Application of wet electrostatic precipitator in 1000 MW coal-fired power plant

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Abstract This paper described the principles and characteristics of wet electrostatic precipitator (WESP), and focused on the application of WESP in 1000 MW coal-fired power plant in China. Some important parameters, for example the polar distribution pattern, the homopolar distance and the spray arrangement have been centered on during the design and operation of WESP. In view of the actual situation of Shanghai Caojing 1000 MW coal-fired power plant, optimal selection design was carried out in order to achieve the goal of ultra-low emission. After WESP was put into operation in Shanghai Caojing 1000 MW coal-fired power plant, the actual polluting dust emission can reach 1.45 mg/m^3, which is much lower than the emission standard of China [1]. This successful application in 1000 MW coal-fired power plant can provide a useful reference for other reforming engineerings of the large coal-fired power plants.

Keywords: Wet Electrostatic Precipitator, 1000 MW Coal-fired Power Plant, Ultra-low Emission

1. Introduction

Air pollution has become increasingly serious in China at present, it not only harms people's normal life, but also a threat to people's physical and mental health [2]. PM10, PM2.5 and other major pollutions come from various sources, and one of the important sources is the emission of coal-fired power plants. As coal is the main source of energy in China, and in a quite long period of time, China's coal-based power supply pattern will not change fundamentally [3]. Thus, reduction of pollutant emissions for coal-fired power plants is particularly important in China.

In order to solve this problem effectively, the new emission standard of air pollutants for coal-fired power plants was released in 2011, which requires the emission limits of the dust, sulfur dioxide and nitrogen oxide in the key-controlling areas under standard condition are 20 mg/m^3, 50 mg/m^3 and 100 mg/m^3, respectively. As the reason of environmental capacity, some provinces in China regulate that the emission standard of coal-fired power plants should achieve ultra-low emission referring to the gas turbines, which means when the reference oxygen content is 6%, the emission concentrations of the dust, sulfur dioxide and nitrogen oxide should be less than 5 mg/m^3, 35 mg/m^3 and 50 mg/m^3, respectively.

In order to meet the ultra-low emission standard, developing ultra-low emission technology is essential. The installation of WESP in coal-fired power plants is considered to be one of the most effective way to achieve this goal [4, 5]. As reported [1], WESP can not only remove PM2.5 effectively, but also have synergistic reaction on the removal of sulfur trioxide and gypsum droplets, inhibiting the formation of 'gypsum rain'. Thus, WESP can reach very low emission limit value (even less than 3 mg/m^3).

2. The principles and characteristics of WESP

As shown in Fig.1, the working principle of WESP is basically the same as dry ESP, which can be divided into four steps: ionization, charging, collecting and cleaning.

Firstly, the gas molecules are ionized into electrons and positive ions by the effect of discharge electrodes. Then the dust surface are charged by colliding with electrons. After that, the charged particles moved to the collecting plate under the effect of electric field force, which are removed immediately with a uniform water film formed on the collecting plate by nozzle spraying.

In summary, the main difference is the dust removal method compared with that of dry electrostatic precipitator. Dry electrostatic precipitator generally uses mechanical vibration or sound wave cleaning methods to remove dust, while WESP uses water to flush the electrodes, forming a uniform water film to remove the dust.

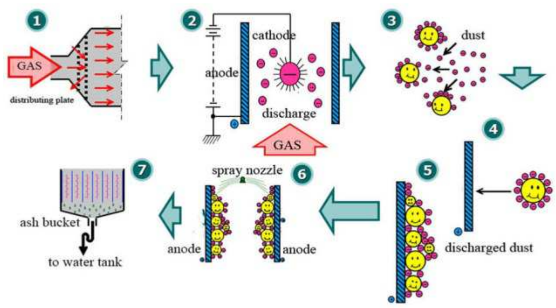

Figure 1. The working principle of WESP

WESP has many characteristics because of its special dust removal method. As reported by Zhou Yihui and coworkers [6], WESP is not affected by the high specific resistance dust, which can achieve a high efficiency of dust removal. And it has no secondary blowing dust, which is conductive to remove fine dust. Furthermore, WESP has low pressure loss, simplicity of operation, low energy consumption, no moving parts, low maintenance cost, compact structure and so on, compared with dry electrostatic precipitator.

3. Application of WESP

3.1 Introduction of engineering

Shanghai Caojing 1000 MW coal-fired power plant belongs to China Power Investment Group, located in Caojing Town, Jinshan District of Shanghai. It has two 1000 MW ultra-supercritical turbine-generators which were put into operation in 2009 and 2010, respectively. This environmental reform project requires installing WESP after desulfurization absorption tower to achieve the goal of ultra-low emission. The process route of Shanghai Caojing 1000 MW coal-fired power plant is shown in Fig.2. The flue gas from boiler was firstly treated in denitration system to remove the nitrogen oxide, and then passed through the dry ESP and desulfurization absorption tower to remove large particles of dust and sulfur dioxide. At last, the flue gas was deeply treated by WESP before discharging into the chimney.

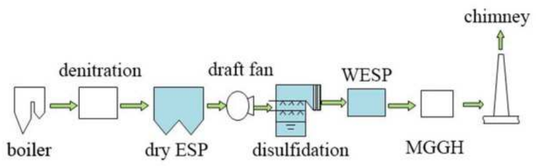

Figure 2. The process route of Shanghai Caojing 1000 MW coal-fired power plant

3.2 Design of WESP

As reported, some important parameters, for example the polar distribution pattern, the homopolar distance and the spray arrangement should be centered on during the design and operation of WESP [7]. In view of the actual situation of Shanghai Caojing 1000 MW coal-fired power plant, the optimal selection design was carried out in order to achieve the goal of ultra-low emission. The main design parameters are listed in Table 1.

Due to the flue gas after desulfurization absorption tower has the characteristics of high humidity and strong corrosion, we optimally designed the WESP basing on the comprehensive consideration of the structures and materials. The schematic structure of WESP for Shanghai Caojing 1000 MW coal-fired power plant is illustrated in Fig.3. For this project, we use metal-plate WESP technology with following features:

(1) The spray system uses one kind of single and continuous spraying technology, which can simultaneously spray on the anode plates and cathode lines. The nozzle arrangement is optimized to achieve the water film uniform on the surface of anode plates. Also, the coverage of nozzle spraying can reach more than 120%, ensuring highly efficient removal of dust and other pollutants with water film.

Table 1. The main design parameters of WESP

Numbers	Name of parameters	Unit	Data of parameters
1	Inlet flue gas volume	m^3/h	3526560
2	Inlet dust concentration	mg/m^3	≤18
3	Fields		1
4	gas temperature	°C	50
5	Homopolar spacing	mm	300
6	Polar distribution pattern		CN anodes + DS cathode lines
7	Outlet dust concentration	mg/m^3	≤4.5
8	Waste water	t/h	22
9	Removal rate of dust	%	≥75
10	Removal rate of sulfur trioxide	%	≥60

(2) The anodes and cathodes are considered to be the most important components in WESP. We have determined the optimal configuration and arrangement of anodes and cathodes through numerical simulation, computer simulation and model test under the actual working conditions of power plant. We use metal-plate type of anode plates and acupuncture type of cathode lines, and the homopolar spacing is 300 mm. This kind of polar distribution pattern can improve the operating electrical parameters with high voltage power supply.

(3) The dust – water balance was established by calculating the water consumption according to the amount of collected dust. Consequently, most of water can be recycled, and only a small quantity of waste water should be discharged out of system. The waste water containing the collected dust, whose concentration is limited blow 2000 ppm, can be used as supplement water for the desulfurization system.

(4) The structure materials was chosen based on the consideration of anticorrosion property. The materials of internal components should have strong anti-corrosion performance as contacting with flue gas directly. Thus, we use 316L stainless steel as the material of anode plates and cathode lines. In addition, we use ordinary steel with a glass flake layer coating on the inner surface as the material of case. Furthermore, the spraying water is recycled after neutralization by sodium hydroxide solution, which can prevent the internal components from acid

corrosion, thus extending the life of internal components.

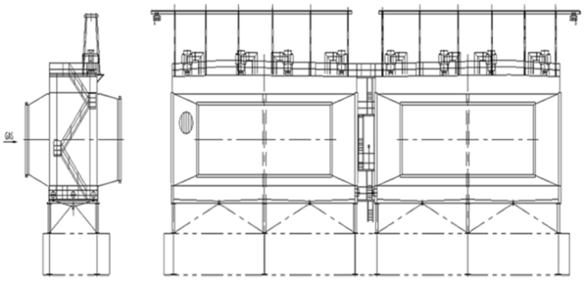

Figure 3. The schematic structure of WESP for Shanghai Caojing 1000 MW coal-fired power plant

3.3 The operation effect of WESP

On November 20th, 2014, the ultra-low emission projects of Shanghai Caojing 1000 MW coal-fired power plant were successfully incorporated into the operating system. WESP, MGGH, desulfurization capacity transformation and other facilities were all put into operation successfully, completing the construction goal. On December 7th, the project successfully passed the 168-hour test run. As tested by authority department, the results showed that the dust, sulfur dioxide and nitrogen oxide emissions are only 1.45 mg/m^3, 13.9 mg/m^3 and 21.6 mg/m^3, respectively, much superior than gas turbines emission standards. The actual removal efficiency of dust and sulfur trioxide are 81.95% and 69.72%, achieving the goal of design requirement. As Shanghai's first ultra-low emission project, it has played a great role of demonstration and promotion on environmental reform of coal-fired plants. The actual picture after operation is shown in Fig.4.

Figures 4. The actual picture of WESP used in Shanghai Caojing 1000 MW coal-fired power plant

4. Conclusions

In summary, we have drawn the following conclusions through this successful application of WESP in Shanghai Caojing 1000 MW coal-fired power plant.

(1) WESP technology is further proven to be especially efficient for the removal of dust and sulfur dioxide, and can achieve the goal of ultra-low emission.

(2) The configurations and materials of anodes cathodes should be determined under the actual working conditions of power plants, which can be propitious to improve the operating condition.

(3) The arrangement of nozzle should be designed optimally to achieve the water film uniform on the surface of anode plates, which is favorable for removal of dust.

(4) The structure materials of WESP should be determined based on the consideration of anticorrosion property.

(5) This successful application of WESP in Shanghai Caojing 1000 MW coal-fired power plant can provide a useful reference for other reforming engineerings of the large coal-fired power plants.

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