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STEAM-TURBINE, GAS-TURBINE, AND COMBINED-CYCLE PLANTS AND THEIR AUXILIARY EQUIPMENT

A Modernized High-Pressure Heater Protection System for Nuclear and Thermal Power Stations

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Abstract—Experience gained from operation of high-pressure heaters and their protection systems serving to exclude ingress of water into the turbine is analyzed. A formula for determining the time for which the high-pressure heater shell steam space is filled when a rupture of tubes in it occurs is analyzed, and conclusions regarding the high-pressure heater design most advisable from this point of view are drawn. A typical structure of protection from increase of water level in the shell of high-pressure heaters used in domestically produced turbines for thermal and nuclear power stations is described, and examples illustrating this structure are given. Shortcomings of components used in the existing protection systems that may lead to an accident at the power station are considered. A modernized protection system intended to exclude the above-mentioned shortcomings was developed at the NPO Central Boiler-Turbine Institute and ZioMAR Engineering Company, and the design solutions used in this system are described. A mathematical model of the protection system's main elements (the admission and check valves) has been developed with participation of specialists from the St. Petersburg Polytechnic University, and a numerical investigation of these elements is carried out. The design version of surge tanks developed by specialists of the Central Boiler-Turbine Institute for excluding false operation of the high-pressure heater protection system is proposed.

Keywords: high-pressure heater protection system, tube rupture, admission valve, false operation, surge tanks, level measurement

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Steam turbine regeneration systems are constructed with the use of surface-type high- and low-pressure heaters (HPHs and LPHs), apparatuses in which water held under high pressure flows inside their tubes, and steam entering into the shell space from the uncontrolled extractions has a lower pressure [1].

Experience gained in Russia and abroad shows that at least two independent protection features must be used in the HPH design and its connection circuit to prevent water from entering into the turbine. The time taken for each of them to come into action must be shorter than the time taken for water to fill the heater shell steam space, which is determined from the expression

$$\tau = \frac{V_{st}}{\mu F \sqrt{\Delta p}}, \qquad (1)$$

where V_{st} is the volume of the heater shell steam space that can be filled with water (this water must be kept from entering into the turbine), m^3; μ is the flowrate coefficient; F is the section area through which water flows out from the tube system into the steam space, m^2; and Δp is the difference between the pressure of water inside the tube system and the pressure in the shell steam space, MPa.

It follows from expression (1) that the heater should be designed so that steam is admitted into the heater upper part in order to achieve the maximal value of V_{st}. Another conclusion that can be drawn from expression (1) is that the heater located first along the water flow is most susceptible for failure, because water in its tube system is under the maximal pressure, and steam in its shell has the minimal pressure; i.e., this apparatus is characterized by the maximal value of Δp.

The selection of water outflow area in the case of tube rupture depends on the HPH type (coil-and-header, chamber, drum-platen, or drum) and on the selected diameter of heating-surface tubes. Determination of the number of ruptured tubes (the outflow area) involves difficulties due to lack of means for detecting leaks in the operating apparatus. Coil-and-header HPHs are widely used in the Russian power industry. The steam space filling process is calculated assuming the rupture of two coils (due to which four holes for water outflow are opened) when failure of