The Newest Technical Results Capable of Remarkably Increasing ESP Efficiency

Wang Weixue   Fang Aimin   Cao Feng
State Power Environmental Protection Research Institute
10 Pudong Road, Pukou, Nanjing, Jiangsu Province, P. R. China, 210031

Since the middle of 1980s, State Power Environmental Protection Research Institute has been dedicating its efforts to the research in increasing efficiency of ESPs, especially those operating under the worst conditions or in collecting dusts with high specific resistance. The profound research is developed in the respects of improvements of power supply's characteristics, adoption of more ideal modes of energization, elimination of back corona hazards etc. and a series of essentially practical technical results have been achieved, which can be concluded as follows:

1 The results in improvements of power supply's characteristics

It is indicated from our research results that the characteristics of the high power supply is especially important in improvement of ESPs efficiency. The innovated DJ series of ESP PC-controlled high voltage power supply systems are capable of remarkably increasing ESP efficiency and have the following properties:

[1] Ability to accurately judge flashover signals and treat them in an optimum way:

Thanks to this achievement, the power supply systems can accurately recognize flashover signals so that the harmful excess current strikes shown in Fig.1 due to false judgments of flashover signals in the fields can be avoided.

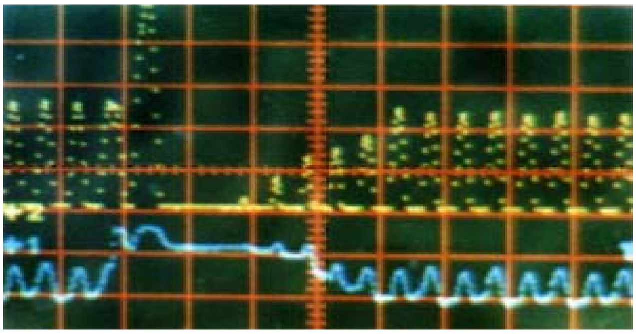

Fig.1

DJ series of ESP PC-controlled high voltage power supply systems can not only guarantee no occurrence of harmful flashover excess current strikes, but also have ability to keep the fields no rest time and resume the voltage at a very high speed. In this way the voltage loss is minimal so that the operating voltage can have the highest value even though the flashovers are frequent shown as Fig.2

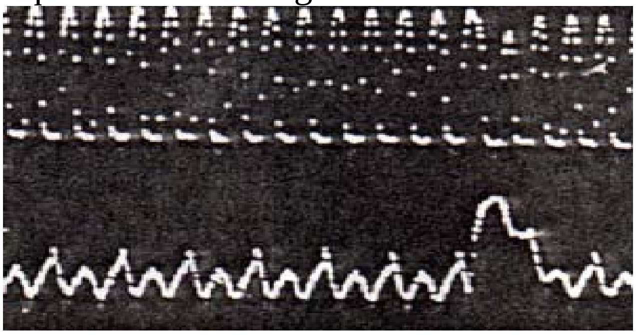

Fig.2

[2] Ability to keep the fields at the level of allowable maximum voltage all along:

To realize this ability, The power supply system should not only have high tracking level, but also can guarantee the voltage loss a fairly small decrease even when flashovers occur frequently. Just as shown in Table (1), under the same operational conditions whether the power supply operates with few spark rate (flashover frequency <10/min.) or high spark rate (flashover frequency ~150/min.), the operational voltage can be kept approximately constant.

Table□1□

Primary Voltage □V□	Primary Current □A□	Secondary Voltage □kV□	Secondary Current □mA□	flashover frequency □1/min.□	Flow Angle
218	32	46	175	8	123
198	27	45	151	0	114
330	54	47	270	149	143
304	49	46	247	152	138

[3] Ability to adjust, control and raise the effective corona current to improve dust charging:

This ability of adjustment and control is confirmed from the test results in Table (1). There is a large increase of corona current in the fields when flashover frequency reaches 150/min from lower flashover frequency (10/min.).

2 The developments achieved by adopting new mode of voltage regulation of power supplies:

AC phase shift voltage regulation is commonly used in high voltage power supply for ESPs. The fatal weakness of this mode lies in too high a phase-shift regulated peak voltage output from the controllable silicon, but very low an average voltage when operational conditions are severe or high specific resistance dusts are precipitated with hazards of back corona. In this case the effect of corona becomes poor and the dust charging is seriously insufficient, leading to great decrease of ESP efficiency.

To counter this situation, the author has successfully developed DJ-TY type ESP power supply systems with a combination of both amplitude modulation and phase shift. These systems not only possess the properties of DJ series power supplies but also can make the operational parameters and ESP efficiency remarkably increase under the severe conditions or in collecting high specific resistance dusts as shown in Table (2) (The contrast of ESP efficiency with a DJ-TY system to that with a common voltage regulation power supply).

Table 2

Contrast Contents	U1（V）	I1（A）	U2（kV）	I2(mA)	ESP efficiency（%）	Dust emission（mg/Nm^3）
Old power supply	244	83	42	340	99.3	120
DJ-Typower supply	293	135	48	644	99.8	34

3 The developments in collecting high specific resistance dusts

A profound research in “back corona phenomena and the hazards” in collecting high specific resistance dusts has been carried out and a series developments have been achieved as follows:

[1] “Three hazards” influencing ESP efficiency due to the high specific resistance dusts

（1） Electrostatic attraction hazard in collecting high specific resistance dusts, which makes the dust layers on the anodes difficult to remove

Electrostatic attraction hazard due to high specific resistance dusts makes the dust layers on the anodes difficult to remove. This phenomenon can be confirmed through the changes of the operational parameters and the dust emission before and after power-off rapping as shown in Fig. 3.

The regular of opacity before and after power-off rapping

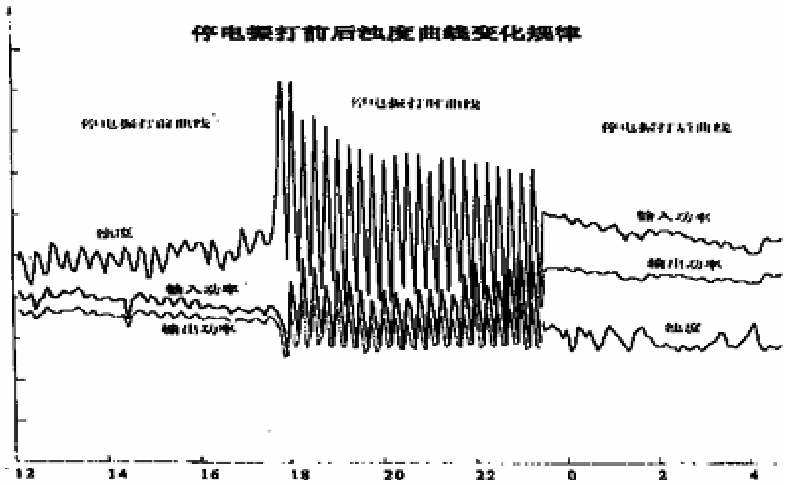

Fig. 3

(2)”Electrostatic attraction hazards” make the movement of dust particles slower and slower

The negative field generated by the negative charges remained on the dust layers on the anodes becomes stronger and stronger with increase of the thickness. The negative field obstructs the negatively charged particles approaching the anodes, makes the approaching speed slower and slower until the particles can not be driven to the anodes.

(3)“Back discharges” lead to lowering breakdown voltage of the fields and poor corona effect meanwhile

When the comprehensive effects of both ”Electrostatic attraction hazards” and ”Electrostatic repulsion” develop to the extremity the “back corona” occurs randomly so that the operational voltage in the fields will be decreased by a big margin, leading to poor corona effect, insufficient dust charging and serious decrease of ESP efficiency.

According to traditional investigation it may be considered that with the development of back corona there would appear a negative resistance zone in the V-A characteristics as shown in Fig.4. However in our research it is discovered that the occurrence of the negative resistance zone is not an inevitable result from back corona, but primarily due to failures of the power supply in recognition of prior signals of back corona. In this case the voltage is not adjusted in time leading to being out of control of the voltage and transition from normal characteristics(fig.5) of power supply to a state of serious flashovers(fig.6).

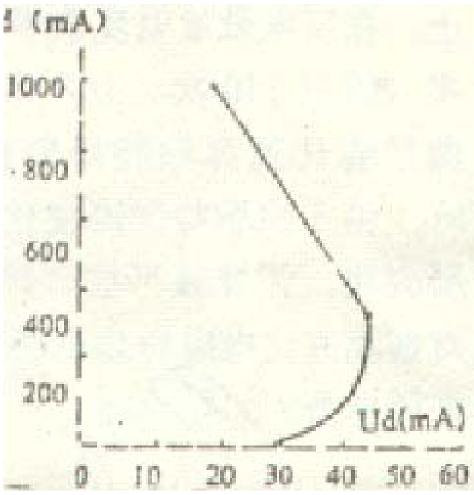

Fig.4

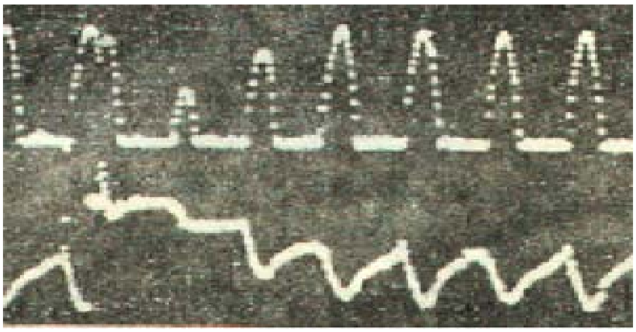

Fig.5

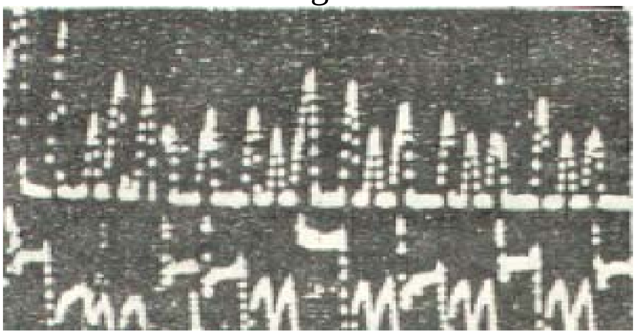

Fig.6

So long as the power supply has the controlling function to recognize the back corona phenomena and reasonably adjusts and controls itself in time the V-A characteristics would not generate negative resistance zone as shown in Fig.7.

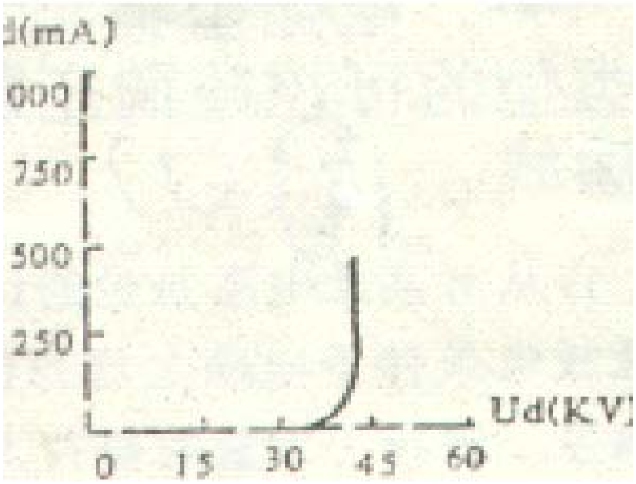

Fig.7

[2] The mutual relationship and consequences of the "three hazards":

The consequences of both "electrostatic attraction hazard" and "electrostatic repulsion hazard" caused by high resistance dusts greatly lower the operational voltage leading to weakening the electrostatic force by the field on the one hand and on the other hand slow down the movement of the charged particles to the anodes and even obstruct them to approach the anodes. When the two hazards reach the extremity the back coronas occur and the normal corona conditions are destroyed.

The combined effects of the three factors mentioned above lead to frequent back corona discharges so that the ESP efficiency of collecting high resistance dusts greatly decreased.

[3] The electrostatic precipitators with narrow gaps have ability to collect high resistance dusts efficiently

Under the same conditions of dust charging (same equivalent electric field strength and charging rate) and geometric sizes the electrostatic precipitators with narrow gaps allow higher efficiency than those with wide gaps. That reason is given as follows:

According to the reduced expression for ESP efficiency:

$$\eta \Rightarrow W \cdot A$$

where η—ESP efficiency, W—shift velocity of the charged particles and A—the total area of the collecting plates.

(1) With the same outside size, narrower gaps mean increase of area of collecting plates. True, under some conditions, increase of A can not lead to improvement of ESP efficiency. But the basic reason of this phenomenon is deterioration of the charging conditions in this case.

(2) In order not to decrease shift velocity of the dust particles, the charging conditions in the narrow gap ESP should be kept the same as in the wide gap ESP. In this case, the travel distance of the particles to the anodes is short. That is equivalent to increase of shift velocity of the dust particles（i.e. W↑）. Meanwhile because both A and W are increased then we have:

$$\eta\uparrow \Rightarrow W\uparrow \cdot A\uparrow$$

That is the reason why the ESP efficiency is increased by use of narrow gap ESP to collect high resistance dusts.

[4] New theoretical basis and measures for increasing ESP efficiency in collecting high resistance dusts

Because the conclusions drawn in our research are just opposite to the traditional ones the theoretical basis and measures for increasing ESP efficiency in collecting high resistance dusts are quite different:

（1）The new theoretical basis：

In collecting high resistance dusts it is impossible to stop the “random back corona discharges”. These may lead to serious decrease of operational voltage (electric field strength) and corona current and then poor ESP efficiency. Therefore we started from improving the characteristics of the power supply to eliminate the negative resistance zone due to back corona discharges. The essential prerequisite to increase ESP efficiency in collecting high resistance dusts lies in trying every means to increase the effective operational values of voltage and current so as to improve dust charging.

(2) New requirements in design of the main body structures

● Strengthening rigidity of both cathodes and anodes is emphasized. It is considered essentially that deformation should be prevented so as to protect energization from deterioration caused by mechanical reasons.

● Excellent discharge properties of the cathodes are emphasized so as to guarantee good corona effects and improve the dust charging.

● Pate gap≤300. Because to stop back corona is impossible in collecting high resistance dusts, increase of area of the plates may compensate part of its influence.

(3) New energization mode

● By use of combination of amplitude modulation/phase shift energization mode to try every means to increase effective current and improve dust charging. With this demand the power supply system must have the same voltage regulation mode and good control properties as in DJ series of ESP PC-controlled high voltage power supply systems.

[5] Practical results in use

The good results are confirmed in use of practical industries. As an example, the results of a retrofitting boiler's ESP for a 30MW generator are given as follows

1The basic situation before retrofitting

● Sulfur content of the coal: 1.25%

● Gap of the plates: 300

● Cathode corona wire: prong type in 1st and 2nd fields, sawtooth type in the 3rd

● common controllable silicon voltage regulation power supply

2The basic situation after retrofitting

● Sulfur content of the coal: 0.65%

● Gap of the plates: 300

● Cathode corona wire: prong type in 1st, 2nd and 3rd fields,

● DJ-TY type amplitude modulation/phase shift power supply

3Comparison before and after retrofitting

● The operational parameters before and after retrofitting are listed in Table (4)

● The efficiency contrasted before and after retrofitting are shown in Table (5)

● The results after retrofitting:

●● The operational parameters are increased remarkably after retrofitting, especially the increase of the voltage and current in the 3rd field is more remarkable.

●● The ESP efficiency is increased from 96.85% before retrofitting to 99.4% after retrofitting.

●● The dust emission is decreased from 500mg/Nm^3 before to retrofitting to less than 70mg/Nm^3 after.

.

Table□4□

Electrostatic precipitator			items	unit	1^{st} field		2^{nd} field		3^{rd} field	
					Primary	Secondary	Primary	Secondary	Primary	Secondary
before	A	A1	Voltage	V	225	50000	190	48000	220	56000
			Current	A	110	0.57	90	0.3	110	0.5
		A2	Voltage	V	200	59000	215	45000	90	40000
			Current	A	67	0.25	125	0.5	10	0.05
	B	B1	Voltage	V	140	50000	260	50000	180	55000
			Current	A	80	0.4	100	0.45	60	0.3
		B2	Voltage	V	170	45000	260	40000	170	30000
			Current	A	60	0.2	150	0.65	50	0.2
after	A	A1	Voltage	V	300	47000	340	52000	330	50000
			Current	A	96.2	0.92	195	0.90	210	0.80
		A2	Voltage	V	310	43000	340	52500	330	54000
			Current	A	105	0.50	210	0.9	200	0.83
	B	B1	Voltage	V	300	44000	330	48000	315	49000
			Current	A	110	0.45	210	0.93	180	0.90
		B2	Voltage	V	330	45000	350	47000	300	47000
			Current	A	120	0.53	200	0.93	160	0.75

Table□ 5 □

No	Items	unit	before						after					
			entrance				exit		entrance				exit	
			A		B		A	B	A		B		A	B
			a	b	c	d			a	b	c	d		
1	Atm. pressure	Pa	101400						101600					
2	Temperature difference of dry and wet bulbs	°C	45				45		37				43	
3	Saturated water vapor pressure	Pa	8258				8258		7816				7816	
4	Temperature of the flue gas	°C	140	146	164	156	140	153	141	145	144	142	142	142
5	Gas dynamic pressure	Pa	87.70	134.78	113.49	120.26	170.37	179.4	108.76	151.12	140.74	148.34	189.21	211.98
6	Total pressure of the flue gas	Pa	-2550	-2670	-2570	-2620	-2980	-3020	-2680	-2730	-2790	-2760	-3000	-3100
7	Static pressure of the flue gas	Pa	-2640	-2810	-2700	-2740	-3150	-3200	-2810	-2940	-2890	-2910	-3490	-3620
8	Humidity of the flue gas	%	5.54				5.54		5.53				5.35	
9	Flow rate of the flue gas	m^3/h	440942	551091	516114	526567	1027845	1070648	491602	583356	561494	575103	1085754	1150015

10	Flue gas	Nm^3/h	260352	320184	288038	298994	605557	615386	289671	339171	328202	337697	636828	673623
11	Concentration of the dust	g/ Nm^3	17.51	17.54	17.53	17.53	0.5254	0.5306	10.11	12.68	11.84	11.42	0.0624	0.0746
			17.53		17.53				11.05		11.63		0.0687	
12	Pressure loss	Pa					364	424					293	325
							395						309	
13	Oxygen content	%	6.98	6.71	7.10	7.20	7.40	7.77	7.12	7.05	7.35	7.45	7.25	7.55
14	Wind leakage rate	%					4.31	4.83					1.27	1.16
							4.57						1.21	
15	ESP efficiency	%					96.87	96.83					99.45	99.35
							96.85						99.40	