A Study on the Arrangement of Outer Steam Cooler for 1000MW Double Reheat Ultra-Supercritical Unit

Weijun Mi[1], Haiwen Chen[2] and Wenfeng Fu[3]
[1]*Shaanxi Xin Yuan Clean Energy Co.Ltd. ,*
Yulin 719400, Shaanxi Province, China
[2]*School of Energy, Power and Mechanical Engineering,*
North China Electric Power University,Baoding 071003, Hebei Province, China
[3]*North China Electric Power University, Key Laboratory of Condition Monitoring and Control for Power Plant Equipment,*
Baoding 071003, Hebei Province, China

Keywords: Double reheat, fuel specific consumption, outer steam coolers.

Abstract: Taking the 1000MW double reheat ultra-supercritical unit as an example, based on analysis of the specific fuel consumption, the effects of following arrangement modes of outer steam cooler (OSC) on the energy consumption of unit are studied, such as the single series arrangement, double series arrangement and double parallel arrangement, etc., and subsequently the optimum arrangement mode of OSCs is obtained, in which case the variation law of specific fuel consumption is analyzed for each part of the thermal system and for the whole unit. Results show that by adopting the OSCs, the feed water temperature is raised, the irreversible loss of boiler is reduced, thus lowering the specific fuel consumption of unit. In the single arrangement mode, the specific fuel consumption can be reduced by 0.632g/kWh at most when the OSC is arranged at No.2 high pressure (HP) regenerative heater (RH);whereas in the double arrangement mode, the specific fuel consumption can be reduced by 1.122g/kWh at most when the coolers are arranged in series at RH2 and RH4.

1 INTRODUCTION

Technical upgrading of coal-fired power plants to achieve ultra-low emissions is an important measure to make the utilization of fossil fuels clean, improve the air quality and ease the resource constraints.

In recent years, the research on the double reheat technology has drawn more and more attention. Bugge et al. (2006) pointed out that, compared with single reheat unit, the extraction steam of the double heat unit has a higher degree of superheat, resulting in a high exergy loss of RH, which suppresses the unit efficiency further improved. In an effort to undermine the adverse effect of steam superheat at the heater inlet on the unit, Xu et al. (2015) devised a scheme to set up a back pressure extraction steam turbine in the system and calculated the improved results. Kan et al. (2014) pointed out that the use of OSC is another simple and effective measures, while having a good load adaptability. Niu et al. (2011) and Xia et al. (2015), respectively, for single reheat unit and double reheat unit, analyzed the effect of OSC on reducing fuel consumption.

The existing research results show that the OSC can play a significant role in reducing the superheat of the extraction steam at the inlet of the double reheat unit and increasing the efficiency of the unit. However, there are few reports on the influence of different arrangement of OSCs on the efficiency of double reheat unit. Therefore, with a 1000 MW double reheat ultra-supercritical unit as the research object, we proposed a variety of schemes to deploy OSCs. And the efficiency of the various schemes is compared, the better arrangement is obtained.

Mi, W., Chen, H. and Fu, W.
A Study on the Arrangement of Outer Steam Cooler for 1000MW Double Reheat Ultra-Supercritical Unit.
In *3rd International Conference on Electromechanical Control Technology and Transportation (ICECTT 2018)*, pages 59-62
ISBN: 978-989-758-312-4

2 METHODOLOGY

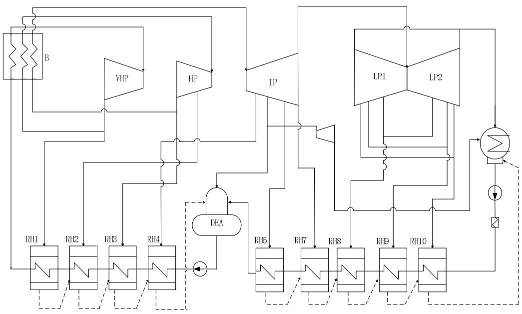

Figure 1: Thermodynamic system of the reference double reheat power plant.

Table 1: Extraction steam parameters at various stages of the system.

Extraction	Pressure (MPa)	Temperature (℃)	Superheat (℃)
1	8.932	415.624	112.824
2	6.009	525.462	249.778
3	3.334	433.645	193.865
4	1.855	529.304	320.691
5	1.038	442.431	260.921
6	0.718	389.589	123.609
7	0.392	309.989	167.109
8	0.127	189.002	82.572
9	0.059	118.761	33.391
10	0.022	61.984	0

Taking a 1000MW double reheat ultra-supercritical unit as the Base Case, its thermal system is shown in Fig.1. The initial parameters of the unit are 31MPa / 600 ℃ / 610 ℃ / 610 ℃, the second and fourth extraction steam are the first extraction after the first reheat and the second reheat, respectively. The regenerative system has four HP RHs, five low pressure (LP) RHs and a deaerator. Table 1 shows the steam parameters of the regenerative system. The OSCs are respectively arranged in single series mode on the extraction pipes of four HP RHs of the unit, all the feed water passes through the steam cooler and then enters the boiler.

3 RESULTS AND DISCUSSION

Table 2: Comparison of thermal efficiency among different arrangements of single OSC.

	Position of OSC	Feed water temperature (℃)	Superheat reduction (℃)	Thermal efficiency of the unit (%)	Specific fuel consumpti-on of the unit (g/kWh)
Base Case	-	304.503	-	50.979	266.826
Schem e 1	RH1	307.992	81.486	51.014	266.659
Schem e 2	RH2	312.452	208.126	51.099	266.207
Schem e 3	RH3	307.783	127.157	51.036	266.592
Schem e 4	RH4	308.562	227.481	51.085	266.361

Based on Ebsilon platform, the thermal system with integrated OSC is simulated and the system node parameters are obtained. The thermal efficiency parameters of the four schemes and the Base Case are calculated as shown in Table 2 by using the analysis of specific fuel consumption. When taking scheme 2, the OSC is arranged in front of the RH2, the best energy-saving effect can be obtained. Compared with the Base Case, the scheme can reduce the specific fuel consumption of the unit by 0.619 g/kWh and the thermal efficiency of the unit by 0.12%. The distribution of additional specific fuel consumption is shown in Table 3. Compared with the Base Case, the additional specific fuel consumption of each equipment in scheme 2 is reduced, except for the feed pump system.

Table 3: Distribution of specific fuel consumption in reference system and scheme 2.

Specific fuel consumption		Base Case	Scheme 2	Reduction of Specific fuel consumpti-on
Additional specific fuel consumption (g/kWh)	Boiler	119.473	118.632	0.841
	Turbine	6.738	6.733	0.005
	Condenser	11.860	11.815	0.045
	RHs	2.901	2.887	0.014
	Pump	1.058	1.069	-0.011
Specific fuel consumption of the unit (g/kWh)		266.826	266.216	0.610

Utilization of the steam superheat at the inlet of the heater reduces the heat exchange temperature difference of RH2 by 208.126K, reducing the additional specific fuel consumption of the RH by 0.014 g/kWh. At the same time, the temperature of feed water is increased by 7.949K, which reduces the additional specific fuel consumption of the boiler by 0.841g/kWh. Due to the increase of feed water mass flow and flow resistance, the additional specific fuel consumption of pump is increased by 0.011g/KWh, but the value is far less than the overall reduction of additional specific fuel consumption of other equipment. In conclusion, the contribution of the OSC to the thermal efficiency of the unit is mainly reflected in reducing the additional specific fuel consumption of the boiler and less affecting the reduction of the irreversible loss of the RH itself. The reason is that the utilization of the superheat of the steam at the heater inlet greatly increases the temperature of feed water to bring it closer to the optimal value of the system.

It can be seen from Table 1 that the superheat of the second extraction and the fourth extraction has the most potential for utilization. Therefore, when using double steam coolers, it should be arranged at RH2 and RH4, respectively, with series and parallel arrangement, recorded as scheme 5 and scheme 6.

Table 4: Thermal efficiency comparison of installing double OSCs.

	Temperature (℃)	Thermal efficiency of the unit (%)	Specific fuel consumption of the unit (g/kWh)
Base Case	304.503	50.979	266.826
Scheme 5	317.124	51.192	265.513
Scheme 6	312.857	51.158	265.742

In scheme 5, the main feed water passes through RH1 and then enters into the double OSCs respectively and then enters the boiler. In order to reduce the thermal deviation at the outlet flow mixing of double OSCs, the feed water mass flow into the RH2 steam cooler is set to be 70% of the total flow. In scheme 6, the inlet water supply of the double OSCs comes from the outlet of their corresponding RHs, respectively. According to the method of Ref. (XU Chuanpu, 1990), the feed water splitting coefficient is chosen. It is calculated that when the mass flow of RH2 steam cooler and RH4 cooler is respectively 5.5% and 3% of the feed water mass flow before shunting, the thermal efficiency of the unit is the best. The comparison of thermal efficiency between the two schemes and the Base Case is shown in Table 4.Compared with the Base Case, the temperature of feed water is increased by 12.621K, the specific fuel consumption of the unit is reduced by 1.313g/kWh, and the thermal efficiency of the unit is improved by 0.213%. Because of the smaller mass flow in the steam coolers in scheme 6, the temperature of the feed water is less increased and the reduction effect is lower than that of scheme 5.

Table 5 shows comparison of specific fuel consumption of between the best single OSC arrangement (scheme 2), the best double arrangement (scheme 5) and the Base Case. Compared with the single arrangement, when the double arrangement is adopted, the superheat of the steam at the inlet of the heater can be utilized to a greater extent. The additional specific fuel consumption of the boiler, turbine, condenser and RHs in the system is reduced. And there is not much difference between the additional specific fuel consumption of the pump system. Therefore, the use of double series arrangement is significantly better than single arrangement.

Table 5: Distribution of fuel specific consumption in different systems.

Specific fuel consumption		Base Case	Scheme 2	Scheme 5
Additional specific fuel consumption(g/kWh)	Boiler	119.473	118.632	117.934
	Turbine	6.738	6.733	6.861
	Condenser	11.860	11.815	11.768
	RHs	2.901	2.887	2.647
	Pump	1.058	1.069	1.081
Specific fuel consumption of the unit (g/kWh)		266.826	266.216	265.483

4 CONCLUSION

When using a single steam cooler, the best effect can be obtained by arranging it at the RH2, which can reduce specific fuel consumption by 0.619g/kWh. When using double OSCs arrangement, arranged in the RH2 and RH4 in series of the best way, can reduce specific fuel consumption 1.313g/kWh.

The OSC enhances the thermal efficiency of the unit mainly by reducing the additional specific fuel consumption of the boiler, while contributing little to reduce the additional specific fuel consumption of the RH itself.

ACKNOWLEDGMENTS

This research is supported by the Special Funds of the National Natural Science Foundation of China (No. 51606066).

REFERENCES

Bugge J, Kjær S, Blum R. High-efficiency coal-fired power plants development and perspectives[J]. Energy, 2006, 31(10–11):1437-1445.
Xu G, Zhou L, Zhao S, et al. Optimum superheat utilization of extraction steam in double reheat ultra-supercritical power plants[J]. Applied Energy, 2015, 160:863-872.
KAN Weimin, SONG Jinghui, ZHOU Luyao, et al. Analysis of variable working condition of installing external steam cooler for ultra-supercritical unit[J]. Turbine Technology, 2014, 01:63-65.
NIU Zhongmin, DING Yiyu. Analysis of thermal economy of installing external steam cooler of ultra-supercritical 1000 MW unit[J]. Thermal Power Generation, 2011, 12:67-69.
XIA Xiaohua, YANG Yu, FAN Shiwang, et al. Heat consumption analysis for the 1000 MW double-reheat steam turbine with external steam coolers[J]. Power Equipment,2015, 29,(3):160-163.
XU Chuanpu. Study on optimal feedwater splitting coefficient of external parallel type steam cooling system[J]. Power Station Auxiliary Equipment, 1990, 3:65-68.