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Refining the Calculation Procedure for Estimating the Influence of Flashing Steam in Steam Turbine Heaters on the Increase of Rotor Rotation Frequency during Rejection of Electric Load

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Abstract—A refined procedure for estimating the effect the flashing of condensate in a steam turbine's regenerative and delivery-water heaters on the increase of rotor rotation frequency during rejection of electric load is presented. The results of calculations carried out according to the proposed procedure as applied to the delivery-water and regenerative heaters of a T-110/120-12.8 turbine are given.

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Overspeed protection of a turbine has always been a top-priority task, and all possible sources of accelerating steam had to be carefully taken into account for solving it. So-called flashing steam [1, 2], which is generated from the condensate of apparatuses residing in them at the saturation line when an abrupt drop of pressure occurs in these apparatuses, is one of such sources.[1] As is shown in [2], simplified procedures for calculating the work done by flashing steam yield a too overestimated rotor acceleration value. The authors of [2] also proposed an engineering procedure for investigation and analysis that gives an estimate considerably closer to the real result, thus relieving excessive requirements for the protection system. In this paper, the procedure for calculating the work done by flashing steam is further refined and substantiated.

REFINED STATEMENT OF THE FLASHING STEAM GENERATION PROBLEM

The amount of flashed condensate is usually estimated from the formula

$$D_{pw} = D_w \frac{i_{w1} - i_{w2}}{r}, \tag{1}$$

where D_{pw} is the amount of flashing steam; D_w is the amount of water in the heater; i_{w1} and i_{w2} are the enthalpies of water on the saturation line at the initial and final pressures in the heater, respectively; and r is the latent heat of vaporization.

This formula does not take into account the decrease of condensate inventory as the pressure reduces, nor does it take into account the variation of the specific heat of vaporization r. Such simplifications may be an additional factor due to which calculations give an overestimated rotation frequency due to the effect of flashing steam entering into the flow path when the electric load is rejected, and due to which an unjustified decision is taken to install check valves, the use of which results in less efficient operation of the steam turbine heaters.

For obtaining an expression that takes into account the variability of the parameters, we will write the thermal balance equation for condensate and flashing steam in differential form at infinitesimal drop of pressure in the heat exchanger:

$$D_w i_w = (D_w + dD_w)(i_w + di_w) + dD_{pw} i_{pw}, \tag{2}$$

where dD_w, di_w, and dD_{pw} are infinitesimal increments of the amount of condensate, its enthalpy, and amount of flashing steam, respectively; and i_{pw} is the enthalpy of flashing steam.

Opening the parentheses and discarding the higher-order infinitesimal product $dD_w di_w$ and bearing in mind that

$$dD_w = -dD_{pw}; \quad i_{pw} - i_w = r, \tag{3}$$

we obtain the expression for the amount of flashing steam in differential form

$$dD_{pw} = -D_w \frac{di_w}{r}. \tag{4}$$

We see that formula (4) corresponds to (1) but contains the minus sign, which shows that the differentials have the opposite signs: the increment of the amount of flashing steam dD_{pw} is positive as the enthalpy di_w decreases.

Unlike (1), D_w in formula (4) is the current amount of condensate, which is correlated with the current amount of flashing steam D_{pw} and the initial inventory of condensate D_{w0} by the following obvious formula:

$$D_{pw} + D_w = D_{w0}. \tag{5}$$

[1] The term “flashing” is used in the article without quotation marks.