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To cite this article: Fangming Xue *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **300** 042031

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Analysis on the Retrofit Scheme of a 660MW Unit Heater

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Abstract. This paper analyzes the cost and benefit of gas-water heat transfer and gas-gas heat exchange scheme by analyzing the retrofit scheme of a 660MW unit heater, and proposes a reasonable feasibility study plan. It can be used as a reference for the unheated wind turbine reconstruction in the southern region.

1. Introduction

A 2x660MW ultra-supercritical coal-fired generating unit was built in a power plant in the south, and flue gas desulfurization and denitration facilities were built simultaneously. The two units were put into operation at the end of 2015 and are basically in good operation. The two boilers are ultra-supercritical parameter variable pressure operation DC furnace, single furnace, one reheat, balanced ventilation, solid slag discharge, all steel frame, full suspension structure; boiler is open-air closed, II-type arrangement; boiler manufacturer is Shanghai Boiler Factory Co., Ltd. The boiler is equipped with two three-segment rotary air preheaters. The air preheater main shaft is vertically arranged, and the flue gas and air exchange heat in a countercurrent manner; the original air preheater inlet air heating mode adopts a hot air recirculation system. The direction of rotation of the air preheater is the flue gas side, to the secondary air, to the primary air, to the flue gas side. In the actual operation process, due to the large content of hot secondary air dust, the heat exchange surface of the rotary air preheater is seriously washed, and the problem of salt and ash accumulation in the cold end heat exchange area of the rotary air preheater appears during operation. After running the fan and the blower blade is very worn, the wear-resistant piece on the blade has been worn through and needs to be returned to the factory for treatment. Therefore, this plan intends to increase the air temperature of the air preheater inlet by adding a fan and blower (secondary) heater at the inlet of the air preheater, replacing the original hot air recirculation system, and discussing the feasibility of this[1, 2].

2. Design boundary conditions determination and calculation

2.1. Original calculation condition

The sulphur content of existing coal-fired power plants is less than 1.0%. If the wind speed is increased after technical upgrading, high-sulfur coal can be used to reduce fuel costs and offset the investment and operating costs of this transformation. Therefore, the original calculation conditions are calculated according to coal consumption using $S_y=1.5\%$, and the temperature rise of the heater is determined [3, 4].



2.2. Primary fan, blower outlet heater temperature rise and power accounting

In the actual operation process of SCR flue gas denitration, the problem of ammonia slipping is inevitable because the nitrogen oxides are discharged to the standard. The sulfur in coal combustion, after combustion, produces SO_3 and mixes with water vapor in the flue gas to form sulfuric acid vapor. Because the SO_3 content in the flue gas is much larger than the ammonia content, ammonia and sulfuric acid vapor react at a certain temperature to form ammonium hydrogen sulfate. Since ammonium hydrogen sulfate is formed in a certain temperature range, when the flue gas containing sulfuric acid vapor and ammonia is easily deposited on the cold end of the air preheater, the problem of salt accumulation of ammonium hydrogen sulfate is generated. Due to the viscous physical properties of ammonium bisulfate, it is difficult to remove the ammonium bisulfate salt on the air preheater by conventional steam purging. Eventually, due to the blockage, the running resistance of the air preheater increases, and the energy consumption of the primary fan, the induced draft fan, and the blower is increased, and the load on the boiler is affected, and the negative pressure fluctuation of the furnace is generated.

The water content of the fuel and the water vapor generated during the combustion of the fuel are the main sources of water vapor in the boiler exhaust. When the heat exchange surface temperature is lower than the dew point temperature of the flue gas ($45\text{--}65\text{ }^\circ\text{C}$), the water vapor condenses on the heat exchange surface, causing corrosion to the heat exchanger, and the condensed water traps the ash particles in the flue gas, resulting in the tail the heat exchanger has fouling accumulation. In addition, due to the sulfur content in the fuel, SO_3 is generated in the combustion process, and SO_3 is combined with water vapor to form H_2SO_4 vapor, which causes the dew point temperature of the flue gas to rise, the corrosion of the equipment increases, and the sulfuric acid vapor condenses to capture fly ash and ammonia. Salt accumulation problem. Therefore, the wall temperature of the heat exchange equipment is lower than the temperature of the flue gas dew point, which is the root cause of low temperature corrosion and low temperature accumulation of salt. In the actual production process, ammonium bisulfate is directly related to ammonia slip and coal sulfur. The melting point temperature of ammonium hydrogen sulfate is $147\text{ }^\circ\text{C}$. When the metal wall temperature of the air preheater is lower than this temperature, ammonium hydrogen sulfate vapor will deposit on the surface of the air preheater to form a salt. At present, the sulphur content of the existing coal-fired coal in the power plant is basically less than 1.0%. In order to reduce the production cost, after increasing the heater device and increasing the outlet air temperature of the primary fan and the blower, the sulphur content can be changed to 1.5%. Coal burning. According to the calculation formula of flue gas dew point of "Boiler Unit Thermal Calculation Standard Method", when the sulfur content of coal-fired boiler is 1.5%, when the water content is 10%, the dew point temperature of the flue gas is $150\text{ }^\circ\text{C}$, that is, the design of the heater is cold. The integrated temperature of the end should be $150\text{ }^\circ\text{C}$. The design requires that the sum of the exhaust temperature of the boiler (the exhaust temperature of the heater outlet) and the ambient temperature (wind temperature) should be higher than the combined temperature of the cold end. In the winter, the lowest temperature in the region is calculated at $5\text{ }^\circ\text{C}$, and the exhaust temperature of the boiler is $125\text{ }^\circ\text{C}$. The sum of the current boiler exhaust temperature and the ambient temperature is calculated to be $130\text{ }^\circ\text{C}$ lower than the combined cold junction temperature of the flue gas. The sum of the exhaust gas temperature at the outlet of the air preheater and the ambient temperature is lower than the cold end of the sulfur-containing 1.5% sulfur-containing flue gas, which is $150\text{ }^\circ\text{C}$, which causes the sulfuric acid to condense at the cold end of the air preheater to produce acid dew point corrosion, and escapes from the flue gas. The ammonia forms crystallization of ammonium hydrogen sulfate, causing serious salt accumulation and corrosion problems in the cold end air preheater.

In order to solve the problem of salt accumulation and corrosion of the air preheater, the integrated temperature of the cold end of the boiler air preheater should be increased by $10\text{--}15\text{ }^\circ\text{C}$ higher than $150\text{ }^\circ\text{C}$. By increasing the exhaust gas temperature or increasing the cold air temperature at the inlet of the rotary air preheater, the sum of the exhaust gas temperature and the inlet air temperature can be made larger than the cold end integrated temperature. According to the calculation of the minimum outlet temperature of the winter air preheater is $125\text{ }^\circ\text{C}$, according to the cold end integrated temperature should

be calculated than the cold end integrated temperature 150°C high $10\text{--}15^{\circ}\text{C}$ design, the inlet air temperature of the heater must be greater than 35°C ($150 + 10 - 125 = 35$), that is, the air temperature of the air inlet of the air preheater should be $35\text{--}40^{\circ}\text{C}$, according to the air temperature of the air preheater inlet 40°C , the design temperature rise of the heater should be determined to be 35°C , which can guarantee the winter situation. The equipment does not suffer from corrosion and salt accumulation. The 35 degree temperature rise determines that the total heat exchange power of the heater is 23400kW .

3. Heat source comparison

3.1. Heat source comparison

The heater is usually heated by hot water or steam as a heat source. The amount of water heated by hot water is large, the heat exchange area of the equipment is large, and the system resistance is large, but the hydrophobic system is not required, and the energy consumption is low; steam heating is usually The auxiliary steam of the power plant is used as the steam source, the heat exchange area of the equipment is small, the equipment volume is small, the system resistance is small, but the hydrophobic system needs to be increased. The following is a comparison of the two heat sources.

3.2. Using gas-water heat exchange

3.2.1. Using low-low temperature economizer outlet hot water as heat source. At the tail of the boiler generator set, four low-temperature economizers are arranged on the inlet flue of each electrostatic precipitator as waste heat recovery devices, and condensed water is used to recover waste heat of flue gas, wherein the condensed water is led from the 7# low-adding outlet condensate pipe to the electricity After the low-efficiency economizer is installed in the pre-flux of the dust collector, the 6# low-input inlet is connected to reduce the inlet flue gas temperature of the electrostatic precipitator to 95°C to improve the dust removal efficiency of the electrostatic precipitator. The outlet hot water temperature of the low temperature economizer is $98\text{--}100^{\circ}\text{C}$. If the low temperature economizer outlet hot water is used as the heater heat source, the cold primary air and the cold secondary air are exchanged, and the inlet water temperature of the heater is 98°C . The outlet temperature of the heater is calculated at 65°C . The heat exchange temperature of the heater and hot water is 48°C . Calculated according to the cold air temperature of 5°C , the air temperature is increased by 35 degrees, that is, the outlet air temperature of the primary and secondary fans is 40°C . The maximum required hot water flow of the unit is 550t/h . The temperature drop of the inlet and outlet of the existing boiler boiler is calculated at 30°C . The maximum hot water flow that the low-temperature economizer can provide is 550t/h . However, due to the actual operation of the power plant, the hot water flow of the low-temperature economizer is usually $220\text{--}300\text{t/h}$, the maximum is 550t/h , especially in winter, it can't reach the maximum amount of hot water. Because the heat exchange water is insufficient, it can't meet the requirements of 5°C below winter, then the scheme is not strong.

3.2.2. Using No. 6 low-adding outlet condensate as heat source. The condensed water of No. 6 low-adding outlet is used as the heat source. Under the normal rated working condition, the water temperature is 125.6°C , and the heating water is taken out from the condensed water mother pipe for $\Phi 457 \times 19$, and sent to the primary air and the blower outlet for heat exchange, and then returned to No. 6 Low inlet condensate main pipe, the diameter of the parent pipe is also $\Phi 457 \times 19$, and the return water temperature is 70°C . The pipeline needs to be sent from the deaeration room of the turbine room to the rear of the boiler room with a low heater arrangement. The pipe is slightly longer. The heat exchange heat source of this scheme has higher taste, heat exchange area and equipment volume are smaller than the scheme. The hot water circulation of the single unit heater is 375t/h , which is smaller than the scheme. The mother tube has sufficient condensed water and the system is highly adjustable. It can meet the heat transfer requirements in extreme winter temperatures. The heat energy consumed by this scheme is

supplemented by the low heating of No. 6, which is equivalent to the consumption of 6-stage low-pressure steam.

3.3. Using gas-vapor heat transfer

3.3.1. Using the induced draft fan back pressure exhaust steam source. The auxiliary steam of the power plant is 4-stage extraction (1.36MPa, 397°C), 4-stage extraction steam supply to the boiler feed pump steam turbine and deaerator, plant steam, and the inlet fan turbine inlet is the boiler low temperature reheater. The outlet (5.63MPa/512°C) is provided, the small steam turbine model is B3.8-5.3/1.3, the steam exhaust steam parameter is 1.3MPa, 350°C. At present, when the surrounding heat load is insufficient, the exhaust steam is sent by the $\Phi 425 \times 10$ pipeline. To the auxiliary steam box, an external heating interface is reserved. The heating steam of the heater can be used as the steam source for the extraction steam of the auxiliary steam box and the back pressure exhaust steam of the induced draft fan, and the heating steam source can be directly extracted from the connecting pipe between the back pressure exhaust pipe and the auxiliary steam header of the induced draft fan. This pipe is located closer to the primary fan and blower outlet.

The steam parameter is 350 °C, 1.3 Mpa, this steam is used as a heat source to increase the inlet air temperature of the primary and secondary air. The rated steam exhaust flow rate of a single unit induced draft fan turbine is 58t/h, which can meet the heat exchange requirements of the heater. However, the steam taste is higher and the value is larger. In the case of strong external heating demand, the economic loss of this program is large.

The steam pressure before entering the heater is 1.3Mpa, and the outlet temperature of the heater is calculated at 95°C. The heat exchange temperature between the steam and the air of the steam heater is 105°C. The heat source pipe diameter of this scheme is $\Phi 426 \times 10$. The distance between the primary fan and the blower is relatively close, and the volume of the equipment is the smallest. The hydrophobic system after heat exchange needs to be considered. The hydrophobicity after heat exchange is collected by the drain tank and then pumped to the deaerator with a drain pump. The heat energy consumed by this solution is a 4-stage low-pressure extraction, and the thermal energy taste is the highest.

3.3.2. Using 6-stage low-pressure extraction steam as steam source. The steam turbine of the power plant has eight stages of regulated extraction. The six-stage extraction steam is supplied to the No. 6 low-pressure heater. The steam parameter is 0.25 MPa and the temperature is 198 °C. The diameter of the main pipe is $\Phi 820 \times 12$, and the pipe needs to be sent from the deaeration room of the steam engine room to the rear of the boiler room with a heater arrangement layer. The pipe is long. Compared with the scheme 4, the equipment volume is relatively small, and the impact on the system is small, and the investment is large.

4. Scheme comparison

1. Scheme 5 uses the steam exhaust fan as the heat source of the heater. The exhaust pipe is close to the installation position of the heater, and the newly added steam main pipe is the shortest. The temperature of the heat source is higher, the heat exchange area of the heater is the smallest, the weight is the lightest, and the initial investment of the project is small. However, due to the higher steam rating, the project runs at the highest cost. Due to the small size of the device, a rotatable structure can be adopted. When the heater does not need to be put into operation, the heater can be rotated to a position parallel to the flue by rotating the execution structure, thereby reducing the problem of increased resistance caused by the heater. .

2. Scheme 2 uses low-temperature economizer to export hot water, adopts 6# low-addition steam extraction and 6# low-addition steam extraction condensate, and replaces the same grade of steam. The equipment investment is moderate and the equipment operation cost is moderate.

3. Scheme 1: The installation position of the low-temperature low-temperature economizer is in the tail flue before the boiler dust collector. The low-level hot water outlet position is close to the installation

position of the heater, and the main water supply pipeline is short. However, due to the limited heat source provided by the low-temperature economizer, the water volume is usually 220t/h-550t/h, corresponding to an increased temperature rise of 15 degrees to 35 degrees; during extreme winter temperature operation, and under low load conditions, at this time The amount of circulating water flowing out of the province is insufficient, and it is unable to meet the requirement that the air outlet temperature of the fan is increased by 35 degrees. Therefore, this program will not be adopted.

4. Scheme 6 uses 6# extraction steam as the heat source of the heater. Because the heat source temperature is high and it is condensing heat exchange, the heat exchange area and equipment weight of the heater are second only to the heater with steam exhaust fan as the heat source. Device. However, due to the lower steam pressure and larger steam flow, the main steam pipe used has the largest diameter, and the heat source point is far away from the installation position of the heater, resulting in a large investment in the main steam pipe. This program is also not recommended.

5. Scheme 2 uses 6# low-addition condensate as the heat source of the heater. Because the 6# low-increased outlet water temperature is high, the pipeline diameter of the scheme is the smallest, and at the same time, the temperature rise of the air temperature at the outlet of the heater is exceeded during winter operation. 35 ° C design requirements, equipment heat transfer surface and weight between 6 # low plus steam extractor and low temperature economizer hot water as a heat source of the heater, equipment investment and operating costs are relatively moderate. This program is ideal.

6. Scheme 3: 7# low-addition hot water is used as the heat source of the heater. The scheme has the lowest steam level and the lowest operating cost. After heat exchange, return to the 7# low inlet, the return water temperature is 50 °C, but due to the lower temperature of the heat medium and the larger flow rate, the initial investment of the scheme is larger, and the heat exchange area and weight of the equipment are higher. Moreover, the increase in the volume of the equipment leads to an increase in the resistance of the new heater to the primary and secondary wind tunnels, resulting in an increase in the power of the primary and secondary air blowers.

7. Scheme 4: Use the 7# low-supply outlet to the low-province inlet condensate main pipe as the heater heat source. After heat exchange, return to the low-sector outlet to the 6# low-injection mother-tube, the heat source temperature is the same as the scheme 3, heat exchange. The temperature of the back water is 45 °C. Since the temperature difference is 5 °C, the size of the equipment is larger than that of the third scheme. However, the required pressure head of the circulation pump can minimize the pressure difference of the existing system, and the heat exchange pipeline can be operated by using the existing pipeline. The cost is also the lowest. However, the alternative steam rating is the same as Schemes 1, 2 and 6.

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