Design study on the efficiency of the thermal scheme of power unit of thermal power plants in hot climates

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Abstract. At the stage of pre-proposals unit of the thermal power plants for regions with a hot climate requires a design study on the efficiency of possible options for the structure of the thermal circuit and a set of key parameters. In this paper, the thermal circuit of the condensing unit powerfully 350 MW. The main feature of the external conditions of thermal power plants in hot climates is the elevated temperature of cooling water of the turbine condensers. For example, in the Persian Gulf region as the cooling water is sea water. In the hot season of the year weighted average sea water temperature of 30.9 °C and during the cold season to 22.8 °C. From the turbine part of the steam is supplied to the distillation-desalination plant. In the hot season of the year heat scheme with pressure fresh pair of 23.54 MPa, temperature 570/560 °C and feed pump with electric drive (EDP) is characterized by a efficiency net of 0.25% higher than thermal schem with feed turbine pump (TDP). However, the supplied power unit with PED is less by 11.6 MW. Calculations of thermal schemes in all seasons of the year allowed us to determine the difference in the profit margin of units of the TDP and EDP. During the year the unit with the TDP provides the ability to obtain the profit margin by 1.55 million dollars more than the unit EDP. When using on the market subsidized price of electricity (Iran) marginal profit of a unit with TDP more at 7.25 million dollars.

At the stage of pre-proposals unit of the thermal power plants for regions with a hot climate requires a design study on the efficiency of possible options for the structure of the thermal circuit and a set of key parameters. In this paper, the thermal circuit of the condensing unit capacity of 350 MW. An additional requirement for the provision of steam distillation desalination plant (DDP). The capital cost is less when using the equipment with the maximum possible standardization of components. Therefore, as a starting point adopted the steam power unit T-330-23,5-2 PJSC "Power machines".

Creation of new brands-ferrous metals heat-resistant steels and trumpets allows you to create the boilers and turbine at higher settings fresh pair [1]. Operation stages of turbines with reactive blading and new designs diaphragm and seals confirmed a significant increase in efficiency of steam turbines.

The main feature of the external conditions of thermal power plants in hot climates is the elevated temperature of cooling water of the turbine condensers. For example, in the Persian Gulf region as the cooling water is sea water. In table 1 shows statistical data on the temperature of the sea water in the vicinity of the city of Bandar Abbas, Iran. When using a typical condenser pressure is estimated with the data given in table 2.

Considered heat scheme with the structure proven for over 25 years. Internal relative efficiency of the regulatory level of efficiency is assumed to be 78.5 per cent, and the efficiency of pressure internal of the cylinder for 92.5 %. Efficiency of the last two compartments efficiency 93–93.5 %. The efficiency of tssd average of 93 %. The efficiency of the latter compartment of LPC of 79.2 %. The length of the working blades of the last stage of 960 mm. Despite the increase in thermal efficiency of the thermal circuit without de-aerator approximately 1% for the export version of the thermal scheme of power unit of 350 MW recommended circuit with the deaerator. In the thermal circuit without de-aerator when
starting from hot and hot conditions is no deaeration of the second regeneration heater, which leads to the appearance of microcracks in pipelines feed circuit is caused by filling them with cold water.

**Table 1.** Average per month and average for the season, sea-water temperature

| Month of the year | The temperature of the sea water | The number of hours | The average temperature for the season |
|-------------------|----------------------------------|--------------------|---------------------------------------|
| January           | 23.0                             | 744                | 22.78                                 |
| February          | 22.3                             | 672                |                                       |
| March             | 23.0                             | 744                |                                       |
| April             | 28.7                             | 744                |                                       |
| May               | 31.3                             | 720                | 30.91                                 |
| June              | 32.6                             | 744                |                                       |
| July              | 32.7                             | 744                |                                       |
| August            | 32.3                             | 720                |                                       |
| September         | 30.8                             | 744                |                                       |
| October           | 27.9                             | 720                |                                       |
| November          | 25.0                             | 744                | 25.15                                 |
| December          | 25.3                             | 720                |                                       |

The average temperature for the year: 27.94

**Table 2.** Operating parameters of the turbine condenser

| Option                                      | The cold season: January–March | The transitional seasons of the year: April, December | Hottest season of the year: May – November |
|---------------------------------------------|---------------------------------|------------------------------------------------------|-------------------------------------------|
| The temperature of the cooling water, °C    | 22.78                           | 25.15                                                | 30.91                                     |
| Cooling water consumption, m³/h             | 36000                           | 36000                                                | 42000                                     |
| The pressure in the condenser, kPa           | 6.2                             | 7.0                                                  | 9.5                                       |
| Duration, h                                 | 2160                            | 1464                                                 | 5136                                      |

Turbopump assembly PTNA 1100-350-17-4 (pump PN 1135-340-4A), PJSC "Proletarsky Zavod" provides the feed water supply to 1160 m³/h (1148 tons/h). The output pressure from the pump of 34.87 MPa. The turbine provides frequency regulation of the flow and pressure of a feed pump.
Distillation-desalination plant (DDP) with capacity of 200 m$^3$/h is connected to the manifold receiving the steam from the regenerative steam extraction number 4. The ejector DDP takes the steam out of the steam extraction number 3. In the calculation accepted the return of the condensate of heating steam in the mixing regenerative heater number 2, and the condensate ejector DDP derived from the thermal circuit. Loss of working medium from the thermal scheme adopted in the amount of 1% of the feed water flow rate (without losses in the DDP). These losses are summarized in two points the thermal circuit from the line of the main condensate after the condensate pump of the second stage and the cold line of a tract of prosperarea. The incremental consumption of water includes all losses of the working environment. Thermal cycle included unit demineralizer (UDM).

Considered thermal scheme of power unit with feed pump electric drive (EDP).

In the hot season of the year heat scheme with pressure fresh pair of 23.54 MPa, temperature 570/560 °C and feed pump with electric drive is characterised by efficiency net 0.25 % higher than thermal circuit with feed turbine pump (TDP). However, the supplied power unit with EDP is less by 11.6 MW. Calculations of thermal schemes in all seasons of the year allowed us to determine the difference in the profit margin of units of the EDP and TDP. During the year the unit with the TDP provides the ability to obtain the profit margin by 1.55 millions more than the unit EDP. When using on the market subsidized price of electricity (Iran) marginal profit of a unit with TDP more at 7.25 million dollars.

In Figure 1 shows a schematic of thermal scheme of power unit with pressure fresh steam 25.44 MPa and temperatures 570/570 °C. The above mode of operation at a power of 350 MW pressure in the condenser is 9.7 kPa. The 1045.3 t/h fresh steam flow the steam flow in a condenser 643 t/h. Mach Number at the average flow speed steam exit of the last stage of LPC is 0.3. Pairs of DDP is taken from the line from the exhaust to drive the turbine. For cooling of this vapor up to 130 °C is used the condensate from the line after the condensate pump 2-stage. Heat rate the turbine to produce electricity 7574 kJ/(kW·h). The net efficiency of the power unit when running on gas 42.09 %, and fuel oil 41.52 %.
Figure 1. Principle heat scheme of the power unit of 350 MW
In Figure 2 is a chart of the process of steam expansion in the turbine at temperatures 570/570 °C and a pressure of fresh steam 25.44 MPa

![Diagram of steam expansion process in the turbine](image)

**Figure 2.** The process of expansion of the steam in the main turbine and pump turbine in h,s - diagram

In Figure 3 is a chart of the distribution of heating in the regenerative heaters.
Figure 3. The distribution of heating in the regenerative heaters

Conclusions

1. Achieved energy efficiency of 330 MW turbines in the domestic turbine manufacture industry and the typical structure of the cycle arrangement with increased parameters of main steam and steam after reheating enables the design of a 350 MW condensing power unit for hot climate with net efficiency of at least 42% when operating on gas. During the cold season of the year, the efficiency is increased by at least 1%.

2. The power unit with an electric feed water pump (EFP) has 0.25% higher net efficiency than the power unit with a turbo feed pump (TFP). At the same time, under the conditions considered, the possible annual marginal profit of the power unit with a TFP exceeds the marginal profit of the power unit with a EFP by 1.55 mill. $. In special pricing conditions this difference can reach 7.25 mill.$.

References

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