Performance Characterization of Electrostatic Precipitators for Ultra-Low Emission 1000mw Coal-Fired Power Plants

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Abstract: Through data analysis on representative electrostatic Precipitators (ESPs) for ultra-low emission coal-fired power plants including the energy consumption, outlet particulate concentration, air leak percentage, pressure drop, it was shown that the energy consumption of 1000MW ESPs per unit generating capacity was 0.18% and which was less than the 0.22% of 600MW ESPs and the 0.3% of 300MW ESPs; the outlet particulate concentrations of 1000MW ESPs most were less than 15mg/m3 and there were many less than 10mg/m3. Then, it showed that the steel weight of 1000MW ESPs was 6% less than 600MW ESPs and 14% less than 300MW ESPs.

Keywords: 1000MW unit; Coal power plant; Ultra-low emission; Electrostatic precipitator; Operating feature

1. Introduction

The State Council issued the Notice of Opinions on Accelerating the Shutdown of Small Thermal Power Generating Units, in which the requirement of “Launch large but shut down small” was put forward, linking new projects with the shutdown of small thermal power generating units, and building large-capacity, high-parameter, low-energy-consumption, low-emission units while shutting down some small thermal power generating units accordingly. The main purpose is to reduce energy consumption and reduce pollutant emissions. Compared with small capacity units, large capacity units have less coal consumption and sewage discharge per unit, and lower power consumption per unit of flue gas treatment [1]. At the same time, the National Energy Saving Action Plan of the 13th five-year Plan issued by the National Development and Reform Commission clearly calls for strengthening the energy-saving transformation of coal-fired boilers and actively carrying out the work of "replacing the small with the large". Large-capacity coal-fired generating units fully reflect its economy and efficiency, and have become the mainstream trend of the development of coal-fired power plants. Since the implementation of 1000MW unit electrostatic precipitator in Zhejiang Yuhuan Power Plant[2-4], its operation is efficient and stable, and it has been widely used in a large area, but the actual operation effect has not yet been comprehensively analyzed, so it is urgent to make a statistical analysis on the operation performance of the 1000MW class electrostatic precipitator which has been put into operation, especially the actual operation effect of the electrostatic precipitator under the requirement of ultra-low emission [5-7].

According to incomplete statistics, China has put into operation more than 100 units of 1000MW ultra-supercritical units. We have tested and analyzed 9 typical 1000MW electric precipitators in different regions since the implementation of ultra-low emission in the past five years, and collected energy consumption data for the optimization of electric precipitators in China, their promotion in other industries, and the promotion of 1000MW electric precipitators abroad, especially for providing reference for the promotion and application of 1000MW electrostatic precipitator in foreign countries, especially in the "Belt and Road" countries.

2. Operation Performance of Electrostatic Precipitator

The operation performance of electrostatic precipitator mainly includes four performance indexes: dust removal efficiency, outlet dust concentration, pressure drop (resistance or pressure loss) and air leakage rate. The operation performance of 9 electrostatic precipitators of 1000MW units which have been put into operation in recent five years are analyzed.

2.1. Dust concentration

This paper makes a statistical analysis on the dust concentration at the designed outlet and the measured outlet dust concentration at the design outlet of 9 1000MW units which have been put into operation in different power plants in the past five years [8-10]. The dust concentration data at the designed outlet of the electrostatic precipitator for 1000MW units are generally shown as $15mg/m^3$ and $20mg/m^3$, as shown in figure 1.

The data show that the dust concentration at the measured outlet of the electrostatic precipitator is about 89% compared with the design, most of the electrostatic precipitator can achieve the outlet dust concentration below $15mg/m^3$, and a number of electrostatic precipitators have achieved the dust "ultra-low emission" requirements below $10mg/m^3$.

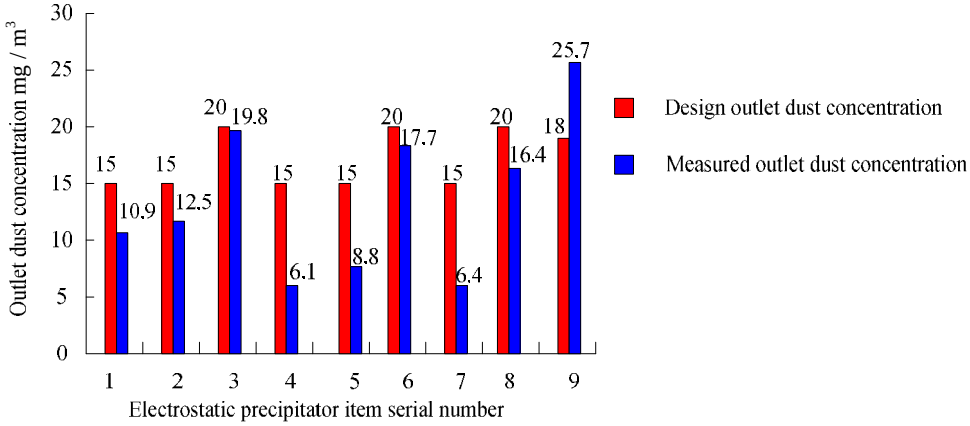

Figure 1. Design and actual outlet particulate concentration of ESPs in 1000 MW coal-fired power units in recent five years

2.2. Typical case study of outlet below $10mg/m^3$

The 1000MW unit of a power plant in Zhejiang was put into operation in October 2015. It adopts low temperature electrostatic precipitator technology, flue gas cooler is installed in front of electrostatic precipitator, each furnace is equipped with two electrostatic precipitators with three chambers and five electric fields, and high frequency power supply is used. The main technical parameters of electrostatic precipitator are shown in Table 1, and the composition of coal and fly ash are shown in Table 2. The effective dust collection area of the electrostatic precipitator in a power plant in Zhejiang is $90675m^2$, and the dust concentration at the designed outlet is $15mg/m^3$. When running at full load, the total power consumption is 2490kW, and the dust concentration at the outlet of the electrostatic precipitator is $6.1mg/m^3$.

Table 1. Inlet parameters of ESPs in a certain 1000 MW coal-fired power unit

Name	Main parameters
Design inlet flue gas temperature	85 ℃
Electric dust collector inlet flue gas volume	Design coal type: 582.0 m3/s Calibration coal type: 570.4 m3/s
Inlet dust concentration	Design coal type: 25.412 g/m3
	Calibration coal type: 24.841 g/m3
Number of electric dust collectors per furnace	Three chambers and five electric fields，2 sets
Effective length of electric field	5×5 m
Effective height of electric field	15.5 m
Effective width of electric field	6×15.6 m
Same pole spacing	400 mm
Specific dust collection area	155.8 m2/m3/s
Specification and quantity of high frequency power supply	2.4 A/72 kV，30 sets
Guaranteed dust removal efficiency	99.95%
Dust concentration at the outlet of electric dust collector	≤15 mg/m3

The dust concentration (6.4mg/m3) at the outlet of the electrostatic precipitator of the first phase 1000MW unit of a power plant in Yuhuan, Zhejiang Province was measured. Domestic electrostatic precipitator outlet dust concentration lower than 10mg/m3 will gradually become popular.

2.3. Pressure drop

Using the method specified in GB/T 13931 to implement the pressure drop of 1000MW electrostatic precipitator with ultra-low emission in recent five years, as shown in figure 2, the test results show that the average pressure

drop of 1000MW electrostatic precipitator is 139Pa, and all are below 200Pa. Low flue gas resistance is one of the biggest advantages of electrostatic precipitator compared with bag precipitator. Mechanical industry standard JB/T 5910 and electric power industry standard DL/T 514stipulate that the pressure drop of large electrostatic precipitator is less than 250Pa and less than 235Pa respectively. At the same time, JB/T 10921 coal-fired boiler bag precipitator stipulates that the pressure drop of bag precipitator is less than 1800Pa, in contrast, the resistance of electrostatic precipitator is significantly lower than that of bag precipitator.

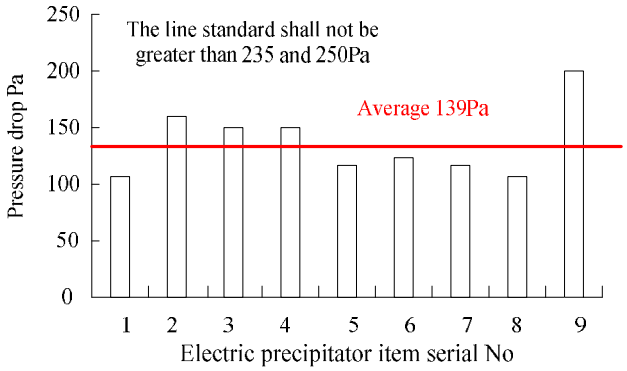

Figure 2. Pressure drop of ESPs in 1000 MW coal-fired power units in recent five years

2.4. Air leakage rate

The electrostatic precipitator machinery industry standard JB/T 5910 and the electric power standard DL/T 514 both stipulate that the air leakage rate of the electrostatic precipitator is not more than 3%. The test results show that, as shown in figure 3, the average pressure drop of the nine electrostatic precipitators supporting the 1000MW unit in the coal-fired power plant is 1.38%, and they are all less than 3%.

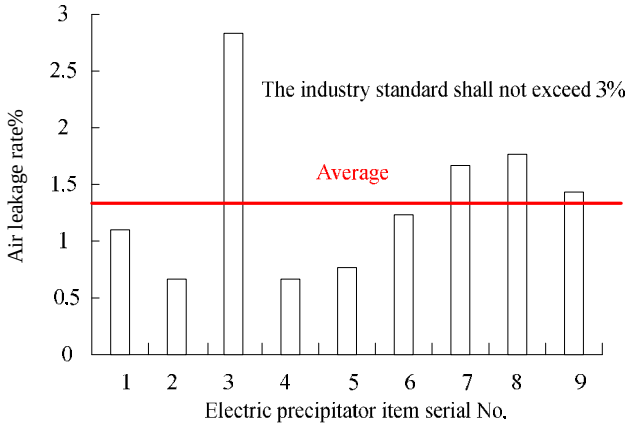

Figure 3. Air leak percentage of ESPs in 1000 MW coal-fired power units in recent five years

3. Energy Consumption of 1000MW Electrostatic Precipitator

Based on the data investigation of 20 sets of electrostatic precipitators of 1000MW units in China, the power consumption of high voltage power supply, low voltage equipment and flue gas resistance of electrostatic precipitator is calculated. The average value is 1683kW h / h, the maximum value is 2928kW h / h, and the minimum value is 1039.8kW h / h. As shown in figure 4, the power consumption below 1200kW h / h accounts for 15%, and 1800kW h / h accounts for 60%.

In order to compare the average energy consumption of electrostatic precipitators of 1000MW units with those of 300MW and 600MW units, the average energy consumption of 78 sets of 300MW and 102sets of 600MW electrostatic precipitators is 896 and 1341 respectively. As shown in figure 5, the power consumption per unit of electrostatic precipitators of 1000MW units is 0.18%, which is lower than 0.18% of 300MW units and 0.30% of 600MW units.

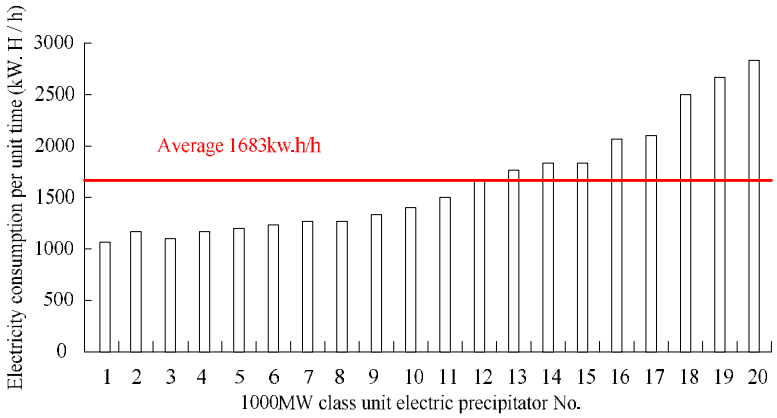

Figure 4. Energy consumption of ESPs in 1000 MW coal-fired power units in recent five years

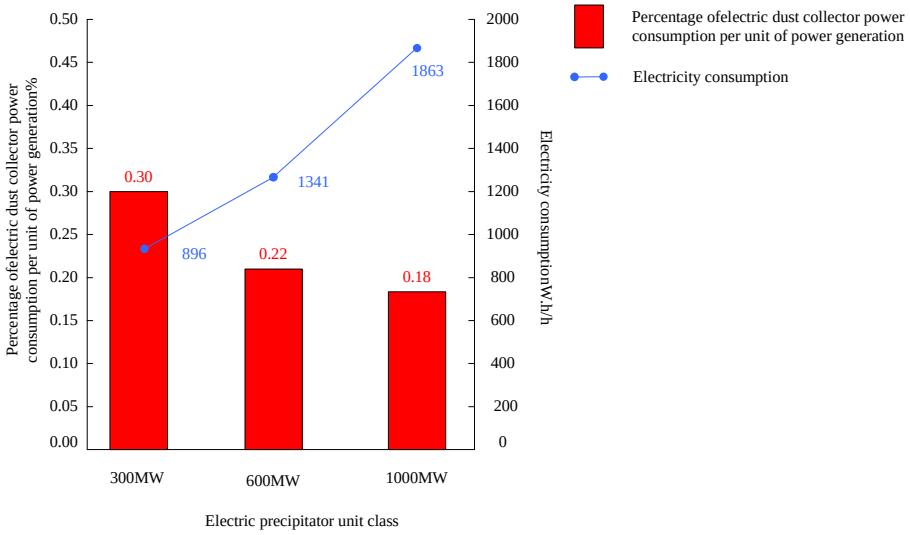

Figure 5. Average energy consumption comparison under different unit capacities

Under the premise of the same power generation, the energy consumption of electrostatic precipitator in 1000MW units is obviously lower than that in 300MW and 600MW units.

4. The Amount of Steel Used for Power Generation per Unit of Electrostatic Precipitator

Each furnace of the unit above 200MW class in coal-fired power plant is generally equipped with 2 electrostatic precipitators. Considering the flue gas flow rate, the number of chambers of electrostatic precipitator is generally configured according to the following rules: 200MW level is generally equipped with single chamber, 200~600MW level is generally equipped with two chambers, 1000MW level is generally equipped with three chambers (figure 6-7), the electrostatic precipitator with four chambers is being installed for the first time. Electrostatic precipitator uses a large amount of steel, and the amount of steel directly affects the cost of material and installation, which is the main factor affecting the primary investment of electrostatic precipitator.

Figure 6. Installation ESPs of one 1000 MW coal-fired power unit in sichuan province

Figure 7. Operating ESPs of one 1000 MW coal-fired power unit in Zhejiang province

In order to compare the amount of steel used in the electrostatic precipitator for different classes of units, under the conditions of the same typical coal type, dust collection area and shell thickness, the primary investment of the electrostatic precipitator is indirectly compared by comparing the amount of steel used per unit of power generation (generating capacity per megawatt).

As shown in figure 8, the unit steel consumption of the electrostatic precipitator of the 1000MW unit is about 6% lower than that of the 600MW electrostatic precipitator and about 14% lower than that of the 300MW unit.

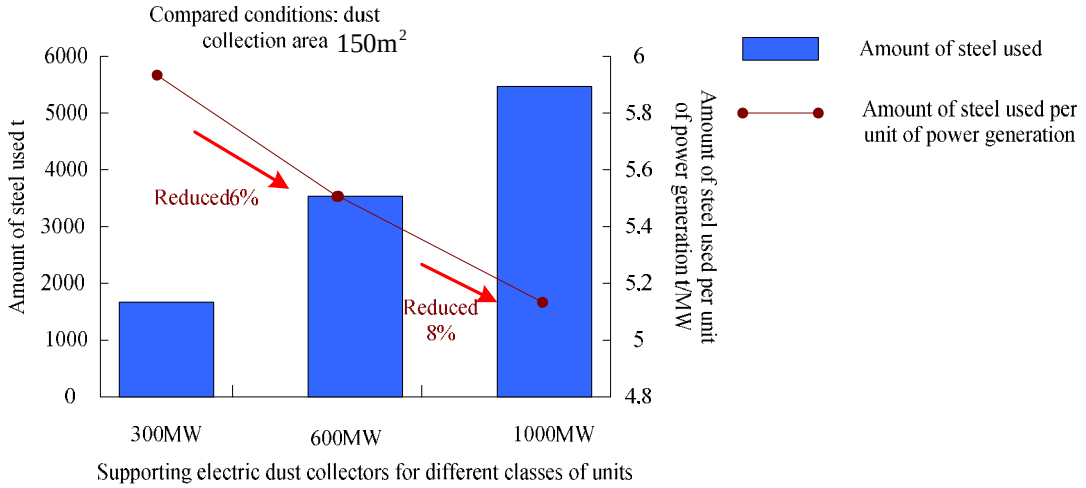

Figure 8. Steel weight comparison with different unit capacities of ESPs

Compared with the electrostatic precipitator equipped with different units, the amount of steel used in the electrostatic precipitator with 1000MW class or above is greatly reduced, and the shell wall is reduced, so the economic advantage is obvious.

In addition, with the further development of gas turbine and other technologies, the steel consumption per unit of power generation using higher-class of 1350MW electrostatic precipitator is expected to be further reduced.

5. Conclusion

The electricity consumption per unit of electrostatic precipitator of 1000MW unit is 0.18%, which is lower than 0.3% of 300MW and 0.22% of 600MW unit.

The dust concentration at the design outlet of the electrostatic precipitator of 1000MW unit is mostly lower than that of 15mg/m3, and many of them have been measured to be lower than 10mg/m3. The performance parameters of pressure drop and air leakage rate stably meet The requirements of the standard.

The unit steel consumption of the electrostatic precipitator of the 1000MW unit is about 6% lower than that of the 600MW electrostatic precipitator, and about 14% lower than that of the 300MW unit, and the economic advantage is obvious.

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References

[1] State administration of market administration, china national standardization administration. Energy efficiency limits and energy efficiency classes of dust collectors: GB 37484-2019. Beijing: China Quality Inspection Press.

[2] Liang Zhihong, Li Shuanbao, Chen Junfeng. PM10 and PM2.5 emission control by electrostatic precipitator (ESP) for coal-fired power plants VII: ESP sizing and refitting with 2×600MW boilers. Science & Technology Review. 2016, 491(05), 86-90.

[3] China environmental protection industry association electric precipitator committee. ultra-low emission technology for flue

gas from coal-fired power plants. Beijing: China Electric Power Publishing House. 2015.

[4] Zhao Haibao, Li Jianguo, He Yuzhong. Research and application on low-low temperature electrostatic precipitator technology. Electric Power. 2014, 47(10), 117-120,147.

[5] Long Hui, Zhou Yuxiang, Huang Jingjing. Selection of "ultra-low emission" technical route for low-quality coal-fired thermal power units. China's Environmental Protection Industry. 2017, (1), 31-34.

[6] Zhao H., He Y., Yao Y. Study on brush of moving electrode type electrostatic precipitator (MEEP). IOP Conference Series: Earth And Environmental Science. 2018, 121(5), 3-5.

[7] Andreas Bäck. Enhancing ESP efficiency for high resistivity fly ash by reducing the flue gas temperature. 11th International Conference on Electrostatic Precipitation. 2008, 406-411.

[8] State Environmental protection administration. GB/T 16157-1996 method for the determination of particulate matter in the exhaust of fixed sources and sampling of gaseous pollutants. Beijing: China Standard Publishing House. 1996.

[9] Department of science and technology standards, state environmental protection administration. HJ /T 397-2007 technical specifications for stationary source exhaust gas detection. Beijing: China Environmental Science Press. 2007.

[10] Ix-Iso. ISO 12141 − 2002 Stationary Source Emissions-Determination of Mass Concentration of Particulate Matter (Dust) at Low Concentrations-Manual Gravimetric Method. 2002.