Transfer of the steam turbine PT-60-130/13 to the adventure T-27/33-1,28 with the replacement of electric motors of feeding electric pumps with a steam turbine drive

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Abstract. For the production of thermal and electric energy, generating enterprises consume fuel, electricity, water for various purposes, thermal energy, etc. The consumption of electricity which is used mainly on the motor of pumping equipment, in the cost of the released energy resource is a significant share. Nowadays, reducing the consumption of energy for the auxiliary needs of generating enterprises is a crucial task to ensure competitiveness according to specific indicators on the wholesale electric power market. This article provides the analysis and justification of the technical decision to replace the electric motor of pumps with a steam turbine drive. A scheme for connecting a steam turbine drive to the feed pumps PE-500-180 (№1) and PE-500-180 (№2) is proposed, taking into account the characteristics of the thermal diagram of the boiler and turbine section. The work schedules of feed pumps have been analyzed, the required steam consumption has been determined, taking into account the loading of the production steam extraction of operating turbines for 200 t/h. According to the results of the analysis of the performance indicators of the station, it was determined that in the condensation modes during the period with a low supply of the thermal energy, the thermal economy of the station decreases, which leads to an increase in the consumption of fuel equivalent in the amount of 1660806 rubles. At the same time, the increase in the volume of sales of electric energy and capacity on the open electric capacity market after the reconstruction will amount to 75493070,81 rubles. Thus, the proposed technical solution for the reconstruction of the feed pump drive is a rather promising direction with the correct construction of the scheme and the presence of consumers of the heat energy.

1. Introduction

Today, it is considered that the power consumption for auxiliary needs of the combined heat and power plant (CHPP) is 5-15% of the installed capacity of the CHPP. The auxiliary needs of station are a set of auxiliary equipment that ensures the smooth operation of its main elements. These elements include lighting systems, emergency power supplies, electric motors of all mechanisms, battery installa-
tions, etc. Such factors like fuel, location and mode of operation, equipment condition influenced on the smooth operation, but analysis of research shows that actual consumption for auxiliary needs of CHP plants can in some cases reach 35% of their production [1].

Figure 1 presents the structure of electricity losses at CHP plants.

![Figure 1. The structure of electricity losses at CHP plants](image)

According to the estimates of the studies carried out over the past 10 years, the average efficiency coefficient of Russian CHPPs is 35-37%. It should be noted that the specific fuel consumption for the generation of one kWh of electricity in recent years has decreased by only 1.5% [2].

The main problems of the modern energy complex of Russian CHPPs include:

- Decrease of the performance of old heat and power equipment, which leads to frequent shutdowns and downtime;
- Decrease in the electricity generation and increase in the specific fuel consumption;
- Low rates of commissioning new capacities using modern technologies;
- Decrease in economy of CHPP operation due to increased energy consumption for auxiliary needs.

As it follows from figure, the main consumers of electricity for the auxiliary needs of CHP plant are engines, mainly for driving injection equipment.

This is especially critical for heating CHP plants operating according to the thermal load schedule during the non-heating period of the year. A characteristic feature of the operation of such CHP plants during the non-heating period is that their electrical load is more dependent on the heat load of the plant. This is due to the fact that such combined heat and power plants use cogeneration turbine. The operation of the main equipment of the CHPP at partial loads leads to the need to regulate the performance of the mechanisms of the auxiliary needs of the plant, as a result of which they operate in the zone of nonoptimal value of the efficiency coefficient. Bypassing and throttling are the main ways of regulating the performance of auxiliary mechanisms, which were laid down in those years when no one thought about the energy efficiency. But, today, these methods are not effective, since the regulation of productivity is achieved by increasing the resistance of the network, and this leads to additional losses on the gate or valve of the mechanism. The most effective way to control the performance of centrifugal mechanisms is to change the rate of rotation of the impeller, which can be achieved by installing variable speed drives, as well as replacing the electric motors by a steam turbine drive, the performance of which can be regulated by changing the supply of steam. [1].
The analysis of the condition of the equipment of the research object (thermal power station (TPS)), its thermal diagrams and heat consumption in the steam and hot water showed that to improve the efficiency of TPS, one of the most effective actions are [2-3]:

- reconstruction of turbine PT-60-130/13;
- installation of the steam turbine motor on feeding pumps.

It should be noted that the TPS was operated by the turbine PT-60-130/13, which has passed 3 life extensions (at the time of the survey the lifetime was 259730 hours), which has a number of observations requiring significant capital investment. The internal relative efficiency factor of the high-pressure cylinder of the turbine PT-60-130/13 was lower than the normative values due to significant wear and tear of the turbine blading, especially the operating blades of the control stage, in the result of cracking the bottom of the stator of the high-pressure cylinder, as well as insufficient rotor geometry and end seal gaps. Considering this condition of the high-pressure cylinder, it is evident that their repair is inadvisable.

For the motor of feeding pumps, the electric motors of the brand AC-4000/6000 with a power of 3150 kW were used. However, losses in turbine generators, losses in transformers of auxiliary needs, losses in transmission of electric energy to the motor and losses in the electric motor are obvious. There is also an overconsumption of electricity on the motor of feeding pumps when operating on partial loads [5-7].

Thus, the following objectives were pursued when implementing a technical solution:

- increasing the efficiency of the production process;
- improving the safety of the production process;
- Significant reduction of electricity losses for auxiliary needs;
- Additional production of electrical energy;
- Optimization of loading of turbines type P;
- Stable maintenance and stepless control of feedwater pressure;
- Increase the operating life, decrease in the number of repairs of shut-off and control valves.

2. Materials and Methods

For the reconstruction of the turbine PT-60-130/13 due to the unsatisfactory condition of passage, it was proposed to dismantle the high-pressure cylinder TG-1 with the replacement of the low cylinder TG-1 pressure on the operation of the stream of 13 ata (the turbine was included). Reconstruction involved dismantling of the rotor stages of the high-pressure cylinder, reconstruction of the steam distribution of the low-pressure cylinder with the organization of new steam starting and installation of new valves [8, 9, 11].

The passage of the low-pressure cylinder in part of the mean pressure is also undergoing reconstruction, namely:

- reconstruction of the steam distribution of the low-pressure cylinder with the organization of new steam starting and installation of new valves;
- dismantling pressure stages;
- installation of mounted discs with new blading to ensure the required throughput capacity
- installation of new vane carriers;
- Low-pressure compartment (pressure stages behind the turning carrier) and condenser are beyond reconstruction.

Steam in the amount of 225 t/h to the reconstructed turbine is supplied from the collector of 13 ata. The installed electrical capacity of the turbine is about 35 MW. After reconstruction, the turbine PT-60-130/13 should be labeled as T-35-13. The additional steam flow rate of 13 ata to the turbine T-35-13 can come from the turbines P-50/60-130/13, PT-135-130 and from the motor turbines of feeding pumps. This solution will increase the loading of turbines type P, increase the thermal energy supply from the rebadged turbine type T-35-13, as well as increase its internal relative efficiency factor.
To avoid losses related to energy losses in the generator windings, electric motor and transformer, it is proposed to use steam turbines for driving feeding pumps of type PE-500-180 (№1) and PE-500-180 (№2).

Turbines to drive feeding pumps compared to traditional axial turbines have a more economical (2%) passage, fewer stages (3 times), fewer nozzle and rotating blades. These benefits reduce the cost of repair works. Moreover, these turbines are cheaper than axial. The use of a turbine to drive feeding pump instead of an electric motor is also advisable, based on the possibility of regulating the flow of feedwater under partial modes (this is not provided by the electric motor).

The turbo drive construction is a single-cylinder turbine installed on the existing foundation frame of the pump unit within the electric motor layout. The weight load from the turbo drive does not exceed the weight load of the replaced electric motor, which allows to install the turbo drive to the place of the dismounted electric motor with the current position of the feeding pump and without the reconstruction of the foundation [4].

Steam distribution of the throttle turbine. Block and control valves are installed in front of the turbine consequentially. The steam supply from the control valve to the steam inlet zone of the front of the cylinder is made by two tubes. Steam exhaust from the back of the cylinder is carried out up by two sides symmetrically [9].

The main characteristics of the passage are presented in table 1.

Table 1. The characteristics of the passage of the turbo motor.

| Parameter                        | Value        |
|----------------------------------|--------------|
| Minor diameter                   | 800 mm       |
| Rotational speed                 | 2985 rpm     |
| Steam flow rate                  | 100 t/h      |
| Internal efficiency factor       | 0,73         |
| Height of nozzle blades          | 20/24/28 mm  |
| Number of nozzle blades          | 70/70/70     |
| Height of rotating blades        | 20/24/28 mm  |
| Number of rotating blades        | 160/160/160  |

The motor turbine is activated between the turbine exhaust pipeline P-20/40-130/30 and the collector of 13 ata.

Installation of turbines as a feeding pump motor will significantly reduce the electricity consumption for auxiliary needs and ensure the optimum loading of TG-2.5. Also, the regulation of the feedwater rate due to the change in the number of rotators of the motor turbine will reduce the specific consumption of electricity for the pumping of the medium [5,10,12].

Turbo motors of the feeding pumps are proposed to be installed in the feedwater diagram of the I stage. At the same time, the steam consumption per feeding pump is 100 t/h, which leads to the loading of the production selection TG-5 at 200 t/h and, accordingly, to the increase of the electrical load on it by 18 MW.

To ensure the required steam temperature released to the consumer, it is important to provide a steam cooler on the exhaust of the turbo motor [13,14].

Figure 2 shows the diagram of connecting a steam turbine to the steam pipelines of a combined heat and power plant.
Figure 2. The diagram of steam lines 30 ata №5 and 6. P=28.5±1.5 kgs/cm², T=430°C.

Figure 3 shows the operation schedule of the feed pump in the power unit of a combined heat and power plant.

Figure 3. Schedule of the feed pump operation.

It can be seen on figure 3 that the operating point A corresponds to the nominal flow rate Qn and the pressure Pn. With a decrease in pump speed, the operating point shifts along the curve of the network characteristic to the position of point B, at which the flow becomes the minimum permissible and the recirculation line is turned on. The unloading of the power unit is mainly limited by the reliability of the boiler operation and is 50% of the nominal power. Less load is observed only when it starts and stops. As a result, at the CHP plant, the smooth regulation of revolutions and change in the performance of the main feed pump can be carried out in the entire operating range of loads with the complete exclusion of throttling [17, 18].
3. Results

Analysis of the technical solution of the modernization of the turbine PT-60-130 by replacing the high-pressure cylinder and the passage of the low-pressure cylinder showed that the nominal capacity of the upgraded turbine PT-70-130/13 will be 67.2 MW, which is higher than the current nominal capacity of the turbine PT-60-130 by 7.2 MW. The maximum capacity of the upgraded turbine PT-70-130/13 will be 86.4 MW, which is higher than the current maximum capacity of the turbine PT-60-130 by 11.4 MW. Thus, this action does not allow to increase the actual value of the electrical power of the plant by 20 MW, as specified in the technical solution.

It should also be noted that a year before the energy survey the total overhaul of the TG was carried out after which the indicators of the economical operation significantly improved and at the moment have slightly conceded indicators of the economical operation of the upgraded turbine. In connection with it, the modernization of the turbine PT-60-130 with the replacement of the high-pressure cylinder and the passage of the low-pressure cylinder seems impractical.

As a result of the analysis of the technical solution, the turbine of the type T-45-15 was selected as included, however, according to the conditions of loading the heat selection and the permissible steam load of the condenser, the turbine will not be able to be loaded over 25 MW. The installed electrical capacity of the turbine is approximately 25 MW.

Steam in the amount of 236 t/h is supplied from the collector of 13 ata to the reconstructed turbine. The additional steam flow rate of 13 ata to the T-45-13 can come from the turbines P-50/60-130/13 and PT-135-130. This solution will increase the loading of turbines type P, increase the thermal energy supply from the relabeled turbine type T-35-13, as well as increase its internal relative efficiency factor.

After reconstruction the thermal economy of the station will decrease due to low economical operation of the reconstructed turbine T-25-13 on condensation modes during the period with low release of the thermal energy. The increase in the consumption of oil equivalent for the year will be 501,86 TW that is equivalent to a cash amount of 1,660,806 RUB.

The increase in the volume of electricity sales in connection with the reconstruction will be 193231,47 kW·h that is equivalent to 23241098,52 rubles.

The increase in the volume of the power sales due to the reduction of the installed capacity restrictions after reconstruction will be 486,03 MW which is equivalent to a cash amount of 52251972,29 rubles.

As a result, the total cost estimate of the economic efficiency of the solution will be 73832264,83 rubles and the payback period will be 9,06 years.

4. Conclusion

Implementation of the technical solution allowed to reduce electricity consumption for auxiliary needs, optimize the loading of the turbine P-20/40-130/31, maintain stable and stepless control pressure of feedwater, improve the safety of the production process and reliability of the provision of thermal energy in the hot water.

Thus, the implementation of technical solutions for the introduction of steam turbine drives at CHP plants, taking into account the operating conditions of the thermal scheme, is a rather promising direction along with the introduction of variable speed drives. Thus, according to the ARCAAdvisory Group (USA), the global market for variable speed drives is estimated at $ 2.5 billion and will only grow in the coming years. In Russia, variable speed drives make up no more than 2.5% of the entire drive market, which opens up the great prospects for the introduction of both variable frequency drives and drives based on the steam and gas turbines.

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