COST ANALYSIS AND RETROFIT OPTIONS FOR EXISTING ESPS OF THERMAL POWER PLANT

N. Gauam[1], P. Rai[2], H. Chandra[3]

[1,2,3]Department of Mechanical Engineering, Vishwavidyalya Engineering College, Lakhanpur, SargujaUniversity Ambikapur C.G., (India)

ABSTRACT

This paper deals with the formulation of the mathematical models of existing ESPs and its cost analysis to predict the emission level for different parameters of ESP and Bag filter. It is observed in this paper that as the time in hours since filter was last cleaned, increases, the pressure drop on the cloth of bag also increases. As the time of operation increases the pressure drop on cloth of bag also increases.

Wider spacing design is cost effective. Wider spacing achieves the performance desired at lower costs, because first, increasing the duct width leads to reduction in the flowing current, and therefore in the electric power consumption.

Keywords:*Bag Filter, Cost Sensitivity, Electrostatic, Fabric Filter,Isosurface, Precipitators (ESPs), Retrofitting.*

I. INTRODUCTION

ESPs have the primary,means of particulate emission control in utility industry. However at particulate emission limit become increasingly stringent ESP have become larger and more addition the use of low sulphurand high ash coal produces high a resistivity fly ash,which result in increased ESP sizing and cost. Fly ash with the high electrical resistivity is difficult to charge and to precipitate from the flue gas thus requiring larger precipitator to maintain collection efficiency in conjunction with flue gas conditioning to reduce ash resistivity for effective collection.

Fabric filters are potential alternative to ESPS because they offer high collection efficiency while relatively independent of the type of coal burned. Unlike ESPs,Fabric filter design and performance is dependent on any physical or chemical properties of the fly ash.

Lower cost option to consider for compliance strategy is the conversion of the existing ESP casing to a pulse jet fabric filter at otter Tail Power Company's Big Stone Plant Unit #1,a475MW cyclone-fired boiler burning investigated by Lugar et al. [1].Visuvasam et al. [2] studied several options of retrofitting of existing ESPs of thermal power plant and they also presented several case studies of such option in their research paper of Indian thermal power plant. They also discussed for retrofitting, the various options available the constraints being faced,the benefits accrued, the response ofusers with case studies.Fantom and cottingham[3] reviewed key factor affecting ESP and fabric filter performance and how this knowledge has been used to improve dust emissions form UK coal-fired power plant and cement kilns.In each case examples of both technical and commercial evaluations are presented and discussed

CPCB [4] presented objective series on topic .Assessment of requirement of bag filter via Electrostatic Precipitator in Thermal Power Plants and discussed the retrofit of ESP with bag filters for different Indian thermal power plants. The costs benefit analysis of both fabric filters also analyzed in report. Steyn et al.[5] provides an overview of one of the project presently in progress at Camden power station on 6x200mw boiler. These fabric filters have a unique 4 cell design allowing for on-load maintenance,bag changes and operating flexibility. Lesson learntfrom previous project and improvement in fabric material and construction through research will ensure that these advanced fabric filters are successful.

Grobbelaar [6] described the original performance of the ESP's,the performance of the FFP's; the factors influencing the decision to improve the plant,and what criteria the new/refurbished plant had to meet. Jedrusik [7] investigated retrofitted horizontal, three zones ESP which was designed in late 1970s. The retrofit consisted of replacing the spiked band corona electrode with a barbed tube unit of special design which raised the efficiency of the precipitator. A restaa et al. [8] investigated a retrofit project related to an Al_2O calcinations flue gas treatment line,consisting in the installation of a fabric filter downstream an existing electrostatic precipitator(ESP).In this case , the replacement of the existing exhaust fan with a moreperforming one would have been potentially exposed the existing precipitator to suction conditions that did not fall within the process condition considered when the ESP was designed.The problem associated with the use of Indian coal is low calorific value and very high ash content. As a result for getting a unit amount of electricity, large amount of pollutants are generated. It is desirable to have a good quality of coal for power generation, as it reduces the pollutants generated /unit of electricity by Ghose and Majee [9]. The result from the burning of fossil fuels ,particularly coal is the emission of fly ash and other air pollutants .To curb the air pollution there are certain norms and standards of CPCB, which has to be met in the present & future by the thermal power plant by Bhattacharyya Subhas C et al. [10]. For a pulverized coal unit 60-80 of ash leaves as fly ash whit the flue gases by GautamPankaj [11], though there are several devices for collection of fly ash ,the two efficient (>_99% collection efficiency) emission control devices are fabric filter and ESPs by Master, GilbertM. et al. [12].

In order to design ESPs, the following problem has been identified which are, very long system resistance,get affected with load swing, very high initial cost is involved.The charged collector plates get covered in dust and airborneresidues, which can be difficult to clean.The collector plates may need hosing down, vacuums cleaning,soaking,or going through the dish washer, every few months to maintain efficiency.

II. MATHEMATICAL MODELING FOR RETROFITTING OF EXISTING ESP WITH BAG FILTER

The retrofitting is obtained by adding a bag house in series with the existing ESP of the power plant. However it is not in operation with the existing ESP, so it can be investigated theoretically, by taking the input data of bag filters from existing literatures. For this purpose the general arrangement of retrofit options can be represented by following figure-

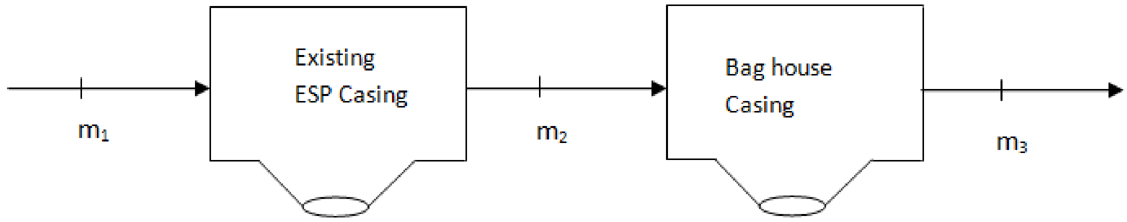

Fig. 1 Retrofitting Existing ESP with Bag House in Series

Fig. 1 shows one of the retrofit options of existing ESP with Bag house. In this figure m_1 represents the inlet dust concentration to the existing ESP while m_2 represents the outlet dust concentration from the existing ESP, which will act as the inlet dust concentration to the Bag house casing and m_3 represents the outlet dust concentration from Bag house.

2.1 Retrofitting of ESPs

The society felt the ill-effect of pollution and therefore the authorities had to tighten the particulate emission within limit. The pollution control legislation keeps on changing continually with the availability of technology and resource. A need has arisen to bring up the old pollution control equipment to the latest level and the concept retrofitting evolved. The retrofitting concept have revolutionized from simple PART to PART replacement to renovation, refurbishment, energisation. The user, consultants and manufacturers of precipitators applied their mind together to arrive at suitable site specific solutions. The different solutions and the implementation part of it on India context is analyzed ach with a case study.

2.2 Need of Retrofitting

Precipitator is a static, effective dust capturing device. After a passage of time, the emission is more than what is supposed to emit or warrant emitting less. It is acknowledged that the reasons could be one or multiple of the factors such as change in environmental legislation , change in fuel properties-poor quality of fuel, alteration of fuel, change in boiler behavior- deterioration in boiler performance , use of multi-fuel firing and change in the plant firing. Precipitator inadequate design of existing precipitator, poor electrical and mechanical condition like improper gas distribution , unstable operating conditions of precipitator , plant beyond serviceable conditions , lack of process knowledge etc.

2.3 Bag Filter Technology

A bag filter consists of numerous vertical bags of 120-400mm diameter and 2 -10m long. They are suspended with open ends attached to a many fold. The hopper at the bottom serves as a collector for the dust. The gas entering through the inlet duct strikes a baffle plates which causes the larger particle to fall due to gravity. The carrier gas then flows to the tube and then outward to through the fabric leaving the particulate matter as a cake on bag surface.

2.4 Filter cleaning

Following are the common method of filter cleaning in a bag filter as rapping, shaking, reverse air flow (back wash) and pulse jet.

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2.5 Modeling Equations of Bag house

Gas–Cloth Ratio or Air Cloth Ratio (ACR) is the capacity of bag to filter gases. Its unit is m^3/min. of gas filtered is one m^2 area of filter.

ACR = V = Volumetric flow rate

Total area of cloth = Q/A (1)

n=no. of bag =A/a

III. COST ANALYSIS OF A WIRE-PLATE ESP

The cost evaluation problemcan beused to analyze the main costs in building and operating an ESP.The total cost is the combination of fixed construction costs and operation costs. The first are usually given by all internal parts, which are as follows:

The total cost, *C*, to build and operate an ESP during the time period *t* may be expressed as follows:**[9]**

$C=C_{W}.P\ .t +2.C_{P}L.L_{Y} +2.C_{C}\ .L(L_{Y+}h) +C_t+Cr+Cm$ (2)

Total capital investment includes costs for the bag house structure, the initial complement of bags, auxiliary equipment, and the usual direct and indirect costs associated with installing or erecting new structures. These costs are described below.

3.1 Bare Bag HOUSE COSTS

Correlations of cost with fabric area for seven types of bag houses are presented. These seven types, six of which are preassembled and one, field-assembled, are listed in Table 1.

Table 1 Bag Prices(2nd quarter 1998 $\$/ft^2$)(2nd quarter 127872Rs/$ft^2$)

Converting dollar ($) into rupees (Rs.) [1$=64Rs]

Type of Cleaning	Bag Diameter	PE	PP	NO	HA	FG	CO	TF	P8	RT	NX
Pulse jet, TRb	4-1/2 to 5-1/8 6 to 8	0.75 0.67	0.81 0.72	2.17 1.95	1.24 1.15	1.92 1.60	NA NA	12.21 9.70	4.06 3.85	2.87 2.62	20.66 NA
Pulse jet, BBR	4-1/2 to 5-1/8 6 to 8	0.53 0.50	0.53 0.60	1.84 1.77	0.95 0.98	1.69 1.55	NA NA	12.92 9.00	3.60 3.51	2.42 2.30	16.67 NA
Shaker, Strap top	5	0.63	0.88	1.61	1.03	NA	0.70	NA	NA	NA	NA
Shaker, Loop top	5	0.61	1.01	1.53	1.04	NA	0.59	NA	NA	NA	NA
Reverse air with rings	8 11-1/2 1.01	0.63 0.62	1.52 NA	1.35 1.43	NA NA	1.14 NA	NA NA	NA NA	NA NA	NA NA	NA NA
Reverse air w/o rings	8 11-1/2	0.44 0.44	NA NA	1.39 1.17	N NA	0.95 0.75	NA NA	NA NA	NA NA	NA NA	NA NA

3.2 Bag Cost

When estimating bag costs for an entire bag house, gross cloth area. Membrane PTFE fabric costs are a combination of the base fabric cost and a premium for the PTFE laminate and its application. As fiber market conditions change, the costs of fabrics relative to each other also change. Prices are based on typical fabric weights in ounces/square yard. Sewn-in snap rings are included in the price, but other mounting hardware, such as clamps or cages, must be added, based on the type of bag house.

3.3 Auxiliary Equipment

It consists of hoods, ductwork, pre coolers, cyclones, fans, motors, dust removal equipment and stacks are common to many pollution control systems, and they are given extended treatment in separate chapters.

3.4 Total Purchased Cost

The total purchased cost of the fabric filter system is the sum of the costs of the Bag house, bags, andauxiliary equipment; instruments and controls, taxes, and freight. Instruments and controls, taxes, and freight are generally taken as percentages of the estimated total cost of the first three items. Typical values, from Section 1, are 10% for instruments and controls, 3% for taxes, and 5% for freight.

3.5 Total Capital Investment

The total capital investment (TCI) is the sum of three costs, purchased equipment cost, direct installation costs, and indirect installation costs. The factors needed to estimate the TCI are given in Table 2. The Table 2 factors may be too large for “packaged” fabric filters-those pre-assembled bag houses that consist of the compartments, bags, waste gas fan and motor, and instruments and controls. Because these packaged units require very little installation, their installation costs would be lower (20–25% of the purchased equipment cost). Because bag costs affect total purchased equipment cost, the cost factors in Table 2 may cause overestimation of total capital investment when expensive bags are used.

Table 2 Capital Cost Factors for Fabric Filters

Cost Item	Factor
Direct costs	
Fabric filter (EC) + bags + auxiliary equipment	As estimated, A
Instrumentation	0.10A
Sales taxes	0.03 A
Freight	0.05 A
Purchased Equipment Cost, PEC	B = 1.18 A
Direct installation costs	
Foundations & supports	0.04 B
Handling & erection	0.50 B
Electrical	0.08 B
Piping	0.01 B
Insulation for ductwork	0.07 B

Painting	0.04 B
Direct installation cost	0.74 B
Site preparation	As required, SP
Buildings	As required, Bldg
Total Direct Cost	1.74 B + SP + Bldg
Indirect Costs (installation)	
Engineering	0.10B
Construction and field expense	0.20 B
Contractor fees	0.10 B
Start-up	0.01 B
Performance test	0.01 B
Contingencies	0.03 B
Total Indirect Cost, IC	0.45 B
Total Capital Investment = DC + IC	2.19 B + SP + Bldg.
Total Capital Investment = DC + IC	2.19 + SP + Bldg.

IV. RESULTS AND DISCUSSION

In this section the results are obtained by using the input data as discussed in the previous sections. All the results are obtained by creating different situations by varying different quantities in its specified variation limits. Then for a specific case by varying the value of migration velocity directly, we will get different values of total collection area.

4.1 Effect of Time on Pressure Drop

Fig. 2 shows the effect of time of operation on pressure drop created due to the deposition of particulate matter on the bag filter cloth. As the time, which is taken in hours passes, the pressure drop on the cloth of bag also increases. This is due to the reason that as the time of operation of bag filter increases, certain amount of dust collected always remains on filter after cleaning the bag filter.

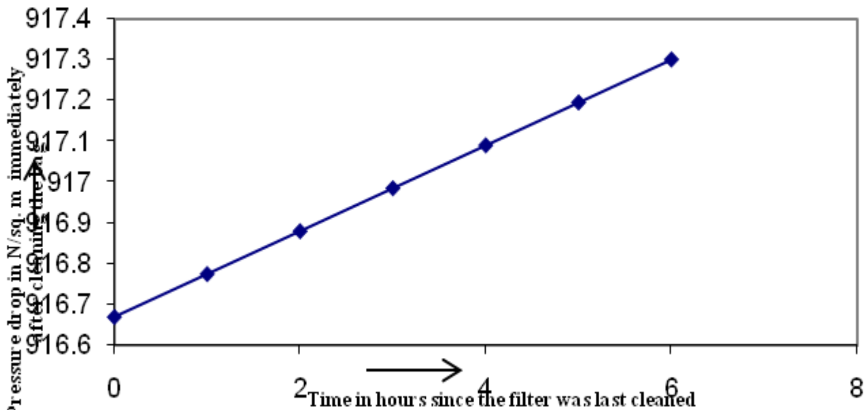

Fig. 2 Effect of time on pressure drop

4.2 Effect of Time on Power Loss

Fig.3 depicts the effect of time of operation on power loss which is required for shaking mechanism of cloths of bag filters. As the time of operation increases the pressure drop on cloth of bag also increases which is the main reason that dust particles remain suspended on the cloths of the bag. As the dust loading increases then more power is required for shaking mechanism to remove dust from the bag filters.

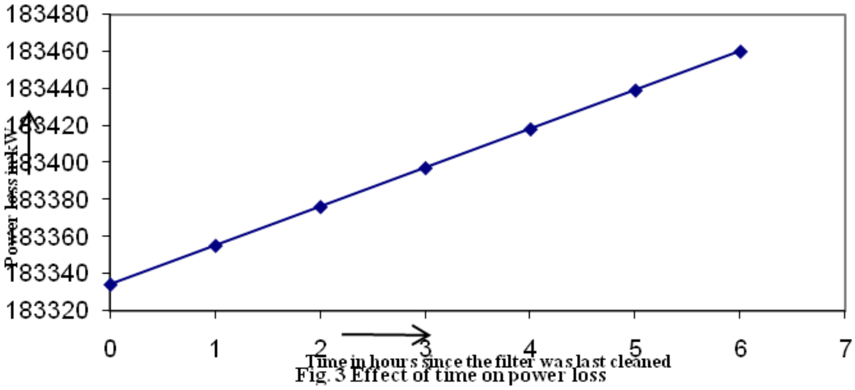

Fig. 3 Effect of time on power loss

4.3 Sensitivity Analysis of Cost

Fig. 4 shows that it would be extremely costly to improve even slightly the collection efficiency by increasing the wire to plate distance

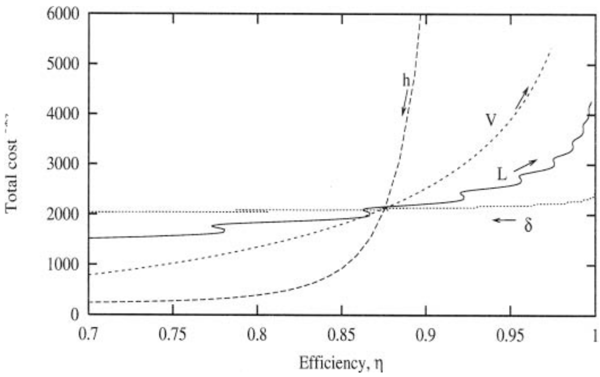

Fig. 4 Sensitivity Analysis of Cost

4.4 Cost Isosurface

Fig. 5 shows in the lower part of fig larger values of efficiency are associated with high voltage, and reduce wire plate distance.

4.5 Efficiency Isosurface

Fig. 6 shows in the upper part of fig we observe that the surface representing the total cost is steeper in this region of the parameter.

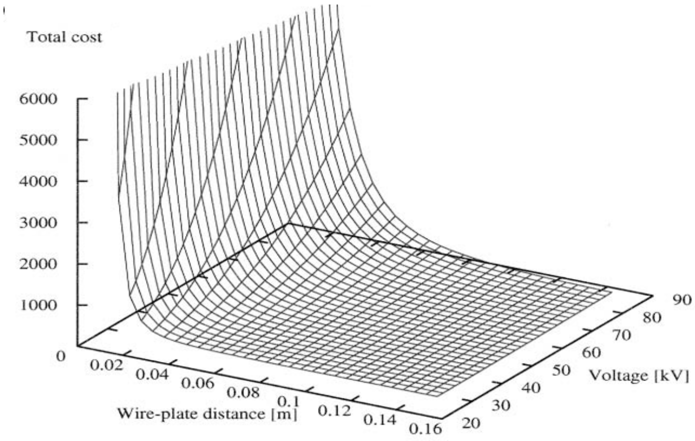

Fig. 5 Cost isosurface

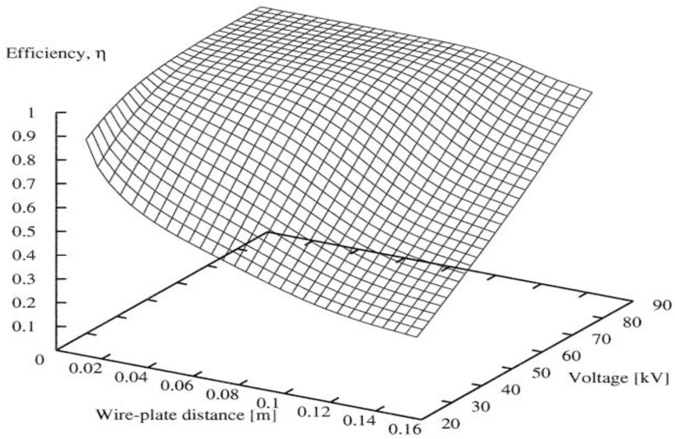

Fig. 6 Efficiencyisosurface

4.6 Cost of Bag Filter

Cost of the Bag filter includes cost of Pulse-jet filter common housing and modular.

4.6.1 Equipment for Pulse-Jet Filter (Common Housing)

Figure 7 shows common-housing Pulse-Jet Filter.

4.6.2 Equipment cost for pulse-jet-filter(modular)

Figure 8 shows common-housing and modular pulse-jet bag houses. Common housing units have all bags within one housing modular units areconstructed of separate modules that may be arranged for off-line cleaning. Note that in the single-unit (common-housing) pulse jet, for the range shown, the height and width of the unit are constant and the length increases; thus, for a different reason than that for the modular units discussed above, the cost increases linearly with size.

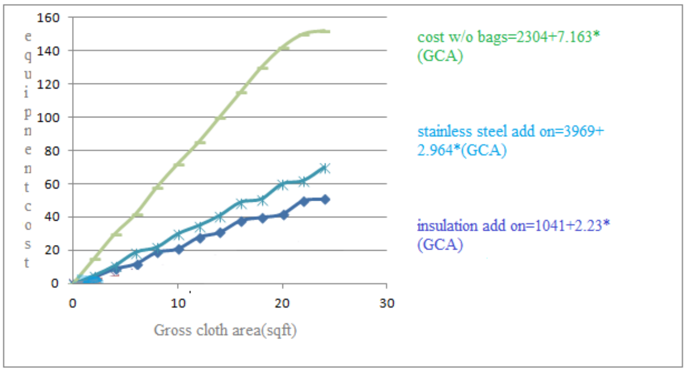

Fig. 7 Equipment for pulse-jet –filter (common housing)

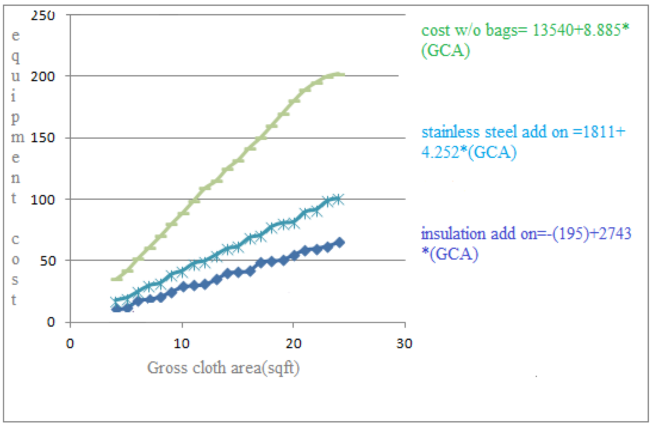

Fig. 8 Equipment cost for pulse-jet-filter (moduler)

V. CONCLUSIONS AND FUTURE SCOPE

Pressure drop and power loss increases with increase in time of operation of bag house. This paper gives the ways to meet the retrofit option of existing ESPs of thermal power plants with bag filters. The periodic required replacement of bag filter because of their limited life requires coordination with outage planning and results in higher maintenance costs than for an ESP.Result indicates that reducing the distance between wires allows for improved efficiency at the lowest cost. Our results also show that the wider spacing design is cost effective.

Future work can be performed on cost analysis for the existing ESPs, which can further consider the cost of retrofitting.This work can be used to prepare some guidelines for modification of existing ESPs of thermal power plants with retrofitting options,which will provide important technical aspects to the management of plant to implement. In future this project will help in pollution control and their role in environment protection.

Nomenclatures

A	total collection area of plates (m^2), total area of cloth
a	area of one bag
C_{ma}	mass-area concentration (kg/m^2)
C_{mv}	mass-volume concentration (kg/m^3)
D	Diameter of bag (m)
ESP	Electrostatic precipitator

FC	Fixed Carbon
FF	Fabric filter
H	hydrogen (per cent by weight of coal composition)
K_1	constant (N.s/m^2)
K_2	constant (s^{-1})
Q	Volume flow rate of gas stream (m^3/s)
M	moisture
M	mass flow rate (kg/s, roughness factor ,dust conc. (gm/Nm^3)
N	nitrogen (per cent by weight of coal composition) ,no. of bags
O	oxygen (per cent by weight of coal composition)
P	pressure
Δp	pressure drop
S	sulphur (per cent by weight of coal composition)
T	temperature
t	time since the filter was last cleaned (s)
V	Gas-cloth ratio or air cloth ratio (ACR)
VM	volatile matter
GCA	gross cloth area
PE	16-oz polyester
CO	9-oz cotton
PP	16-oz polypropylene
TF	22-oz Teflon felt
NO	14-oz Nomex
P8	16-oz P84
HA	16-oz homo polymer acrylic
RT	16-oz Ryton
FG	16-oz fiberglass with 10% Teflon
NX	16-oz Nextel
TR	Top bag removal (snap in)
BBR	Bottom bag removal
$	Dollar
Rs.	Rupees
V	electric potential applied to the wire
h	wire to plate distance
Q	flow rate
L	length of the precipitator
C_w	electric supply
C_t	electric equipment
C_r	collector rapping

C_m	man power
C_c	cost of casing
Oz	ounces= a unit of weight equal to 16th of a pound or 16 drams or 28.349grms
DC	Direct cost
IC	Indirect cost
SP	site preparation

Subscripts

e	ESP
b	bag filter
1	inlet
2	inlet, outlet
3	outlet

Greeks

η	collection efficiency
η_d	design efficiency
δ.	Wire-to-wire-distance

REFERENCES

[1]. Lugar, W.T., Endrizzi j., Schreurs S., and Haggerty D.J. , 2009, The Ultimate ESP Rebuilt: Casing Conversion to a pulse jet fabric filter A case study , electric power conference , Rosemont, IL May 2009 .

[2]. Visuvasam D., Sekar S., and Anand K M , Retrofitting Pollution control Equipment in Indian power Plants and Other industries to meet the present more stringent Norms, ICESP IX

[3]. Fantom I ., and Cottingham C ., 2005, Should I Replace my Electrostatic Precipitator (ESP) with a fabric filter (FF)? paper to filteration society 10 march , 2005

[4]. CPCB, Assessment of requirement of bag filter via a Electrostatic precipitator in thermal power plants , Ministry of Environment and forest , Gov. of India, Delhi , program objective series probes/105/2007

[5]. Steyn F., Baidjurak L. and Hansen R., Fabric filter retrofits an Electrostatic precipitator Upgrade Technology , Proceeding ICESP X, Australia,2006, paper n. 9CI.

[6]. Grobbelaar H. D., Retrofitting Fabric Filter Plants into Small Electrostatic Precipitator Casings, Proceedings ICESP X, Australia, 2006, Paper no. 9C2, pp. 1-8.

[7]. Jedrusik M., and Jedrusik J., Industrial Scale Study of a Retrofitted Electrostatic Precipitaotr, Proceedings ICESP VIISep. 20-25, 1998, Korea.

[8]. Arestaa P., Pilatob S. D., Derudia M., and Nanob G., CFD - Assisted Safety Design in a Flue Gas Treatment Plant Retrofit, Chemical Engineering Transactions, Vol. 31,pp. 865-870, 2013.

[9]. Ghose, M. K, and Majee, S. R., 2000, Sources of Air Pollution Due to Coal Mining and Their Impacts In Jharia Coal Field, Environment International, Vol. 26, pp. 81-85.

[10]. Bhattacharyya Subhes C., 1995, Thermal Power Generation and Environment: A Review of the Indian Case, International Journal of Energy Research, Vol. 19, pp. 185-198.

[11]. GautamPankaj, December 2001, "Energy Saving and Efficiency Improvement of ESP", Dissertation of M.Tech. in Energy and Environmental management, Centre for Energy Studies.

[12]. Masters, Gilbert M., 2000,: Introduction to Environmental Engineering and Science. 4th ed., New Delhi, Prentice Hall of India Private Limited pp. 351-354.