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STUDY ON REDUCING THERMAL EMISSIONS BY IMPROVING THE EFFICIENCY OF ELECTROSTATIC PRECIPITATOR (ESP)

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ABSTRACT

The worry with the earth regarding air pollution is turning out to be serious, in the day to day life of everybody. A concrete contribution with the ecological issue is requested from the administrations, organizations and, in the end, from the general public overall. The factors, for example, charging strategy, particle size, Corona Power, Field voltage and drift speed and so on assume a vital part in the effective operation of Electrostatic Precipitator (ESP). The effective working of ESP ordinarily implies limiting the power utilization and boosting dust accumulation. With the air contamination control prerequisites turning out to be progressively stringent, it is basic to nearly screen and precisely control the key parameters of ESP control framework. In this paper the strategies to enhance the productivity of ESP are talked about.

Index Terms- Electrostatic Precipitator (ESP), SPM, efficiency, Parameters, Power

INTRODUCTION

Power plants in view of coal based boilers cause generous air contamination which incorporates So_x, No_x and Suspended particles (fly fiery remains) through pipe gas outflow. Likewise, handling plants, for example, concrete factories and steel plants, additionally cause air contamination through their fumes gases. In 2014, Vishal Vasistha conducted a study that the thermal power station in India results in adding ash estimated 12.21 million tons fly ash in to the environment a year of which nearly a third goes in to air and the rest is dumped on land or water[18]. The studies by Maureen Cropper in 2012, show that health damages associated with particulate matter, sulfur dioxide (SO2), and nitrogen oxides (NOx) from individual coal-fired power plants results in premature cardiopulmonary deaths associated with air emissions for persons 30 and older. It shows that 75 percent of premature deaths are associated with fine particles that result from SO2 and ash emissions[17]. An electrostatic precipitator (ESP) is a filtration gadget that uses the drive of an electrostatic charge to move fine particles out of the streaming gas stream and get it stored onto the collection plates. As shown in Figure No.1, our common ESP has thin wires called electron release terminals, which are uniformly divided between huge plates used for ash accumulation, which are grounded. The particles are given an electrical charge by drifting them to go through a corona, an area in which molecular stream and hence fiery debris particles are floated to the gathering plates. Once the particles are gathered on the plates, they are expelled from the plates without re entraining

them into the gas stream by thumping them free from the plates, permitting the gathered layer of particles to slide down into hoppers from which they are evacuated. The collection efficiency is an important parameter for determining the performance of the ESP and hence needs to be calculated. Some theoretical research has been previously done on ESP to predict the efficiency. In 2008, M. C. R. Falaguasta & J. Steffens shows that better results were attained when utilizing the classical Deutsch-Anderson model for collection efficiency than Kihm model and Riehle model was used[12]. In 2012, Theodre simulations of change in Precipitator length to obtain collection efficiency were performed by Joseph P. Reynolds & James Marino. In 2014, A.Buekens using Deutsch Model to analyse effect of change in resistivity on collection efficiency of ESP[15].

The first section of present paper gives a general introduction of Thermal Power Plant ,type of Pollution and its effects and initiate with a Review of Research work on effect of thermal plant emissions on air pollution and research carried on to show effect of various factors on ESP. Second section explains the research methodology used to simulate effect of various parameters on collection efficiency. Section third, explains the results obtained from different methods and their analysis to obtain collection efficiency. Fourth section shows comparison with existing methods. Moreover section fifth covers the conclusion of research carried out.

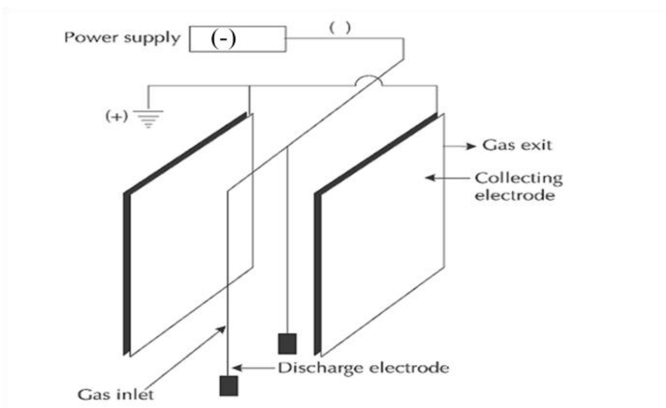

Figure No. 1 Electrode Collecting with Gas

PROPOSED METHEDOLOGY

Calculation of accumulation proficiency is essential thought of ESP plan. The conditions give a hypothetical gauge of the general gathering effectiveness of the unit working under perfect conditions. Various working parameters can unfavorably influence the accumulation proficiency of the ESP. Here Impact of various operating parameters on Collection Efficiency of ESP is analyzed. It is based upon GUI (graphical user interface) in MATLAB. It is an effort to further grasp the fundamentals of MATLAB and validate it as a powerful application tool. Equation No. 1 gives Deutsch Anderson

Model which depicts Collection Efficiency is used as basic tool in simulation process by program files in MATLAB.

$$\eta = 1-e^{-w(A/Q)} \quad (1)$$

Here: η= Collection efficiency (ESP), w = Migration velocity, cm/s, e = Base of natural logarithm = 2.718, A = The effective collecting plate area of the ESP, m^2, Q = Gas flow (through the ESP) in m^3/s.

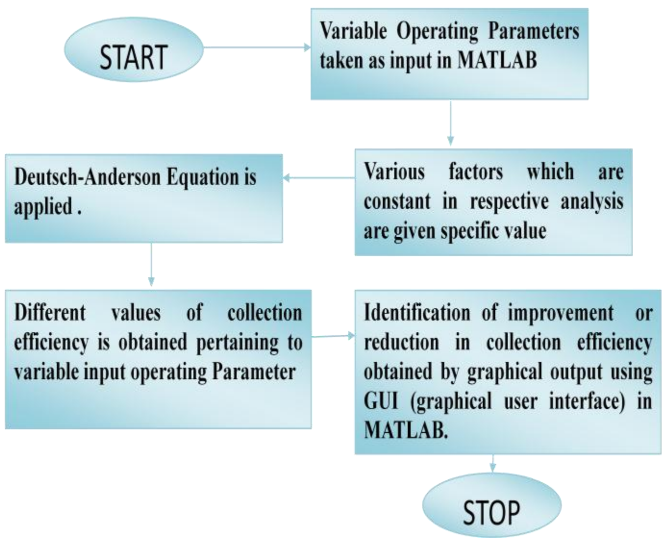

Figure No.2 : Area of Collection plates Vs Collection Efficiency

Here Figure No. 2, shows simulation process carried out in MATLAB to study effect of various parameters on collection efficiency.

RESULT AND DISCUSSIONS

The collection efficiency is the primary consideration of ESP design. Various equations give a theoretical estimate of the overall collection efficiency of the unit operating under ideal conditions. Unfortunately, a number of operating parameters can adversely affect the collection efficiency of the precipitator.

A. Corona Power

Corona power is related to the penetration and efficiency by

$$\text{Log } q = \log(1-\eta) = KP/Q \quad (2)$$

Here: P= corona power level (W), q= fractional penetration K= empirical constant (-0.021 to -0.21 cfm/W), & Q= flow rate (cfm).

Generally change in voltage is not easy in electronically controlled ESP, so Corona power can be varied with change of charging current. In Figure No. 3 we see that, with variation of 35 to 70 kV peak voltage and the 60 to 550 mA /section (0.1 to 1 mA/ft of wire) give corona power in range 5 to 40 KW. With increase in Corona power, collection efficiency can increase up to 99.9%.

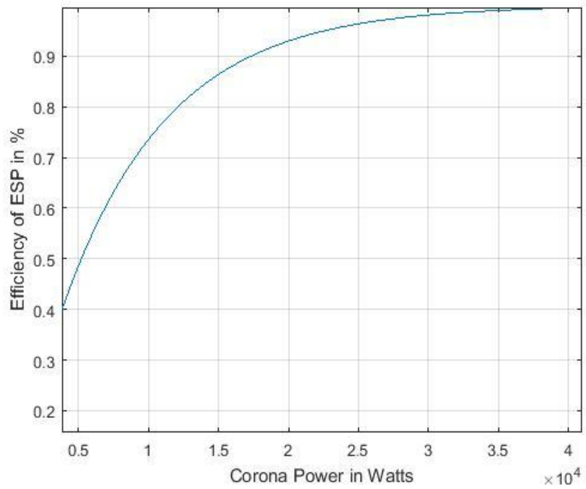

Figure No. 3: Corona Power Vs Collection Efficiency

B. Drift Velocity

The Drift speed or molecule movement speed is the speed at which a molecule once charged, moves toward the grounded accumulation terminal. Factors influencing molecule speed are measurement of molecule, the quality of the electric field, and the consistency of the gas. How promptly the charged particles move to the gathering anode is depicted by the w, called the molecule movement speed. The molecule movement speed parameter speaks to the collectability of the molecule inside the bounds of a particular ESP. The Drift speed is given by:

$$W = \frac{C_c q E}{3\pi \mu_f d_p} \quad (3)$$

Where:

$C_{C=}$ Cunningham slip factor

q = particle charge in s

μ= fluid viscosity = 1.81 x 10-5 kg/ms for air at normal temperature

E = strength of electric field , V/m

d_p = diameter of the particle, µm

Movement speed relies upon the voltage potency of both the charging and gathering fields. Hence, the precipitator must be outlined utilizing the most extreme electric field voltage for greatest accumulation productivity. The molecule gathering inside the ESP relies upon the outflow gas speed and the electrostatic drive of the ESP framework. The normal gas speed inside the gathering area of an ESP differs from 0.5 m/s to 2 m/s. The stream with high speed leaves the gathering area with poor molecule accumulation. The particles require adequate treatment time to get charged and gathered inside an ESP. The electrostatic field, which is created after the electric potential applied to the release cathodes, is clearly identified with the speed of the particles. Figure No. 4 and 5 demonstrates the change of accumulation proficiency with increment in drift speed from 0.5 m/s to 2 m/s while field strength and molecule size is changing.

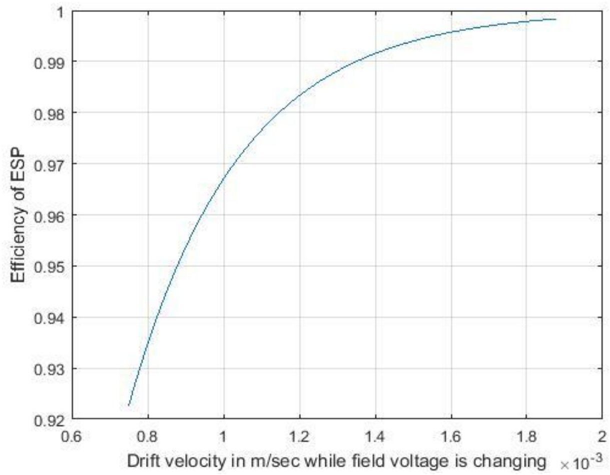

Figure No. 4: Drift Velocity Vs Collection Efficiency

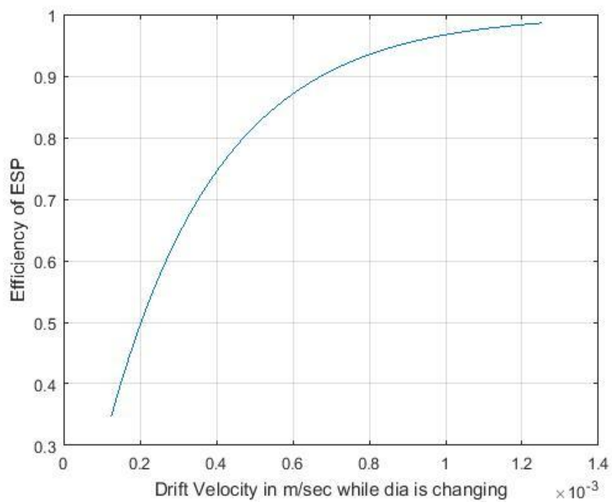

Figure No. 5: Drift Velocity Vs Collection Efficiency

C. Particle Size

The accumulation proficiency additionally relies on molecule estimate. As size of molecule expands it gets troublesome for electric field to occupy course and float the fiery debris particles to the gathering plates. Up to some level accumulation effectiveness diminishes with increment in molecule size .The molecule gathering inside the ESP likewise relies on upon the outflow gas speed and electrostatic field strength of the ESP. The molecular Diameter for the most part differs from 0.3 micro meter to 5 smaller scale meter. Figure No.6 demonstrates that with increment of molecule size to 1 micro meter brings about fall of accumulation effectiveness up to 89% level.

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D. Operating Voltage

The working voltage ought to be kept highest feasible for maximum electron discharge. The dismal infiltration may be resulted with some sparking. Sparking relies upon the working voltage, cathode separation, gas specifications, molecule concentration, ash layer and resistivity of the ash particles. The working voltage is rectified ac current and further undergoing study for a square wave voltage. The peak voltages for mechanical high-voltage ESP are primarily 35 to 70 kV. The field qualities will for the most part be 4 to 5 kV/cm. Correspondingly Figure No.7 demonstrates that accumulation proficiency can enhance up to 99.8%.

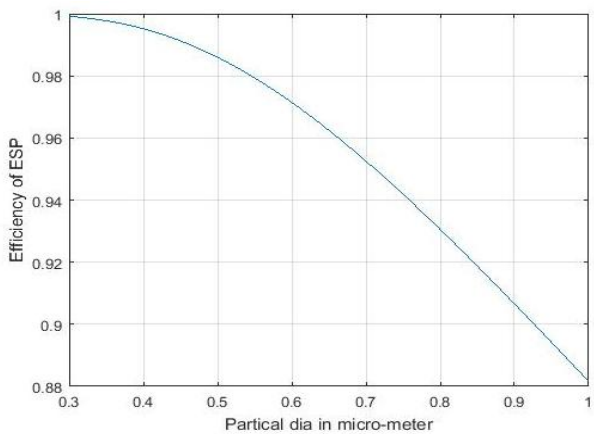

Figure No. 6: Particle Diameter Vs Collection Efficiency

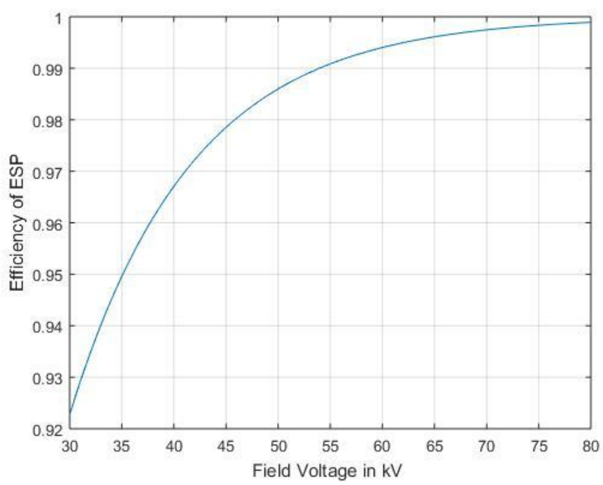

Figure No.7: Field Voltage Vs Collection Efficiency

E. *Dislodging of Gathered Material*

The dust particles which are floated to the gathering plates must be expelled from gathering anode. In low-voltage ESP , the development is sufficiently moderate that the cleaning is typically done by closed down of the plant; in any case, for the high-voltage ESP, the ash develop is fast and expulsion must be done regularly, while the unit is running. The most broadly utilized expulsion system is the hammering of electrodes. Sledges are utilized to tap the collection plates and cause the ash layer to tumble off. How forcefully to rap and when to rap is crucial concern. Magnetic pulse hammering or compacted air rapping is frequently done at 1 to 2 raps for every minute per anode for the initial field. Vibrating the anode at around 50 to 100 Hz might be utilized for cleaning. The primary segment ought to be cleaned more frequently in comparison with last segment. Dislodging of ash particles at optimum time can decently increase accumulation proficiency of ESP.

F. *Gas Flow*

Collection efficiency also depends upon gas flow of flue gases through electrostatic precipitator. Its relation with efficiency is given by Deutsch Anderson equation. As the flow of gas increases, particle remains for less time inside electric field which results in reduction of collection of these particles on collection plate. Correspondingly Figure No.8 demonstrates that accumulation proficiency decrease up to 92.8%, when gas flow increased from 150m^3/sec to 400 m^3/sec.

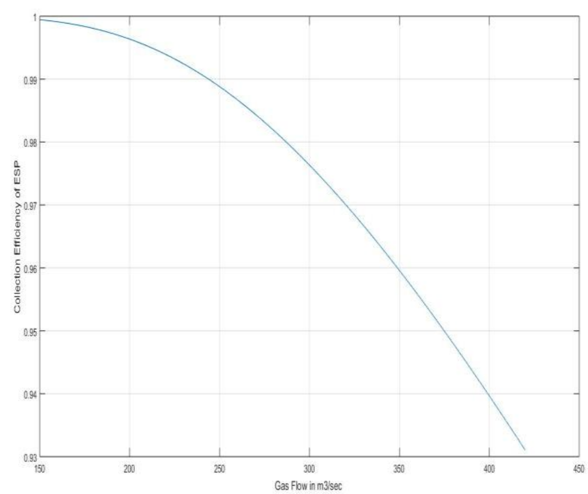

Figure No. 8: Gas Flow Vs Collection Efficiency

G. *Area of Collection Plates*

Determining the collection area of electrostatic precipitator of utmost importance. It the major component of ESP design. Its relation to collection efficiency is also given by Deutsch Anderson equation, in which it is directly proportional to collection efficiency.

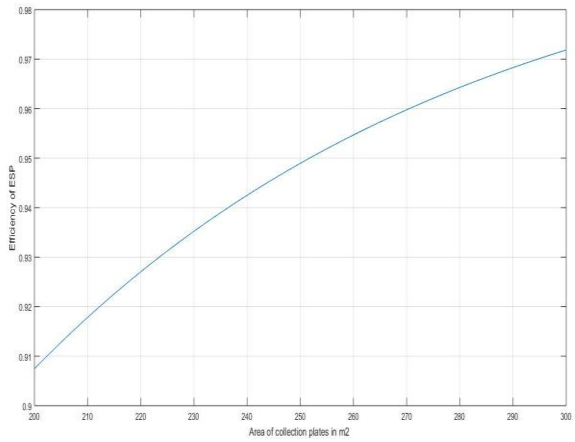

Figure No.6: Area of Collection plates Vs Collection Efficiency

Figure No. 9, demonstrates the change of accumulation proficiency from 92 to 98 % with increment in area of collection plates from $200m^2$ to $300\ m^2$.

COMPARISON WITH EXISTING METHODS

Various research has been carried out to obtain effect of some operating factors on collection efficiency. In the present work some more parameters are studied and analyzed. The Table 1. Appended below shows a comparative study between existing work and the present work carried out further in this field.

Table 1: Comparison Table of Literature review

Author Name & Year of Publication	**Method Used**	**Result**
M. C. R. Falaguasta & J. Steffens, 2008. [12]	The effect of change in particle size on collection Efficiency of ESP by Deutsch-Anderson model Kihm and Riehle model.	Better results were attained when utilizing the classical Deutsch-Anderson model for collection efficiency than Kihm and Riehle model was used in the efficiency calculations.
Joseph P. Reynolds & James Marino, 2012. [14]	ESP collection efficiency obtained by change in Precipitator length using Theodre Model.	Collection Efficiency of ESP increases with increase in Precipitator Length.

A.Buekens, 2014. [15]	Using Deutsch Model effect of change in resistivity on collection efficiency of ESP	Collection efficiency of ESP increases with decrease in resistivity.
Narendra Gajbhiye, V Esvarna & A.K. Saha, 2015 [16]	Studied the effect of change in particle size on collection Efficiency of ESP.	Particles of diameter more than 4 μm get picked up by the collector plates for wire potentials of 30 kV.
Present Work	The effect of change in field voltage, corona power, gas flow, particle size and drift velocity on collection Efficiency of ESP using Deutsch Model (Simulation through MATLAB)	Collection Efficiency of ESP **Increases with increase in** Field voltage,Drift velocity (while field voltage is changing),Drift velocity (while Particle Diameter is changing), Corona Power & **Decreases with Increase in** Gas flow and Particle size**.**

CONCLUSION

In majority of the coal based power plants stack discharge level of suspended particles is on the higher side when compared with the permissible limits. In any case change in concentration of Nox and Sox in flue gases is little and is under permissible standards. Collection efficiency of electrostatic precipitator (ESP) increases with increase in field voltage, drift velocity (while field voltage is changing), drift velocity (while particle diameter is changing), area of collection plates, corona power and frequency of removal of collected ash particles. On the other hand collection efficiency of electrostatic precipitator decreases with increase in gas flow and particle size. Quantitative investigation uncovers that outflow concentration of suspended particles can be lessened beneath permissible limit. Resultantly, the degree of contamination all around can be decreased and it will reduce air pollution in the environment.

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