Study on Improving the Performance of Electrostatic Precipitator in the Large-scale Semi-dry Flue Gas Desulfurization System

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Abstract: Dedusting unit is necessary in the circulating fluidized bed flue gas desulfurization (CFB-FGD) system, a semi-dry FGD technique which is widely used in air pollution control projects. The dedusting unit is located after the FGD absorber, to collect the desulfurization absorbent for recycle, and also to ensure to satisfy the dust emission standards. Electrostatic precipitator (ESP) is most popularly used in large-scale semi-dry FGD system. But the ESP operating conditions in FGD system are much different from those in general use, with high dust concentration, high humidity and high specific resistivity. According to the ESP operating cases in the semi-dry FGD projects, the effect factors on ESP performance are studied in this paper, such as dust specific resistivity, dust concentration, gas humidity, dust cleaning mode and power supply. The measures to improve the collection performance are also studied in this paper, from the stage of design, installation and operation.

Keywords: collection performance, ESP, semi-dry FGD

1 INTRODUCTION

Coal is the most important primary energy in China. The coal-fired electricity generation has been occupying about 70% of the total installed capacity all the time in power industry. But at the same time, coal combustion produces some pollutants like dust and sulfur dioxide, causing serious environmental problems. Circulating fluidized bed flue gas desulfurization (CFB-FGD) system is widely used in the air pollution control engineering, due to its high desulfurization efficiency, small land and water demand, low investment and operating cost. When the semi-dry FGD system is applied, dedusting unit is necessary to collect the desulfurization absorbent for recycle, and also to ensure to satisfy the dust emission standards. Electrostatic precipitator, usually named ESP2, is most popularly used in large-scale semi-dry FGD system. But the ESP operating conditions in FGD system are much different from those in general use, with high dust concentration, high humidity and high specific resistivity, which puts forward higher requirements to ESP2 [1,2]. Research on the performance of ESP2 in large-scale semi-dry FGD system not only can promote wider application of ESP, but is also the practical requirement for the matching relationship between dedusting unit and desulfurization unit.

2 DESCRIPTION OF DESULFURIZATION AND DEDUSTING SYSTEM

This paper takes the semi-dry FGD project of a 300MW coal-fired boiler as research object, which was designed and built by Wuhan Kaidi [3]. This air pollution control engineering follows the process as below. Flue gas from the coal-fired boiler firstly passes through the air preheater, then it divides into two paths, and enters an ESP, which is located before the desulfurization absorber, usually named ESP1. The ESP1 in this project is designed with one electric field and two rooms. After most dust is removed in ESP1, flue gas enters the CFB-FGD absorber. The acid component in the flue gas reacts with absorbent (i.e. calcium hydroxide $Ca(OH)_2$) under suitable temperature and humidity in absorber. The mixed compounds of reaction products and unreacted absorbent come into the subsequent electrostatic precipitator (i.e. ESP2). The solid particles are collected in the ESP2, to transport to the absorber for recycle. Then the clean gas discharges to the stack through the induced draft fan (ID Fan). The flow diagram of this desulfurization and dedusting system is shown in Fig. 1.

In this system, the ESP2 is one of the key equipments. It is not only for absorbent recycle, but also to ensure to meet the emission standards. The ESP2 was designed by Wuhan Kaidi. The main design parameters of ESP2 are shown in Table 1.

3 THE EFFECT FACTORS ON ESP PERFORMANCE

3.1 Dust Specific Resistivity

Dust specific resistivity is a critical effect factor on ESP performance. Its suitable range is 104Ω·cm-1011 Ω·cm for ESP. If the specific resistivity is below 104 Ω·cm, the electric conductivity is so good that the collected on plates may probably go back to the gas current. If the specific resistivity is larger than 1011Ω*cm, the dust in the fields is difficult to charge, and the charged particulates are difficult to discharge. When the charged particulates accumulate to an unsafe thickness, the phenomenon of back corona will appear, causing secondary blowing dust. The specific resistivity is decided mainly by the dust components. Some research shows that the resistivities of Na_2O, K_2O, SO_3 and SiO_2 are lower while those of Al_2O_3, CaO and MgO are higher [4]. In the system studied in this paper, the composition and specific resistivities of boiler fly ashes and desulfurization products are shown in Table 2 and 3, respectively. It can find that the specific resistivities of both fly ashes and desulfurization products are very high, due to their components. In the semi-dry FGD system, the ESP1 is used to collect the boiler fly ashes, and the ESP2 is used to collect the desulfurization products. Both of the two precipitators are operating under the condition of high dust specific resistivity, which is adverse for dust collecting, so several measures were taken to improve the ESP performance in commissioning and operating for this project.

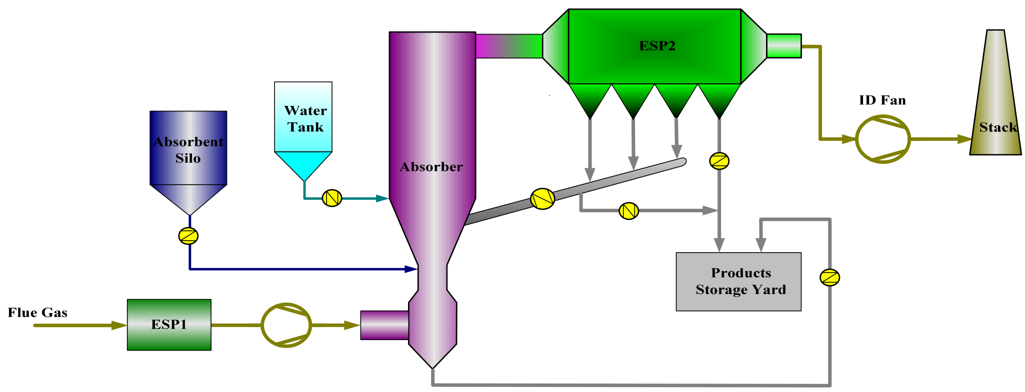

Fig. 1 The flow diagram of desulfurization and dedusting system

Table 1 The main design parameters of ESP2

Item	Unit	Value	Item	Unit	Value
Type	/	horizontal	Gas velocity	m/s	1.18
Rooms	number	2	Total collecting area	m^2	54282
Fields	number	4	Specific collecting area	$m^2/(m^3/s)$	96.6
Gas flow rate (110% BMCR)	m^3/h	2022 000	Inlet dust concentration	g/Nm^3	800
	Nm^3/h	1294000	Collecting efficiency	%	99.9875
Channels	number	2×38	Operating temp.	□	70-80
Height of plate	m	15.05	Operating pressure	kPa	-(5.5-7.0)
Length of plate	m	5.76	Pressure drop	Pa	≤400
Section area	m^2	471	Leakage rate	%	< 2.5

Table 2 The composition and specific resistivity of boiler fly ashes

Item	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	TiO_2	Na_2O	K_2O	P_2O_3	SO_3	Specific resistivity*
Unit	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	Ω·cm
Value	47.63	33.61	8.37	0.74	4.37	0.73	0.11	0.57	0.13	3.74	4.3×10^{11}

*Test conditions: 120 □, 500 V voltage.

Table 3 The composition and specific resistivity of desulfurization products

Item	$CaSO_3$	$CaSO_4$	$CaCO_3$	CaO	$CaCl_2$	CaF_2	$Ca(OH)_2$	Specific resistivity*
Unit	wt%	wt%	wt%	wt%	wt%	wt%	wt%	Ω·cm
Value	40±15	20±10	10±5	10±5	7±5	8±5	5±3	$2.3\sim8.8\times10^{12}$

*Test the conditions: 80 □, 500 V.

3.2 Dust Concentration

In the semi-dry FGD system, the absorbent reacts with acid component in the absorber. Then the reaction products and unreacted absorbent come into the ESP2. The dust concentration at the location of absorber outlet will be up to 600 mg/Nm^3-1200 mg/Nm^3, but ESP has a limitation to the dust concentration. So high a concentration will result in a sharp drop of the collecting efficiency, even cause corona blocking. At this case, the secondary current will drop to nearly zero, and the ESP performance gets deteriorated seriously. So, a pre-dedusting facility was introduced before the ESP2. It can collect more than 50% dust in advance by the effect of gravity and inertia, making the dust concentration drop to a suitable level for the ESP2.

3.3 Gas Humidity

Gas humidity has a significant effect on the ESP performance. At the condition of higher gas humidity, the surface of dust will be activated, resulting in a decrease of specific resistivity. And also, more vapour in the gas can ameliorate the volt-ampere characteristic, and ESP operating voltage will increase. In addition, more water vapour in the gas will make the fine particles agglomerate into larger ones, which are much easier for collecting. So for the dust of high specific resistivity, water spraying for flue gas conditioning is commonly applied, which can improve the collecting performance obviously. In the system referred in this paper, water spraying was taken into study, due to its high dust specific resistivity. The experiment was taken for half an hour, and the water flow rate was 2.6 t/h, the testing results are shown in Table 4, which indicates that water spraying can improve the ESP performance observably, especially at the condition of high specific resistivity.

Table 4 The experiment results of spraying water

Item	Generated power	Gas flow rate	Primary voltage	Primary current	Secondary voltage	Secondary current
Unit	MW	Nm^3/h	V	A	kV	mA
Before spraying	300	1,110,000	120	10	40	100
After spraying	300	1,110,000	160	100	45	350

3.4 Dust Cleaning Mode

After an ESP is put into operation, the collecting efficiency will drop as time goes on. One of the main causes is too much dust is accumulating on the electrode wires and plates [5]. The ESP mentioned in this paper took the way of top vibration as the dust cleaning mode, but the vibration force was not satisfied after a period of operation. Acoustic wave dust cleaning mode can compensate this deficiency. Acoustic wave dust cleaning mode takes compressed air as the source energy, and then this potential energy is converted into acoustic energy of low frequency (i.e. □20 Hz), through the self-oscillation of a metal diaphragm. The acoustic energy is transmitted to the places with thick dust layer, producing the effect of acoustic fatigue. After several times of this repeated effect, dust layer is destructed, and departed off the wires and plates. Acoustic wave dust cleaning mode is available, and it can improve the collecting performance effectively and economically, also guarantee the stability of ESP operation.

3.5 Power Supply

High frequency power supply (i.e. 20~50 Hz) offers another approach for the upgrading of ESP [5]. Its frequency is about 400~1000 times to conventional transformer rectifier (T/R) power, so its output is nearly direct current. And its voltage fluctuates quite small when spark discharges in the electric fields. While for the T/R power, it can't output high power in the condition of back corona. A high frequency power supply of 50 Hz/400 mA was applied in the system referred in this paper, the secondary current reached to 400 mA, while it was 100~300 mA for T/R power. Otherwise, high frequency power supply can work stably for a along period as expected.

4 THE MEASURES TO IMPROVE ESP PERFORMANCE

4.1 Improving the ESP Performance from Design

The operating conditions of ESP2 in the semi-dry FGD system are much different from those in general use, with high dust concentration, high humidity and high specific resistivity. These measures below are proposed to take from the stage of design.

A pre-dedusting facility is necessary before the ESP2. The dust concentration at the absorber outlet is too high for ESP, but the pre-dedusting facility, which mainly includes refraction sheets and baffles, can collect more than 50% dust in advance, making the dust concentration decrease to an acceptable level.

Optimizing the opening of distribution plate is another method. When the flue gas with dust enters the ESP2, it appears that the concentration at the bottom is higher than that at the top. It is recommended that the opening ratio at the bottom should be smaller, to reduce the gas velocity at the bottom.

Optimal electrode configuration is usually used in ESP2. Because of the concentration gradient at the section area, different styles of electrode wires are applied. Barbed wires are often adopted at the bottom, where the dust concentration is higher, to avoid corona blocking.

4.2 Improving the ESP Performance from Installation

Besides design and manufacture, installation is also very important to an ESP. The dimension deviation, weld and leakage, material thermal expansion need special attention when installing [6].

The dimension deviation is one of the most important questions. Almost all the parts of an ESP need to assemble on site, how to eliminate the different kinds of dimension deviation is a critical problem. For example, the support pillars, beams, girders and cathode framework should be horizontal; the cathode framework and plates should be vertical; and the plates must be plane and the interval between electrodes should be the same.

Weld is a common question while installing because ESP is made of steel and a lot of locations needs welding. Leakage is usually caused by welding defect. Leakage will lead to larger gas flow, lower gas temperature and dewing. The leakage of ESP can be checked by permeating and smoke under the condition of positive pressure.

The material thermal expansion is inevitable under high temperature. The ESP1 is operating at about 130℃, and the ESP2 is working at about 75℃. While installing, enough space should be left between plates, plates and ESP itself.

4.3 Improving the ESP Performance from Operation

During the period of operation, the ESP collecting performance is guaranteed through routine maintenance and fault treatment [7].

The main task of routine maintenance is to find and remove hidden dangers, and determine the minor repair, regular repair and major repair according to the operation conditions. The minor repair is mainly determined by daily operation conditions, to deal with little defect and trouble. The regular repair should follow the device service life, and then make a repair plan, such as 1 or 2 times a year. The major repair is always performed simultaneity with the major repair of power generating unit, to replace the damageable parts.

The operation fault can usually be speculated from the abnormality of electric voltage and current. If the current is exaggerated high but the voltage can't rise to the expected level, it is likely that a wire drops and keeps in touch with the plate, or some sundries connect the positive and negative electrodes, or the dust hopper is too full that the dust reaches to the electrode wire. If the electric current is extremely low, it is probable that the high concentration dust causes corona blocking, or too much dust accumulates on the electrode wires or plates. The corresponding measures can be taken according to the fault phenomenon that appears.

5 CONCLUSIONS

According to the commissioning and operating for an ESP2 in a semi-dry FGD project, the following conclusions can be obtained in this paper.

Dust specific resistivity is a critical effect factor on ESP performance. Dust with high content of silicon or aluminum, or low content of sulfur will results in a higher resistivity.

Corona blocking may appear under the condition of high dust concentration, so a pre-dusting facility is necessary before the ESP2.

Gas humidity has a significant effect on the ESP performance. Water spraying can improve the ESP performance obviously, especially at the condition of high dust specific resistivity.

Acoustic wave dust cleaning mode is available, and it can improve the ESP collecting performance effectively and economically.

High frequency power supply provides nearly direct current, whose output can provide higher energy stably.

The measures to improve the ESP performance should be taken from the stage of design, installation and operation. The specific measures are also proposed in this paper.

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