

Diagrams of Regimes of Cogeneration Steam Turbines for Combined-Cycle Power Plants

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Abstract—General considerations regarding the form of the steam-consumption diagram for a three-loop cogeneration-type combined-cycle plant are formulated on the basis of well-known approaches. According to these considerations the diagram should consist of the main chart and numerous corrections that must be taken into account in using the diagram. The steam-consumption diagram of the T-113/145-12.4 steam turbine for the PGU-410 combined-cycle plant at the Krasnodar cogeneration station is presented.

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The steam-consumption diagram of turbines drawn in graphic form expresses the dependence between the live steam flowrate (G_{turb}), electric power output (N_{el}), heat load of turbine units (Q_{h}), and other parameters determining the operating mode of turbine units and their thermal efficiency. A steam-consumption diagram is constructed taking into account the operation of each particular turbine unit as a whole, including the condensation plant and the feedwater heating system. If the steam-consumption diagram of a turbine unit is available, it becomes possible to outline the region of its possible operating modes and determine the thermal efficiency of each of these modes. Clarity, convenience of use, and accuracy sufficient for a wide range of practical applications are factors due to which steam-consumption diagrams have found wide use in designing and operation of cogeneration power stations (CSs) [1, 2].

A steam-consumption diagram is constructed using the results of calculations of thermal balances in variable modes of a turbine unit. The parameters determining its thermal efficiency are quite large in number. The list of these parameters includes, apart from G_{turb} , N_{el} , and Q_{h} , the pressure in the district-heating extraction (p_{h}), live steam temperature (t_0) and pressure (p_0), cooling water flowrate ($W_{\text{c.w}}$) and temperature ($t_{\text{c.w}}$), and others. Accordingly, the steam-consumption diagram for a Type T turbine should in the general case express the following dependence:

$$F(G_{\text{turb}}, N_{\text{el}}, Q_{\text{h}}, p_{\text{h}}, p_0, t_0, W_{\text{c.w}}, t_{\text{c.w}}) = 0. \quad (1)$$

The steam-consumption diagram of steam turbines for combined-cycle power plants (CCPs) has a few specific features. The number of parameters determining the thermal efficiency of a turbine unit for a CCP (the CCP can be either a two-loop or a three-loop one with steam reheating) is considerably larger: along with the high-pressure steam flowrate (G_{HP}),

N_{el} , and Q_{h} , it is necessary to take into account the intermediate-pressure steam flowrate G_{IP} (in the case of using a three loop CCP), low-pressure steam flowrate (G_{LP}), high-pressure steam temperature (t_{HP}), reheat steam temperature $t_{\text{r.s}}$ (for a three-loop CCP), low-pressure temperature (t_{LP}), the pressure of high-pressure steam (p_{HP}) and in the district-heating extraction (p_{h}), the temperature of return network water (τ_2), $t_{\text{c.w}}$, $W_{\text{c.w}}$, and the outdoor air temperature ($t_{\text{o.a}}$). Accordingly, the steam-consumption diagram of a Type T turbine for a CCP should in the general case express the following dependence:

$$F(G_{\text{HP}}, G_{\text{IP}}, G_{\text{LP}}, N_{\text{el}}, Q_{\text{h}}, p_{\text{h}}, t_{\text{HP}}, p_{\text{HP}}, t_{\text{r.s}}, t_{\text{LP}}, \tau_2, W_{\text{c.w}}, t_{\text{c.w}}) = 0. \quad (2)$$

Equations (1) and (2) can be depicted on a plane without distortions if the number of terms $n \leq 3$. If $n > 3$, the image of a steam-consumption diagram on a plane can be obtained only if the real interrelation of variables is replaced by approximate dependences. Such a replacement introduces an error into the steam-consumption diagram; the larger the number of variables in Eqs. (1) and (2), the more considerable the error will be. Therefore, it is advisable to limit the number of independent parameters for constructing a steam-consumption diagram.

The list of main variables for constructing a steam-consumption diagram for Type T turbines includes G_{turb} , N_{el} , and Q_{h} . Accordingly, Eq. (1) will have the form

$$F(G_{\text{turb}}, N_{\text{el}}, Q_{\text{h}}) = 0.$$

The list of main variables for constructing a steam-consumption diagram of turbines for CCPs includes G_{HP} , G_{IP} , G_{LP} , and Q_{h} . These parameters determine the value of $N_{\text{el,h}}$ in cogeneration modes with sufficient accuracy. The remaining parameters are taken to be constant.