ISSN 0040-6015, Thermal Engineering, 2013, Vol. 60, No. 6, pp. 420–425. © Pleiades Publishing, Inc., 2013.
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STEAM-TURBINE, GAS-TURBINE, AND COMBINED-CYCLE PLANTS AND THEIR AUXILIARY EQUIPMENT

Selecting the Initial Steam Temperatures in Starting Combined-Cycle Plants in Compliance with the Conditions of Heating the High-Pressure Steam Superheater Outlet Headers

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Abstract—Results from an analysis of permissible initial steam temperatures and heating rates of the outlet headers of high-pressure steam superheaters and the steam lines of combined-cycle plants at which their cyclic strength is ensured are presented. A procedure is proposed using which startup assignment schedules for different thermal states can be constructed proceeding from the heating rates and initial steam temperatures selected depending on the initial temperature state of the high-pressure steam superheaters' outlet headers.

Keywords: combined-cycle power plant, high-pressure steam superheater, outlet header, initial difference of steam and metal temperatures, heating rate, startup, cyclic strength, startup assignment schedule

DOI: 10.1134/S0040601513060086

Combined-cycle power plants (CCPPs), which owing to their high efficiency are designed to operate predominantly in base-load modes with a limited number of startup-shutdown cycles (around 20–40 startups a year) are more and more frequently involved to participation in the control of power. According to the maneuverability requirements [1], the average number of CCPP startups must be around 330 a year (10000 "startup–steady mode of operation–shutdown" cycles for 30 years of operation).

To prevent the occurrence of damage caused by high temperature stresses arising in thick-walled elements of boilers during CCPP startup and shutdown operations, the manuals for operating thermal power equipment and methodical guides prescribe the maximum permissible heating up–cooling down rates [2] at which the number of "startup–steady mode of operation–shutdown" cycles complying with the maneuverability requirements is ensured during operation.

However, none of regulatory documents specifies the permissible values of initial steam temperatures depending on the initial temperature state of the outlet headers of steam superheaters used in the CCPP heat-recovery steam generators (HRSGs), although it is exactly the initial difference between the temperatures of steam and metal that determines the possible maximum of stresses arising in the wall of a header as it is heated during the startup process.

It should also be pointed out that the outlet headers of high- and intermediate-pressure steam superheaters (for three-loop HRSGs with steam reheating), as well as the inlet headers of the HRSG economizer are the CCPP's critical elements that impose constraints on the rate of carrying out startup operations at the initial stages of the startup process [3].

MAIN FACTORS DETERMINING THE LONGEVITY OF THE OUTLET HEADERS IN HIGH-PRESSURE STEAM SUPERHEATERS

The list of main factors affecting the stress-strain state of the header during the HRSG startup and shutdown processes includes the initial difference of temperatures between the steam and header wall, steam temperature variation rate, steam flowrate through the header, and internal pressure. In calculations of the headers, the stresses caused by the initial difference of temperatures and by the distribution of temperatures over the wall thickness resulting from convective heat transfer and internal pressure are summed. As a rule, only one or two of the above-mentioned factors play the determining role at different moments of the startup and shutdown processes. Thus, the difference between the temperatures of steam and header metal can play the key role initially in the startup process, especially if the boiler is started from cold and warm states, whereas steam flowrate and pressure have a relatively small effect.

Initially in the startup process, a steplike change occurs in the heating steam temperature with respect to the initial temperature of header metal, due to which a growth of stresses in it arises in the first minutes after admission of hot gases from the gas-turbine unit (GTU) into the HRSG [4]. At a small value of heat-transfer coefficient initially in the steam generation process in the HRSG (which corresponds to the GTU rotor idle running mode), this process is charac-