# The Application Practices of the Double-zone ESP in Coal-fired Power Plant

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**Abstract:** Through intensifying respectively functions of the charge zone and the dust collection zone of the electric fields, double-zone ESP is able to avoid back corona and to collect dust negatively charged and dust positively charged at the same time consequently to increase dust removal efficiency. Through the application effects of the mating four sets of double-zone ESPs and 4 sets of traditional horizontal type ESPs for the 4×300 MW unit in some power plant, it is proven that the double-zone ESP possesses higher dust removal efficiency and is able to increase dust migration velocity and to save floor space, steel consumption and power consumption, as compared with the conventional ESP.

**Keyword:** Streamer, double-zone electric field, migration velocity, economical efficiency

## 1 INTRODUCTION

Through gas discharge theory, it is known that breakdown of non-uniform electric field (as ESP electric field breakdown) are all due to the formation and extension of streamer.

Definition of streamer: In some parts in the gas, the formed mixing zone of positive and negative ions which possesses high conductance passage is called as streamer. It is one of the gas discharge ways (corona discharge and streamer discharge) of non-uniform electric field.

Cause of streamer formation: Normal negative corona is electron-avalanche-like extrication in corona zone. However when the bared voltage of the ESP electric fields rises continually, the photon will be discharged at the electron avalanche head as a result of the compounding of the positive and negative ions or that the excitonic atom regains normal state. The generated electron extricated by photon is entitled as photoelectron, which is at the corona outer region and forms even more extricated electron avalanche(no longer extricate through the high field intensity of the sharp electrode, while extricate through photoelectron), this even more extricated electron avalanche converges with the avalanche head of the main electron avalanche and in some parts of the gas of corona outer region forms mixing zone with high conductance of positive and negative ions. The mixing zone is called as streamer. After streamer forms, by the effect of basic electric field, the charges in streamer section are to part and go ahead the both ends of the section, hence to weaken electric field in the streamer. Thus, although streamer occurs at the edge of the corona zone, the potential from it to opposite electrode is almost the same with that to the sharp electrode, because the interior electric field intensity of streamer is very weak (i.e. streamer obtains the ability to transmit potential), which is equivalent to that the sharp electrode extends forward and makes extrication develop at the depth of the electric field gap (corona outer region) and results in breakdown (spark.) Thus, the breakdown course of ESP electric fields is finished in three segments, i.e., corona zone electron avalanche (corona)-corona outer region streamer-electric field breakdown. Therefore the formation of streamer is premonition of electric field breakdown; it is also acceptable to say that the streamer formation is the sufficient condition of electric field breakdown. As for conventional ESP with single zone and negative corona, this kind of pre-breakdown streamer is unfavorable, in respect that streamer will speed up discharge development and make breakdown voltage decrease. What is more important, streamer formation makes cation and positive dust charged by cation appear in corona outer region (in the streamer, the appearance of cation at corona outer region will enhance DE ionization making the corona current increase, streamer tend to develop and breakdown voltage fall. At the same time, as for the dust, cation reduces the charge capacity of negatively charged dust and even charges the dust positively to make positive corpuscles form at corona outer region of the electric fields.) Whereas ESP with single zone and negative corona can not collect positive corpuscle dust charged by the cation in the streamer, therefore dust leakage rate increases, the deposited dust layer on the corona wire will become thick, which brings the ESP operation exacerbation.

At corona outer region of conventional ESP, cation and positive corpuscle dust charged by cation also exist. One of the sources is before electric field breakdown gas discharges and forms streamer, which is the mixing zone of the positive and negative ions. Its second source is cation and positive corpuscle dust charged by cation formed because of back corona. Its third source is the carbon in the dust with much fly ash combustible substance, which tends to be charged positively and form cation and positive corpuscle dust charged by cation. Since the cation and positive corpuscle dust charged by cation exist at corona outer region, then these ions and dust must have an escape hatch, therefore a sort of structure needs to be designed to collect them.

It is common knowledge that dust charge requires high corona current in the electric field, while collection of charged dust requires high field intensity but not high current. Thereby, charge and dust collection is contradictory at the corona current aspect. Especially for collection of high specific resistance dust, too high current will give birth to high electric field on the collected dust layer and cones- quently result in dust layer gap breakdown, back corona and dust removal efficiency drop. As against double-zone ESP, the charge zone and dust collection zone of the double-zone electric field are structurally completely separated and is able to be intensified respectively.

Through variant wire-plate tests, Longking has developed a new model of double-zone ESP - mechanical and electronic multiplex double-zone ESP (hereinafter referred to as double-zone ESP.) In November 2005, the double-zone ESP obtained China national patent with the patent number of ZL 2004 2 0040845.5. It is composed of charge zone structure of the conventional needle bared wire & flat plate type BE plate and the dust collection zone structure of tube type auxiliary electrode & flat plate type BE plate. These two structures is configured alternatively, each of which is energized by independent power supply. Thus, charge and dust collection functions are intensified respectively and forms a sort of mechanical and electronic multiplex structure. In no-load electric pressure build-up test, no spark over appears in the fields composed of tube type auxiliary electrode and flat plate type BE plate with the gas passage spacing of 400 mm, when the electric field intensity reach 4.2 kV/cm. During actual operation, its secondary voltage is able to reach 80 kV in general, which intensifies enormously dust collection function.

## 2 WIRE-PLATE FORM OF DOUBLE-ZONE ESP AND DOUBLE-ZONE ELECTRIC FIELD CHARACTERISTICS

### 2.1 Wire-plate Form

In the new double-zone model structure ESP design, fore stage electric fields adopts conventional BE model wire-plate form to emphasize dust charge and collect charged dust with CE plate. The BE model standard subsections in the end electric field is designed as a complex double-zone electric field (Q.V. Fig. 1) The double mast DE frame in every standard subsection is divided into two single mast DE frames, each of which corresponds to two pieces of CE plates. The two neighboring single mast DE in downstream direction is discharge type DE and auxiliary electrode type DE in sequence. Discharge type DE together with two pieces of CE plate constitute charge zone 1 or charge zone 2 sharing the same set of high-voltage power supply. Auxiliary electrode type DE together with two pieces of CE plate constitute dust collection zone 1 or dust collection zone two sharing the same set of high-voltage power supply too.

### 2.2 Characteristics of the Double-zone Electric Field

The cold state electric field voltage-current characteristic test shows that when the gas passage spacing is 400mm, the secondary voltage of double-zone electric field dust collection zone exceeds 80 kV, while the secondary voltage maximum value of the charge zone is around 70 kV. Generally in thermal state operation, the voltage of dust collection zone is able to reach 80kV which is about 20 kV higher than that of the charge zone, while the corona current is about only 15% of that of the charge zone. It can be seen that the operating voltage and electric field intensity of dust collection zone are both higher than those of the charge zone, while the corona current of dust collection zone is very low. Besides, because of the adoption of the tube type auxiliary electrode, plate current density distribution is very uniform, consequently, this section not only does not tend to occur back corona, but also is able to collect more fine charged dust particle and positive corpuscle dust. Furthermore, high field intensity also increases the electric adhesive force of the low specific resistance dust, accordingly depresses the possibility of that the dust retrains into flue gas from CE plate on account of gas flow disturbance[1].

As compared with traditional structural electric field, double-zone electric field obtains the following four merits: (1) Average efficiency of dust collection is comparatively higher. (2) It is able to collect more fine charged dust particle. (3) It has tube type DE wire of comparatively big surface area, which can collect dust particle charged positively. (4) It has adaptability for wider scale of flue dust and is suitable to collect high, media and low specific resistance dust.

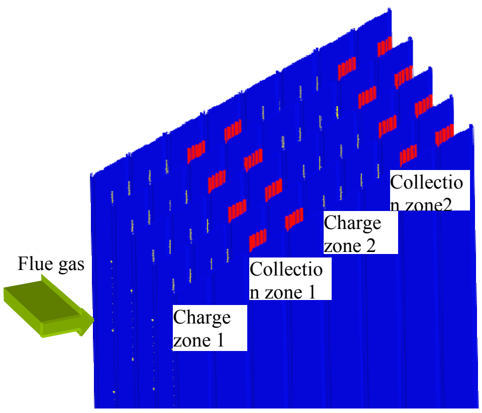


**Fig. 1** Double-zone electric field wire-plate form configuration

## 3 APPLICATION EXPERIENCES

### 3.1 Application in 2×300MW Unit

The first two sets of mates with the 2×130 t/h pulverized coal fired boiler in certain power plant in east china region, was put into service respectively in April 2004 and June 2004 and both passed the device inspection successfully because of its high dust removal efficiency and low emission (dust removal efficiency 99.93%, emission value 27.4 mg/DNm$^3$.) In first half year of 2006, Longking had rebuilt four sets of ESP mating 2×300 MW unit of #1 and #2 boilers in period 1 of another power plant in the same region, adopting double-zone electric precipitation technology again. Boiler BMCR load was 1025 t/h, the mating ESP of each of which before rebuilding was of double columns, double chambers, four electric fields and cross-sectional area of 2×221 m$^2$. The four sets of ESP were put into service from second half-year of 1996. Owing to coal sort fed to the boiler changed frequently, after operation for several years, the dust emission could not satisfy new Chinese environmental requirements (≤50 mg/DNm$^3$.) The performance testing result was as follows: the

ESP outlet flue dust emission value of #1 and #2 boilers was respectively 127.0 mg/DNm$^3$ and 148.0 mg/DNm$^3$. Its dust removal efficiency was respectively 99.09% and 98.96%.

In the second half-year of 2005, the power plant put forward the rebuilding plan of the #1 and #2 boiler ESP, which required the designed coal sort is based on the Jingbei soft coal of Shanxi, China, at the same time, the burnt coal was allowed to fluctuate within a certain scale. Besides, it was also required to rebuild the original ESP with the highest value-cost ratio scheme, which required not to replace the CE plates of the original four electric fields, but only to overhaul the four electric fields, as well as to add one electric field advisably. After rebuilding, the ensured dust removal efficiency must be ≥99.60% and the outlet dust emission concentration must be ≤50 mg/DNm$^3$.

When perambulating the site conditions, it was found that only a limited site of 4.8 m long is available at the outlet side to add an electric field. If the rebuilding of the #1 and #2 boiler ESP adopted conventional method to add one electric field at the outlet side, then the maximal specific collecting area was to be 78.30 m$^2$/m$^3$/s calculated according to inlet flue gas volume supplied by the user. As Longking's experiences of burnt coal for the power plant boiler and its contrastive analysis, it was found that the rebuilding result will be difficult to satisfy customer requirements. Therefore, after many times of technical argumentation, Longking finally decided to adopt double-zone technology in the new add fifth electric field, in which the independently developed CS10A type needle wire functioned as DE corona wire for charge zone and the tube-type auxiliary electrode for dust collection zone. The CE plate was the same with the forestage electric fields, adopting BE plate. Simultaneously the twisted wire in the fourth electric field of the original ESP was replaced by CS10B type needle wire so as to increase discharge performance. The new added fifth electric field was equipped with four sets of high-voltage power supply, which energized the charge zone and the dust collection zone respectively. Meanwhile, the original high and low voltage control system of the four electric fields was rebuilt adopting the latest digital technology and was configured with power control rapping technology.

ESP for each boiler was rebuilt as double columns, double chambers, five electric fields, of cross-sectional area of 2×221 m$^2$ as the original one, gas passage spacing is 405mm and general dust collection area is 41685 m$^2$ containing dust collecting area of the tube type auxiliary electrodes in the end electric field.

The ESP of two boilers was completely rebuilt respectively in April and May of 2006. Four months after being put into service, the local power environmental monitoring research center station proceeded efficiency test towards the ESP of two boilers in the first ten days of August, 2006, of which the test result Q.V. Table 1.

As chart 1 shows, under the condition that the #1 and #2 boilers employed design coal sort, the mating ESP's efficiency reached the design requirement and outlet flue dust concentration coincided with environmental requirements, when practice treatment flue gas volume is more than its design value.

During test period, in the charge zone, the secondary voltage was 48~55 kV and the secondary current was 520 mA-650 mA; in the dust collection zone secondary voltage was 72 kV-80 kV and secondary current was 60 mA-75 mA.

**Table 1** efficiency test result of the #1 and #2 boilers ESP after rebuilding

| Parameter | Unit | Design Value | #1 Boiler | #2 Boiler |
|---|---|---|---|---|
| Boiler load | t/h | 1025 | 897.1 | 763.2 |
| Inlet flue gas volume | m$^3$/h | 1819512 | 2018000 | 1845200 |
| Inlet concentration | g/DNm$^3$ | 12.600 | 14.570 | 16.040 |
| Outlet concentration | mg/DNm$^3$ | 50.0 | 44.3 | 49.3 |
| Efficiency | % | 99.60 | 99.69 | 99.69 |

Note: When calculating dust removal efficiency, body air leakage rate is not under consideration.

At the same time of rebuilding #1 and #2 boilers 2x300MW unit of period 1, the power plant was expanding #3 and #4 boiler of period 2. Mating four sets of ESP are still designed and supplied by Longking. Because the purchase contract was earlier than that of the #1 and #2 boilers, the double-zone technology was not employed. The mating ESP for each boiler was of double columns, double chambers, five fields, cross-sectional area of 2×278 m$^2$ and gas passage spacing of 410mm, general dust collection area was 48874 m$^2$

Five months after the mating ESP of #3 and #4 boilers was put into service, the local power environmental monitoring research center station proceeded ESP performance test of the #4 boiler at the end of the Oct., 2006, the test results is as Tbale 2.

**Tbale 2** the ESP efficiency test results of the #4 boiler

| Parameter | Unit | Designed value | Test value |
|---|---|---|---|
| Boiler load | t/h | 1025 | 945 |
| Flue gas volume | m$^3$/h | 1821315 | 1830800 |
| Inlet concentration | g/DNm$^3$ | 15.000 | 12.110 |
| Outlet concentration | mg/DNm$^3$ | 50.0 | 31. 7 |
| Efficiency | % | 99.67 | 99.74 |

Notes: the burnt coal quality of the #4 boiler when under taking test is almost the same with that of the #1 and #2 boilers.

### 3.2 Improvement Coefficient

Through the parameters in Chart 1 and Chart 2, the main test parameters of the ESP of the #1, #2 and #4 boilers can be compared and analyzed, of which the parameters Q.V. Table 3. Among the chart 3, the dust migration velocity($\omega_k$) is obtained according to the Matts' modified formula to Deutsch-Anderson formula (the value of the index $K$ is 0.5 )[2].

Not considering the affects of the other factors, adopting the Matts' modified formula to Deutsch-Anderson formula (the value of the index $K$ is 0.5). It can be reasoned that when the expected dust removal efficiency of the #4 boiler ESP is 99.69%, the required SCA is 90.50 $m^2/m^3/s$.

**Table 3** the comparison of main test parameters of the ESP of the #1, #2 and #4 boilers

| Parameter | Unit | #1 Boiler | #2 Boiler | #4 Boiler |
|---|---|---|---|---|
| SCA | $m^2/m^3/s$ | 74.36 | 81.33 | 96.10 |
| Efficiency | % | 99.69 | 99.69 | 99.74 |
| $\omega_k$ | cm/s | 44.87 | 41.03 | 36.87 |

It can be seen that compared with the conventional ESP, the double-zone ESP requires for smaller SCA under the same expected dust removal efficiency, because the dust migration velocity increase resulted from the bigger fields intensity of the collection zone. For example, when the expected dust removal efficiencies of the #1, #2 and #4 boilers are 99.69%, the SCA of the double-zone ESP of #1 and #2 boilers is respectively the 82.17% and 89.87% of that of the #4 boiler. The average SCA of the 4 sets of the double-zone ESP is the 86.02% of that of the #4 boiler, which means the SCA improvement coefficient is 13.98%.

### 3.3 The Application In Another 300 MW Unit Power Plant

The #2 1025t/h pulverized coal fired boiler in a certain power plant in the north of China with 300 MW turbo unit was put into service in February 1997. The original mating ESP was two sets of the double-chamber and three-field ESP, of which the dust removal efficiency is very low and the emission concentration was over 500 $mg/DNm^3$ after long-term operation. The power plant required to rebuild the ESP of which the outlet dust emission concentration after rebuilding should be ensured to be ≤50 $mg/DNm^3$.

During October to December of 2007, Longking undertook the following thorough rebuilding of the original ESP: added a double-zone field at the outlet side of the original three fields thereby to make the ESP two sets of four-field double-zone ESP, simultaneously replaced the CE and DE system of the original three fields and increased the height of the ESP to increase its cross-sectional area and to decrease electric field flow rate. In March, 2008, the local power experiment institution undertook performance test of the rebuilt two sets of the double-zone ESP. The test result shows, when the unit electricity generation load is 318 MW, the outlet flue dust emission concentration of the two sets of ESP are respectively 36.6 $mg/DNm^3$ and 36.7 $mg/DNm^3$, which accorded with the environment requirements.

### 3.4 Application Experiences

Up to now, the set number the double-zone ESP which is designed by Longking and is during installation (installed included) is 50 in total, of which the 4 sets are for the new built 660 MW unit of period two in the power plant of north east of China, 30 sets for 300 MW level unit, 5 sets for those in the scale of 100 MW to 200 MW and 11 sets for units below 100 MW.

## 4 ECONOMICAL EFFICIENCY ANALYSIS

### 4.1 Floor Space and Steel Consumption

Through the contrastive analysis between the performance effects of the mating double-zone ESP and conventional horizontal ESP for the 4×300 MW unit in a certain power plant in northeast of China, it is obvious that with the same design input parameters, the 4 sets of double-zone ESP can save 13.98% SCA. However, according to the performance parameters of another several sets of the double-zone ESP, the improvement of the dust migration velocity and SCA saving amount of the double-zone ESP are all related to the power plant boiler model, boiler burnt coal sort and are depending to the practical dust characteristics and the flue gas characteristics. Generally speaking, when the flue dust specific resistance reaches over$10^{11}\Omega\cdot cm$, the five-field double-zone ESP for 300 MW unit can save more than 10% SCA (auxiliary electrode SCA included), more than 12% floor space and about 130 tons of steel materials, compared with conventional horizontal type ESP.

### 4.2 Electricity Consumption

The charge zone and collection zone of the double-zone ESP are energized separately by independent HV power supply. The charge zone employs power supply according to conventional plate current density. However, since in the collection zone the on-site operation voltage is very high and the current is very low, when the gas passage spacing is 400mm, the voltage is chosen as 80 kV. For the dust with not too high specific resistance, 90 kV level can be chosen; the plate current density is general between 0.05 mA-0.08 $mA/m^2$. Compared to conventional ESP fro 300MW unit, to reach the same dust removal efficiency, the double ESP can save 15%-18% electricity consumption.

## 5 CONCLUSIONS

In double-zone electric fields, the wire-plate form of the charge zone is almost the same with the conventional electric fields, which not only charges the dust, but also collect the negatively charged dust. The collection zone is composed of the tube type auxiliary electrodes and ordinary plate type CE plates, which possesses characteristics of high electric voltage, low current and more uniform plate current density distribution.

The industrial application results show when collecting coal burnt boiler dust, the double-zone ESP can be adaptable to comparatively wide scale of coal without back corona in the dust collection zone and with more stable operation. Besides the dust removal efficiency, dust migration speed and value-cost ratio are all higher than the conventional horizontal ESP. The last but not the least, it can reduce the flue dust emission concentration below 50 $mg/DNm^3$ thereby to reduce the fine dust emission, which is favorable to protect atmosphere environment and human health.

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