ADVANCED TECHNOLOGIES AND POWER INSTALLATIONS FOR THERMAL AND ELECTRIC ENERGY GENERATION

6.1. Improvement of the thermal cycle of traditional combined-cycle TPPs

6.1.5. Estimation of costs at the combined heat and electricity generation at CHPP

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At CHPP a problem of cost sharing between two types of products became acute recently again. It is explained by thermal energy overrating at application of widely used physical method for cost differentiation. Along with this physical method, many authors recommend to use the exergic method (direct opposite to a physical one).

More frequent refusal of heat industrial consumers from TPP services contributed to development and implementation of the ORGRES method. At Department of Thermal Power Plants of MPEI, a method of separate profitability for the cost division at CHPPs by types of products was developed and proposed.

The main difference at usage of any of the listed methods consists in estimation of fuel consumption for heat and electrical energy, generated at CHPP.

Fuel consumption for heat and electrical energy generation using the physical method are defined by the following formulas:

$$B_e = B - B_Q\,,$$

where B, B_Q and B_e - total fuel consumption at CHPP and for generation of heat and electrical energy, correspondingly; Q_{te} - the amount of supplied heat to the consumer; Q^l_w - heat of fuel combustion; $\eta_{Q\,CHPP}$ – CHPP efficiency on heat generation.

According to the exergy method specific reference fuel consumption per unit of exergy is equal to the following:

$$b_e = \frac{B_A}{E_E + E_T}$$

where B_A is an annual reference fuel consumption, t r.f/year; E_e and E_T - exergies of electrical and thermal energy, correspondingly.

E_e is calculated by the simple conversion of measuring units by the formula:

$$E_e = 3{,}6 \cdot 10\text{-}^3 Э_A,\ \text{GJ/year},$$

where $Э_A$ is taken in kW · h/year.

E_h is calculated by the following formula:

$$E_T = \sum(\tau_{ei} Q_i),$$

where i – is the ordinal number of steam bleeding of certain parameters; Q_i - amount of heat, extracted from the i-th bleeding, GJ/year; τ_{ei} - exergy function of i-th bleeding, determined by the expression:

$$\tau_{ei} = 1 - \frac{T_a}{T_{av.i}}$$

where T_a - ambient temperature, K; $T_{av\ i}$ - average temperature of converted steam, K, which is equal to the following:

$$T_{av\,i} = \frac{h_{bl\,i} - h_{c\,i}}{S_{bl\,i} - S_{c\,i}}$$

where $h_{bl\ i}$ and $S_{bl\ i}$ — enthalpy and entropy of steam in the bleeding, $h_{c\ i}$ и $S_{c\ i}$ — enthalpy and entropy of condensate of this steam.

From E_e and E_h according to the known dependence $B = E_т b_e$, the annual fuel consumption for electrical energy B_A^e and heat B_A^T generation are determined.

Heat consumption for electrical energy according to the ORGRES method is calculated as follows:

$$B_e = BK_e, \qquad (6.11)$$

where B is an amount of reference fuel, combusted in power boilers over a certain period of time (for example, for a year); K_e — a factor, evaluating a part of costs connected with fuel, combusted in power boilers, referred to the electrical energy generation.

Coefficient K_e from the formula (6.11) is determined by the relation:

$$K_e = \frac{Q_e + \Delta Q_e}{Q_e + \Delta Q_e + Q_{bl}} \qquad (6.12)$$

where Q_e – heat consumption for electrical energy generation, GJ; ΔQ_e – increase in heat consumption for electrical energy generation at the absence of heat supply to the external consumers from the bleedings, GJ; Q_{bl} – heat supply from the heat bleedings, GJ. Heat consumption for electrical energy generation Q_e from (6.12) is calculated by the formula:

$$Q_e = D_0 h_0 + D_{ssh}(h_{ipc}' - h_{hpc}'') - G_{fw} h_{fw} - Q_{bl},$$

where D_0 is consumption of live steam, entering the turbine, thous. tons; h_0 — enthalpy of live steam before the turbine, kJ/kg; D_{oh} — steam consumption, entering the secondary (intermediate) superheater, thous. tons; h'_{IPC} and h''_{HPC} - steam enthalpy, correspondingly, in the intermediate pressure cylinder (after the intermediate superheating) and at the output from the high pressure cylinder (before the intermediate superheating), kJ/kg; G_{fw} — flow of feed water, thous. tons; h_{fw} — enthalpy of feed water, kJ/kg; Q_{bl} — heat supply from the heat bleedings, GJ.

In (6.12) ΔQ_e is calculated as follows:

$$\Delta Q_e = \sum \Delta Q_{bl\,i}\,(1-\xi_i) + Q_{d.v.}(1 - \xi_{d.v.}) + (Q_c - Q_{d.v.}),$$

where $Q_{bl\ i}$ is an amount of heat, supplied to the external consumers from the bleedings; Q_c and $Q_{d.v.}$ — the same from all condensers and from condensers with the degraded vacuum; ξ_i и $\xi_{d.v.}$ — coefficient of heat value, supplied from each bleeding and from the condenser at degraded vacuum operation. Essence of the method of specific reduced cost definition for electrical energy and heat in the combined scheme of generation, called as the method of the separate profitability, consists in the following. The price for 1 kW·h of electrical energy, generated at the CHPP, is assumed equal to the price, which the energy system pays to CHPP. In these calculations, the price was assumed equal to the specific reduced cost for electrical energy generation at the substituting condensing power plant (CPP) of the energy system C_{CPP}. Then, from the total reduced cost C_{CPP}, the sum, received by CHPP for a year from electrical energy sales in the amount of $E_{A\ CHPP}$, was taken and the annual reduced CHPP costs for heat generation ($C^т$) in the amount of $Q_{A\ CHPP}$ were defined. After that, by dividing

(C^{T}) by $Q_{A\ CHPP}$ there was defined a cost of heat considering the planned profitability, which in our calculations was taken about 12% of capital investments. When the cost of heat, calculated in such a way, is below the reduced cost for heat generation in a separate boiler, then CHPP is more economically effective than the separate installation, when the cost of heat is exceeding, then CHPP is less economically effective, and when the prices of heat at CHPP and in a separate installation are the same, both ways have the same economical effect.

The reduced cost for heat generation by the method of separate profitability $C_{s.p}^{h}$ are the following:

$$C_{s.p}^{h} = C_{CHPP} - C_{CPP} \cdot E_{A\ CHPP}$$

The results of calculations, performed for CHPP with T-250-240 turbines at different values of fuel component share in specific reduced cost for electrical energy generation at the CPP C^{T} are shown in Fig. 6.3.

For comparison demonstrativeness of the reduced cost at CHPP and in the separate scheme, differences between the annual reduced cost in the substituting separate scheme and in the combined installation at the same annual generation of electrical energy and heat were calculated. The results of calculations show that the proposed method of separate profitability allows to define the border of practicability of combined electrical energy and heat generation at CHPP and to establish reasonable rates (at equal profitability) for both types of products.

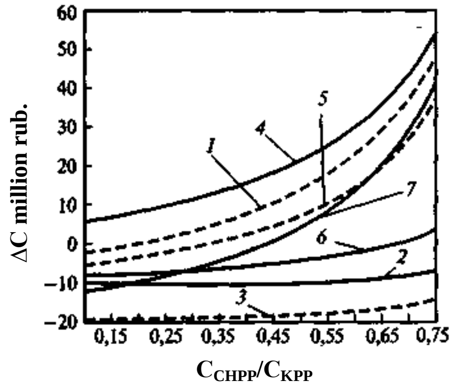

Fig. 6.3. Difference between the annual reduced cost at CHPP with four turbines T-250-240 and in the substituting separate scheme:

1— for electrical energy using the physical method ΔC_{PE}; *2* — for heat using the physical method ΔC_{PH}; *3* — for electrical energy using the exergy method ΔC_{EE}; *4* — for heat using the exergy method thod ΔC_{EH}; 5 — for electrical energy using the ORGRES method, $\Delta C_{E.ORGRES}$; *6* — for heat using the ORGRES method $\Delta C_{H.ORGRES}$; 7— for heat using the method of separate profitability $\Delta C_{S.P.H}$