of oscillations of temperature of outside air, change of temperature in locations and influence of these criteria on hydraulic stability of system of heat supply in general [10].

Algorithm of calculation of criteria according to technical and economic indices:

- According to metering devices the main sentries and annual indices of operation of the studied system of heat supply for each subscriber are defined.
- The number of customers for installation of AITP is defined with the optimum percent of equipment received earlier as a result of the carried-out simulation [11].
- The composition, the cost of the equipment and costs of project installation works is determined by directories of vendors and suppliers of personal thermal points.
- For each of the selected customers the potential of saving of thermal energy is defined with implementation of AITP.
- Taking into account change of a heat load on customers, hydraulic calculation of the considered system of heat supply is carried out.
- The economic efficiency from implementation of schedulable energy saving technologies is defined and the payback period of the offered actions is defined [12].

3. Results of work

By this technique an assessment of power efficiency of the realized energy saving actions (introduction of AITP) on the example of the residential quarter No. 38 to Kazan has been given.

The efficiency of any implemented projects and actions by optimization of systems of heat supply is defined by a ratio of expenses and the results considered actions.

Assessment of commercial effectiveness was carried out I taking into account the following requirements:

- the capital investments put in calculations are indexed according to price indexes on capital investments and elements of their technological structure;
- the cost of design installation works is accepted according to settlement prices of the partner companies (producers and suppliers of the equipment).

As the main criterion of commercial effectiveness the discounted payback period (return of the capital), internal standard of profitability, the index of profitability (profitability), the net discounted income is accepted [13, 14].
The discounted period of payback (DPB) is the time demanded for a covering of all discounted capital expenditure at the expense of the gained income.

\[ \text{Inv} = \sum_{t=1}^{\text{DPB}} \frac{C_{Ft}}{(1+r)^{t-1}}, \]

Inv - initial investments; CFt - a pure cash flow of month of t; \( r \) - monthly discount rate.

The net discounted income (NPV) considers dynamics of change of profit during the settlement period.

\[ \text{NPV} = \sum_{t=1}^{\text{Tp}} \frac{C_{Ft}}{(1+r)^{t-1}} - \text{Inv}, \]

Tp – the settlement period.

The index of profitability (PI) – the relation of the given effects to the size of the discounted capital investments:

\[ \text{PI} = \frac{\sum_{t=1}^{\text{Tp}} \frac{C_{Ft}}{(1+r)^{t-1}}}{\text{Inv}}, \]

The internal standard of profitability (IRR) – characterizes intensity of return of the spent means,

By results of calculation the summary table of the key financial performance of implementation of the project on introduction of AITP for a quarter No. 38 is made and the schedule of payback is constructed.

| Indicator                                      | Value  |
|-----------------------------------------------|--------|
| Simple period of payback of tentative expenses (PB), month. | 31     |
| The discounted period of payback of tentative expenses (DPB), month. | 35     |
| The net present value (NRV), rub.             | 51,55  |
| Profitability index (PI)                      | 3,45   |
| Internal rate of return (IRR),%               | 66,6   |

Ratio of the discounted and simple period of payback of initial expenses are reflected in the figure 2.

According to the carried-out calculations the annual expected effect of realization of actions for optimization of systems of heat supply will allow to save on average up to 30% consumed and that isn't less important, the paid thermal energy. The payback period of the incurred capital expenditure on average doesn't exceed three and a half years.

Thus, proceeding from the analysis of indicators of economic efficiency the introduced actions in this case are economically expedient.
4. Conclusion
At management of the modern systems of heat supply the issues of providing consumers the required heat carrier parameters connected with installation of the set pressure, distribution of streams, etc. are resolved.

Comparison of the results received at various ways (mathematical modeling, a laboratory experiment, a calculation method) allows to give more exact assessment to power efficiency of the introduced energy saving actions.

For making decision by investors (the managing director heat generating and transporting the heat carrier to the companies) on expediency of participation in implementation of the project on equipping by automatic metering stations both regulations of consumers of thermal energy, and their influence on hydraulic stability of all system in general except technical efficiency, for detailed assessment, it is also necessary to make calculation of commercial effectiveness of the offered actions.

On the basis of the technical and economic indicators received when calculating for the offered technique the conclusion about efficiency and expediency of introduction of the Project and also about reliability and non-failure operation of work of system of heat supply is drawn when holding actions for energy resources saving for the purpose of reduction of volumes of consumption or more rational use of fuel and energy resources.

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