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COST PRICE OF PRODUCTS IN THE SYSTEM OF HEAT, REFRIGERATION AND ELECTRIC ENERGY PRODUCTION COMBINED AT THERMAL POWER PLANT

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Abstract. Nowadays combination of electric, heat and refrigerating energy production (trigeneration) is one of the modern technological solutions for energy efficiency increase and ecological problem solution [1]. Two types of refrigerating machines can be used for both energy and heat production combined: compression aggregates consuming electric energy and absorption aggregates using hot water heat, vapor or other heat conductors.

1 Goal setting

There is a goal of combined determination of tariffs for cold, heat and electric energy in trigeneration system and also purposeful area of different types of refrigerating machines use.

There are methods of expenses division for three types of products in the system of trigeneration developed on the basis of Ginter's triangle in the present work [2]. It allows calculating cost of refrigerating products developed in compression and absorption types of machines depending on coefficient of expenses distribution between heat and electric energy at thermal power plant and also determine economically efficient area of application of these types of machines.

2 Methods of expenses distribution for heat and electric energy production according to Ginter's triangle

Peculiarities of cost determination and formation of tariffs at thermal power plant producing two kinds of energy – heat and electric are presented in [2, 3]. As a basic method there is one offered by the authors according to which expenses for electric energy and heat production can be distributed between two kinds of produce in any way, but as the sum of expenses does not change because of it, the results of all possible variants of distribution are on one line (Picture 1, line ST) – 'Ginter's triangle'.

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3 Calculation of production cost in the system of trigeneration

3.1 Basic data for calculation

As an example calculation of release cost price from thermal power plant with three types of turbine plant T-118/125-130-8 (electric energy, heat for hot water supply and refrigeration in the conditioning system) in the summer at turbine working according to heat graph on the basis of real energy characteristics has been made [4]. Climate region – Omsk for which design temperature for heating is $t_{DH.}$ = -37°C [5]; design temperature for conditioning is $t_{D.C}$ = +35°C [5].

The following refrigerating machines have been considered:

1) single-staged absorption bromide-lithium refrigerating machine with refrigeration capacity Q_0 = 1000 kW (absorption refrigerating machine -1000). Refrigeration coefficient ε_A depends on the temperature of direct network t_{DN} and is determined according to the catalogue of absorption refrigerating machine of the company Broad [6];

2) vapor compression refrigerating machine. Refrigeration coefficient of vapor compression refrigerating machine has been adopted according to the data of electronic resource of the company Termogaz and is equal to ε_K = 3 [7].

3.2 Basic calculation

Nominal load of selection of T-118/125-130 $Q_{\text{Sel}}^{\text{Nom}}$ = 219 MW. Load for hot water supply Q_{HWS} is equal to 20% from maximum heat load of thermal power plant Q_{TPP}, designed with account of district heating coefficient [8]. Cost of reference fuel $C_{R.F}$ = 3200 R/t.

$$Q_{\text{TPP}} = \frac{Q_{Sel}^{\text{Nom}}}{\alpha_{\text{TPP}}} = \frac{219}{0.6} = 365 \text{ MW}, \quad (1)$$

$$Q_{\text{HWS}} = 0.2 \cdot Q_{\text{TPP}} = 0.2 \cdot 365 = 73 \text{ MW}. \quad (2)$$

Maximum refrigerating load has been estimated for the region of joined heat consumers in accordance with relation:

$$\frac{Q_{\text{TPP}}}{Q_{\text{C}}^{\max}} \approx \frac{(t_{\text{Ins.r}} - t_{\text{DH}})}{(t_{\text{DC}} - t_{\text{Ins.r}})}, \quad (3)$$

where $t_{\text{Ins.r}} = 18\,^{\circ}\text{C}$ - average temperature inside rooms.

A number of hours of maximum load of refrigerating machines use $\tau_{\text{C}}^{\max}$ has been determined as:

$$\tau_{\text{C}}^{\max} = K \cdot \tau = 0.5 \cdot 2160 = 1080\,\text{h}, \quad (4)$$

where K – coefficient of maximum load use for refrigeration production (equal to 0.5 on the basis of recommendations presented in [8]): τ – total number of hours for three summer months.

Maximum production of heat from turbine Q_{T}^{C} selection for absorption refrigerating machine for refrigeration production has been determined as $Q_{\text{T}}^{\text{C}} = Q_{\text{C}}^{\max} / \varepsilon_{\text{A}}$, where ε_{A} -

refrigerating coefficient of absorption refrigerating machine. Additional electric capacity of thermal power plant for the work of vapor compression refrigerating machine has been estimated in accordance with refrigeration coefficient of compressive machine ε_C.

Production of electric energy and heat for hot water supply from thermal power plant has been considered as a primary variant. Limitations on maximum consumption of water via network installation (for T-118/125-130-8: $G_{NW}^{max} = 1250$ kg/s [4]) have been considered in the new mode of combined release of heat from thermal power plant for hot water supply and conditioning. It has been accepted that working conditions of hot water supply consumers have not been changed in the new mode.

The sum of operating costs in the primary variant has been received from costs for electric energy and heat production:

$$C = C_E + C_H \tag{5}$$

Refrigeration is used as consumed product besides heat and electric energy in the system of trigeneration, and there are also operating costs for its production C_H^C at thermal power plant:

$$C' = C'_E + C'_H + C_H^C \tag{6}$$

4 Graph solution of the goal on the basis of Ginter's triangle

Heat and electric energy cost values were received at calculation of the basic variant according to physical method of expenses distribution (point R on the line ST, figure 1). Point R has been received at arbitrary expenses distribution. Thus, straight line PR, line segment TO and SO form Ginter's triangle.

Triangle NOM (fig. 1.) has been received for the system of combined release of heat, electric and refrigerating energy according to the results of design. Point 'C' corresponds to physical method of expenses distribution between electric energy and heat released from turbine differentiation by outer consumer. Line OE depicts dependence of refrigeration cost developed at absorption refrigerating machine on the method of expenses distribution for electric energy and heat in the system. There is a case depicted in the figure 1 (line OG) when electric energy at vapor compression refrigerating machine is received according to the cost price from the system of cogeneration (line ST) which allows comparing this variant with the variant of refrigeration production at absorption refrigerating machine (absorber works in the system of trigeneration) according to technical and economic data.

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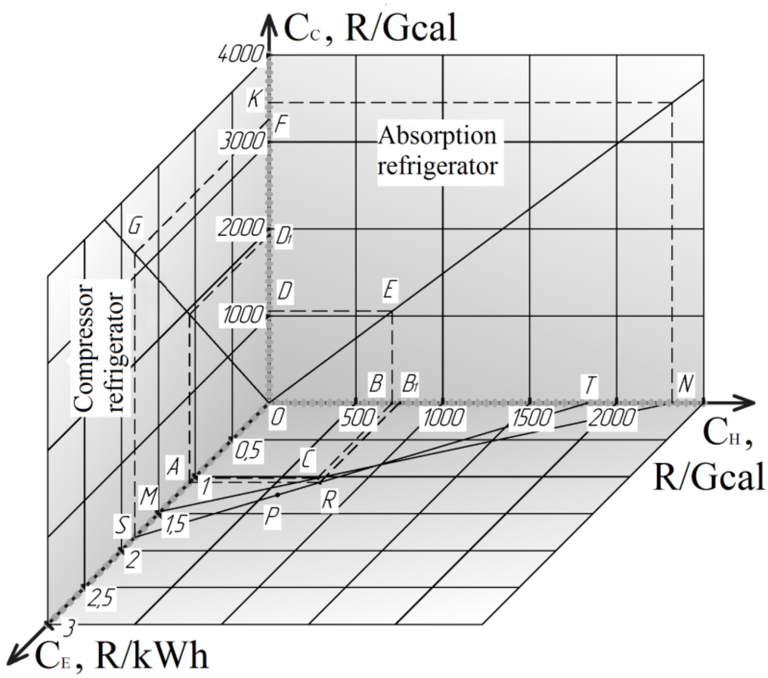

Fig. 1. Dependence of refrigeration cost price on heat and electric energy cost price in the system of trigeneration.

5 Conclusion

There are methods of graphic and analytical determination of production cost price in cogeneration and trigeneration systems for analysis of competitiveness of vapor compression refrigerating machine and absorption refrigerating machine using heat and electric energy of thermal power plant in the present work. Economically efficient areas of vapor compression refrigerating machine and absorption refrigerating machine application depend on the method of expenses distribution at thermal power plant between electric and heat energy. Trigineration decreases production cost price at expenses distribution between heat and electric energy according to physical method.

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