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OPTIMIZATION OF UNDERGROUND HEAT ACCUMULATORS IN HEAT PUMP SYSTEMS

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Application of the heat accumulators in general, and the underground ones in particular, allow the raising of the efficiency of heat pump systems by means of balancing the rates of production and consumption of neat. The system also eliminates operation of the heat pump of low load. It is most efficient to use water-carrying ground layers as natural underground heat accumulators, also developed a mathematical model and carried out experimental investigation on the proposed system.

Keywords: heat accumulator, Heat pump systems, Mathematical Model, Optimization

The climate conditions in our country, and especially of its southern regions, enables the use of various heliosystems: for direct water heating and solar assisted heat pumps.

Research on the application of heliosystems [1] showed the necessity of using heat accumulators to increase their effectiveness.

For heat pump systems which are being investigated for the conditions of Ukraine, the need for heat accumulators is expressed by:

- balancing graphs of production and utilization of heat;
- elimination of the need to use heat pumps at part load conditions.

Economically based abroad, the night tax for electric power and other taxes for equipment exploitation are not yet actual for Ukraine. Short-rate peak heat loadings seem more reasonable to be covered with direct electric heating, which greatly lowers expenses for the creation of the system.

Heat accumulators differ of charging-discharging, consequently there appear the demands to their work..

As an example of the system (Fig. 1) [2], authors analyzed the system of heat and cold supply on the basis of the absorption heat pump, as such a system is the most suitable due to the number and temperature levels of the heat accumulators. The system possesses two heat accumulators one with high and medium potential with 24-hour accumulation and the other with low potential of seasonal heat accumulation. A special characteristic of the summer condition of the system operation is the charging of the low potential heat accumulator.

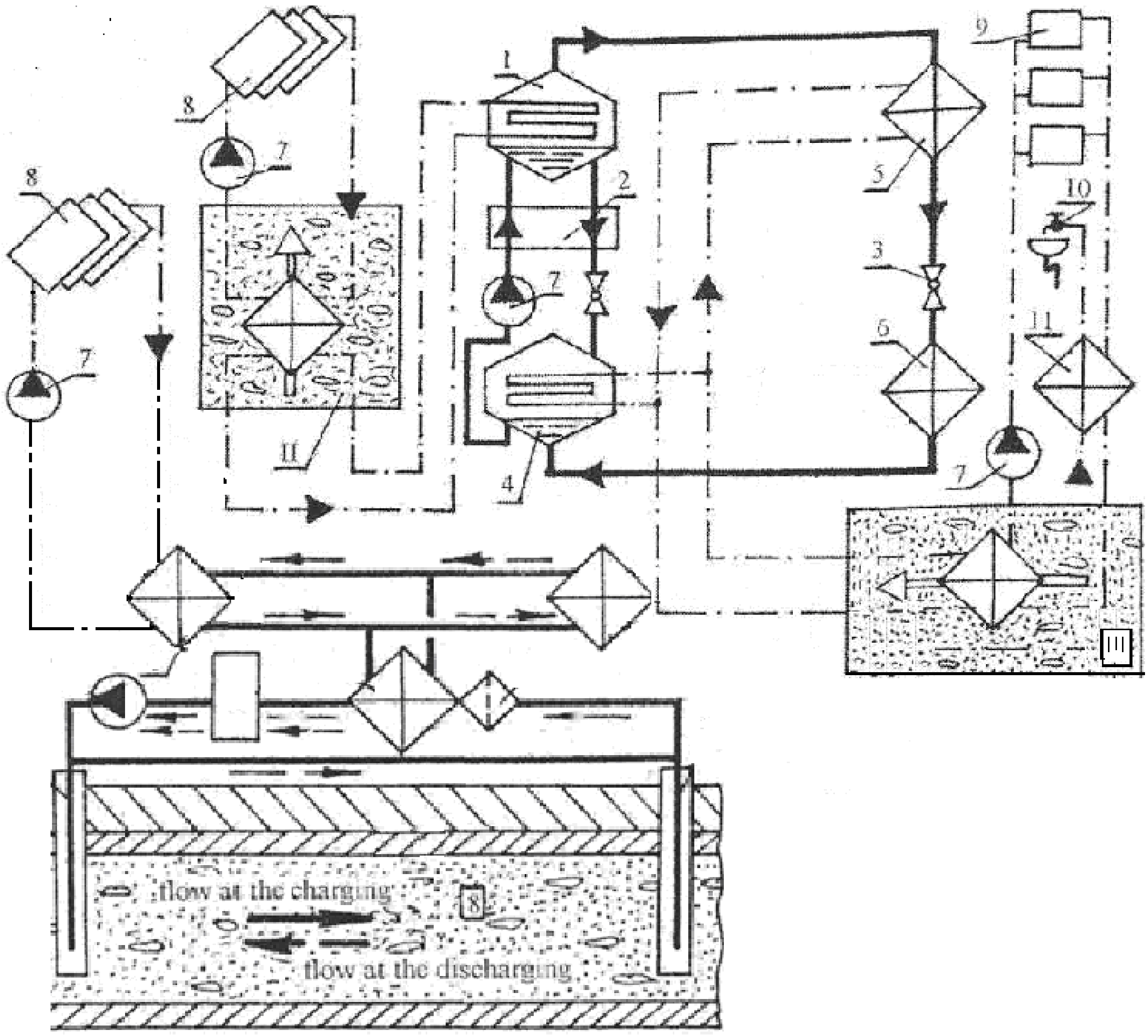

Fig.1. Schematic solution of the heat-and-cold supply system on the based of the absorpion heat pump with the heliosystem:

II – accumulator of the high potential heat; III – accumulator of the medium potential heat; IV – accumulator of the low potential heat; 1 – generator; 2 – heat exchanger of solutions; 3 – throttle valve; 4 – absorber; 5 – condenser; 6 – evaporator; 7 – pump; 8 – solar collectors; 9 – heating system; 10 – hot water supply system; 11 – boiler of the hot water supply; —— - refrigerant of the heat pump; — • — • — - heat-and-cold carriers between the heat pump and peripheral equipment, water.

Application of thermo-economic (exergoeconomic) principle of optimization [4-8] is based on estimation of energy losses in system by money. In this case use the of economic characteristics incorporated in energy estimation of system. Such approach unites energy and economic estimation and does not concede on objectivity of generality technico-economic optimization [3…6].

Let's consider homogeneous system consisting of various elements where one flow h_i consistently and unitary cooperates with *n* flows (Fig. 2) [7].

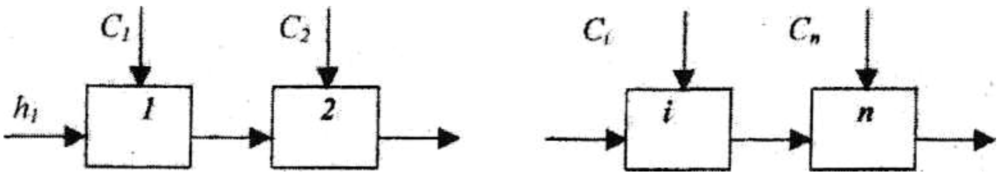

Fig. 2. The linear scheme of power system

In this case of optimum synthesis problem can be formulated as; it is necessary to distribute the set of flows C_1, i =1, 2 , … , n along the flow h_j, j=1, so that the flow parameters h_i after system were in given interval of meanings, and the chosen optimization criterion accepted the minimal value [3].

Let's accept expression of total thermo-economic expenses in the system as optimization criterion

$$\sum_i \sum_j Z_{ij} = Z_{\Sigma}^{min}, \quad (1)$$

where Z_{ij} – thermo-economic expenses in *i*-th element of system (*as* = 1)

$$Z\left\{Z_{i_p}^{(p)}\right\}, \ \ p = 1, 2, ..., k; \ i_p = 1, 2, ..., [N-(p-1)]. \quad (2)$$

The $Z\left\{Z_{i_p}^{(p)}\right\}$ can be broken on *k* subsets $Z\left\{Z_{i_p}^{(p)}\right\} = \prod_{p=1}^{k} Z_p\left\{Z_{i_p}^{(p)}\right\}$.

Here subset

$$Z_p\left\{Z_{i_p}^{(p)}\right\} = \left\{Z_1^{(p)} Z_2^{(p)}, ..., Z_{i_p}^{(p)}, ..., Z_{[N-(p-1)]}^{(p)}\right\} \quad (3)$$

is possible meanings of thermo-economic expenses on some stage *p*, *p*<*k*.

Then, on each intermediate stage *p* it is necessary to choose such flow for which

$Z_{i_p}^{(p)} \in Z_p\left\{Z_{i_p}^{(p)}\right\}$

$$Z_{i_p}^{(p)} = Z_{min}^{(p)}, \ i_p = 1, 2, ..., [n-(p-1)]$$

$$, \qquad (4)$$

where $Z_{\min}^{(p)}$ n – is minimal thermo-economic expense for stage *p*. Then the chosen flow is excluded from the further consideration. Thus, for numbers of elements *p*-th and (*p* - *1*) – the subset the ratio is fair

$$Z_{p}\left\{Z_{i_p}^{(p)}\right\} = Z_{(p+1)}^{(p)}\left\{Z_{i_{(p+1)}}^{(p+1)}\right\}. \qquad (5)$$

For achievement given parameters for flow h_j it is necessary $k \le n$ elements, i.e. necessary to find the set of flows $C_k \in C$ for eq. (7) was carried out.

Generally thermo-economic criterion of optimality is

$$Z_{\Sigma} = \left(\frac{\sum_n C_n \Pi_n + \overline{K_n}}{\sum_k e_k}\right), \qquad (6)$$

where C_n, Π_n – cost and annual energy consumption from external sources; $\overline{K_n}$ – annual capital and other expenses associated with *n*-th element; e_k – annual energy charge for *k*-th product reception.

Eq. (6) has more simple kind for special cases. For example, for installation with one product (where *B* is output of product)

$$Z_{\Sigma} = \min\left(\frac{\sum_n c_n \Pi_n + \overline{K_n}}{B}\right), \qquad (7)$$

Thus, the optimization problem can be generally shown to search extremer of functions

$$Z_{opt} = \min Z_{\Sigma} \qquad (8)$$

or for parametrical optimization

$$\eta_{opt} = \max \eta_e^{\Sigma} \qquad (9)$$

Of special interest represents the geometrical device of exergo-economic optimization.

Conclutions

The obtained calculated design data of technical characteristics of underground heat accumulators included into the heat pump equipment coincide well with the experimental data of systems operating around the world. This underlines the correctness of the theory of designing the underground heat accumulators and the mathematical model for their calculation.

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ОПТИМІЗАЦІЯ ПІДЗЕМНИХ ТЕПЛОВИХ АКУМУЛЯТОРІВ У СИСТЕМАХ ТЕПЛОВИХ НАСОСІВ

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Запропоновано застосування підземних теплових акумуляторів для підвищення ефективності систем теплових насосів за допомогою збалансування швидкості виробництва і споживання тепла. Система також виключає роботу теплового насоса при *низькому навантаженні. Найефективніше використовувати підземні води як природні підземні теплові акумулятори. Розроблено математичну модель і проведено експериментальні дослідження запропонованої системи.*

Ключові слова: акумулятори тепла, системи з тепловим насосом, математична модель, оптимізація

ОПТИМИЗАЦИЯ ПОДЗЕМНЫХ ТЕПЛОВЫХ АККУМУЛЯТОРОВ В СИСТЕМАХ ТЕПЛОВЫХ НАСОСОВ

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Предложено применение подземных тепловых аккумуляторов для повышения эффективности систем тепловых насосов при помощи сбалансирования скорости производства и потребления тепла. Система также исключает работу теплового насоса при низкой нагрузке. Наиболее эффективно использовать подземные воды как природные подземные тепловые аккумуляторы. Разработана математическая модель и проведены экспериментальные исследования по предлагаемой системе.

Ключевые слова: аккумуляторы тепла, системы с тепловым насосом, математическая модель, оптимизация