

Discussion on energy saving optimization of supercritical secondary reheat unit

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Abstract. It aimed at the secondary reheat ultra-supercritical unit to study the direction of energy saving, through comparing the design reasonable optimization and energy saving, improve the cycle thermal efficiency, reduce the coal consumption, achieve the goal of saving energy and reducing consumption. From the traditional heat extraction scheme, by setting the cooler, increase the heat series to design a new solution method, such as energy saving optimization scheme of different performance, investment, such as comparative analysis, finally to determine the best solution. Through the design of a series of studies show that for secondary reheat ultra-supercritical unit, can adopt the following means to improve the efficiency of generating units: one is to increase external steam cooler, make full use of the extraction period of heat; The second is to increase the steam recovery series and rationally distribute the enthalpy drops at all levels. After the above energy-saving optimization and transformation technology, the generating efficiency of the unit is increased by 1.6%, and the coal consumption of power supply is reduced by 6.6g/kWh, achieving a good energy-saving effect.

Keywords: Secondary reheat, Thermal system, External steam cooler, Optimization of regenerative series, Energy saving effect.

1 Introduction

China is a large coal consumption country, more than half of the coal is used for power generation, so it is necessary to strengthen the research on coal-fired generating units, adopt suitable ways to save energy and reduce consumption. Thermal power units has been developing rapidly in recent years, ultra supercritical second reheat unit was introduced into domestic thermal power market, in order to further improve the efficiency of power generation, require a second reheat of ultra-supercritical units to strengthen energy-saving optimization design, this article choose domestic mainstream of 1000 mw ultra-supercritical second reheat unit as the research object, revolves around the unit second reheat energy saving optimization design, Firstly, the performance and energy saving effect of the traditional scheme are analyzed, and the optimization design scheme is proposed on the basis of the traditional scheme, providing sufficient theoretical and data support for the

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future research and development of energy saving optimization design of the ULTRA-supercritical secondary reheat unit.

2 Preliminary design of thermal system for ultra-supercritical secondary reheat unit

2.1 Overview of conventional eight - stage extraction steam heat recovery scheme

At the present stage, ultra-supercritical units occupy a large share in China, but most of them are primary intermediate reheat units, using the conventional scheme, that is, equipped with eight-stage exhaust steam and heat recovery equipment. This scheme is relatively conventional and can be used as a reference unit. A variable pressure dc boiler is selected, and a steam turbine equipped with ultra-supercritical and primary intermediate reheat is configured. In the initial stage of unit operation, the main steam pressure is 26.5MPa, and after entering the reheat stage, the pressure changes to 5.555MPa. The unit is equipped with an eight-stage non-adjusted heat recovery and extraction system. The power generation efficiency can reach 44.78% and the power generation coal consumption is 273.9g/kWh during operation.

2.2 Secondary reheat unit based on conventional scheme (Scheme 1)

Secondary reheat unit and primary reheat unit are similar in principle, relatively simple, in the primary reheat unit on the basis of the increase of ultra-high pressure cylinder, to achieve secondary reheat, need to add reheater, medium pressure cylinder and other equipment, respectively set in different positions. During the normal operation of the unit, steam is first discharged from the high-pressure cylinder of the turbine, and then it undergoes an intermediate reheat. After entering the primary medium pressure cylinder, the secondary intermediate reheat is started, and then the steam is discharged into the low-pressure cylinder and finally enters the condenser. Compared with conventional primary reheat scheme, secondary reheat can improve power generation efficiency and is suitable for units with relatively high initial pressure ^{[1][2]}. Therefore, on the basis of the conventional scheme, secondary intermediate reheating equipment can be equipped, and the process parameters should be fine-tuned according to the actual situation. After adjustment, the scheme is as follows: First, the main steam pressure is raised to 31.9mpa, the temperature is consistent with the conventional scheme, and the heat recovery and extraction scheme remains unchanged. When the system is arranged, the advanced foreign experience is referred to. The heat recovery system is composed of hybrid deaerator, high pressure heater and low pressure heater. Attention should be paid to the selection of reheat steam parameters and pressure control in main steam pressure of 0.3 times ^[2], due to plan the optimized structure is more complex, in order to protect the safety of the unit, scheme optimization design to ensure the reheat steam temperature a little higher, but also control the boiler's heating surface temperature deviation, leave some allowance, appropriate for the reheat steam temperature control at 600 °C.

2.3 The performance comparison

Thermodynamic calculation was carried out to compare all aspects of performance of reference unit and scheme 1, and the data were shown in Table 3 below. It was found that

scheme 1 improved power generation efficiency by 1.81% and reduced power generation coal consumption by 10.41 g/kWh, which had obvious energy-saving effect.

Table 1. Performance analysis of reference unit and scheme 1.

Parameter	Reference unit	Scheme 1
Unit heat consumption rate/kJ·kWh ⁻¹	7402.16	7118.6
Power generation efficiency/%	44.75	46.56
Power generation coal consumption/g·kWh ⁻¹	274.57	264.16

3 Optimization of setting of external steam cooler in thermal system of secondary regenerative unit

During the production and operation of large thermal power units, the steam turbine will lose a lot of heat loss due to the high extraction superheat. As the name implies, the secondary reheat unit is designed with primary reheat and secondary reheat, leading to the high superheat during operation, bringing more losses. The extraction stage temperature is extremely high, forming a larger temperature difference. In order to solve this problem, a steam cooler can be added to properly release part of the heat by using superheat. On the one hand, it can reduce the loss caused by overheat, and on the other hand, the superheat heating can be used to improve the temperature of the water supply.

3.1 Setting external steam cooler on the basis of eight-stage secondary reheat unit (Scheme 2)

On the basis of scheme 1, two external steam condensers are set, adding two in total, one of the external steam cooler place between high pressure heater and boiler economizer, another place in the low-pressure heater and deaerator entry position, low collector, reference to a foreign power plant before and after the division of the way.

3.2 Optimize the location of external steam cooler (Scheme 3)

Reference foreign power plant set up later, found that the low pressure heater can reduce the amount of extraction, but not the aim was to raise the temperature of feed temperature, extraction steam temperature far beyond eventually feed temperature, therefore it is necessary to use this part of the degree of superheat, take the suitable way to transfer heat, based on the design concept, decided to layout optimization of steam cooler, Considering the actual situation of the thermal system, the two-stage steam cooler is finally set up based on the principle of cascade utilization, so that the low-pressure steam cooler can be arranged in the heat recovery system with high extraction parameters, which can rationally utilize the superheat, improve the water supply temperature, improve the power generation efficiency and reduce unnecessary coal consumption^[3].

3.3 Comparing the calculation results

The thermodynamic performance calculation of different schemes was carried out, and the calculation results were shown in Table 2. Compared with scheme 1, the power generation efficiency of scheme 2 was increased by 0.62%, and the coal consumption of power

generation was reduced by 3.59g/kWh. Compared with scheme 1, scheme 3 improves power generation efficiency by 0.91% and reduces coal consumption by 4.97g/kWh.

Table 2. Performance comparison of secondary reheat units.

Thermal economic index	Reference unit	Scheme 1	Scheme 2	Scheme 3
Unit heat consumption rate/kJ·kWh ⁻¹	7402.16	7118.6	7029.89	6986.6
Power generation efficiency/%	44.75	46.56	47.18	47.47
Power generation coal consumption/g·kWh ⁻¹	274.57	264.16	260.57	259.19

4 The thermal system of secondary reheat unit is further optimized

4.1 Adopt ten-stage heat recovery and extraction scheme (Scheme 4)

During the actual production and operation of the secondary reheat unit, as the unit is designed for secondary intermediate reheat, it will maintain a high superheat close to the exhaust port and lose a lot of heat, so the heat exchange effect cannot be guaranteed and the economy of the heat recovery system is affected. Therefore, it is necessary to adjust the allocation of enthalpy rise and collect the existing data to carry out reasonable calculation. It was found that most of the enthalpy rise was allocated to the low-pressure heater in the conventional heat recovery and extraction scheme. In order to further improve the feed water temperature, the heat was allocated to the high-pressure heater as much as possible. Therefore, the ten-stage heat recovery and extraction scheme was selected [4].

In optimizing the allocation of enthalpy rise, inconvenience, we must keep the other parameters in the intermediate pressure cylinder adding extraction, reached the standard of ten steps back to the heat, but also add heater and deaerator equipment, including high pressure heater is set near the extraction mouth, also set up the external steam cooler, have certain promotion effect to unit in the thermal efficiency, At the same time, this part of the heat transfer to the feed water part, in order to eliminate the negative impact of overheating too high, but also need to combine with the actual demand to improve the feed water enthalpy rise, high pressure heater from the original 160kJ/kg to 240kJ/kg, deaerator re-allocation, take 100kJ/kg.

4.2 Comparison of optimization results

After reasonable allocation of feedwater enthalpy rise is completed, thermodynamic calculation can be carried out to compare unit performance of different schemes, and specific data are shown in Table 3 below. Compared with scheme 1, scheme 4 improves the generating efficiency by 1.67% and reduces the coal consumption by 8.91g/kWh.

Table 3. Comparison of energy saving effects of different heat recovery series schemes.

Thermal economic index	Reference unit	Scheme 1	Scheme 2	Scheme 3	Scheme 4
Unit heat consumption rate/kJ·kWh ⁻¹	7402.16	7118.6	7029.89	6986.6	6887.1
Power generation efficiency/%	44.75	46.56	47.18	47.47	48.23
Power generation coal consumption/g·kWh ⁻¹	274.57	264.16	260.57	259.19	255.25

After a series of optimization design, the energy-saving effect of the unit is greatly improved, among which the energy-saving effect of scheme 1 is the most obvious. Although there is some improvement in the follow-up, but the range is not high, and there is no need to introduce any materials, and there is no need to improve the equipment effect, but there is still a long way to go from the international advanced level. After a series of optimization, such as adding an external steam cooler and location optimization, and adding steam extraction series, scheme 4 has the largest energy saving space, but the unit is also greatly changed, and the initial investment of equipment is relatively large. Therefore, when improving the unit, it can be rationally selected according to the actual needs. It should be noted that different improvement schemes have different scope of adaptation, and only the most suitable scheme can achieve the best energy saving effect [5].

5 Conclusion

Ultra supercritical unit increases the super high pressure cylinder, forming after reheat unit can improve the heat cycle temperature, let crew have higher power generation efficiency, at the same time also can reduce the coal consumption, but because of the second reheat, also increases the degree of superheat, regenerative system instead of part of heat loss, at the right position to consider setting external steam cooler, It can not only reduce the superheat of the steam in the extraction section, but also improve the temperature of the water supply. In order to ensure the energy saving effect, it is necessary to choose a separate scheme before and after. More than a reheat unit, secondary system configuration of the reheat unit is more complex, cannot allocate feed-water enthalpy rise, this can increase the heat series, through a series of optimization design, improve the efficiency of power generation and reduce coal consumption, and the optimization design does not need to use the new material, are relatively easier to operate, can undertake reasonable promotion.

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