

Study of change in 300 MW power unit efficiency operation under reduced loads

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Abstract. The article presents the results of the study of technical and economic parameters of power unit's operation under reduced turbine generator loading, related to the night power dip and wear of power plant units. Changes in fuel consumption under reduced loading, change in power unit efficiency and change in main specific characteristics of the power unit were investigated. Conclusions on the 300 MW power unit's operation modes under different turbo-generator loads were drawn based on the results of the calculations and investigations.

1 Introduction

Condensational thermal power plants (CTPP) and nuclear power plants (NPP) of installed power constitute a great part of Russian Unified Energy System. The efficiency output of such power stations, as a rule, does not exceed 40% for thermal power plants. Such efficiency value of CTPP is due to the nature of technological process, however it may be impacted by other than nominal operation modes and physical wear and tear of power equipment. In reduces operation modes, the power equipment of the TPP operates at reduced initial steam parameters, which leads to a decrease in the rated capacity of power units, and as a result, of the whole power plant efficiency [1].

Nowadays, among the power plants with an installed capacity of over 1000 MW, the most of the CTPP (67-68%) operate with an efficiency not exceeding 40%. This is mainly due to the loss of heat carried away by the waste gases, along with the combustion products, the spent circulating water necessary for the complete condensation of steam in the turbine, as well as with a decrease in the operating parameters of the steam at the turbine input [2].

The decrease in steam parameters is due to the fact that the main equipment of modern thermal power plants, especially those operating on solid fuel, is heavily worn out. The steel of which the boiler equipment and the nozzles of the turbine plants are made is not capable of withstanding the rated load for a long time, which entails a decrease in the installed capacity of the TPP power units, and this negatively affects the efficiency of the entire power plant [3].

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Thus, with a decrease in the nominal load of the power unit, the specific fuel consumption for the generation of a unit of electricity increases, which leads both to an increase in production costs and to a decrease in the efficiency of the power unit. In addition to the technical condition of the equipment, the power plant capacity is also affected by the schedule of the consumed power system capacities. At night, electricity consumption decreases, the so-called night power dip, which leads to the necessary natural decrease in the power unit load. This also affects the efficiency of the turbine unit [4].

2 Study of the power unit's efficiency operation under reduced loads

Unloading a power unit, though of a small capacity, has its own characteristics depending on the type of power unit. For example, coal-fired power units can only be unloaded up to 70% of their nominal capacity. With a greater decrease in power, the stability of the combustion of the flame in the boiler furnace may be disturbed. However, technical and economic indicators such as the net efficiency of the power unit and the specific consumption of equivalent fuel remain of high importance in the operation of the power unit under variable modes. To carry out the research on the change in efficiency of a 300 MW power unit at reduced loads the standard power unit of 300 MW with the turbine K-300-240-2 KhTGP (Figure 1) [5,6].

The research was carried out at the nominal operating parameters of a 300 MW power unit [7]:

- initial steam pressure 23,5 MPa;
- steam temperature 540 0C
- condenser steam pressure 3,43 kPa
- turbine unit power range 200...300 MW

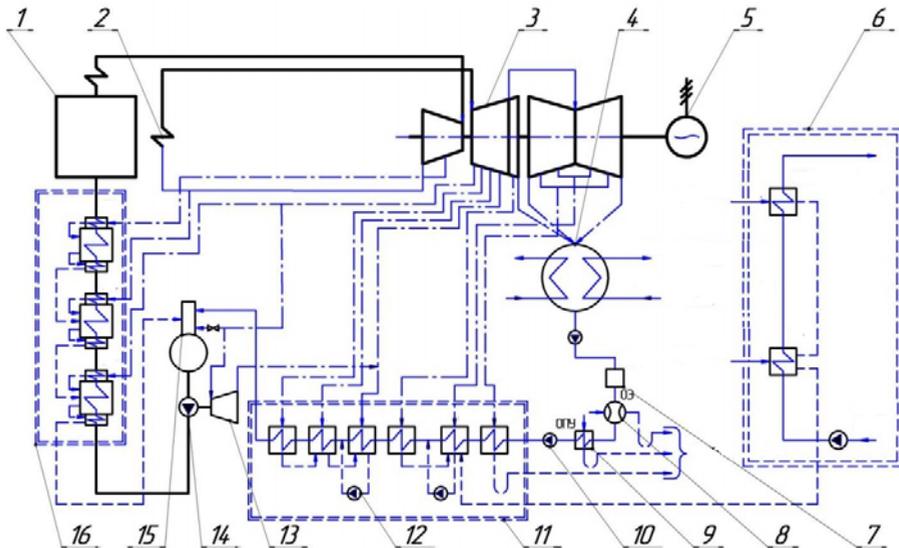


Fig. 1. K-300-240-2 KhTGP turbine plant:

- 1 – boiler; 3 – boiler superheater; 3 – steam-turbine; 4 – steam-turbine condenser; 5 – turbine generator; 6 – network installation; 7 – ejector; 8 – supporting ejector; 9 – water treatment equipment; 10 – condenser pump; 10 – LPH group; 11,12 – condensate pump; 13,14 – turbine driven feed water pump; 15 – deaerator; 15 – HPH group.

To carry out the research of operating modes of thermal power plant the mathematical model was developed implemented in the Excel software environment added by WaterSteamPro 6.5 the program to determine the parameters of steam and water for different pressure and temperature in different parts of technological scheme [8,9]. In the mathematical model, the net efficiency of a power unit (1) expresses the ratio of the generated electricity to the amount of heat of the burned fuel:

$$\eta_c^u = \frac{N_g \cdot (-\mathcal{E}_{ch})}{Q_c} \tag{1}$$

With a decrease in the electrical load, this indicator drops significantly, so for a 300 MW power unit the change in the net efficiency will look as follows (Figure 2):

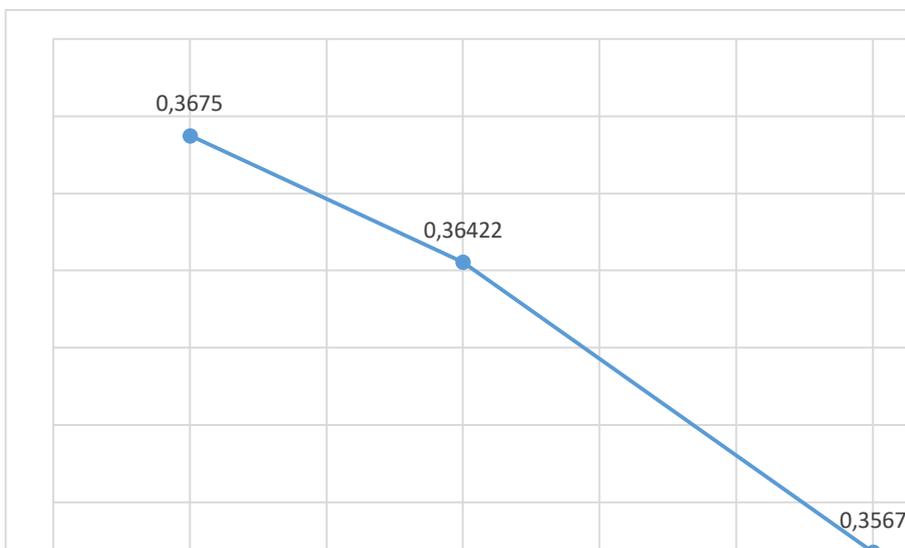


Fig. 2. Change in the net efficiency with a drop in power at the turbine unit.

With a decrease in the efficiency of the power unit, its economic efficiency decreases, this is shown by such indicator as the specific consumption of equivalent fuel, determined by the dependency (2):

$$b_{ym}^u = \frac{0,123}{\eta_c^u}, \quad \text{kg/(kW}\cdot\text{h)} \tag{2}$$

For a 300 MW power unit, the dependence of the increase in specific fuel consumption will be as follows (Figure 3):

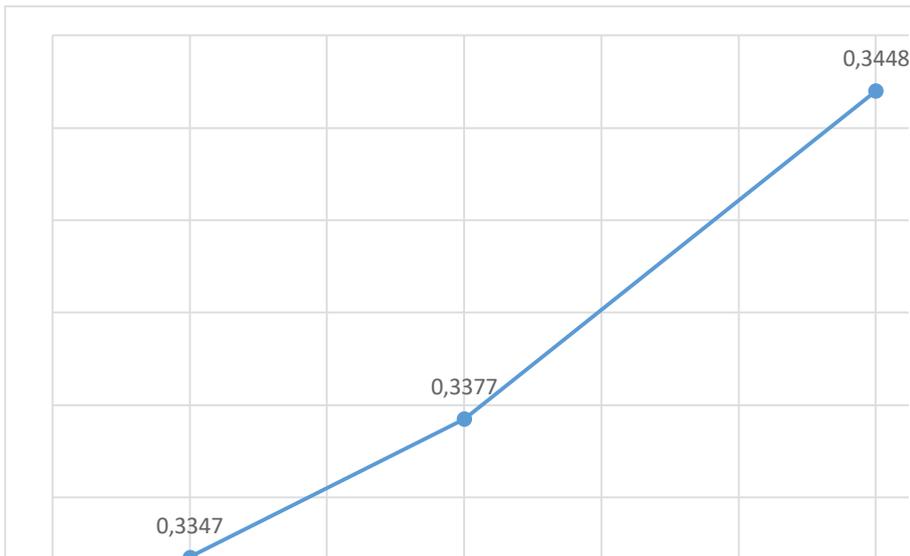


Fig. 3. Changes in specific fuel consumption with a decreased power unit load.

The 300 MW power unit at Novocherkassk GRES uses AC brand coal (anthracite coal), the internal heat of combustion of which is significantly lower than that of the equivalent fuel. The actual consumption of natural fuel will change with decreased load downward, however, the consumption of specific fuel for the generation of 1 kW of electric energy will increase (Figure 4):

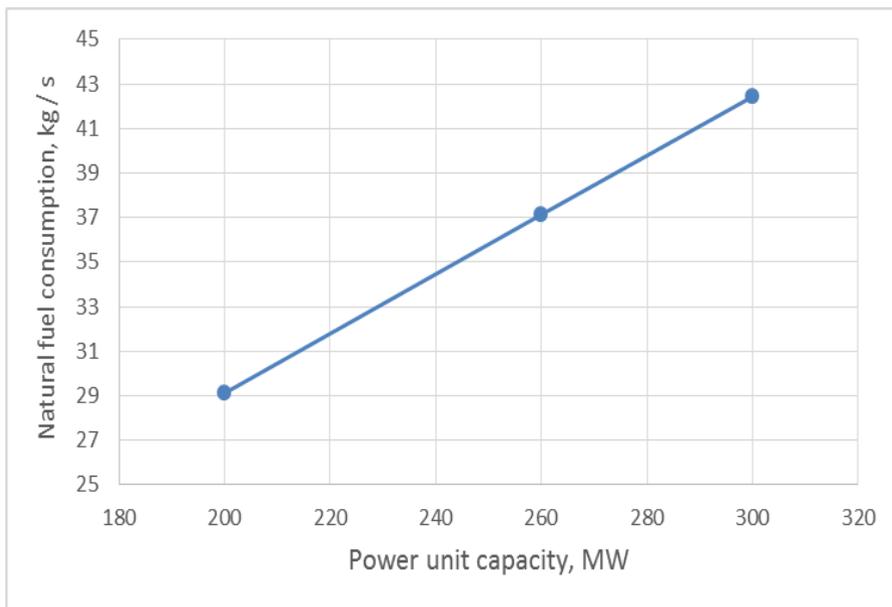


Fig. 4. Natural fuel consumption with various capacities of a 300 MW power unit.

In addition to showing the main characteristics of economic performance (Table 1) of the unit varies and secondary characteristics, such as specific consumption of heat for turbine. By reducing the load, this figure rises which in turn shows the deterioration of efficiency of the unit [10]. With a decrease in the load on the turbine unit, the heat

consumption for the generation of 1 kW of electricity is greater than at nominal loads (Figure 5):

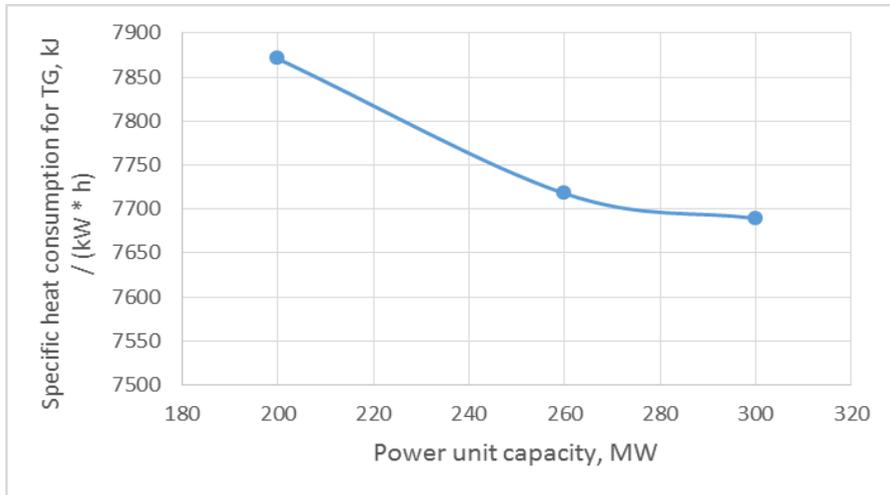


Fig. 5. Change in the specific heat flow turbine with power regulation unit.

Table 1. Technical and economic performance of the power unit in the range from 300 to 200 MW.

Parameter	Unit of measurement	300 MW	260 MW	200 MW
Q_{tu}	kW	664319,4	578984,2	454231,41
q_{tu}	kJ/(kW*h)	7689,33	7717,7	7870,92
N_e^{tpump}	kW	11021,5	10074,3	7756,26
η_{tu}		0,468	0,466	0,4574
η_{tu}^{eff}		0,4516	0,449	0,44
η_{tu}^a		0,4516	0,449	0,44
Q_{boil}	kW	680605,65	594812,4	466222,13
η_{pipe}		0,976	0,9734	0,9743
Q_s	kW	773106,27	677457,62	530510,1
η_s^{br}		0,3975	0,39422	0,3867
η_s^{net}		0,3675	0,36422	0,3567
q_s^n	kJ/(kW*h)	9795,92	9884,14	10092,5
B_{fuel}	kg/s	26,38	23,115	18,1
$B_{n.fuel}$	kg/s	42,41	37,16	29,1
b_{fuel}^n	kJ/(kW*h)	0,3347	0,3377	0,3448

3 Conclusion

Taking into account the results obtained during the study of the technological and economic parameters dependence of a 300 MW power plant on changes in the heating and electrical load, one can conclude as follows:

- with a decrease in electrical power, the efficiency of the power unit significantly deteriorates by more than 1% with a decrease in the load to 200 MW
- analysis of the results obtained shows a tendency towards an increase in the consumption of coal equivalent from 0.3347 grams/kWh to 0.3448 grams / kWh, with reduced loads.
- with a decrease in the load, the specific characteristics of the heat consumption of the turbine unit increase from 7689 to 7870 kJ/kWh in condensing mode, which shows a significant excess of the fuel consumption for the production of a unit of electricity;
- the results obtained in the course of the study are intended to optimize the operating modes of a 300 MW power unit with a steam turbine K-300-240-2 KhTGZ, which allows to reduce the cost of electricity generation

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