The Ways to Improve the Efficiency of Binary Cogeneration Plant Operation by Use Additional of the Exit-Gas Heat Behind the Recovery Boiler

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Abstract. The exit-gas temperature behind the recovery boiler depends on the location, climate conditions, operation modes of the gas and steam turbine equipment at the combined-cycle cogeneration plant and can be slightly higher than the minimum admissible value. It leads to emergence of additional of exit-gas heat behind the recovery boiler. However the high-grade heat of the steam turbine extraction not only for own flows needs but also system water is used for heating. It reduces profitability of work of all power plants. The ways of use of the additional of the exit-gas heat behind the recovery boiler system water heating and chemically treated water of district heating makeup heating are offered. It leads to production the extra power by steam turbine and to improve the efficiency of binary combined-cycle cogeneration plant operation.

1. Introduction

Content of oxygen in the exhaust gas-turbine plant gases directed to a waste-heat recovery unit can reach 15% and more. This feature of binary combined-cycle plant in many respects distinguishes structure of products of burning from composition of gases of the utility boiler seeking to reduce excess of air to a minimum. Therefore value of temperature of a flue gases dew point in the waste-heat recovery, is at lower level, than in utility boiler [1].

For this reason heat-recovery boilers for binary combined-cycle plant are projected, proceeding from the fact that temperature of the exhaust gases after them will be maintained at the level of 80 ÷ 100 °C [2]. Temperature of the exhaust gases after heat-recovery boiler is influenced, on the one hand, by temperature of the exhaust gas-turbine plant gases, with another – condensate temperature on an entrance to the condensate gas heater. For maintenance of necessary temperature of condensate at the level of 50 ÷ 60 °C in the thermal scheme of a heat-recovery boiler there is a condensate recirculation pump. Regulation of a consumption of condensate in the line of recirculation of a condensate gas heater, and also temperature on an entrance to a surface leads to change of temperature of the exhaust gases after a heat-recovery boiler. At the same time, in actual operating conditions temperature of the exhaust heat-recovery boiler gases, can be slightly higher than minimum admissible value 80° C. And depending on the location, climatic data, operating modes of the gas and steam-turbine equipment of the combined-cycle cogeneration plant within a year, it can reach 110 ÷ 120 °C, sometimes and above
[3]. Thus, the additional amount of heat of the leaving gases appears. At realization of low-cost actions in the thermal scheme of the combined-cycle cogeneration plant, this amount of heat could be used for increase in efficiency of operation of the station.

2. Problem definition

These actions are directed to obtaining additional electric power on the steam turbine as follows.

1) Partial replacement of steam tapping on network water heaters, and heating of network water in a gas network water heater by the exhaust gases after a heat-recovery boiler (fig. 1a).

2) Decrease in a consumption of steam through pressure-reducing unit by replacement of a stream of steam directed for heating of the chemically treated network water, and use for this purpose of the exhaust gases after a heat-recovery boiler (fig. 1b).

3) Partial replacement of steam tapping on network water heaters and through pressure-reducing unit, and consecutive utilization of warmth of the exhaust gases after a heat-recovery boiler in a gas-water heater of the chemically treated network water and in a gas-network water heater (1c).

In the figure 1a the scheme of obtaining additional electric power on combined-cycle cogeneration plant due to partial replacement of steam tapping on network water heaters, and heating of network water in a gas network water heater by the exhaust gases after a heat-recovery boiler is submitted. When using a gas network water heater the temperature of network water after a network water heater top can be reduced. As a result of incomplete loading of heat extractions the possibility of obtaining additional electric power appears (due to reduction of a consumption of steam by network water heaters) [4, 5].

![Figure 1a. The schematic diagram of CCP-thermal power plant with heating of network water by the exhaust gases after a heat-recovery boiler](image)

1 – gas turbine plant; 2 – heat-recovery boiler; 3 – steam turbine plant; 4 – turbine condenser; 5 – network water heater top; 6 – network water heater lower; 7 – gas network water heater.

In schemes of binary combined-cycle plant, for heating of the chemically treated network water the steam from a collector of low pressure is used. This steam after pressure-reducing unit to a heater of the chemically treated network water is brought. Besides, the same steam of steam from pressure-reducing unit also to make-up deaerator is brought. Use of warmth of the exhaust gases after a heat-recovery boiler for heating of the chemically treated network water, in the established gas-water heater
of the chemically treated network water, will allow to exclude the corresponding stream of steam for auxiliaries through pressure-reducing unit. Having directed this steam to the steam turbine it is possible to develop additional electric power. In this case, steam through pressure-reducing unit will go only to the make-up deaerator for deaeration of the chemically treated make-up water. The scheme of obtaining additional electric power on combined-cycle cogeneration plant at the expense of fuller utilization of heat of the exhaust gases after a heat-recovery boiler in a gas-water heater of the chemically treated network water of combined-cycle cogeneration plant is submitted in the figure 1b [6].

![Figure 1b. The schematic diagram of CCP-thermal power plant with heating of chemically treated makeup water by the exhaust gases after a heat-recovery boiler.](image)

1 – gas turbine plant; 2 – heat-recovery boiler; 3 – steam turbine plant; 4 – turbine condenser; 5 – network water heater top; 6 – network water heater lower; 8 – pressure-reducing unit; 9 – makeup deaerator; 10 – chemistry department; 11 – gas-water heater of the chemically treated network water.

As temperature of the exhaust gases after a gas-water heater of the chemically treated network water continues to remain rather high, this stream can be sent further to the gas network water heater for heating of network water. When using the gas network water heater the temperature of network water after a network water heater can be reduced. As a result of incomplete loading of heat extractions the possibility of obtaining additional electric power appears (due to reduction of a consumption of steam by network water heaters). In the figure 1c the scheme of consecutive utilization of warmth of the exhaust gases after a heat-recovery boiler of binary combined-cycle cogeneration plant for heating of make-up water and network water is submitted [7]. As during the winter period temperature of the exhaust gases after a heat-recovery boiler is comparable to temperature of network water, it is expedient to finish heating up the network water by means of the exhaust gases after a heat-recovery boiler only during the summer period.
3. Results

Calculations of schemes were carried out for conditions of Novrossiysk city and the following structure of the equipment of binary combined-cycle cogeneration plant: 2 gas-turbine V-64.3A installations, 2 heat-recovery boilers and T-56/70-6.8 steam turbine. Technical characteristics of the gas-turbine V-64.3A installation are accepted on [2], the T-56/70-6.8 steam turbine are accepted on [8]. Calculations of economic efficiency are executed at a electricity tariff of 3.6 rub/kWh and cost of metal of heaters of 40 rub/kg.

Expediency of these of an action is defined by profitability of the additional electric power received on steam-turbine installation within a year. The efficiency of these actions by the following formula is determined:

$$\Delta E = \sum_{i=1}^{l} \Delta N_i \cdot \tau_i \cdot T_e - C_h$$

where $\Delta E$ – economic benefit of obtaining additional electric power, million rub; $\Delta N_i$ – the additional electric power of steam-turbine installation in structure of combined-cycle cogeneration plant on i-m the mode, kW; $\tau_i$ – operating mode duration within a year, h/year; $T_e$ – a electricity tariff, rub/(kW · h); $C_h$ – total capital investments in heaters, million rub/year.

Change of economic benefit $\Delta E$, developments of additional electric power $\Delta N$ and capital investments in heaters from temperature of technological streams is shown in figures 2 - 4.

In the figure 2 dependence of indicators of combined-cycle cogeneration plant when using gas network water heater from temperature of the exhaust gases after gas network water heater is shown.
Change of temperature of the exhaust gases after gas network water heater from 80 to 100 °C leads to reduction of the developed additional electric power of steam-turbine installation from 4.12 MW to 1.75 MW. Increase in temperature of the exhaust gases after gas network water heater means decrease in utilization of heat after a heat-recovery boiler. The surface of heat exchange of the gas network water heater, at the same time, is reduced, and according to capital investment decrease from 38.86 million rub to 12.67 million rubles. In general economic benefit of realization of additional electric power is in limits of 22.42 million rub – 13.01 million rubles.

![Figure 2. Dependence of indicators of combined-cycle cogeneration plant when using gas network water heater from temperature of the exhaust gases after gas network water heater](image)

In the figure 3 dependence of indicators of combined-cycle cogeneration plant on temperature of the chemically treated water after gas-water heater of the chemically treated network water is shown. Calculations of economic benefit of gas heating of the chemically treated water in comparison with option of use of steam from pressure-reducing unit for this purpose have been executed at a variation of temperature of make-up water at the exit from heater of the chemically treated network water. It is caused by the following circumstance. The difference of temperatures of the chemically treated water on an entrance and an exit to heater of the chemically treated network water exerts impact on size of steam demand from pressure-reducing unit. Reduction of temperature at the exit of make-up water from heater of the chemically treated network water (at a constant temperature on an entrance to heater of the chemically treated network water) leads to decrease in a consumption of steam from pressure-reducing unit, and, therefore, to the additional admission of steam in a steam path and generation of additional electric power. But at the same time the comparative effect of makeup water gas heating implementation decreases and vice versa.

Properly from the figure 3, temperature increase of the makeup chemical treated water at the exit from a heater on 10 °C leads to increase in generation of additional electric power of steam-turbine installation by 0.8 MW. At the same time the area of a heatexchange surface of gas-water heater of the chemically treated network water will increase by 455.8 m², and capital investments will increase on 1.47 million rubles. Economic benefit is in limits of 13.0 million rub – 19.02 million rubles.
In the figure 4 dependence of indicators of combined-cycle cogeneration plant when using gas-water heater of the chemically treated network water and gas network water heater from temperature of the exhaust gases after gas network water heater is shown.

Properly from the figure 4, change of temperature of exhaust gases after a gas network water heater (during the summer period) with 80 to 100 °С leads to reduction of additional electric power steam-turbine installation from 4.325 MW to 3.39 MW. Increase in this temperature means reduction of utilization of warmth after gas-water heater of the chemically treated network water.

Figure 3. Dependence of indicators of combined-cycle cogeneration plant on temperature of the chemically treated water after gas-water heater of the chemically treated network water.

Figure 4. Dependence of indicators of combined-cycle cogeneration plant when using gas-water heater of the chemically treated network water and gas network water heater from temperature of the exhaust gases after gas network water heater is shown.
At the same time, the total area of heat exchange of gas-water heater of the chemically treated network water and gas network water heater decreases (at the expense of gas network water heater) and total capital investments are reduced from 13.02 million rubles to 6.6 million rubles.

In general economic benefit of realization of additional electric power due to use of warmth of the warmth of the exhaust gases after a heat-recovery boiler in consistently established to gas-water heater of the chemically treated makeup water and in a gas-network water heater is in limits of 45.82 million rub – 33.49 million rubles.

4. Conclusions

1) Ways of use of excess warmth of the exhaust gases after a heat-recovery boiler of binary combined-cycle cogeneration plant for heating of network water and/or the chemically treated makeup water are offered. It leads to generation of additional electric power of the steam turbine and increase in overall performance of binary combined-cycle cogeneration plant.

2) The carried-out preliminary technical and economic analysis of possible ways of use of excess warmth of the exhaust gases after a heat-recovery boiler has shown the following. For the accepted basic data consecutive utilization of warmth of exhaust gases after a heat-recovery boiler of binary combined-cycle cogeneration plant for heating of the chemically treated makeup water and network water is more effective.

References

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