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HEAT ACCUMULATION IN THE NETWORK OF EFFICIENT HEAT-AND-COLD SUPPLY SYSTEM OF A RESIDENTIAL BUILDING

The paper analyzes variants of operation of the heat-and-cold supply system for a residential building, which includes heat pumps and heat accumulators. Study of the influence of heat pump power on the storage tank volume and daily expenses for electric energy have been performed taking into account two- and three-zone electricity accounting system. Dependence of the heat storage tank volume for hot water supply system on hot water and cold supply power ratio has been obtained. Feasibility boundaries of implementing the cogeneration heat-an-cold supply systems in buildings are determined.

***Keywords**: heat accumulator, heat-and-cold supply system, heat pump, zonal accounting of electric energy consumption.*

Introduction, problem statement

One of the most important current tasks is to reduce the imported natural gas consumption and to increase energy efficiency of the objects of housing and communal services in Ukraine. In the centralized heat supply systems natural gas is expedient to be replaced by coal and its mixtures with biomass. To our mind, however, in the conditions of decentralized heat supply systems with the application of heat pump technologies would be the most prospective ones.

Such equipment enables application of such alternative energy sources as the heat of soil, air, exhaust air, groundwater, river water, wastewaters, etc. [1]. This provides sufficiently high fuel utilization coefficient, minimal environmental impact of the system, high level of safety, automation and production standards. Disadvantages of heat pump systems include high capital investments and significant energy consumption. At the same time, heat pumps can also produce cold during the hot season for cooling the indoor air. Therefore, such cogeneration system makes it possible to reduce the cost of heat and cold production.

Residential building with the heating system rated power of 202,7 kW, of hot water supply system - 157,1 kW and of cooling system - 4,7 kW [2] has been chosen as research object.

In order to reduce capital investments into the heat-and-cold supply system and electric energy consumption in the warm season, the following engineering solution was used for cold generation [3]: cold supply system is connected to the evaporators of heat pump units, which enables simultaneous heat energy generation at the condensers of heat pumps for hot water supply system and cold generation at the evaporators of heat pumps for cold supply system (Fig. 1). Such solution also enables application of passive cooling of the building.

One of the main characteristic features of residential buildings is significant non-uniformity in the consumption of heat for the system of supplying hot water and cold for indoor air conditioning. Daily variations in heat load of the hot water supply systems (HWS) and simultaneous heat and cold generation in the warm season requires application of energy accumulation systems. Therefore, this work **aims** at estimation of the efficiency of heat accumulation in the heat-and-cold supply system of the residential building.

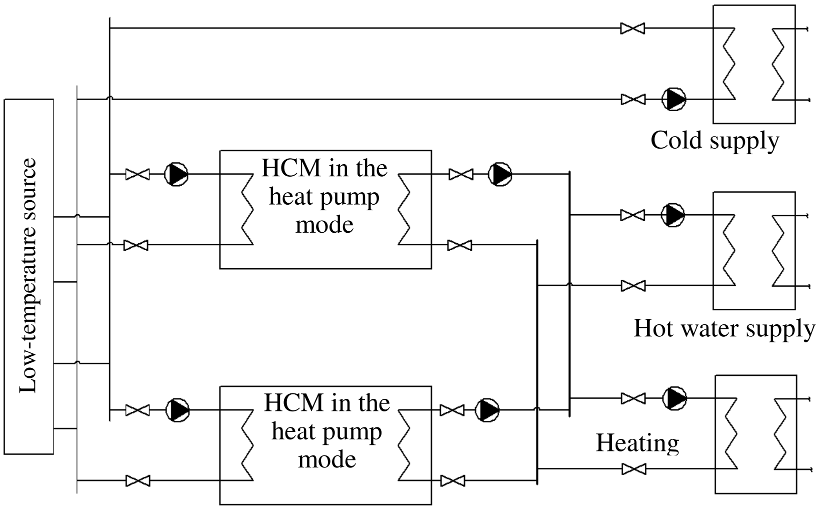

Fig. 1. Network of the energy-efficient heat-and-cold supply system of the building

Main research

In order to balance the daily load on HWS, hot water accumulators are usually used. Such method makes it possible to simplify regulation of the heat pump unit and to reduce its peak loads. Taking into account rated power of HWS system and characteristic daily power distribution [3], it was determined that average daily power of the system is 100.1 kW. If heat pump unit operates around the clock with such power, the necessary volume of the stoage tank will be 6.51 m^3.

Heat power unit is a powerful consumer of electric energy while currently ever more attention is paid to two-zone accounting of electric energy consumption. In order to reduce expenses for electric energy, it is expedient in such case to increase the heat pump power during the night period of minimal electric energy consumption (from 11PM to 7 AM). Fig. 2 shows how the heat pump power at night influences the volume of heat accumulator tank and expenses for electric energy (full tariff for electricity is assumed to be 1.4 UAH / kWh. In this case two variants of the electricity tariffs at night are taken into account – 0.7 and0.5 of the full tariff. For three-zone electricity consumption accounting this coefficient is 0.4, at the half-peak period – 1.0 and during the peak period – 1.5.

In order to obtain results, presented in Fig. 2, numerical studies were conducted for HWS heat pump power, which increases at night from 100.1 to 170 kW with respective reduction of the required power at daytime (for two-zone accounting) from 100 to 65.5 kW. For such conditions the volume of heat storage tank increases by 2.43 times.

For a system with three-zone electricity accounting the heat pump power was selected for peak and half-peak period, provided that minimal expenses for electricity would be ensured. Inflection of the graph of expenses for electric energy (Fig. 2) for the three-zone accounting system is explained by the fact that expensive “peak” electricity may not be used during the night period, when heat pump power exceeds 126 kW.

According to data in Fig. 2, installation of two- and three-zone electricity accounting systems makes it possible to reduce expenses for it: for two-zone systems with night tariff coefficient 0.7 – by 10 %; for two-zone systems with night tariff coefficient 0.5 – by 16.7% ; for three-zone systems with night tariff coefficient 0.4 – by 9.6%.

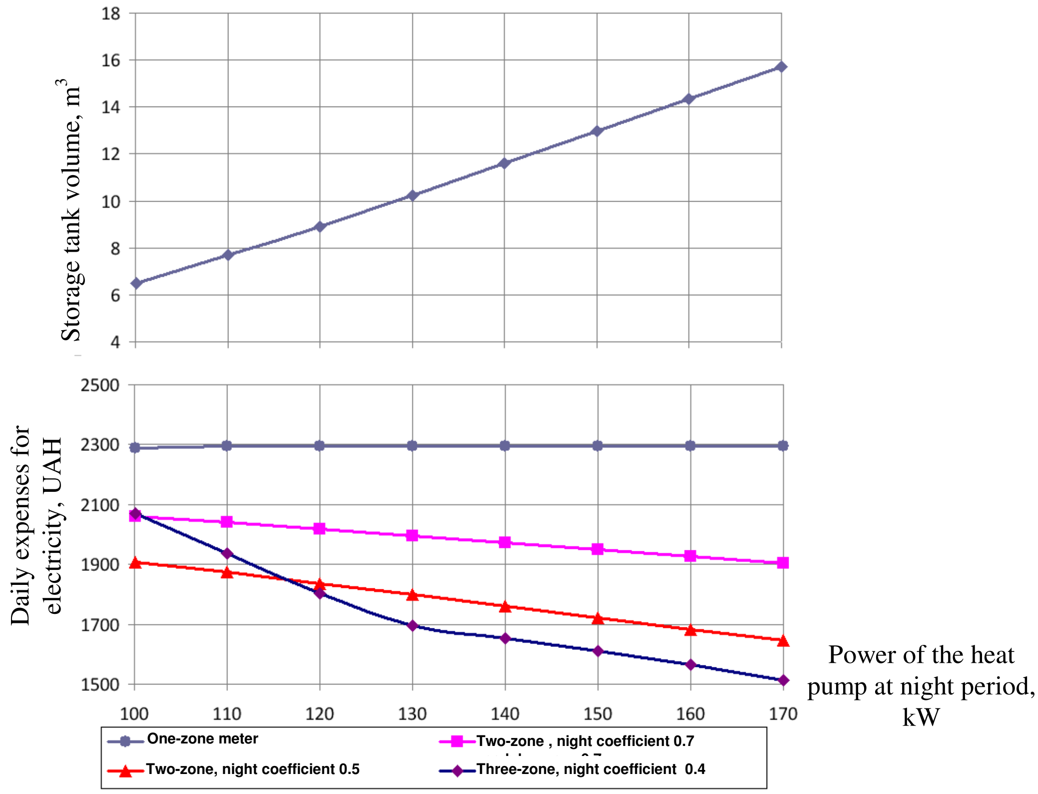

Fig. 3. Influence of the power of heat pump for HWS during night period on the storage tank volume and on daily expenses for electricity

Total economy of expenses for electricity with its zone accounting and installation of heat storage tanks of the hot water supply system is as follows: for two-zone tariff with night coefficient 0.7 – 16.9%; for two-zone tariff with night coefficient 0.5 – 28.2%; for three-zone tariff with night coefficient 0.4 – 33.9%.

It should be noted, that with the application of additional peak heat sources such as electric heaters [5], the obtained economic effects could be somewhat increased. Thus, heat accumulation for HWS systems can provide significant economy of expenses for electricity but requires considerable initial expenses due to the increased installed power of the equipment and mass-size parameters of the entire system.

For the cogeneration heat and cold scheme, proposed in [3], in the warm season there is a necessity to coordinate powers of HWS system, connected to the condenser, and of the cold supply system, connected to the evaporator of the heat pump unit.

Both systems have a non-uniform daily power schedule and, therefore, for coordinated operation of the systems it was proposed to use storage tanks. It has been discovered that it is more expedient to use hot water accumulators since they have a much smaller volume (3.6 m^3), than water accumulators of cold (24 m^3). In practice other variants of cold accumulation are used [6], which are characterized by smaller mass-size parameters. However, high capital investments in such systems reduce, to a great extent, the efficiency of their application.

Fig. 3 shows how HWS and cold supply power ratio influences the hot water accumulator volume.

From the curve, presented in Fig. 3, boundaries of the most efficient usage of the proposed scheme of the heat-and-cold supply system for a building could be determined. It is evident, that in the case of HWS and cold supply rated power ratio exceeding 2.4, such cogeneration system operates most efficiently and heat accumulator is not required as power at the heat pump evaporator, which works for HWS system, will be sufficient to provide the necessary amount of cold. If power ratio of HWS and cold supply is below 1.5 – 1.6, application of the proposed scheme will require installation of large-volume storage tanks.

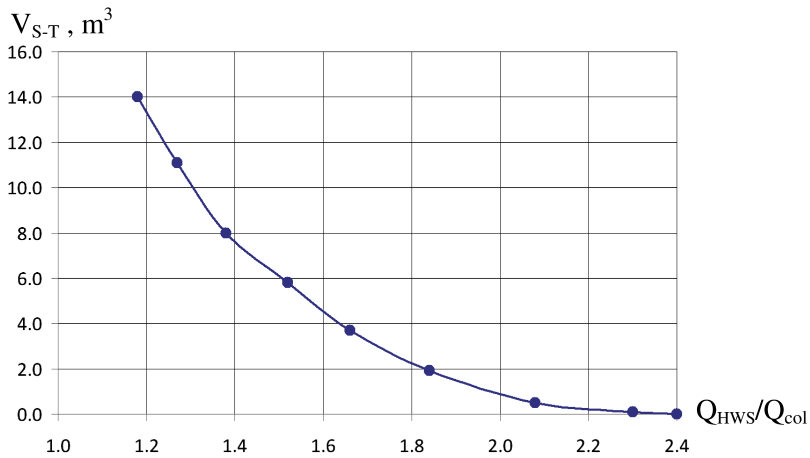

Fig. 3. Dependence of the necessary volume of the hot water storage tank on HWS and cold supply power ratio

Thus, implementation of the proposed energy efficient scheme of the heat and cold supply system will be most effective for residential buildings, washhouses, sanatoria and swimming pools as well as for other objects with significant hot water consumption and low power of cold supply system.

Conclusions

1. A prospective trend of reducing fossil fuel consumption in decentralized heat supply systems is, to our mind, application of heat pump equipment, which enables efficient use of alternative energy sources. High capital investments and electric energy consumption can be compensated by simultaneous heat and cold generation using the same equipment. As heat and cold consumption in residential buildings is characterized by significant non-uniformity during 24 hours, such systems require installation of energy accumulation equipment. It has been proved that in residential buildings installation of heat accumulators is more reasonable in terms of cost-effectiveness than installation of cold accumulators.

2. It was found that installation of zone electricity accounting systems and heat accumulation systems provides 16.9...33.9% savings of expenses for electricity depending on the tariff coefficients. It should be noted that savings due to implementation of zone accounting systems themselves amount to 9.6...16.7%.

3. Regularity of the influence of hot water supply and cold supply power ratio on the storage tank volume has been determined as well as feasibility boundaries in the application of cogeneration heat-and-cold supply systems. It is noted that the best efficiency indices of such system will be observed for the objects with considerable hot water consumption and relatively small powers of cold supply systems.

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