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Technology of using excess heat of return network water for heating before being fed to a decarbonizer

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Abstract

A new technology of using the excess heat of reverse network water as a heating medium in an air heater installed in front of the decarbonizer of a water treatment plant of a thermal power plant is considered. The formulas for calculating the main indicators of the precarbonizer of source water using reverse network water are demonstrated. As a result of the calculation, the efficiency of the use of the new technology was revealed.

Keywords: water treatment plant, return network water, thermal power plants, decarbonizer, cooling water, cooling towers

To increase the efficiency of the preparation of the source water in the cycle of the water treatment plant of a thermal power plant, it is recommended to install a decarbonizer [1]. The principle of operation of the decarbonizer is to contact the water with the oncoming air stream supplied by the fan, as a result of which the CO₂ released from the water is removed together with the air stream through the upper pipe. As you know, improving the quality of decarbonization of the source water depends on the temperature of the supplied air. It is recommended to maintain the air temperature in the range from 30 to 40 °C, and the allowable air flow rate from 20 to 40 m³ per 1 ton of source water [2]. Since the outside temperature for a longer period of use is below the specified parameters, especially in winter, there is a need to install an air heater.

Basically, high-potential steam of industrial selection or reduced steam of a steam boiler through a quick reduction installation is used as the heating medium of the air heater, which in turn leads to an increase in the cost of water treatment [3].

The authors of the article developed a new technology for heating the source air supplied to the decarbonizer using reverse heating-system water as a heating medium in the research laboratory “Heat energy systems and installations” of UISTU. The main criterion for the application of the new technology is equal, or close to equal parameters of decarbonization of the source water in the water treatment plant of the thermal power plant.

Fig. 1 Water treatment plant of a thermal power plant: 1 – source water pipeline, 2 – source water heater, 3 – source desalination or softening unit, 4 – decarbonizer, 5 – tank-battery of decarbonized water, 6 – deaerator, 7 – tank-deaerated battery water, 8 – pipeline recycled heating-system water, 9 – booster network pump, 10 – network heater, 11 – steam turbine, 12 – condenser, 13 – fan, 14 – air heater.

The main indicators for assessing the energy efficiency of these technologies are the equivalent fuel consumption of fuel equivalent for heating the air before feeding 1 ton of the source water for decarbonization to the decarbonizer.

Since the heating medium of the air heater is return network water, after passing through the heater it is cooled and hence there is a need to compensate for the used heat of the return network water by increasing the load of the heating selections. Then the equivalent fuel consumption for heating the air required for decarbonization of 1 ton of the source water B (fuel equivalent / source water) is found by the formula:

$$B = \frac{(t_a^{\text{out}} - t_a^{\text{in}}) \cdot G_a \cdot (h_s^{\text{h.s}} - h_s^{\text{tur}})}{h_s^{\text{h.s}} - h_{\text{sc}}^{\text{h.s}} \cdot (h_{\text{ss}}^{\text{tur}} - h_{\text{sc}}^{\text{tur}}) \cdot (h_{\text{ss}}^{\text{tur}} - h_{\text{fw}})} \cdot Q_{\text{ef}} \cdot \eta_b \quad (1)$$

where t_a^{out} - air temperature at the outlet of the air heater, °C; t_a^{in} - air temperature at the inlet to the air heater, °C; G_a - air flow through the heater, t; $h_s^{\text{h.s}}$ - enthalpy of steam of heat-extraction selection, kcal / kg; $h_{\text{sc}}^{\text{h.s}}$ - enthalpy of condensate of steam of cogeneration selection, kcal / kg; $h_{\text{ss}}^{\text{tur}}$ - enthalpy of sharp steam at the turbine inlet, kcal / kg; $h_{\text{sc}}^{\text{tur}}$ - enthalpy of steam at the turbine inlet, kcal / kg; h_{fw} - enthalpy of feed water, kcal / kg; Q_{ef} - specific heat of combustion of equivalent fuel, kcal / kg; η_b - boiler efficiency.

Since for a given electrical load, the maximum effect of a steam turbine is achieved through the use of exhaust steam, i.e. maximum efficiency of a steam turbine is achieved with a minimum flow of steam into the condenser (preferably to the level of technological minimum). The most effective step in the use of exhaust steam is the cogeneration selection of a steam turbine, the loading of which is mainly dependent on the temperature of the return network water. When using this technology, an average annual decrease in the temperature of the return network water by 1°C is observed, which contributes to the additional loading of cogeneration samples and a decrease in the passage of steam into the turbine condenser. The temperature of the return network water when using the technology is determined by the formula:

$$t_{\text{n.w}}^{\text{ch.ret}} = \frac{(G_{\text{n.w}}^{\text{ret}} - G_{\text{h.a.}}) \cdot t_{\text{n.w}}^{\text{ret}} + G_{\text{h.a.}} \cdot t_{\text{h.a.}}}{G_{\text{n.w}}^{\text{ret}}} \quad (2)$$

where $G_{\text{n.w}}^{\text{ret}}$ - is the flow rate of the return network water, t / h; $G_{\text{h.a.}}$ - consumption of the heating agent for the heater, t / h; $t_{\text{n.w}}^{\text{ret}}$ - return water temperature, °C; $t_{\text{h.a.}}$ - the temperature of the heating agent at the outlet of the heater, °C.

Since water is used in the process of steam condensation, its flow rate depends on the temperature at the inlet to the condenser itself. To reduce the temperature of the cooling water, cooling towers are mainly used, the water loss of which is 1 - 1.5% for evaporation and 0.5 - 3.5% for the drop-off by the wind of cooling water. Therefore, there is a need for compensation of cooling water [4].

Hence, the flow rate of cogeneration steam is determined by the formula:

$$G_s^{\text{h.s}} = \frac{(t_{\text{n.w}}^{\text{sup}} - t_{\text{n.w}}^{\text{ret}}) \cdot G_{\text{n.w}}^{\text{ret}}}{h_s^{\text{h.s}} - h_{\text{sc}}^{\text{h.s}}} \quad (3)$$

where $t_{\text{n.w}}^{\text{sup}}$ - the temperature of the water in the supply pipe, °C.

Consequently, with a decrease in the temperature of the return network water the flow rate of the heating recovery steam increases, this is determined by the formula:

$$\Delta G_s^{\text{h.s}} = \frac{(t_{\text{n.w}}^{\text{sup}} - t_{\text{n.w}}^{\text{ch.ret}}) \cdot G_{\text{n.w}}^{\text{ret}}}{(h_s^{\text{h.s}} - h_{\text{sc}}^{\text{h.s}})} \quad (4)$$

When the temperature of the return network water decreases, the consumption of steam of the heating system increases, and therefore this steam does not enter the condenser. But with an increase in the load of district heating selection, the generation of electricity decreases, hence the need arises to supply an additional amount of steam to the turbine, which is necessary to compensate for the under-production of electricity that goes through the entire turbine cycle and is supplied to the condenser.

Steam consumption for underproduction of electricity due to an increase in steam consumption of district heating selection:

$$G_s^{\text{con}} = G_s^{\text{h.s.}} \cdot \frac{(h_s^{\text{h.s.}} - h_s^{\text{tur}})}{(h_{ss}^{\text{tur}} - h_{sc}^{\text{tur}})} \quad (5)$$

Steam consumption for underproduction of electricity by increasing the consumption of steam of district heating at a reduced temperature of the return network water:

$$\Delta G_s^{\text{con}} = \Delta G_s^{\text{h.s.}} \cdot \frac{(h_s^{\text{h.s.}} - h_s^{\text{tur}})}{(h_{ss}^{\text{tur}} - h_{sc}^{\text{tur}})} \quad (6)$$

Thus, there is a decrease in the flow rate of steam into the condenser with the installed electric load due to the load of the heating selection, but in order to maintain a given electrical load, it is necessary to expend additional steam for underproduction of electricity. Hence, the flow rate of steam supplied to the condenser is determined by the formula:

$$G_{\text{con}} = (\Delta G_s^{\text{h.s.}} - G_s^{\text{h.s.}}) - (\Delta G_s^{\text{con}} - G_s^{\text{con}}) \quad (7)$$

Then the flow rate of cooling water is determined by the formula:

$$G_{\text{c.w.}}^{\text{con}} = \frac{G_{\text{con}} \cdot (h_{sc}^{\text{tur}} - h_w^{\text{con}})}{h_{\text{c.w.}}^{\text{out}} - h_{\text{c.w.}}^{\text{in}}} \quad (8)$$

where $h_{\text{c.w.}}^{\text{out}}$ – the enthalpy of cooling water at the outlet of the condenser, kcal / kg; $h_{\text{c.w.}}^{\text{in}}$ – enthalpy of cooling water at the inlet to the condenser kcal / kg.

Accordingly, the lower the passage of steam into the condenser, the lower the flow rate of cooling water, and therefore there is less loss on evaporation and wind ablation.

Based on the data provided at the Ulyanovsk TPP-1, a comparative analysis of existing technologies with a new one was performed. The application of the new technology saves 44.22 tonne of oil equivalent per year compared to industrial turbine extraction steam and 97.31 tonne of oil equivalent per year compared to reduced steam of a steam boiler through quick reduction installation. Also, the use of new technology makes it possible to increase the load of cogeneration sampling of a steam turbine, which in turn helps to reduce the flow of steam into the turbine condenser, and, consequently, to reduce the loss of cooling water in the cooling towers. With losses on evaporation and ablation by wind equal to 2%, the annual saving of cooling water is 74377 tons, with losses on evaporation and ablation by wind equal to 5% the annual saving of cooling water is 185943.

Conclusion

1. A new technology is proposed for using the excess heat of the return network water as a heating medium in an air heater before being fed to the decarbonizer. The new technology allows you to completely abandon the use of high-potential heat sources as a heating medium in an air heater or be used in conjunction with existing ones.

2. The cost-effectiveness of using the proposed technology in comparison with the ones operating at a thermal power plant has been proved by calculation. The performed calculation was performed while maintaining the same decarbonization parameters of the source water.

3. Based on a comparative analysis of the new technology with the existing one, a decrease in the temperature of the return network water has been revealed, which contributes to the efficient loading of cogeneration taps and a decrease in the steam flow into the condenser, which reduces the loss of cooling water due to evaporation and wind ablation in the cooling towers.

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1. Water treatment plants and water-chemical regime of thermal power plants. Terms of creation. Norms and requirements. STANDARD NP INVEL STO 70238424.27.100.013-2009.
2. Sharapov V.I., Sivukhina M.A. Decarbonizers / Ulyan, state. tech. un-t - Ulyanovsk: UISTU, 2000. -204 p.
3. Patent No. SU 1267015. IPC F01K17 / 02. The method of preparation of makeup water heating system / V.I. Sharapov, R.M. Kadyrov, V.I. Maximov.
4. RD 34.22 505 Guidelines for the operation of cooling towers.