PARTICULATE REDUCTION USING A SERIES OF ESPS IN A COAL BASED THERMAL POWER PLANT

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ABSTRACT:

Performance of Electrostatic Precipitator (ESP) deteriorates over the years and they are not able to meet the required emission standard. In the present paper we discuss the performance of ESP's in a power plant, which is situated right in the centre of a mega city. As the power plant is surrounded by densely populated area of the city the other emmision control methods like flu gas treatment with SO3/NH# cannot be applied due to a further risk of pollution. Pulse charging methed has also limited scope of further enhancing the particulate collection efficiency of ESPS. The decision was taken to put additional unit of ESP along with existing unit of ESP. Performance Guarantee (PG) tests were carried out for the whole ESP systems. Samples were collected from the inlet and outlet of the each ESP systems. The collection efficiencies were determined for individual and for the whole set of ESPs. The results indicate a significant deterioration of collection efficiency old ESP unit at the level of (90-93)% against designed value of more than 99%. The new ESP unit, which was put ahead of old ESP unit, was operating in the range of (93-96)% of collection efficiency. The over all Collection efficiency of the system exceeded all the time more than 99.5%.

1. INTRODUCTION:

An electrostatic precipitator (ESP) is integral parts of coal based thermal power plant to control particulate emissions. ESPs are being used at DVB IP stations in Delhi. Initially BHEL-make ESPs were being used for 60 MW boiler at unit-5 of DVB IP stations. Over the years the performance of BHEL ESPs deteriorated and they are not able to meet the required emission standards. As IP station is right in the heart of city, the other emission control methods like flue gas treatment with SO_3/NH_3 can not be applied due to a further risk of pollution. Pulse charging method has also limited scope for improving the particulate collection efficiency of ESP. The decision was, therefore, taken to put additional units of ESP along with existing ESPs supplied by BHEL.

In order to meet the particulate emission standards, DVB IP station has acquired additional set of ESPs from Alstom Power Boiler Ltd., Shahabad-585229. These ESPs are working in series with existing BHEL ESPs for 60 MW boiler at DVB IP station unit-5, Delhi. The flue gases coming out from the boiler are allowed to flow through two passes namely A and B. A set of ESPs consisting of ALSTOM ESPs followed by BHEL ESPs are fixed in each of the pass. The clean flue gases from pass A and pass B are combined and then passed through stack. The probing ports are available at the inlet and outlet of Alstom ESP. The inlet ports for BHEL ESP are the outlet ports for the two ALSTOM ESPs. However, the outlet probing ports for the A&B passes of BHEL ESPs are common after ID fan but before entry to stack. A schematic diagram of the gas cleaning system consisting of ESPs is shown in figure-1.

2. INVESTIGATIONS:

The emission level from the power plant depends on the stable operation of boiler and efficient functioning of ESPs. Performance Guarantee PG tests unit-5 of DVB IP station Delhi were to be carried out when the boiler got stabilized at about 60% load in the first week of March 2002. For carrying out dust loading tests at various parts of ESP systems, the services of SIMA (Sophisticated Industrial Materials Analytic) Labs Pvt. Ltd. Okhala Industrial Area, New Delhi- 110020 were acquired. Simultaneous dust loading test were carried out in a given pass at the inlet of ALSTOM ESP, at the common junction of outlet/inlet of ALSTOM/BHEL ESPs and at final out let of ESP systems. The test were conducted in pass A and B. Two sets of readings were obtained at different times on each points. Besides the measurements of dust concentration, other parameters like flue gas flow rates, flue gas temperatures, pressure drops etc. were also measured. A record of electrical operating parameters of each field in ALSTOM and BHEL ESPs were kept besides boiler side reading of unit 5.

(i) The stack monitoring parameters are listed in Table1. The measured parameters are flue gas temperature (^{0}C); inlet/outlet and final velocities in side the duct (m/s), flue gas volume flow rates (NM^3/hr), and suspended particulate matter, SPM, (mg/ NM^3). In all 12 sets the measurements have been taken at different points in the two passes A and B. The reading recorded have been depicted in figure.1 enclosed.

(ii) The electrical parameters in each field of ALSTOM ESP have been recorded during the investigation periods. Primary voltage (V) and current (A), secondary voltage (kV) and current (mA), spark rate per minute in all six fields (3 each in pass A and B) have been recorded at different times.

(iii) The operative electrical parameters in BHEL supplied ESPs, which following the ALSTOM make ESPs in each pass have also been recorded at different intervals during investigations.

3. RESULTS AND DISCUSSIONS:

Based on the observations made during investigations the particulate collection efficiency of ALSTOM ESPs and overall efficiencies of the system have been evaluated and other observations have been made. The results are summarized as follows:

(1) If one observes the volume flow rate of flue gas (QE/Hr) in table 1, the total volume of gas flow on pass (A) +pass (B)is more than the final outlet flow. A similar trend is observed through out the investigation. This shows leakage of gases in the path between the outlet of ESPs and final out let. (Ref. in the figure 1). The gas flow rate vary between 178638 Nm3/hr (49.62 Nm^3/sec) to 190774 Nm3/hr (52.99 Nm^3/sec). The leakage of gas varies in the range (6-10)%. It might result in higher reading of SPM (Solid Particulate Matter) per unit of volume than the actual, as the flue gas will leak leaving SPM behind. Pluging the leakage will result in actual observed values.

(2) The operating parameters are as follows:

Gas flow rate ≈101.6 m^3/s, Gas temperature ≈ 130 ^{0}C
Specific consumption rate ≈ 0.8 Tons/MW/hr.
Electrical load ≈ 37 MW, Coal ash ≈ 40%, Fly ash ≈ 90%
≈ 29.13 gm/ m^3 at 130 ^{0}C ≈ 43.0 gm/ NM^3

$$\text{Inlet dust concentration} \approx \frac{37 \times 0.8 \times 0.9 \times 0.4}{101.6 \times 3600} \times 10^6 \text{ gm/m}^3$$

Thus, this value matches well with those measured values of SPM (mg/ NM^3) and shown in table 1 & figure 1.

(3) The observed values shown in table 1 has been used to calculate the collection efficiencies of ESP systems. The dust collection efficiency has been calculated using following relations

i) Dust collection efficiency of ALSTOM ESP/BHEL ESP

$$= \frac{\text{Inlet dust loading at pass A or B – Outlet dust loading at pass A or B}}{\text{Inlet dust loading at pass A or B}}$$

ii) Dust collection efficiency of overall system:

$$= \frac{\text{Inlet dust loading at pass A– Final outlet}}{\text{Inlet dust loading at pass A}}$$

iii) Theoretical efficiency of ESP may be calculated by using Deusch- Anderson equation as follows:
where, A = Total collection area of plates (m^2)
Q = Gas flow rate (m^3/s)
W = Average migration velocity of charged dust particles (m/s)

$$\text{Collection efficiency } (\eta) = 1 - \exp\left(-\frac{A}{Q} w\right)$$

The dust collection efficiencies of ALSTOM ESPs and overall collection efficiencies have been calculated using expressions in 1 and 2 and are shown in Table A. As one can observe from table A, the collection efficiencies of ALSTOM supplied ESPs in pass A and pass B varies between (93.48-95.74) % with average 94.60 % . While the overall collection efficiencies of the whole systems varies between (99.59-99.73) % with average 99.63 %. The designed values of dust collection efficiency of ALSTOM supplied ESPs is 93 % at gas flow rate of 148 M^3/s (94 Nm3./sec). As in present case the ESP is operating at gas flow rate (~101.6 NM^3/s), the efficiency is likely to be effected if all other operating conditions remain same (equation at iii). The collection efficiencies of BHEL supplied ESPs varies between (90.60-93.86)% with average 93.23%.

(4) The electrical parameters for all the ESPs have been noted.. There are five fields in each pass of ESP. The values of charge ratios have been kept constant. These values are 1:7 for 1st field, 1:11 for second field, 1:15 for third field, 1:17 for fourth field and 1:21 for fifth field. Only in the 1st field some back corona has developed as indicated by sparks. Otherwise most of the time, back corona has been suppressed as no sparks have been observed in other field. Secondary voltages in the five fields vary from 35 kV in first field to ~22 kV in last field. Similarly secondary current in first field (~ 65 mA) are higher than in last field (~ 14 mA). Normal practice is however to set lower current in initial field and higher currents in final fields.

(5) The variation of electrical parameter of ESP supplied by ALSTOM has been noted. As may be observed quite high secondary voltages high (>50 kV) have been maintained in all three field and both pass of ESP. No sparks have been observed during the operation, which shows the absence of back corona. As the voltage maintained are high, a higher migration velocity is expected resulting in higher collection efficiency.

(6) Plant load varies from 30 MW to 39 MW during the observation period. The gas temperature are almost constant; 136 ^{0}C in pass A and 130 ^{0}C in pass B. Temp. difference of 4-8 ^{0}C between airheater outlet to ESP inlet gives an impression of considerable air infiltration which dilutes the flue gases coming from boiler. Mechanical Draught is produced by Forced Draught (FD) and Induced Draught (ID) fans. FD fan, which is installed at the inlet of air preheater consumes less power and operates at near constant current rating (21 Amp and 23 Amp for pass A and B respectively). The ID fans are located near the stack, they handle hot combustion gases and their power requirements are higher. The ID fans are operating at constant rating of 48 Amp in both passes. The gas flow even at lower Boiler load is more than 100% Boiler load which may overload ID fans resulting sometime puffing effect in the furnace. The opacity reading is also shown in figure, however, because of their positioning and calibration problems; these may not be relied upon.

(7) Particle size analysis has been carried for the fly ash samples collected at the inlet and outlet of pass-A of the ESP systems. The particle Size are thus been measured at the inlet and outlet of ALSTOM ESP in pass-A. A GALAI-CIS-1 computerized Inspection system (Laser based particle size analyzer) has been used for particle size measurements. Table 2 and Table 3 show volume distribution of particles in different ranges at the inlet and outlet of ESP respectively. As can be observed from Table2 that around 56% of particles are having sizes less than 10 micron , a total of 44% are in larger range (18.41% in 10-20 micron, 13.31% in 20-30 micron, 10.93% in 30-4- micron and 0.49% in 40-50 micron range). At the outlet of ESP on the other hand, as shown in table7 the fraction of particles up to size of 10 micron goes up to 93% and only 7% are in the range of 10-20% micron range .The sample size was too small at the final out let for taking any meaningful size distribution measurements. However the fraction of smaller size particle (<10 micron) should still be more.

4. CONCLUSIONS:

The Over-all collection efficiencies for particulate have been improved by putting two ESPs in series. Further improvement is possible on adopting following steps.

- Plugging of leakage in the boiler / ESP system upto stack. This will minimise infiltration as well as make ID fans operation suitable to create adequate suction in the furnace.
- Operating the boiler at stable load with minimum fluctuation.
- Increasing current level of collecting electrodes of BHEL ESPs with lower current in initial fields and higher current in final fields.

ACKNOWLEDGEMENT

I wish to thank Mr. D.B. Singh, C.E., Mr. D. K. Khattar, S.E., Mr. S.C. Jain, and their associates for providing the necessary facilities at the site of D.V.B., I.P.Station, Unit-5, New Delhi. I wish to also thank Mr. A.K.Rastogi and Mr. S.B. Kulkarni of ALSTOM Power Boiler Ltd. for various discussions. The assistance rendered during the investigations by Dr. Subodh Kumar, Mr. L.D.Kala, and Mr. Bhaskar is thankfully acknowledged.

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Table 1.

RESULT OF STACK MONITORING CARRIED OUT AT
I.P. POWER STATION, DELHI

	Temperature °C	Velocity M/Sec	Q.E. NM^3/Hr	S.P.M. Mg/NM^3
INLET PASS (B) 2:30 PM	128	14.33	185552	**42651**
OUTLET PASS (B)	123	13.77	178638	**1819**
FINAL OUTLET	120	18.28	339940	**115**
INLET PASS (A) 3:25 PM	126	14.38	186092	**37840**
OUTLET PASS (A)	121	14.21	183878	**1638**
FINAL OUTLET	120	17.86	334665	**154**
INLET PASS (B) 4:15 PM	125	13.84	181013	**38998**
OUTLET PASS (B)	124	14.69	188179	**2540**
FINAL OUTLET	122	18.26	340428	**156**
INLET PASS (A) 5:45 PM	129	14.77	190774	**41730**
OUTLET PASS (A)	123	14.24	183335	**2635**
FINAL OUTLET	119	17.86	335519	**166**

Table A: Collection Efficiencies of ESP systems Based on Observations made

S. No.	Path	Inlet Dust Loading (mg/NM^3)	Outlet Dust loading of ALSTOM ESP (mg/NM^3)	Final Outlet_ust Loading (mg/NM^3)	Collection Efficiency of ALSTOM ESP (%)	Collection Efficiency of BHEL ESP (%)	Overall Collection Efficiency (%)
1	B	42651	1819	115	95.74	93.68	99.73
2	A	37848	1638	154	95.67	90.60	99.59
3	A	41730	2635	166	93.69	93.70	99.60
4	B	38998	2540	156	93.49	93.86	99.60
5	Average	40307	2173	147	94.60	93.23	99.63

Table2. Particle size distribution Pass A-Inlet

VOLUME DISTRIBUTION TABLE (RANGES)

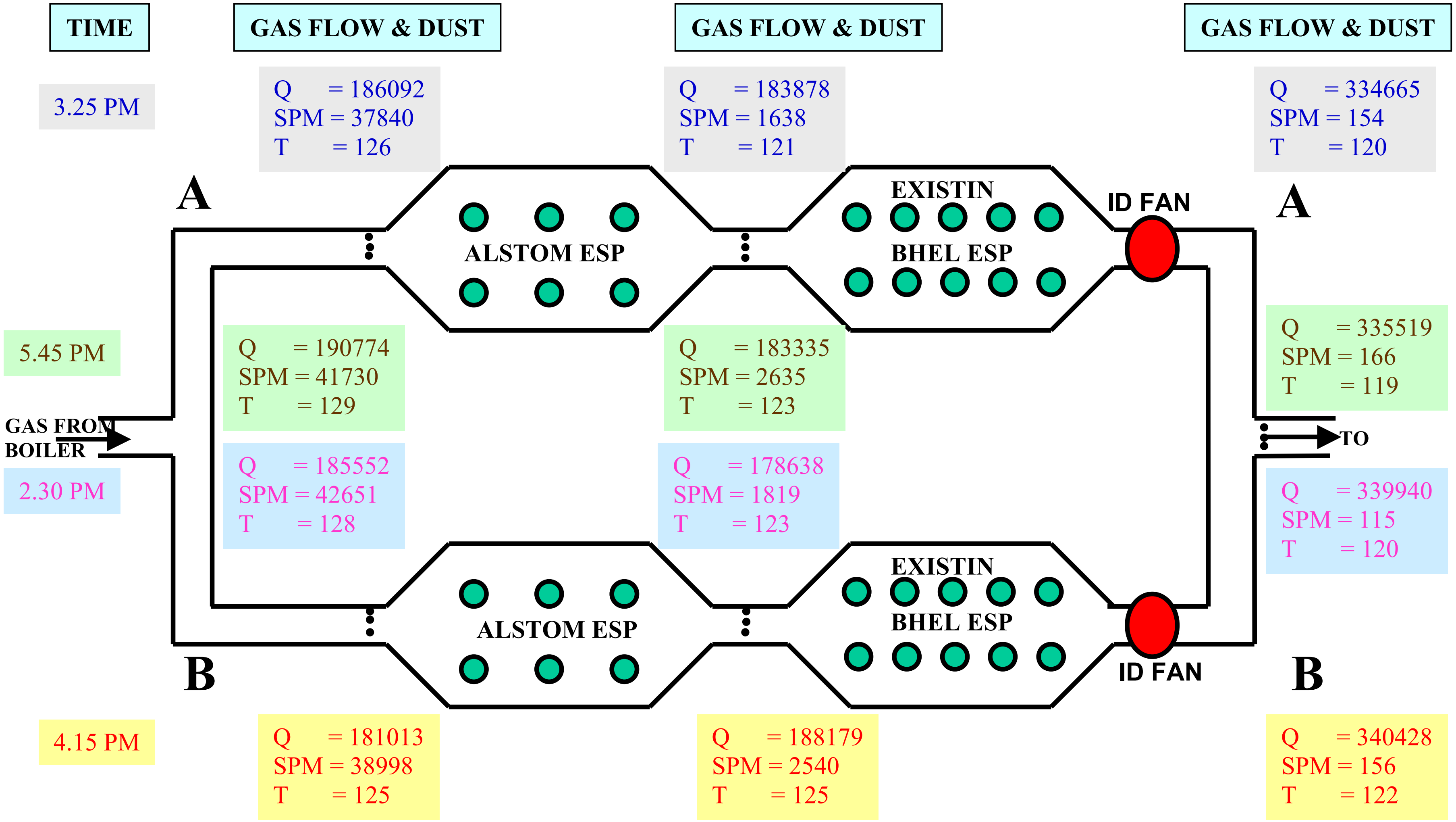
RANGE (microns)	LOCAL (%)	UNDER(%)-CUMULATIVE	-OVER(%)
0.0 - 1.0	1.71	1.71	98.29
1.0 - 2.0	8.39	10.10	89.90
2.0 - 3.0	8.04	18.14	81.86
3.0 - 4.0	10.35	28.49	71.51
4.0 - 5.0	10.39	38.88	61.12
5.0 - 6.0	7.51	46.39	53.61
6.0 - 7.0	4.62	51.01	48.99
7.0 - 8.0	2.37	53.38	46.62
8.0 - 9.0	1.61	54.99	45.01
9.0 - 10.0	1.86	56.86	43.14
10.0 - 20.0	18.41	75.26	24.74
20.0 - 30.0	13.31	88.57	11.43
30.0 - 40.0	10.93	99.51	0.49
40.0 - 50.0	0.49	100.00	0.00

Table3. Particle size distribution Pass A-Outlet

VOLUME DISTRIBUTION TABLE (RANGES)

RANGE (microns)	LOCAL (%)	UNDER(%)-CUMULATIVE	-OVER(%)
0.0 - 1.0	2.82	2.82	97.18
1.0 - 2.0	14.34	17.16	82.84
2.0 - 3.0	14.22	31.38	68.62
3.0 - 4.0	19.79	51.17	48.83
4.0 - 5.0	19.43	70.60	29.40
5.0 - 6.0	10.27	80.87	19.13
6.0 - 7.0	6.43	87.30	12.70
7.0 - 8.0	2.77	90.07	9.93
8.0 - 9.0	1.59	91.66	8.34
9.0 - 10.0	1.44	93.10	6.90
10.0 - 20.0	6.90	100.00	0.00
20.0 - 30.0	0.00	100.00	0.00
30.0 - 40.0	0.00	100.00	0.00
40.0 - 50.0	0.00	100.00	0.00

13/03/2002



PROBING PORTS

ESP

Q Gas Flow, Nm^3/hr

SPM Particulate Matter, mgm/Nm^3

T Temperature, ^0C

Fig. 1: Electro Static Precipitator system at unit-5