Optimization of Cold End and Regeneration System of 1000MW Ultra-supercritical Secondary Reheat Unit

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Abstract: This paper takes the preparation project of high-efficiency ultra-supercritical secondary reheat 1000MW unit of Guohua Beihai Power Plant as the research object, takes the existing mature boiler and steam turbine high-temperature material as the boundary condition of selection, analyzes and compares the thermal economy and investment economy of the unit under different steam parameters, and thus determines the steam parameters. The cold end optimization analysis was carried out. This paper discusses the ways and methods to reduce the irreversible loss of temperature difference heat transfer and improve the overall energy efficiency of the steam turbine reheat system. The author has carried on the detailed analysis here, in order to provide the reference basis.

1. Introduction

Coal is the main source of power generation in China, with large pollution emissions. In the face of severe environmental protection situation, we should develop clean and low-pollution nuclear energy and renewable energy to generate electricity (wind, solar, biomass energy, etc.), along with improving the steam parameters, increasing the capacity of a single machine, and adopting secondary intermediate reheating. Aiming at the thermal system of the secondary reheat turbine set, this paper discusses the design scheme of the new thermal system and quantitatively calculates the economy under different schemes. Based on the analysis of the variation of the construction cost of the steam extraction pipeline and the heat recovery heater, the exhaust backpressure of the steam turbine is determined and the pressure of the main steam, the reheat steam and the extraction steam is optimized according to the different meteorological conditions. At the determined temperature of main steam and reheat steam, the maximum potential of the thermal system is excavated, so that the comprehensive thermal performance of the engineering unit can reach the optimal state.

2. Theory and application method of cold end optimization

2.1 Principle of Cold end optimization

The high thermal efficiency of a turbo-generator set is mainly achieved by increasing the initial steam parameters and reducing the back pressure of the unit. On the basis of Rankine cycle, the ultra-supercritical thermal generating set is optimized. The work process of the steam turbine can be seen in the Rankine cycle (See it in Fig.1):The Fig. 12341 schematic diagram of the inlet and exhaust parameters of Rankine cycle steam turbine in the figure shows that, if the inlet parameters remain unchanged, the exothermic temperature of the turbine will decrease significantly after the back pressure is optimized. 12 '3' 4 '1 is the schematic diagram of Rankine cycle after back pressure optimization drops.

In Fig. 1, when the cold end parameters of a steam turbine set move down, the average heat release temperature and the average heat absorption temperature of the steam turbine set will be reduced. Among them, the average exothermic temperature decreased significantly, while the average endothermic temperature was less affected by the cold end parameters and mainly affected by the steam inlet parameters of the steam turbine set, so the decrease was less.

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It is obvious that reducing the cold end parameters can improve the circulating heat efficiency.

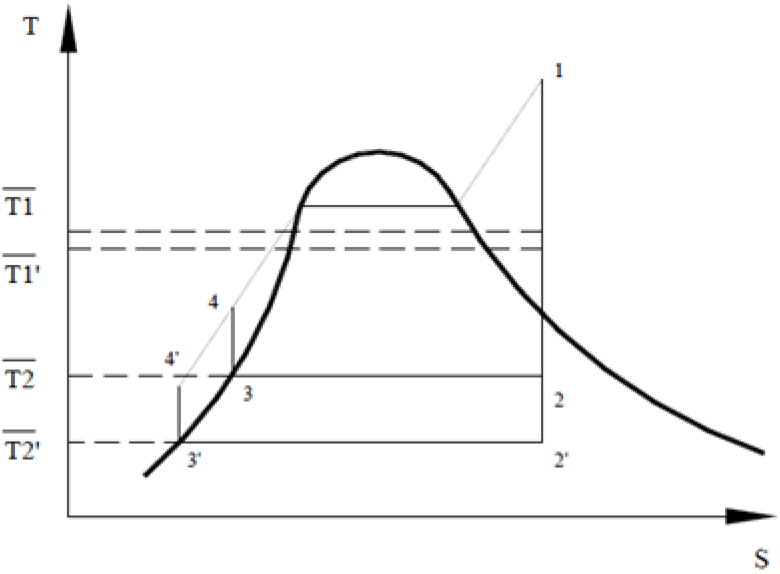

Fig. 1 Schematic diagram of Rankine cycle of steam turbine

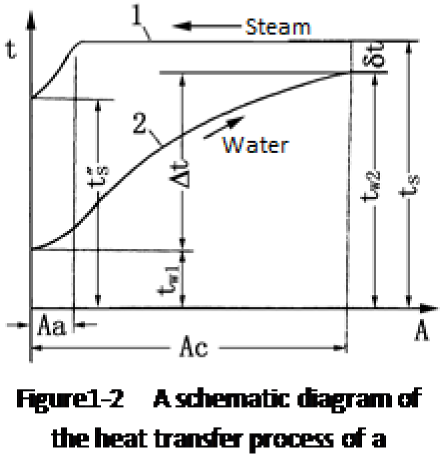

Fig. 2 Schematic diagram of heat transfer process of condenser

It can be seen from the thermal process of the surface condenser shown in Fig. 2 that the temperature of the condensed water after the steam exhaust of the steam turbine is determined by the inlet temperature of the circulating water, the outlet temperature of the circulating water, and the heat transfer end difference. The temperature of the circulating water inlet water is determined by the ambient temperature and the performance of the cooling tower; the outlet temperature of the circulating water is determined by the unit load and the amount of circulating cooling water; the heat transfer end difference is determined by the heat transfer area, the flow rate of the cooling water, and the thermal conductivity of the cooling tube material. The "cold end" of the thermal system of the power station is formed by a condenser, a low pressure cylinder and a water supply system.

2.2 Conventional cold junction optimization method

The water in the wet cooling tower is a heat sink, and the air is a heated body. The air absorbs heat from the water and then exits the tower and enters the atmosphere. Therefore, the outlet temperature of the cooling tower is closely related to the temperature and humidity of the environment, the thermal performance of the cooling tower, and the like. Beihai is located in the low latitude inland area north of the Tropic of Cancer. Its climate is obviously affected by the East Asian monsoon. The dry and wet are distinct, and the rain and heat are in the same season. The summer is very hot with a long time of the sunshine, and the air humidity is large; The winter time is short, the cold air in the north comes down to the south when the weather is cold, the spring cold is obvious, and the temperature difference between day and night is large.

Turbine back pressure is an important indicator to determine the energy consumption of the unit. When the other conditions are constant, the flow, temperature and flow rate of the circulating water supply system determine the back pressure of the unit [21]. The cooling tower has a sufficiently large cooling area to reduce the temperature of the circulating cooling water of the condenser, which is beneficial to reducing the exhaust pressure of the steam turbine and improving the effective downsizing of the unit, but increasing the construction investment of the cooling tower. Increasing the amount of cooling water, under a certain unit load, can reduce the temperature rise of the circulating cooling water of the condenser, and it can also reduce the steam exhaust pressure of the steam turbine, improve the thermal efficiency of the unit, but increase the power consumption of the circulating water pump. It is possible that the increased power generation is insufficient to compensate for the increase in the power consumption of the circulating water pump [22]. In order to achieve optimal investment benefits for Guohua Beihai units and create operational conditions for unit operation optimization, based on the meteorological data of Guohua Beihai Power Plant, the cold end of the unit should be optimized as a whole with the goal of high investment efficiency and economical unit operation, to determine the circulating water supply temperature, water supply flow, condenser heat exchange area and cooling tower design selection, turbine back pressure.

3. Optimization of regenerative system for ultra-supercritical secondary reheat 1000MW unit

3.1 Water supply and power generation system optimization of BEST machine

The water supply and power generation system based on the BEST machine is composed of steam inlet pipe, steam inlet regulating valve, exhaust pipe, exhaust pipe, feed water pump set (feed water pump and front pump), power frequency motor, speed regulating gear box, fixed-speed ratio gear box, transformer, etc., as shown in Fig. 3. BEST is coaxial with the feed water pump set and the power-frequency synchronous generator. One end of the shaft of BEST drives the feed water pump directly, and drives the pump after decelerating through the fixed-speed ratio gear box. The other end of the BEST shaft drives the synchronous generator at 3000rpm through a gearbox.

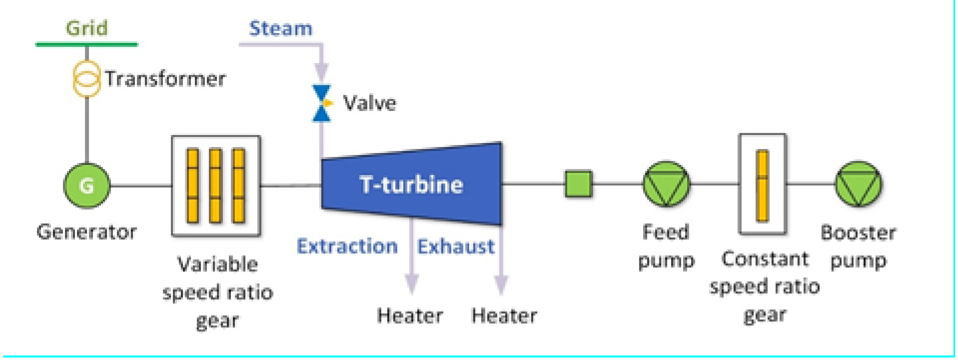

Fig. 3 Schematic diagram of connection structure between turbine and generator

The transmission mechanism of variable speed gearbox governor is composed of planetary transmission and fixed shaft transmission, among which planetary transmission is widely used in various fields due to its characteristics of automatic transmission and strong bearing capacity. Planetary gear consists of solar wheel, planetary wheel, gear ring, planetary frame and wheel shaft. The relative rotation of each gear is used to realize the conversion of different gear positions. The planet tooth ring does not move, the sun wheel drives the planet frame to achieve low block; The sun wheel does not move, the gear ring drives the planetary frame to realize the middle block; The sun wheel does not move, the planetary frame drives the gear ring to achieve high gear; The planet frame does not move, the sun wheel drive gear ring to achieve reverse gear.

Through the design of planetary gear row number and transmission relationship, the conversion of different gear positions of the transmission can be realized to achieve the effect of speed regulation, so as to meet the demand of frequent power supply.

3.2 Modeling and calculation optimization of thermal characteristics of n1000-31.5/600/620/620 steam turbine based on BEST machine

Fig. 4 shows the comparison between the heat recovery and extraction superheat of the BEST machine's thermal system and the external steam cooler's thermal system. By Fig. 4 can clearly see that the BEST machine, after 3 ~ 6 levels of extraction steam superheat were significantly lower, among them, 4, 5, and 6 levels of extraction steam superheat even reduced to 0 ℃. Therefore, it can be seen that the adoption of BEST can effectively reduce the irreversible loss caused by the temperature difference heat transfer of the regenerative heater, thus improving the circulation efficiency of the unit. At the same time, the steam inlet temperature of the corresponding high pressure heater is greatly reduced, which can save the amount of steam extraction pipe and heater high temperature material. In addition, since the steam side of these heaters is dominated by condensation heat transfer, the heat transfer area can be reduced, thus saving construction investment.

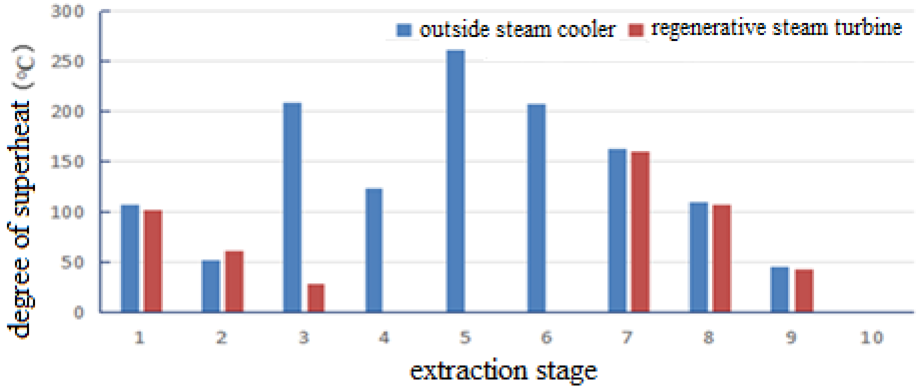

Fig. 4 Comparison of superheat of solid heat extraction in two thermal systems

Fig. 5 shows the comparison of the thermal efficiency between the n1000-31.5/600/620/620 steam turbine based on BEST machine and the thermal system based on external steam cooler. As can be seen from Fig. 5, when the unit is running at more than 55% load, the thermal efficiency of the BEST engine heat system is better than that of the external steam cooler, but when the unit load is lower than 55%, there is no significant difference between the two. After the unit adopts the BEST machine to reheat the steam, although the irreversible loss caused by the large temperature difference heat transfer of the four heaters is significantly reduced, the final feed water temperature is not lower than that of the external steam cooler, so the BEST system improves the thermal efficiency. Not very significant. When the unit is under low load, the feed water flow rate and temperature rise are reduced, the extraction steam flow is reduced, and the BEST machine uses the energy saving effect of the extraction superheat degree to be reduced.

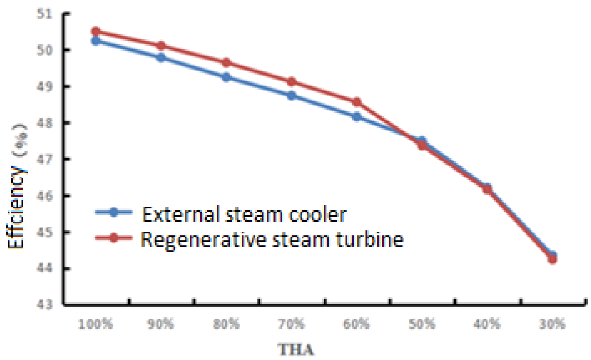

Fig. 5 Comparison of thermal efficiency random group load changes between BEST machine and steam cooler thermal system

4. Conclusion

This paper proposes that the optimization scheme can significantly reduce the steam turbine throttle in a section of load, but the adjustment effect of the steam valve and the relief valve is limited, and full load regulation cannot be achieved. The throttle regulation is still required under ultra-low load. To achieve the power matching between the small steam turbine and the feed water pump, the system design needs further optimization, and the control strategy needs to be further improved. The energy saving effect of the unit will continue to be improved on the basis of safe and reliable operation.

(1) The calculation process of this paper and the established simulation model do not consider the air leakage of the unit shaft seal. If the subsequent research can consider this part of the energy loss in the system, the calculation accuracy can be improved.

(2) In the calculation of variable load, only the typical load is calculated. In order to obtain the comprehensive variable working condition, the whole working condition can be calculated in the subsequent research.

(3) In the numerical simulation of the high water tower, only the single working condition is numerically simulated. In the subsequent research, the numerical simulation can be carried out for the variable working condition and even the whole working condition, and the more perfect simulation data can be compared for comparison. Optimize calculations to improve.

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