Comparative Study of Distribution of Collecting Plate Current Density on Electrostatic Precipitations with High Direct Current and Pulse Power Supply

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Abstract: ESP has been applied widely in environmental protection. In this paper, the measure methods and tested setup of the collecting plate current density on ESP were introduced. In pulse engergization and direct current power supplies, distribution of collecting plate current density in vertical and parallel direction of corona discharge line on ESP are contrastively measured. It is concluded that distribution of collecting plate current density on ESP with pulse engergization was more uniform than that with direct current power supply in experiments, and it is advantageous to improve dust performance of ESP.

Keywords: pulse engergization, direct current power supply, electrostatic precipitations (ESP), current density

1 INTRODUCTION

Electrostatic precipitation (ESP) emerged from nearly a century of being a laboratory curiosity to a successful method for removing fine articles from industrial gases in the early 1900's [1]. ESP has high collection efficiency, small pressure loss, large capacity of treatment gas and less operation cost, and has been applied widely in environmental protection. There are many factors to affect the collection efficiency of ESP. The distribution of collecting plate current density is one of important factor to effect collection efficiency of ESP. The more uniform the distribution of collecting plate current density in ESP is, the higher its collection efficiency is. Power supply mode influences directly the distribution of collecting plate current density on electrostatic precipitations. There are two power supply mode, that is, high direct current and pulse power supply in ESP. The conventional direct current power supply is applied broadly in ESP, but there is some problems such as back corona, which decreases collection efficiency and effects operation, especially for high resistivity ash. Some researches have shown the pulse energization system has many advantage and is very suitable to be applied to ESP [1-2]. But, there was no report to explain pulse power supply to affect the distribution of collecting plate current density on electrostatic precipitations.

2 METHODS AND EXPERIMENT SETUP

2.1 The Measured Methods of Current Density of Collecting Plate

The measured collecting plate shape was shown in Fig. 1. The measured collecting plate area is 15×15cm^2, is scribed 36 small cell area 2.5 cm^2×2.5 cm^2, which each other are isolated. The measured collecting plate was placed in ESP. The current in small cell are measured. Current density is calculated by follow formula (1).

$$J_i=I_i/A_m \tag{1}$$

where, J_i —current density on number i small cell, A·m^{-2}.

I_i—current on number i small cell, A·m^{-2}. i=1, 2,…,36.

A_m—area of cell, m^2.

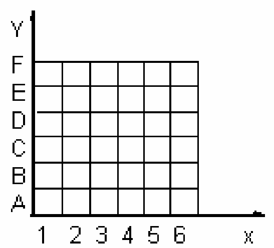

Fig. 1 The measured collecting plate

The collecting plate current density in each small cell with high direct current and pulse power supply were measured under base voltage 35 kV, 45 kV or 55 kV, on the electrode spacing 300 mm, 400 mm or 600 mm, respectively.

2.2 Assessment of Distribution Uniformity of Collecting Plate Current Density

The distribution uniformity of collecting plate current density are assessed by distribution standard deviation of current density on parallel- and vertical- direction of corona discharge line and whole plate, respectively. The calculation formula of the distribution standard deviation of current density was shown as follow (2) [3-5].

$$\mu_j = \sqrt{\frac{\sum_{i=1}^{n}(J_i - J_p)^2}{n-1}} \tag{2}$$

J_p is the average collecting plate current density. μ_j is the distribution standard deviation of current density. The smaller μ_j is, the better distribution uniformity of collecting plate current density is.

The ratio of the max value of the collecting plate current density J_{max} and the average collecting plate current density J_p (J_{max}/J_p) was also used to assess the distribution uniformity of the collecting plate current density. The bigger value of J_{max}/J_p is, the bigger variation of the collecting plate current density in ESP, the worse distribution uniformity of collecting plate current density is.

2.3 The Experiment Setup

The principle of the experimental device was shown in Fig. 2. This power supply had two modes of high direct current and pulse power supply. The galvanometer, C251 type, was used to measure the direct current of each small cell. The commonly used barbed nail corona electrode was used here, the height of prickle and barbed spacing are 10 mm and 50 mm, respectively. K was the transfer switch. The main parameters of pulse power supply were as followed: the pulse width is 0.1 μs-30 μs; the pulse repetition frequency is 50 pps-100 pps; the pulse amplitude is about 1.1-3 times of the base voltage.

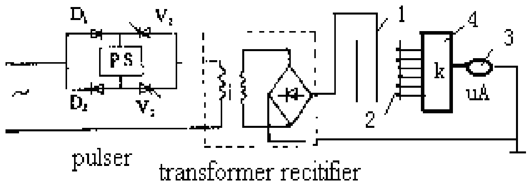

Fig. 2 The principle diagram of the experimental device for measuring current density
1- the corona discharge line, 2-the measured collecting plate, 3- the galvanometer, 4- the transfer switch

The testing plate which was made up of 36 small cell of 2.5 cm^2×2.5 cm^2 was setup parallel to corona electrode by insulating fixed frame. The space distance of homoelectrode was selected 300 mm, 400 mm or 600mm according to the experiment requirement. Every small piece unit had a bidirectional switch to connect a galvanometer. The area of every small piece unit was 6.25×10^{-4} m^2. In generally, the corona current measured were range from 10^{-4} to 10^{-5} A in normal condition, the interference signal was commonly less than this magnitude so that it can't make a large tested data error.

3 THE RESULTS AND DISCUSSION

3.1 Distribution Uniformity of Collecting Plate Current Density on the Vertical Direction

Under the same base voltage, the distribution uniformity of collecting plate current density on the vertical direction with high direct current and pulse power supply were measured, and the result were showed in Table 1 and Table 2, respectively. According to the measured data in the Table 1 and Table 2, on the same base voltage and the space distance of homoelectrode (300 mm, 400 mm and 600 mm), the standard deviation of distribution of current density on the vertical direction with pulse power supply μ_j and J_{max}/J_P were both less than that of with high direct current power supply, respectively. It is showed that the distribution uniformity of collecting plate current density on the vertical direction at pulse power supply was better than which at high direct current power supply in the same condition.

Table 1 the distribution of collecting plate current density on the vertical direction at base voltage 35 kV

The electrode spacing, mm	Power supply mode	$J_p\times10^{-4}$, A/m^2	$\mu_j\times10^{-4}$, A/m^2	J_{max}/J_p
300	direct	14.35	4.11	1.54
300	pulse	9.04	2.56	1.5
400	direct	6.69	1.29	1.45
400	pulse	4.96	1.08	1.15
600	direct	3.86	1.2	1.40
600	pulse	2.67	0.98	1.12

Table 2 the distribution of collecting plate current density on the vertical direction at base voltage 45 kV

The electrode spacing, mm	Power supply mode	$J_p\times10^{-4}$, A/m^2	$\mu_j\times10^{-4}$, A/m^2	J_{max}/J_p
300	direct	31.47	9.14	1.52
300	pulse	22.03	8.13	1.39
400	direct	15.57	7.82	1.89
400	pulse	14.88	6.29	1.7
600	direct	3.72	3.8	2.58
600	pulse	3.16	2.75	2.5

3.2 Distribution Uniformity of Collecting Plate Current Density on the Parallel Direction

Under different the space distance of homoelectrode and base voltage condition, the tested results of the distribution of collecting plate current density on the parallel direction are showed in Table 3 and Table 4, respectively. According to the measured data in Table 3 and Table 4, on the same base voltage and the space distance of homoelectrode(300 mm, 400 mm and 600 mm), the standard deviation of distribution of current density on the vertical direction with pulse power supply μ_j and J_{max}/J_p were both less than which at high direct current power supply, respectively. It is showed that the distribution uniformity of collecting plate current density on the parallel direction at pulse power supply is better than that of at high direct current power supply in the same condition.

Table 3 The distribution of collecting plate current density on the parallel direction at base voltage 35 kV

The electrode spacing, mm	Power supply mode	J_p×10^{-4}, A/m^2	μ_j×10^{-4}, A/m^2	J_{max}/J_p
300	direct	14.35	2.86	1.29
300	pulse	9.04	0.88	1.17
400	direct	6.69	1.18	1.36
400	pulse	4.96	1.17	1.24
600	direct	3.86	1.16	1.32
600	pulse	2.67	1.01	1.10

Table 4 The distribution of collecting plate current density on the parallel direction at base voltage 45 kV

The electrode spacing, mm	Power supply mode	J_p×10^{-4}, A/m^2	μ_j×10^{-4}, A/m^2	J_{max}/J_p
300	direct	31.47	10.26	1.53
300	pulse	22.03	4.49	1.43
400	direct	15.57	6.03	1.71
400	pulse	14.88	2.23	1.20
600	direct	3.72	1.47	1.12
600	pulse	3.25	1.43	1.06

3.3 The Distribution of Current Density for the Whole Collecting Plate

The tested results of the distribution of the current density for the whole collecting plate are showed in Table 5 ,Table 6 and Table 7. According to the measured data in Table 5 , Table 6 and Table 7, on the same base voltage and the space distance of homoelectrode (300mm, 400mm and 600mm), the standard deviation of distribution of current density on the whole collecting plate with pulse power supply μ_j and J_{max}/J_P were both less than that of at high direct current power supply, respectively. It is showed that the distribution uniformity of current density on the whole collecting plate at pulse power supply was better than that of at high direct current power supply in the same condition. It is consistent to the results of related literatures [3].

According the measured data in Table 5 ,Table 6 and Table 7, it also shows that the standard deviation of the distribution of the whole collecting plate current density with pulse power supply and high direct current power supply μ_j and J_{max}/J_P were both decreased with the space distance of homoelectrode increasing at same the base voltage, respectively. It means that the distribution uniformity of the whole collecting plate current density with both pulse power supply and high direct current power supply tends to be better while the space distance of homoelectrode increased on the same condition. The main reason is that when the space distance of homoelectrode increased, the electrostatic field strength gradually weakened, the distribution uniformity of the electric field tends to better, the whole collecting plate current density decreased, so that the distribution uniformity of whole collecting plate current density tends to be better. It also shows that the bigger space distance of homoelectrode can effectively improve the distribution uniformity of the whole collecting plate current density of ESP. On the other hand, no matter with pulse power supply or high direct current power supply, the average of the whole collecting plate current density increased with the supply base voltage increasing, the distribution uniformity of the whole collecting plate current density tends to be worse.

Table 5 The distribution of collecting plate current density at base voltage 35 kV

The electrode spacing, mm	Power supply mode	J_p×10^{-4}, A/m^2	μ_j×10^{-4}, A/m^2	J_{max}/J_p
300	direct	14.35	8.53	2.41
300	pulse	9.04	3.94	1.91
400	direct	6.69	2.89	3.1
400	pulse	4.96	2.19	1.44
600	direct	3.86	1.56	1.42
600	pulse	2.67	1.21	1.25

Table 6 The distribution of collecting plate current density at base voltage 45 kV

The electrode spacing, mm	Power supply mode	J_p×10^{-4}, A/m^2	μ_j×10^{-4}, A/m^2	J_{max}/J_P
300	direct	31.47	16.36	2.20
300	pulse	22.03	11.18	2.04
400	direct	15.57	11.62	2.96
400	pulse	14.88	8.50	2.19
600	direct	3.72	3.66	3.10
600	pulse	3.16	3.15	3.61

Table 7 the distribution of collecting plate current density at base voltage 55 kV

The electrode spacing, mm	Power supply mode	J_p×10^{-4}, A/m^2	μ_j×10^{-4}, A/m^2	J_{max}/J_P
300	direct	52.70	20.06	2.31
300	pulse	29.30	14.42	2.10
400	direct	28.76	13.96	2.90
400	pulse	19.60	9.61	2.21
600	direct	5.53	4.19	3.21
600	pulse	4.92	3.65	3.13

4 CONCLUSIONS

According to the analysis of the above results, the conclusion can be obtained as followed:

(1) Under the same condition, the distribution uniformity of collecting plate current density on the vertical direction with pulse power supply was better than that of with high direct current power supply. The distribution uniformity of collecting plate current density on the parallel direction with pulse power supply was better than that of high direct current power supply.

(2) The distribution uniformity of the whole collecting plate current density with pulse power supply was better than that of with high direct current power supply.

(3) Under the same condition, as the space distance of homoelectrode increased, the distribution uniformity of the whole collecting plate current density with both pulse power supply and high direct current power supply trended to be better.

(4) No matter with pulse power supply or high direct current power supply, as the base voltage increased, the average of the whole collecting plate current density increased, the distribution uniformity of the whole collecting plate current density trended to be worse.

(5) The paper only researched the distribution of the collecting plate current density of barbed nail corona electrode. But, the electrode shape how to affects the distribution of the whole collecting plate current density, and the base voltage how to affects the distribution of the whole collecting plate current density, and so on, will be deeply researched.

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