Ultra-clean electrostatic-fabric integrated precipitator technology realizes ultra-low emission

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Abstract In recent years, the ultra-low emission policies have been issued and the dust emission has been required to be below 5 mg/Nm^3 by some local governments and electric power groups, which has made dust removal technology be improved. This paper introduces the coal-fired unit of Zhuhai 700 MW Power Plant realizing ultra-low emission of below 5 mg/m^3 successfully after it adopted the ultra-clean Electrostatic-Fabric Integrated Precipitator (EFIP) technology. The advantages of ultra-clean EFIP technology in achieving the ultra-low emission policy were discussed.

Keywords: Ultra-clean EFIP, Ultra-low Emission, Process Scheme

1. Introduction

In recent years, the severe haze weather has happened in Beijing-Tianjin-Hebei region, which has made Chinese government strengthen the air pollution control efforts, and the initiative on air pollution control has been improved by some local governments and power companies [1]. Based on the National Standard of GB13223-2011, “Emission Standard of Air Pollutants for Thermal Power Plants”, the power companies including Zhejiang Energy Company and Guohua Power Company of Shenhua Group first proposed the “near-zero emission” requirements for the air pollutants of coal-fired units, and the Zheneng Jiahua and Zhejiang Guohua Zhoushan units had been put into operation successively as the ultra-clean demonstration projects. The National Development and Reform Commission, Ministry of Environmental Protection and National Energy Administration jointly issued the No. 2093[2014] notice on “The Action Plan of Upgradation and Renovation for Energy Saving and Emission Reduction for Coal-fired Power Plants (2014-2020)”, indicating that the dust emission should below 5mg/m^3 in the Pearl River Delta area. On 24 February, Guangzhou municipal government of Guangdong province issued “the Working Plan for Ultra-Clean Emission Renovation of Coal-Fired Power Plants in Guangzhou”, which put forward the “50355” renovation targets for the coal-fired power plants ($NO_x \leq 50$ mg/Nm^3, $SO_2 \leq 35$ mg/Nm^3, and dust ≤ 5 mg/Nm^3). Due to a series of ultra-low emission policies, the existing dust removal devices need to be upgraded.

As the coal types are complex and varied in China, the problem of “market coal” for coal-fired power plants has long been influencing the boilers’ stability seriously. Most coals burned in boiler have common problems of low calorific value, high ash content and varied, which causes the dust concentrations changed in a big range and the efficiency of dry-type ESP fluctuate [2], so that the stable outlet emission can not be obtained within the design value scope in a long term, and especially can not meet the ultra-low emission requirements. EFIP system organically combined the advantages of ESP and Fabric Filter, which can not only keep the low emission in a long-term stability, but also offer the favorable basis for the ultra-low emission by its special construction. If the process improvement were done for the available EFIP system, it can achieve ultra-low emission, simplify processing, reduce land occupation, save investment and operating cost, and becomes the optimum technique that can meet the ultra-low emission standard for coal-fired power plants.

2. Principles of EFIP

EFIP, a wholly new dust removal technology innovated and developed after ESP and Fabric Filter, is the organic integration and incorporation of the advantages of “charge dedusting” of ESP and “filtration interception” of Fabric Filter. Firstly, it fully takes the advantages of high dust removal efficiency and particles can be charged in the electric field to collect more than 80% of the total dust by one or two electric fields in operation, significantly reducing the dust loading before entering into the bag zone. The remaining 10~20% dust will be intercepted via the bag zone that followed, which greatly reduces the bag zone loading and the bag abrasion caused by particle erosion, and the structure of the dust cake layer on the surface of filter bags is improved. EFIP has strengths including high dust removal efficiency, low pressure drop, energy saving, low operation cost, and less occupied area [3].

EFIP technology is not the simple superposition of ESP and Fabric Filter for particles removal, but makes use of the interaction mechanism of these two technologies, that is the particles are charged with the action of front electric field, while the charged particles then will affect the structure of the dust cake layer, filtration and ash removal characteristic in bag zone [4]. The filtration test of filter media showed that the particles are charged and polarized via the action of electric field, which will help in forming the well-aligned and looser particle layers (Fig. 1) to reduce the filtration pressure drop obviously. Cellfibre particle capturing test shows that as for the particle which is difficult to be charged, its polarization caused by electrical filed is beneficial to particle chain on the fiber to capture fine particles and to form a well-ordered deposit. (Fig. 2).

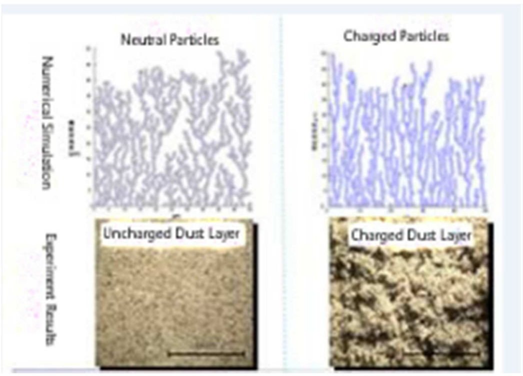

Figure 1. Particle accumulation condition on the bag surface

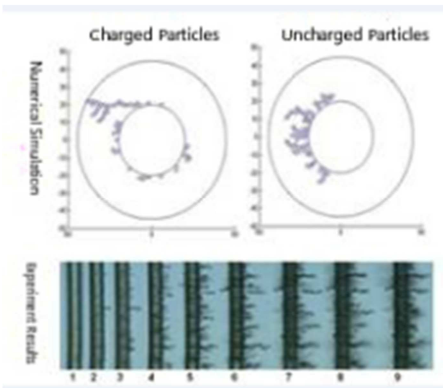

Figure 2. Particle deposition condition on the single fiber surface

3. Technical measures for the dust removal of Ultra-Clean EFIP

In structure, EFIP is the organic integration of ESP and Fabric Filter, of which the inlet dust loading directly affect the selection of electric field and the outlet emission, so the optimum parameter matching of electrical field and bag zone is the key to ensure the optimal cost-effectiveness and low emission. From the principle of EFIP, we can find that enhancing particle charging can not only improve the capturing performance of electric field, but also greatly perfect the accumulating condition of dust on the surface of filter bag, which will strengthen the collecting capacity for the fine particles. The theoretical research and a good deal of engineering practices of EFIP have shown the key factors that affect its emission including the coupling-matching of electric field and bag zone, uniformity of air flow distribution, filter precision of filter media, inlet dust loading of bag zone, filtration velocity, charging and agglomeration level of fine particles in electric field, flue gas leakage inside the equipment, and the manufacturing and installation quality of the device. Among which the filter bags, EFIP's terminal control elements, are the key unit to determine the outlet emission concentrations, its filtration precision has the direct bearing on emission value.

Ultra-Clean EFIP refers to the outlet emission of the precipitator must be lower than 5 mg/m^3. In order to achieve this requirement, the following measures will be adopted: ensuring the parameter matching of electrical zone and fabric filter zone to reduce the dust loading for bag zone, strengthening the particle charging effect to improve the reliability of electric field, adopting high precision filter media and uniform gas flow distribution. Following are the specified analyses.

3.1. Ensuring parameter matching of electrical zone and fabric filter zone to reduce the dust loading for fabric filter zone

EFIP collects more than 80% of the dust via electrical zone and reduces the dust loading of gas before entering the fabric filter zone. Thus, bag abrasion caused by particle erosion is avoided. However, the dust removing efficiency of electrical zone decreases exponentially. Beginning with the third zone, the economy of electrical zone is poor. The results of filtration simulation of charged particles and experimental research show that when inlet dust concentration of FF zone is below a certain value, the filtration pressure loss has no obviously change with the change of filtration velocity (Fig. 3).

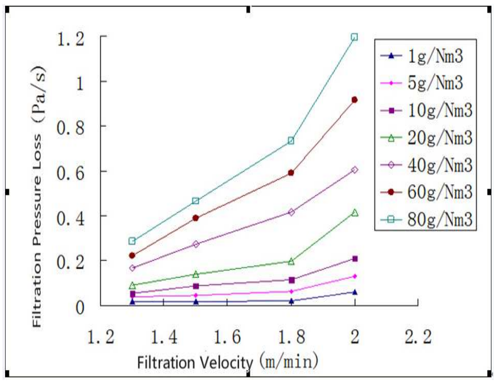

Figure 3. Filtration pressure loss changes with the filtration velocity

A large number of project application and research prove that dust concentration has some impact on outlet emission of fabric filter zone. The emission increases slowly with the increase of dust concentration. When the dust concentration goes to a certain value, the emission is steady. To reduce the dust loading of FF zone, electrical zone should be increased, which causes the increase of investment and the poor economy. Therefore, in consideration of the economy, the Ultra-clean EFIP should set the inlet dust concentration for the FF zone according to the concrete situations.

From the above analysis, we can know that the outlet emission of precipitator reduces when the dust concentration of FF zone decreases. However, to reduce the dust loading of FF zone, electrical zone should be increased, which causes the increase of investment and the poor economy. Therefore, in consideration of the economy, the Ultra-clean EFIP should set the inlet dust concentration for the FF zone according to the concrete situations.

3.2. Strengthening particle charging effect to improve the reliability of electric field

(1) Improving the electrode configuration pattern of the electric field. It can improve electrical charging and efficiency of dust removal to adopt the electrode configuration pattern with high discharge performance and high field strength in the electric field. Experimental research shows that arista electrode with high discharge performance can strengthen the discharge performance of arista end, electric current density, electric field intensity and charge quantity of particles.

(2) Adopting subarea power supply technology in the front and back of the electric field to improve the reliability. Every mechanical electric field is divided into two independent power subareas with 2 transformers respectively for power supply so that the average working voltage of every mechanical electric field rises and charge of particles increased accordingly. It especially plays an important role for fine particles charging and electric agglomeration. At the same time, two working subareas can improve the reliability of electric area, even if one of the electricity subarea malfunctions, the other subarea can still work.

3.3. Adopting high-precision filter materials

Filter bag, as the terminal control element of EFIP, is the key component to determine the outlet emission concentrations. Filtration precision of bag is directly related to dust emission. Ultra-clean EFIP refers to outlet dust emission of the precipitator must be less than 5 mg/m^3. To meet the requirement, we not only need to increase the efficiency of dust removal in the electrical area, but also improve the filtration precision of bags.

The commonly used filter materials are PPS, PI, PTFE and blended fabric of different materials and coated filter materials in the industrial applications. Under the same conditions, the filtration precision ranks from high to low as follows: PTFE coating filter material, superfine fiber gradient filter material and common filter material. Filter bags of different materials have different adaptability to the working conditions of flue gas and outlet emission. After comprehensive considerations on flue gas oxygen content, flue gas temperature and outlet emission requirements etc., of Zhuhai Power Plant, we adopted filter materials of PPS+PTFE blending and PTFE base cloth, and added PPS superfine fiber on the dust side of the bags, which not only ensured stronger resistance to acid corrosion and oxidation of the filter bags, but also improved the removal efficiency of PM_{10} and $PM_{2.5}$ to realize ultra-low emission.

3.4. Other measures

In order to meet the requirements of Ultra-clean EFIP, we must ensure the uniform gas flow distribution inside EFIP (i.e. the relative deviations of flow uniformity for different chambers of bag zone is less than 5%). In addition, we need to make strict check on design, manufacture, installation, operation and maintenance etc. The major measures include canceling gas bypass, ensuring the air tightness of the precipitator, strengthening quality control on filter bag processing and strengthening the leakproofness of tubesheets installation.

4. Two rocess schemes for ultra-low emission

4.1. Ultra-clean EFIP + high-effective desulfurization

By adopting Ultra-clean EFIP, the outlet dust emission of the precipitator can be less than 5mg/m^3. However, to achieve ultra-low emission, only the precipitators meet the standard is not enough for the dust removal process scheme of coal-fired power plants. The corresponding desulfurizing devices follow. When the dust content is less than 5mg/m^3 at the inlet of desulfurizing tower, dust content (including gypsum from droplet) should be less than 5mg/m^3 at the outlet of desulfurization tower. Adopting the process of "Ultra-clean EFIP and high-effective desulfurizing without WESP" can save investment, space, reduce operation and maintenance costs without any sewage discharge.

4.2. High-efficiency EFIP + FGD + WESP of conductive glass reinforced plastics

In practice, the demisters of wet FGD in some power do not work so well and "gypsum rain" often happens. The FGD process produces a lot of water vapor, sulfuric acid mist and fine aerosol. Because of various factors such as space limitation, the project cannot be renovated so the dust content often increases after FGD process. Under such circumstances, high-efficiency EFIP can be adopted, which is followed by wet FGD and a WESP with honeycomb-style conductive glass reinforced plastics. The specific process scheme is as follows: flue gas from boiler→ economizer→ denitration system→air pre-heater → high-efficiency EFIP → wet FGD →WESP →stack. The WESP with honeycomb-style conductive glass reinforced plastics has been applied in the industries of metallurgy and sulfuric acid for many years. When it is used in power plants, greywater from the WESP can be discharged into FGD tower without water-cycle system and water treatment system, and the whole system is simple.

In both of the above 2 schemes, EFIP plays an important role in ensuring ultra-low emission. At the same time, EFIP reduces the quantity of dust entering the FGD tower, so as to reduce equipment trouble and increase the stability of system.

5. Engineering case

5.1. General introduction

No.1and 2 power units (2×700 MW) of Zhuhai Power Plant originally used horizontal and dry-type ESP. This device had the disadvantages of low dust removal efficiency and exceeded dust emission standard, and the flue gas with high dust concentration entered the FGD system, which resulted in GGH blocking after FGD. After series of evaluation, the power plant decided to renovate the ESP.

5.2. Renovation plan

Original bracket, case, hopper and inlet nozzle etc were retained. The cathode and anode systems and the rapper system of the first electric field were renewed. The subarea power supply technology was adopted for the cathode system. The rectifier transformers were retained. The second and third electric field was renovated to bag zones. 1electric field with 2 subareas for power supply was set, followed by 3 chambers in the bag zone.

5.3. Main technical parameters

Main technical parameters of EFIP are shown in Table 1.

Table 1. Main technical parameters

	Item	Parameter
Performance Parameters	Inlet Gas Quantity m^3/h	4000000
	Inlet Gas Temperature	≤150
	Dust Content of Inlet Gas g/m^3	≤25
	Emission Content of Outlet Gas mg/m^3	≤20
	Total Resistance (Normal/ largest) /Pa	800/1200
	Air Leakage Rate %	≤2
Electric Field	Column of electric field	2
	Chamber of electric field	2
	Total Dust Collection Area m^2	22464
Bag Field	Total Filter Area m^2	60433
	Filtration Rate m/min	1.1
	Bag Material	（PPS+PTFE）blending + PTFE base
	Specification and Model of EMP Valve	submerged /4 inch
	Air Consumption m^3/min	～24

5.4. Main technical features of the renovation

In accordance with the features of large quantities of flue gas, high inlet dust concentration, limited space and compact structural arrangement of this project, a series of advanced technologies was adopted in Ultra-clean EFIP to ensure ultra-low emission, which mainly included the following 2 aspects:

(1) Subarea power supply technology was adopted to improve the reliability of the electric field. The precipitator had a big mechanical electric field and the subarea power supply technology in the front and back of the electric field was adopted in the cathode system. Each subarea was equipped a transformer, and if one of the two transformers broke down, the other one could work regularly. It would increase the reliability of electric field.

(2) Filter material with high filtration precision was adopted. The parameters, such as flue gas oxygen content, flue gas temperature and outlet gas concentration requirement etc., were comprehensively considered and higher requirements on selection of filter bags were put forward. We finally adopted filter materials of PPS+PTFE blending and PTFE base cloth, and added PPS superfine fiber on the dust side of the bags, which improved the filtration precision and service life.

5.5. Renovation effects

The outlet dust concentrations of original ESPs for No.1&2 boilers of Zhuhai Power Plant were in the range of 70~100 mg/m^3, and even reached 140 mg/m^3 now and then. At the same time, the GGH was blocked seriously and the resistance rose to 1500 Pa after running less than half years. The system had to be suspended and chemical cleaning was carried out subsequently. After the ESP was renovated to EFIP, the outlet emission of No.1 and No.2 boiler were 3.15 mg/m^3 and 2.55 mg/m^3 respectively, and running resistance was below 800 Pa, GGH had no longer blocked and the pressure was stable.

6. Conclusions

This project is a typical case of Ultra-clean EFIP, which realizes ultra-low emission successfully. It has proofed that ultra-low emission can be realized with simple process and low cost when technology improvement is made on EFIP. Therefore, Ultra-clean EFIP is one of the preferred technologies to meet the current ultra-low emission policies.

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