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Controlling the Startup Modes of Cogeneration Steam Turbines Operating as Part of Combined-Cycle Power Plants

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Abstract—The results obtained from investigations of combined-cycle power plants produced by the Ural Turbine Works aimed at achieving high maneuverability, reliability and longevity of cogeneration steam turbines taking into consideration the possibilities of modern automated process control systems are presented. The dynamic models for simulating the heating of a steam turbine cylinder's parts with the use of limited computation capacities are developed.

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Specialists of the Ural Turbine Works (UTZ), working jointly with specialists of the Ural Federal University's (UrFU) Department of Turbines and Engines, carry out works on achieving high maneuverability, reliability, and longevity of cogeneration steam turbines (STs) through setting up in-depth monitoring and control of equipment parameters [1], due to which lower probability of errors that can potentially be committed by the operating personnel should be achieved.

UTZ specialists have developed projects of combined-cycle power plants (CCPs) for cogeneration stations equipped with a heat-recovery boiler (CCP-based CSs with an HRB) and for CCP-based CSs with a parallel process scheme. For the cogeneration steam turbines operating as part of CCPs produced by UTZ the authors develop the technological principles of a system for automated control of startup operations taking into account the modern possibilities of automated process control systems (APCSs) in which efficient control algorithms are implemented using microprocessor devices. It should be noted that certain works should be carried out for each family of cogeneration steam turbines operating as part of a CCP (their interconnection is shown in Fig. 1 [2]):

—studying the temperature and thermally stressed state of the main structural elements of a cogeneration steam turbine;

—revealing the most thermally stressed elements of a cogeneration steam turbine and selecting the critical one among them;

—working out design measures for achieving better maneuverability of equipment;

—working out software for microprocessor devices; and

—setting up real-time monitoring of the temperature and thermally stressed state of the critical element (individually for each family of cogeneration steam turbines used as part of a CCP).

This paper presents the results obtained from an investigation carried out as applied to the CCPs produced by UTZ in accordance with the above-mentioned top-priority works.

The time taken to start a CCP is primarily governed by the time required for starting the steam turbine [3], which in turn depends on the thermally stressed state of its parts. The highest temperature stresses arise in the high-pressure rotor (HPR), in the intermediate-pressure rotor of turbines with steam reheating, in the casing of the high-pressure cylinder, and in the stop valves. The data used as input information for microprocessor computing devices include directly measured parameters such as rotor rotation frequency, steam turbine power output, steam temperatures, and the casing metal temperature of the high- and intermediate-pressure cylinders (HPC and IPC). The output information produced by these devices is the difference of temperatures or stress in the critical (i.e., the most stressed) zone of the critical part. In starting a turbine, it is advisable to maintain the difference of temperatures (stresses) in the critical elements at the maximum permissible level; as regards the other reliability criteria, they must not exceed the permissible (regulated) values.

The cogeneration steam turbines for CCP-based CSs with HRBs designed by UTZ [4–6] use an all-forged high-pressure rotor. Throttle steam admission in combination with independent control of the high-, low-, and (if any) intermediate-pressure stop and control valves is used in all loops through which steam is supplied to the turbine. The high-pressure rotor does not contain a control stage. The HPC consists of standardized parts. If the HPC has a cast-and-welded design, the casing of the high-pressure part is made by casting and has a design similar to the casing of the