Hybrid System to Enhance Particulate Collection Efficiency in Coal Based Thermal Power Plants

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Abstract

An integrated hybrid system consisting of an ESP topped by mechanical collector and bottomed by fabric filter has been proposed. It is shown that such system has got better collection efficiency, lesser collection area compared to equivalent ESP alone system

1. Introduction

The **electricity sector in India** had an installed capacity of 223.625 GW as of April 2013 the world's fifth largest. Captive power plants generate an additional 34.444 GW. Non Renewable Power Plants constitute 87.55% of the installed capacity and 12.45% of Renewable Capacity India generated 855 BU (855 000 MU i.e. 855 TWh) electricity during 2011–12 fiscal.

In terms of fuel, coal-fired plants account for 57% of India's installed electricity capacity, compared to South Africa's 92%; China's 77%; and Australia's 76%. After coal, hydropower accounts for 19%, renewable energy for 12% and natural gas for about 9%[1]

Gross power generation in India was around 855 Terawatt hour (TWh) in 2011-12. Of total generation, around 70% was from coal and lignite-fired units, 13.5% from hydel power, 9.6% form gas fired units, 3.0%form nuclear power, 3.5% from renewable and 0.5% from diesel units [1]. The coal fired power plants , thus contribute the majority of power in India and will continue to be major source of power in future till 2030 and may be beyond. The total 89 coal and lignite plants had a total capacity of 75877MW distributed among 397 units as of March 31.2009[2]. Of the 385 coal fired units in India 138 were of 210 MW, 81 of 100-150MW, 88 of 100MW or below,37 of 500Mw, 17 of 500MW, 17 of 250 MW and 24 of 195-20MW.

For particulate control ESP are used almost in all but one or two coal fired unites. Some of the common features of ESPs[3] in India are(a) The dust loading at the input of ESP, because of feed coal characteristics (low heating value, high ash and low sulphur contents} is invariably is very high in the range(40-120) g/Nm3 (b)The SCA is also is very high in the range(130-218)m2/m3/s and more,(c)The effective migration velocities are in the range(2.8-4.7)cm/s. The low migration velocities indicate very high values of electrical resistance of fly ashes generated in power plants. The values of resistivity vary in the range (10^{12}-10^{14}) ohm.cm as measured in labs [4].It lead to develop back corona near the collecting electrodes. As a result the performance of ESP detoriates. The size of ESP in India is, therefore, is quite large compared to ESPs elsewhere for similar electric power generation.

In some of the power plants the emissions have been reduced in the existing ESPs [3] by adopting either or more of the following methods (1) water fogging (2) intermittent charging (3) ammonia dosing of flue gases and (4) sodium conditioning of the fuel before feeding it to the boiler. While there is limited reduction in emission levels due to water fogging, quite appreciable reductions in emission levels have been observed due to intermittent charging. The other methods e.g. ammonia conditioning of flue gases and sodium conditioning of the fuel hold great promises to reduce the emission levels. SO_3 conditioning of flue gases is another method to reduce the emissions not, popular in India.

However, most of the power plants in India are struggling to achieve emission levels of 100mg /Nm3.The reduction in size and hence in cost and improvement in collection efficiencies are the major challenges in India. In Particular majority 210 MW or lower capacity plants, where ESPs are working with lower efficiencies compared to the designed one because of inferior quality of coal feed.

2. Integrated Hybrid system

In the following section, we propose an integrated hybrid system consisting of an

ESP topped by mechanical collector and bottomed by fabric filter. In fact an ESP system consisting of many fields can be converted to an integrated hybrid one, where first one or two fields may be converted as dummy fields, working as mechanical collector followed by powered fields working as ESP and last one or two fields are filled with fabric filters. The system should work as follows: the dummy field works as mechanical collector (collecting up to 40-50% of inlet coarse dust load), the ESP will thus work with reduced dust load at a collection efficiency in the range (95-99) %, the rest of the fine dust not collected by ESP will be taken care by the fabric filters filled (efficiency >99%) in the outer fields. The system is shown in the figure 1.The collection efficiency is given by well known expression proposed by Deutsch and Anderson as follows:

$$\text{Efficiency } (n_{esp}) = 1\text{-exp } [-w.SCA] \qquad (1)$$

Where, w= effective migration velocity of charged particles.

SCA= specific collection area

The percentage efficiencies for the various values of the parameter r(w.SCA) are listed in the following table 1 based on equation 1

(w.SCA) is an important parameter as depending on the value of w, the migration velocity attained inside the ESP the specific collection area and hence the size of ESP is determined to obtain a particular efficiency and the emission levels from the power plant. Some important inferences can be made from table 1: (a) the migration velocity should be large to reduce the size of ESP (as to reduce the capital cost, the running cost of ESP and finally the cost of electricity produced) for specific collection efficiency desired in the power plant. The migration velocity in the ESP depends on the electrical resistivity of the coal burned in the boiler of the power plant. It is quite low (<5.0cm/s) for the coals having high (>10 ^{11} ohm.cm). Coal feed in the power plants in India in general has high (>10 ^{11}ohm.cm) electrical resistivity (because of low sulphur<0.5%), low calorific vale, and high ash (>40.0%) contents. As a result the power plants in India generate fly ash to be collected several times higher than those generated elsewhere, for similar electricity production. To reduce the size of ESP for high Collection efficiencies (>99.5%) is the major challenge in India particular. (b) Once migration velocity is settled in an ESP, the collection efficiency can be increased by increasing SCA of ESP. There is rapid increase initially as the SCA is increased. However, the advantage of increasing the SCA diminishes in terms of efficiency as can be observed form table-1. The collection efficiency reaches a value of 95.0% as the size is equivalent to 3.SCA(three times the collection area compared to one times of SCA, when, collection efficiency is 63.2%). The gain in collection efficiency is 3.02%, 1.3%, 0.24% for respective increase of size of ESP by 33.3%, 66.7% and 100% compared to size at equivalent to 3SCA. In order to meet the emission standard an efficiency of 99.6% or more are required in a typical power plant in India, which require a size equivalent to 6SCA, which turns out more than 150m2/m3/s in most of the case, resulting a very large ESP having substantial capital and running cost. Thus reducing the emission levels by increasing the size of ESP is not the economic.

An integrated hybrid system is shown in Figure1.The dummy field is actually an ESP field, without charging. As it has got large number of collecting and emitting electrode, a good amount of fly dust will be entrapped over on these which can be separated using rappers in to the hopper place below the ESP units. In order to collect the fine ash particles (not collected efficiently by ESP) the last field (having an efficiency <1.0%) may be filled with fabric. The overall collection efficiency is calculated by equation (2). The overall collection efficiency of the system reduces to that of ESP if dummy (n_{dummy}) and fabric filter (n_{ff}) fields are removed.

$$n = n_{dummy} + n_{esp}\left(1 - n_{dummy}\right) + n_{ff}\,\left[1 - n_{esp}\,\left(1 - n_{dummy}\right)\right] \quad \ldots\ldots\ldots\ldots\ldots (2)$$

For a typical power plant having an inlet dust loading of 40g/NM3/s efficiencies of the order of 99.6% (for existing emissions standard of 150mg/NM3/s) and 99.75% (for near future standards of 100mg/NM3/s) are required. As per table it corresponds to 5.5x (w.SCA) and 6.0x (w.SCA) to meet the emission levels. For a typical power plant operation at constant migration velocity of 3.35 cm/s, the corresponding SCA calculates out to (164 , 179) m2/m3/s. These are enormous sizes indeed.

The concept of integrated hybrid system is applied to calculate the overall collection efficiencies using equation2 for various cases. The cases are:(1) the values the dummy field (n_{dummy}) are varied between 5.0% to 30.0% as there are many collecting surfaces in the dummy field, where fly ash can be collected to be removed in to the hopper. Only one dummy field corresponding to an area of one SCA is assumed to exist. (2) the collecting areas of ESP corresponding to 3,4 and 5 timed of one SCA are varied. (3) The collection efficiency (n_{ff}) of Fabric filter field corresponding to one SCA is assumed 63.2% in all the cases. The following table 2 shows the total collection efficiencies of integrated hybrid system for various cases.

Some interesting observations can be made based on the calculations in table 2. The topping dummy field, working as mechanical collector of the dust improves the overall collection efficiency on the integrated hybrid system as compared to ESP alone system even at very low efficiencies of 5%.The overall efficiency of the system reaches to 99.76% with (5.SCA), collection area compared to (6.SCA) collection area with ESP alone system. Beside the finer particles collection will be better in integrated system because of the presence of fabrics in the last dummy field. The capital and running cost will be much smaller in filling one dummy field with fabrics compared to the system based on fabrics alone. As the collection efficiency of the topping field increases the advantages become more pronounce both in terms of collection efficiency and ESP collection area.

3.Conclusions

The collection efficiency of integrated hybrid system is found to be better than the equivalent ESP alone system. Investigations show that as the collection efficiency of the topping field increases the advantages become more pronounce both in terms of collection efficiency and ESP collection area. The finer particles are expected to be collected better.

The expenses for attending the conference; registration fee, boarding and lodging and travel have been met out of professional development fund generated by the author while serving at IIT Delhi. Sincere thanks are to IRD division of IIT and FITT, IIT Delhi for granting necessary permission to utilize them.

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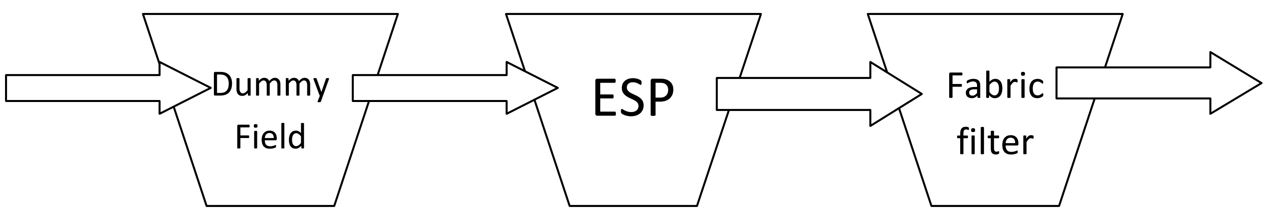

Hybrid system for particulate collection for thermal power plants

Table1: Variation of Efficiency with (w.SCA)

w.SCA	0.5	1.0	2.0	3.0	4.0	5.0	6.0	6.91	10.0
n_{esp}(%)	39.3	63.2	86.5	95.0	98.2	99.33	99.75	99.9	99.995

Table2: Total collection efficiencies of integrated hybrid system for various cases.

S.NO.	n_{dummy} (%)	n_{esp}(%)	n_{ff} (%)	n_t(%)
1.(3.SCA)	5	95	63.2	98.25
2.(4.SCA)	5	98.02	63.2	99.30
3.(5.SCA)	5	99.33	63.2	99.76
4.(3.SCA)	10	95	63.2	98.33
5.(4.SCA)	10	98.02	63.2	99.33
6.(5.SCA)	10	99.33	63.2	99.77
7.(3.SCA)	15	95	63.2	98.43
8.(4.SCA)	15	98.02	63.2	99.37
9.(5.SCA)	15	99.33	63.2	99.79
10.(3.SCA)	20	95	63.2	98.52
11.(4.SCA)	20	98.02	63.2	99.41
12.(5.SCA)	20	99.33	63.2	99.80
13.(3.SCA)	30	95	63.2	98.73
14.(4.SCA)	30	98.2	63.2	99.48
15.(5.SCA)	30	99.2	63-2	99.82