Technical Transformation and Energy saving Analysis of Desulfurization System in Coal-fired Power Plant

Ming Chi
Datang Northeast Electric Power Test Research Institute Co., Ltd, Changchun, Jilin, 130000, China
cm17390009267@163.com

Abstract. Taking a 200 MW coal-fired power plant in North China with a limestone-gypsum wet desulfurization system transformation project as an example, the effect of energy-saving transformation of the desulfurization system was evaluated by analyzing the impact of the transformation on the desulfurization efficiency and main energy-consuming equipment. The practice shows that the desulfurization efficiency is greatly improved and the average energy consumption of the desulfurization system is reduced by 29%, achieving the purpose of improving efficiency and saving energy.

1. Introduction
Limestone-gypsum wet desulfurization is the most widely used desulfurization process in large coal-fired power plants in my country, with a market share of over 85%. As national environmental protection laws and regulations become more and more stringent, power plants have also put forward higher requirements for the performance of environmental protection equipment. Coal-fired power plants began to implement the ultra-low emission policy in 2014. As of 2018, the ultra-low emission retrofit units put into operation nationwide accounted for 80% of the total coal-fired power generation units [1-3]. Most of the ultra-low emission transformation of the desulfurization system is carried out on the basis of the original system. Due to the unreasonable flue layout and the aging of the equipment, there is a general demand for energy saving and economic improvement. Coal fired power plants are important control objects for China to achieve the goals of carbon peak and carbon neutralization by 2030 and 2060 respectively. Energy saving transformation is one of the ways to achieve this goal [4].

Based on an engineering example of a coal-fired unit's desulfurization system energy-saving transformation, this paper uses the continuous flue gas monitoring system (CEMS) monitoring data and field test results to analyze the impact of the transformation on the desulfurization efficiency and equipment, and evaluate the effect of the desulfurization system energy-saving transformation.

2. Process status of desulfurization system
A 200MW coal-fired power generation heating unit in North China adopts a limestone-gypsum wet desulfurization process, equipped with 5 slurry circulation pumps and 5 spray layers, and adopts a three-layer ridge demister. The design flue gas volume at the inlet of desulfurization tower is 858366 Nm³/h(dry basis, 6% O₂), the flue gas temperature is 147 °C, the particulate matter content is ≤10 mg/Nm³, and the SO₂ content is 3000 mg/Nm³. The inlet flue gas parameters of the desulfurization tower are shown in Table 1. The outlet flue gas is subject to ultra-low emission standards, that is, the
emission concentration of soot, sulfur dioxide, and nitrogen oxides (6% O₂) shall not exceed 5 mg/Nm³, 35 mg/Nm³ and 50 mg/Nm³ respectively.

Table 1. Flue gas parameters.

| Item                        | Unit  | Data  | Remark          |
|-----------------------------|-------|-------|-----------------|
| 1  Flue gas parameters      |       |       |                 |
| Flue gas flow               | Nm³/h | 943784| Wet basis,6%O₂  |
| Flue gas flow               | Nm³/h | 858366| Dry basis,6%O₂  |
| Design flue gas temperature | ℃     | 147   |                 |
| 2  Pollutant concentration at the entrance |       |       |                 |
| SO₂                         | mg/Nm³| 3000  | Dry basis,6%O₂  |
| SO₃                         | mg/Nm³| 50    | Dry basis,6%O₂  |
| HCl                         | mg/Nm³| 50    | Dry basis,6%O₂  |
| HF                          | mg/Nm³| 30    | Dry basis,6%O₂  |
| ash                         | mg/Nm³| 30    | Dry basis,6%O₂  |

The desulfurization system currently has a need to save energy, reduce consumption, and improve economy. The main reasons are unreasonable layout of spray layer of desulfurization system, insufficient output of slurry circulating pump, poor atomization effect of nozzle, low spray coverage rate and low desulfurization capacity of spray layer, resulting in the increase of number of slurry circulating pumps and power consumption in operation; The design liquid gas ratio of the empty absorber is high, but the utilization rate of the actual slurry is low, and there is no power saving adjustment method; Due to the blending of coal, the inlet SO₂ has been operating beyond the design value for a long time, which brings great difficulties to the operation adjustment; In addition, the power saving of the desulfurization system was not considered during the transformation of the desulfurization system, resulting in the high auxiliary power consumption rate of the desulfurization system. The highest auxiliary power consumption rate of desulfurization system is 2.5%.

In order to solve the problem of low desulfurization efficiency and high energy consumption of the desulfurization system, domestic coal-fired power plants mainly improve the performance of the desulfurization system by optimizing spraying, adding efficiency devices (alloy trays, swirling couplers, etc.), and optimizing the flow field [5-7]. In this paper, gas liquid chaos reactor technology is used to improve gas-liquid reaction efficiency and achieve the purpose of energy saving.

3. Transformation project

3.1. Main energy-consuming equipment

A typical system consists of 6 subsystems: absorbent preparation system, flue gas system, absorption system, gypsum dehydration system, process water system and desulfurization wastewater treatment system. According to the analysis, there are three types of energy-consuming equipment in the energy-consuming equipment of the desulfurization system that account for more than 10% of the daily power consumption, namely induced draft fans, slurry circulation pumps and oxidation fans. When studying the energy consumption of the wet desulfurization system, some scholars found that the power consumption of the absorption system and the flue gas system was significantly higher than that of the other four subsystems. The daily power consumption accounted for more than 90%, which were the two main energy-consuming systems [8]. The main operation parameters of induced draft fan, slurry circulating pump and oxidation fan are shown in Table 2.
Table 2. Operation parameters of main equipment.

| Equipment name                      | Rated current (A) | Motor power (kW) | Lift (m) | Flow (Nm³/h) |
|-------------------------------------|-------------------|------------------|----------|--------------|
| No.1 slurry circulating pump        | 70.49             | 630              | 16.84    | 8785         |
| No.2 slurry circulating pump        | 91.6              | 800              | 20.5     | 8785         |
| No.3 slurry circulating pump        | 79.9              | 710              | 18.67    | 8785         |
| No.4 slurry circulating pump        | 92                | 710              | 22.4     | 6400         |
| No.5 slurry circulating pump        | 92                | 710              | 24.37    | 6400         |
| No.1/No.2 Oxidation fan             | /                 | 412              | /        | 8000         |
| No.1/No.2 Induced draft fan         | /                 | 2400             | /        | 615000       |

3.2. Transformation contents

The gas liquid chaos (GLC) reactor was added in this transformation. The core structure of GLC technology is the disturbance mass transfer part. Different from the purpose of trays and sieve plates is to improve efficiency, the main function of the disturbed mass transfer part is to improve the utilization rate of the slurry for the purpose of energy saving. Indirectly, the contact time between the slurry and the flue gas is increased, the specific surface area is increased, and the desulfurization efficiency is improved while saving energy. There is almost no liquid holding layer on the disturbed mass transfer part, and the flue gas resistance is only about 150Pa.

This transformation optimizes the slurry spraying and replaces the nozzles. The new nozzle adopts a hollow cone nozzle. The angle of the nozzle on the circumference of the tower wall is 90°, and the angle of other nozzles is 110-120°. The first to third spray layer flow rate is 8785 Nm³/h, and the fourth and fifth spray layer flow rate is 6400 Nm³/h.

Due to multiple technical transformations, the flue layout is unreasonable, there are many turns, and the turning angle is too large. Therefore, this transformation optimizes the design of the original flue and the elbow of the clean flue to reduce the resistance of the flue gas.

4. Transformation effect analysis

4.1. Desulfurization efficiency analysis

Under normal circumstances, the unit can not run at full load, and most of the unit load is between 70%-90%. Before and after the transformation, the desulfurization efficiency of the desulfurization system can reach more than 99%, but the number of slurry circulating pumps is not the same. According to the online detection data of sulfur dioxide in desulfurization system under different loads, the total desulfurization efficiency is calculated, and then the average desulfurization efficiency of each layer is calculated. In this paper, the data of long-term stable operation of the unit before and after the transformation are counted, and the results are shown in Table 3.

It can be seen from table 3 that before the transformation, when the flue gas is under high load of the boiler, five spray layers are operated, and the average SO₂ concentration of the original flue gas is less than 3417 mg/Nm³, which can ensure the ultra-low emission of sulfur dioxide. After the transformation, three spray layers are operated, and the average SO₂ concentration of raw flue gas is more than 3424 mg/Nm³, which can ensure the ultra-low emission of sulfur dioxide. The reason is that the gas-liquid reaction efficiency is improved and the desulfurization energy consumption is greatly reduced by increasing the efficiency increasing layer and optimizing the spray layer.
### Table 3. Desulfurization efficiency data.

| Unit   | MW | Layer | Number of layers | Inlet SO2 concentration | Outlet SO2 concentration | Total desulfurization efficiency | Desulfurization efficiency of each layer |
|--------|----|-------|-------------------|-------------------------|--------------------------|-----------------------------------|----------------------------------------|
| Before transformation |     |       |                   |                         |                          |                                   |                                        |
| 140    | 5  |       |                   | 3417                    | 13.0                     | 99.62                             | 67.19                                  |
| 150    | 5  |       |                   | 3319                    | 15.6                     | 99.53                             | 65.77                                  |
| 160    | 5  |       |                   | 3300                    | 14.3                     | 99.56                             | 66.22                                  |
| 170    | 5  |       |                   | 3167                    | 16.1                     | 99.54                             | 65.92                                  |
| After transformation |     |       |                   |                         |                          |                                   |                                        |
| 140    | 3  |       |                   | 3424                    | 12.8                     | 99.63                             | 84.53                                  |
| 150    | 3  |       |                   | 3883                    | 15.0                     | 99.61                             | 84.26                                  |
| 160    | 3  |       |                   | 3760                    | 16.0                     | 99.58                             | 83.87                                  |
| 170    | 3  |       |                   | 4144                    | 15.3                     | 99.63                             | 84.53                                  |
| 200    | 4  |       |                   | 4830                    | 15.5                     | 99.68                             | 76.22                                  |

#### 4.2. Energy consumption analysis

Due to the two in one transformation of induced draft fan and booster fan of desulfurization system, the energy consumption of desulfurization flue gas system is distributed according to the proportion of energy consumption of original equipment, and the energy consumption of desulfurization flue gas system is calculated as 40% of the total energy consumption of induced draft fan.

The energy consumption of desulfurization system is affected by many factors, such as flue gas condition, limestone quality, operation adjustment and equipment status [9]. The transformation mainly improves the slurry reaction and reduces the flue gas resistance, thus greatly reducing the energy consumption of the absorption system and the flue gas air system. Under different loads, the energy consumption of desulfurization system is shown in Figure 1.

![Figure 1. Energy consumption diagram of desulfurization system equipment.](image)
pump is not affected by the load change. The energy consumption of induced draft fan increases with
the increase of load. Before the transformation, the energy consumption of induced draft fan under
55%, 70% and 85% load is respectively 2053 kW•h/h, 2372kW•h/h, 3290kW•h/h. After
transformation, the energy consumption of induced draft fan under 55%, 70% and 85% load is
respectively 1161 kW•h/h, 1706 kW•h/h, 2694kW•h/h; After transformation, the energy consumption
of induced draft fan is greatly reduced. Under 55%, 70% and 85% load, the energy consumption after
transformation is 57%, 72% and 82% of that before transformation respectively.

5. Conclusion

- The GLC reactor is used for technical transformation, the gas and slurry form a large-scale
chaotic state. By increasing the utilization rate of droplets, the spray layer is reduced, the efficiency is
improved and the energy is saved at the same time. Under the premise of SO2 emission ≤ 35 mg/Nm3,
the number of spray layer is reduced by 1-2 layers.
  - After the transformation, the energy consumption of the slurry circulating pump and the
induced draft fan is reduced, and the average energy consumption is saved by 29%.
  - After the transformation, 1-2 slurry circulating pumps are reduced, and the safe and reliable
operation of environmental protection facilities is increased.
  - After the transformation, coal with higher ash content and sulfur content can be used to further
reduce the power generation cost.

References

[1] Xu Jingxin, Zhu Fahua, Wang Sheng, etc. 2020. Comprehensive Comparison of ultra-low emission
coal-fired power plants and gas-fired power plants. Electric Power. 53(2) p 164-172.
[2] Wei Dan. 2020. Current situation of air pollution prevention and control in coal-fired power plants
and super retrofit technology. Resource conservation and environmental protection. (4). p 73.
[3] Ministry of Environment and Environmental Protection, National Development and Reform
Commission, National Energy Administration. 2015. Fully implement the ultra-low emission
and energy-saving transformation program of coal-fired power plants.
[4] Zhu Fahua. 2017. Methodologies on choosing appropriate technical route for ultra-low emission of
flue gas pollutants from coal-fired power plants. Electric Power. 50(3). p 11-16.
[5] Zhu Yue. 2018. Key technical issues of environmental protection island of thermal power plant.
Power Generation Technology. 39(1). p 1-12.
[6] Li Xinghua, He Yudong. 2015. Study on modification of ultra-low SO2 emission in coal-fired
power plants. Electric Power. 48(10). p 148-151.
[7] Yang He, Liu Fangfang, Xi Ling. Discussion on energy saving scheme of desulfurization by liquid
column injection and atomization spray. Water Conservancy & Electric Power Machinery.
41(9). p 49-52.
[8] Liu Jian. 2013. Study on energy efficiency evaluation method of wet desulfurization system for
coal fired units. Electrical application. (S2). p 91-94.
[9] Qiu Guohua, Wei Hongge, Liang Xiujin, etc. 2020. Energy consumption analysis and energy
saving operation prospect of ultra low emission desulfurization operation of thermal power
units. Power Generation Technology. 41(05). p 510-515.