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Selection of optimal reheat temperature in heat recovery boiler at combined heat and power plant with GT-topping

Olga Romashova[1], *Alexander* Tubolev[1,*], *Anastasia* Matveeva[1], *Andrey* Zenkov[1], and *Valentin* Asmolovsky[1]

[1]National Research Tomsk Polytechnic University, 634050 Tomsk, Russia

Abstract. Calculations to determine optimum value of steam reheat temperature in relation to the cycle arrangement of steam turbine power plant with gas turbine topping are conducted in this paper. Operation of T-250-240 turbine unit in cogeneration mode has been considered during steam reheat displacement from steam boiler to heat recovery boiler.

1 Introduction

There are various possibilities for reconstruction and extension of steam power stations durability, some of which are discussed in [1-6]. One of them involves gas turbine (GT) topping to increase efficiency and capacity. Such cycle arrangements are used today at coal-fired power plants, where natural gas is used as backup fuel. The most common cycle arrangement is heating of feed water and condensate in heat recovery boiler (HRB), which is called GT-topping with regeneration displacement.

Analysis of CCGT operation with K-300, T-250 steam turbine units shows that displacement of regeneration has significant disadvantages [1, 2]:

1) efficiency of the steam cycle is reduced as a result of heat loss increase in condenser;

2) capacity of steam turbine decreases due to limitation of the maximum steam flow through the last stage of the turbine.

An alternative to regeneration displacement at unit thermal power plants is displacement of steam reheat (RH) from steam boiler (SB) in HRB using the residual heat of gases to heat the main condensate in a group of low-pressure preheaters (LPP).

Advantages in the economics of such a solution for condensing units in comparison with displacement of regeneration are shown in [1]. At the same time, maximum efficiency of CCGT is reached at RH temperature equal to the nominal value.

Relevance of reheat and selection of its parameters is not obvious for cogeneration steam turbine plants (CSTP), which operate most time of heating season with maximum heat output to external consumer, because the effect from annual power generation increase due to RH does not always exceed the loss of profitability. This is explained by the

*Corresponding author: tubolev@tpu.ru

influence of RH on steam temperature at the inlet in low-pressure section (LPS) and an increase of minimal vent pass to cool the blades of turbine's last stages.

For this reason, extraction turbines operating at initial pressure of 13 MPa, such as T-110-130, T-175-130, etc., are constructed without RH in contrast to condensing units operating at the same pressure (K-210-130, K-160-130).

2 Experimental setup and limits

Considering the fact that temperature of RH has an ambiguous effect on the economics of the units in cogeneration mode, calculations in this paper are conducted to determine its optimum value in relation to the cycle arrangement of T-250-240 steam turbine power plant with GT-topping with RH displacement from steam boiler to HRB. The cycle arrangement with heat transfer on the surfaces of HRB is shown in Figure 1.

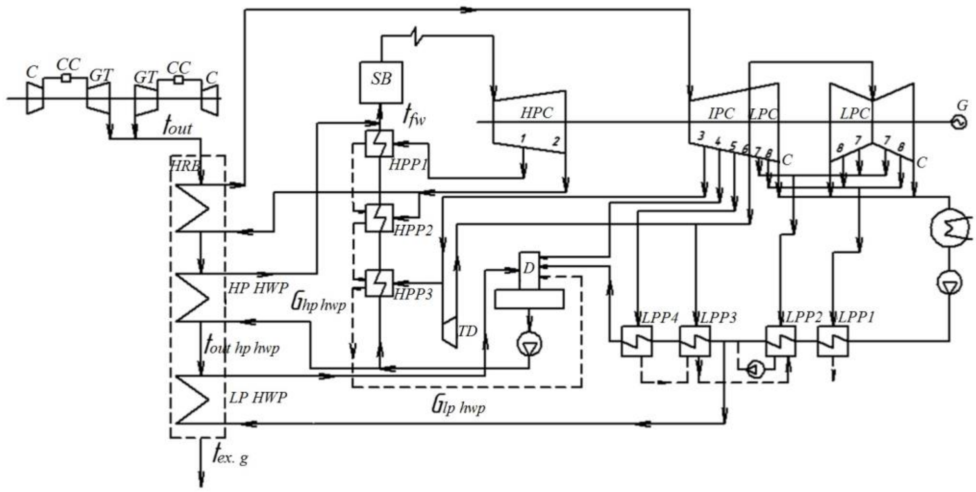

Fig. 1. Developed T-250/300-240 cycle arrangement with GT-topping.

Siemens V64-3A was considered as a gas turbine (GT) in this paper. Gas flow rate of GT is 154 kg/s and remains constant in variants calculations. Decrease in RH temperature at constant gas parameters after GT leads to decrease in RH thermal capacity and to increase of gases temperature after it. Residual heat is used to heat the main condensate and feed water.

Dependences of change in steam ventilation pass into condenser from steam temperature at LPS input for T-250-240 turbine are considered on the basis of this turbine operation analysis in cogeneration mode with a shut-off valve at LPS input and its supply from external source after humidification and steam separation [7], and also taking into account experimental data of the manufacturer.

3 Equations and mathematics

Figures 2 and 3 show the main calculations results of considered regimes for T-250-240 cogeneration unit. Minimal fuel consumption of CCGT during operation in cogeneration mode corresponds to the temperature of 480-490^{o}C, which is significantly lower than the nominal value of this parameter in traditional mode of T-250 turbine (t_{rh} = 540^{o}C - in all modes).

Availability of optimal RH temperature and value close to 480°C has also been confirmed by similar calculations for K-210-130 turbine unit of Surgut GRES-1, switched to operation mode with maximal heat release from controlled extraction. Figure 4 presents dependence of steam flow rate for LPS cooling from steam enthalpy after the last stage of IPS, obtained during testing of K-210-130 turbine. Calculations for this turbine are based on this dependence.

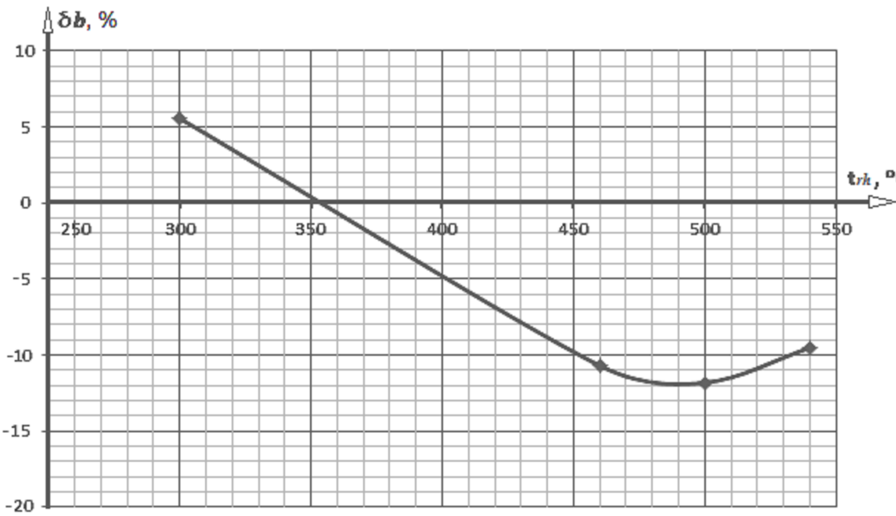

Fig. 2. Change of specific reference fuel consumption from reheat temperature in HRB for T-250/300-240 turbine with GT-topping at constant gas flow rate (operation in cogeneration mode).

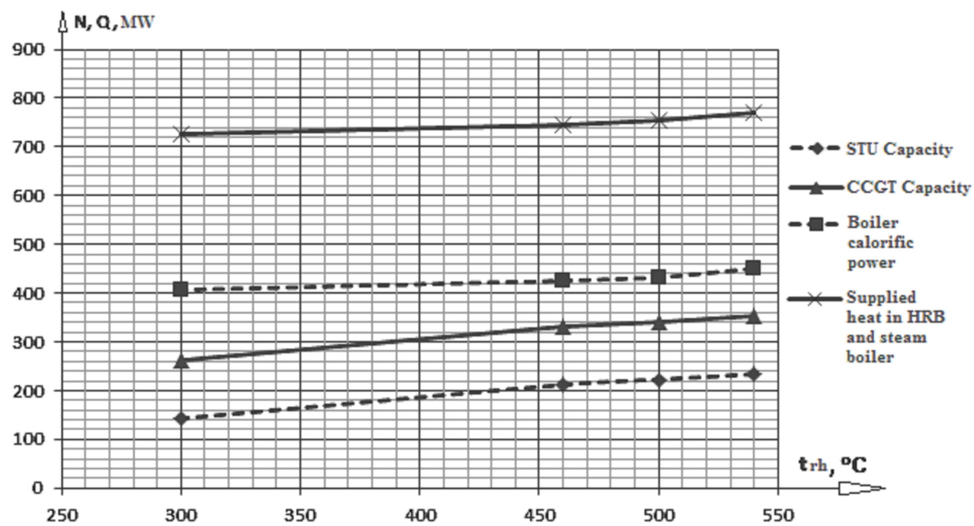

Fig. 3. Change of CCGT performance with T-250 units from reheat temperature.

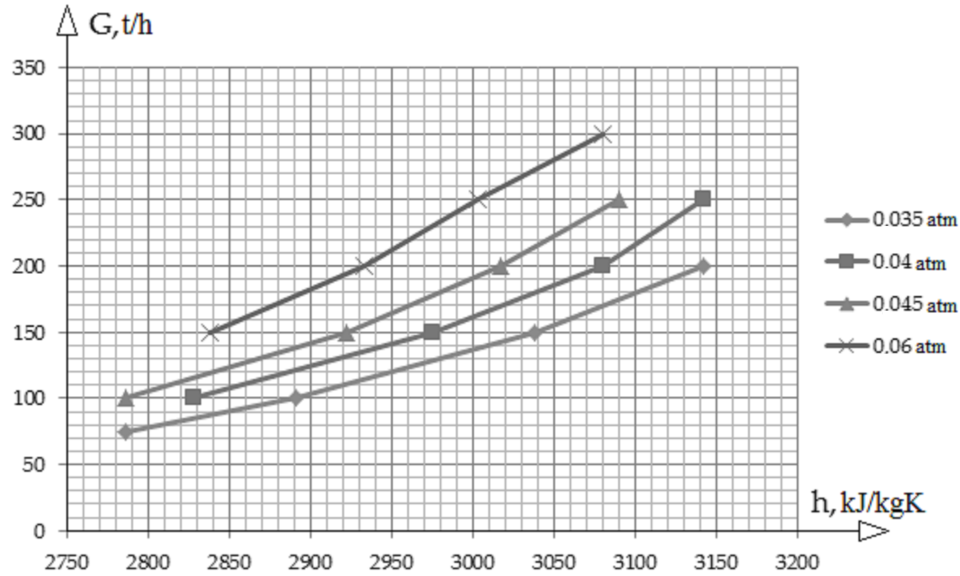

Fig. 4. Dependence of minimal steam flow in LPC of K-210-130 turbine from enthalpy before LPC at different pressures in condenser.

3 Conclusion

1. Optimal temperature of reheat in heat recovery boiler was determined by variants calculations for cogeneration power units with reheat at thermal power plant with GT-topping during operation in cogeneration mode that is well below nominal value (540°C) and lies in the range of 480-490°C.
2. Specific consumption reduction of reference fuel at optimal RH temperature is about 4% in comparison with nominal reheat temperature in traditional cycle arrangement.

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