REGARDING THE QUESTION OF THE ANALYSIS OF EFFECTIVENESS OF HEAT PUMPS USING IN THE DISTRICT HEATING

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Last time the discussion about the advantages and disadvantages of district heating and distributed heating is raised again. The goal of the discussion is to define the prospects of the residential and industrial energy supply systems development.

During the time of former USSR, the Belarusian energy system was oriented to the combining cycle and district heating. It was the essential mean of energy demand satisfaction of the cities and industry and it was economically advisable. Nevertheless, last ten years there is a tendency of the distributed heating systems development. Here we could be mentioned the construction of the roof boiler houses, the replacement of basement boiler houses by block-module ones of less capacity, the decentralization of industrial heat supply systems, the installation of diesel and gas-engine small-scale CHP. It could be explained by a diversity of objective and subjective factors.

There are a lot of traditional technical problems of district heating: considerable losses in the district heating networks; accelerated corrosion hot water pipes; lack of coincidence of power and heat consumption modes; relatively high steam parameters in the heat-extractions of CHP turbines; lack of possibility to use the district heating to cover the industrial and residential cooling demand in summer. Last time the new problems were added to the previous ones: non-system introduction of the regulatory control on the demand side; reduction of the district heating water temperature that is technically and economically unjustified; cross-funding of heat energy consumers; considerable reduction of financing of repair works, modernizing and introduction of new capacities on the heat energy sources and heat pipelines; lack of coincidence in declared and actual heat load etc. Moreover the effective CHP equipment appears on the energy market. The reduction of financing of repair works, modernizing and introduction of new capacities on the heat energy sources and heat pipelines leads to rising of emergent damages probability in the district heating systems and consequently the interruption of heat supply that leads to social and economic losses.

Nowadays the Republic of Belarus can't provide budget financing for expensive long-term programs of modernization and rehabilitation of the large-scale CHPs and extensive heat networks. The general economic situation in certain degree put the obstacles in the way of heat energy development possibilities to concentrate combined heat and power generation. At the same time the search of alternatives in innovative policy in power and heat production including on the basis of small-scale CHP construction is predetermined by the transition to the market relations between the energy generator and consumer, the power energy tariff growth in terms of monopoly of generator and rising of fuel prices. In this case the application of distributed heating enlarges the possibilities of combined power and heat generation.

On the other hand there are some changes in the world's tendencies of the development of heat/cool supply systems [1]. Later the preferences were given to the individual heat/cool supply systems or to large-scale district heating systems. Now there is a tendency to find the optimal alternatives of combination of individual and district heating according to the local conditions and available energy sources. The exact tendency to unite systems of power, heat and cool supply together to the combined energy supply system is observed. Moreover there are the endeavours to use resources in the most optimal way to reduce the energy losses, exergy losses and to increase environmental friendliness and economic and financial attractiveness of district heating. The availability of using of heat pumps in the district heating/cooling is outlined.

In nowadays situation the consideration and complex analysis of the technical solutions using of which could increase the efficiency of district heating are actual. For example in the issue [2] the scheme of

the district cooling from CHP with heat pumps on demand side is shown. This solution allow to reduce the temperatures of hot and cool water in the district heating system, that could lead to both increase of power generation and decreasing of heat losses in district heating pipes. This scheme could be added to with some elements allowing to use heat pump for cooling in summer and to smooth the demand curve using heat storage. If all district heating customers are equipped with compressive heat pumps, the temperature chart of this system could be reduced to the level of 50/10°C. It would allow on one hand to reduce the temperature of steam-extraction from CHP turbine and on other hand to partially utilize heat raised within condensing waste steam with the temperature of 30°C.

Compressive heat pumps create additional power demand that is lacking in traditional district heating system. However there are a lot of advantages: reduction of temperature condition of the pipelines down to 50/10°C and as a result heat losses decrease and increase of life time of pipes and other equipment and consequently augmentation of district heating reliability; increase of power generation on CHP due to decrease of parameters of steam extraction under modernization of CHP equipment; the possibility of reverse operation of heat pumps in summer as an air-conditioner and as a result increase of heat demand in summer; the possibility to use waste heat of heat pumps after cooling to heat water in summer; extension of possibility to control the intensity of heating and cooling, temperature of hot water on demand side directly; decrease of heat pollutions; the possibility of more flexible regulation of power and heat demands; the opportunity to decrease the fuel consumption saving the quantity of generated heat and power and as a result reduction of CO_2 and other hazardous substances emissions that arise during organic fuel incineration.

Therefore the utilization of heat pumps and heat storages in the district heating systems on demand side could considerably reduce variable costs as well as increase the comfort and reliability of district heating, however additional fix expenses are necessary. The efficiency of this scheme using should be estimated with the help of complex approach and multicriterion analysis included energy, exergy, economic and ecological criteria. At that it is necessary to research operating characteristics of system within day, week, season and year.

This research is implemented on the base of the methods of structure parametric optimization. To conduct this the simulation in the form of formalized description of the prototype system was composed [3-7]: the description of technological scheme on the basis of graph theory, the balance equations set, the limitations and the criterion functional.

During the development, designing and creation of complex objects the knowledge of quantitative and qualitative regularities peculiar to concerned systems is necessary. This knowledge could be obtained on the base of the method of mathematical modelling. The balance equations set that sets up dependencies between coupling parameters, consist of the equations of energy and weight balance and alterations of enthalpy and pressure of every heat carrier. General forms of these equations are [4]:

Energy balance equation for every k^{th} element:

$$\sum_{j=1}^{J_k - R_k} \left(\eta_{\Pi} \cdot G \cdot h\right)_j + \sum_{r=1}^{R_k} \left(\eta_{\Pi} \cdot N\right)_r = 0\,; \tag{1}$$

Weight balance equation for every l^{th} heat carrier of kth element:

$$\sum_{j=1}^{J_{kl}} G_j = 0\,; \tag{2}$$

Hydrodynamic (aerodynamic) balance equation:

$$\left(P' \pm \Delta P - P''\right)_{kl} = 0\,; \tag{3}$$

Enthalpy alteration equation:

$$\left(h' \pm \Delta h - h''\right)_{kl} = 0\,, \tag{4}$$

where $k = 1,2,...,K;\ j = 1,2,...,J_{kl};\ l = 1,2,...,L_k;\ r = 1,2,...,R_k;$ G - consumption of energy carrier; N - capacity of power or mechanical connection; P, h - pressure and enthalpy of energy carrier on outgoing (') and ingoing ('') connections of element; ΔP и Δh - characteristics of alterations of pressure and enthalpy of process in element; η_{Π} - coefficient considering energy losses of flow; J - total number of connections; R - total number of single-parameter connections. The sign «minus» in the equations (1) and (2) correspond to the processes of expansion and cooling; sign «plus» correspond to compression and heating.

The interesting issue in the research is examination of the operating mode of heat storage. Whether it should operate as a heat storage or as a cool storage during summer. The response to this question could be obtained if the dynamics of demand alterations of whole system is taken into consideration. The using of reverse heat pump as a air conditioner is proposed to maintenance comfort conditions inside. The waste heat from cooling heat pump in summer could be used to heat water for hot water supply.

All researches and decision making should be grounded on multicriterion analysis. The next issues should be taken into account: technical perfection and of the system, comfort provided to the consumer, reliability of energy supply, contribution to the energy independence of country (considering last tendencies in energy policy of the Republic of Belarus), the possibility to ensure autonomous heat supply in urgent situations, safety of the system for both people who works for it and people who use it, attainment of synergy effect, exergy advantage, reduction of heat emissions to environment, decrease of CO_2 and other hazardous pollutants emissions (taking into consideration Kyoto protocol), economic advisability on the consumer level, economic advisability on the levels of generator, distributor and supplier of heat and power (taking into consideration coming restructuring energy system of the Republic of Belarus), economic advisability on the macroeconomic level (matching of economic interests of generators and consumers of energy), financial analysis (taking into consideration non-simultaneousness of cash inflow and outflow), psychological aspects of possibility of transition to the new type of district heating for both consumer side and generator side (sluggishness), the possibility to attract both private and foreign investment to such projects and finally the possibility to attract ESCO (energy service companies) to fulfill these projects.

In the course of curried out survey and research the major aspects of implementing of district heating with heat pumps on the demand side are discovered. The results have displayed the availability of this line of investigation and it would be viable within construction of new residential and administrative buildings and rehabilitation of old ones. Obtained results allow estimating the possibility to implement such schemes for different conditions and could be used by design organizations.

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