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Factors Affecting the Performance of Dry Electrostatic Precipitator: A Review

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Abstract:- Electrostatic Precipitator are the devices which removes the entrained particulate contaminants and unwanted fine particles from the exhaust gases. The use of ESP, in particular power generation plant will help to reduce the environmental problems in two ways- On one hand, reducing the heavy or large particles, dust, fume or mist in exhaust gas and on the other hand it helps in cement industries for manufacturing the portland cement and bricks. It mainly works on the principle of electrostatic attraction (like charges repel; unlike charges attract). The contribution of this work lies in the comparative study and assessment of different factors that affects the performance of dry Electrostatic Precipitator in a developing country India to reduce the pollution particles.

Keywords:- *Electrostatic precipitator, contaminants particles, exhaust gases, Portland cement.*

I. INTRODUCTION

In today's era of large power requirements, there is a big problem of entrained particulate contaminants in exhaust gases. An ESP is a device which works on the electrostatic principle i.e. attractions and repulsions of electric charges, like charges repel; unlike charges attract. Every particle either has or can be given charge- positive or negative. A high voltage system provides power to the discharge electrode to generate an electrical field, to work on electrostatic principle.

ESPs can be classified according to the structure design as follows:

- <u>The structural design and operation of discharge electrodes as Tubular and plate ESPs</u>. Tubular precipitators consist of cylindrical electrodes (tubes) with discharge electrodes (wires) located in the center of the cylinder. Plate precipitators consists of plates, wire, it can have wire, rigid frame, or occasionally, plate discharge electrodes.
- <u>The method of charging as single stage and two stage</u>. In single stage high voltage of 50 to 70 KV to charge particles and all process of charging and collecting of particles is done in same stage. In two stage the charging and collection is done in two chambers i.e. first chamber is charging at low voltage of 12 to 13 KV and second chamber for the collection of charged particle by opposite charge.
- <u>The temperature of operation as cold-side or hot-side</u>. It refers to the temperature of flue gas entering into the ESP and the location where it is has been installed. Hot side ESPs are used for temperature greater than 300^0C and located in front of air pre heater. Cold side ESPs are used for temperature less than 204^0C and located behind the air pre heater.
- <u>The method of particle removal from collection surfaces as wet or dry</u>. Wet ESPs are the ESPs where the collection of dust particles is done by the water flow in the wet state, it is used where the potential for explosion is high, or dust is very sticky, corrosive. Dry ESPs are the ESPs where the collection of dust particles is done by the rappers in the dry state.

Fly ash particles, which are produced from coal fired thermal power plants in the form of suspension in the flue gas from combustion units, contribute to an increased suspended particulate matters (SPM) in surrounding environment.

II. CONSTRUCTION

The construction of a dry electrostatic precipitator is as follows:

- It includes two electrodes i.e. positive and negative. The positive electrode is in the form of plates and negative is in the form of the wire and are arranged vertically or horizontally based on the applications, generally kept as vertical due to large area.
- The connection of these electrodes is done by a common DC source. The distance between the electrodes and the supply voltage is to be corrected on the basis of dust particles, generally the distance is kept as 12 to 16 in.
- The main components of ESP include electrodes, 3 phase supply 50 Hz 440V, control cabinet, high voltage transformer, rectifier, electrodes, rappers, hooper and insulators.
- The control cabinet is applicable for connecting the transformer and 3 phase supply.
- Transformer is used to step-up & step-down the receiving voltage according to need.
- Rectifier is applied after the transformer to rectify the AC in the DC supply.
- Electrodes are used to charge and collection of the dust particles.
- Rappers are devices used to remove the accumulated dust on the collector electrode i.e. plates by rapping them with help of hammers.
- Hooper is the storing tank of collected dust particles and ash from ESPs.

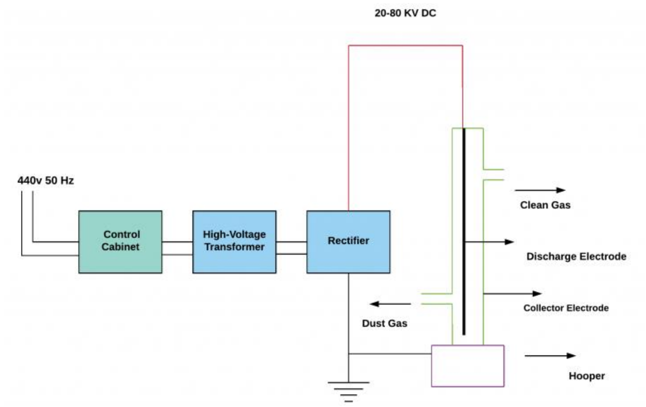

Fig. 1:Linediagram Of Components Of The ESP

Detailed diagram of ESP is a below:

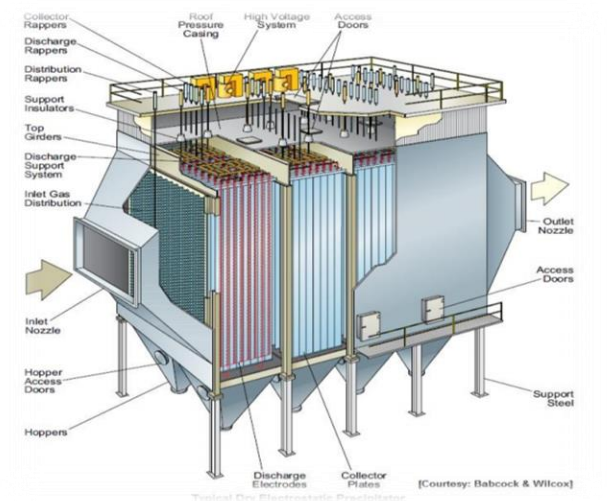

Fig. 2: Detailed Diagram Of An ESP

III. WORKING PRINCIPLE

An ESP works due to electrostatic attraction. It uses high voltage electrostatic field to separate dust from a gas stream. Every particle either has or can be given a charge, by high voltage system discharge electrode generates the electric field to charge the particles of stream. The particles are then attracted towards the collector plate, and form a dust layer on the plate. Periodic rapping helps to separate the accumulated dust layers from the electrodes. The rapped particles then collected into the hopper and removed by the ash handling system to different locations according to the treatment of the ash.

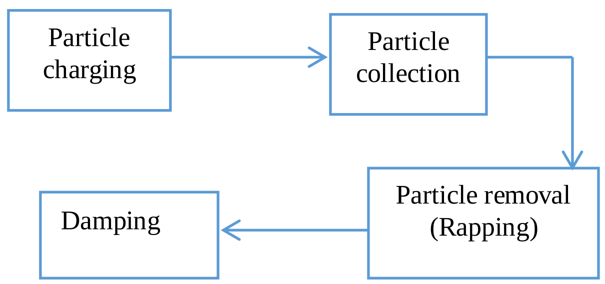

Fig. 3: Line Diagram Of The Working Principle

- Particle charging: In this process the dust particles is given a charge with the help of the high voltage system, during charging the electric field is strongest near the discharge electrodes and weakest at the collected electrodes. The particles are generally charged by the any of the two mechanisms: field charging or diffusion charging. Field charging cause a local dislocation of the electric field as they enter the field whereas diffusion charging occurs due to the random Brownian motion of the negative gas ions i.e. higher the temperature, more the movement.
- Particle collection: In this process the charged particles are collected by the collector electrodes. When a charged particle reaches the collection electrode, the charge is slowly leaked to the collection plate. A portion of the charge is retained and contributes to the inter-molecular adhesive and cohesive forces that hold the particles onto the plates. Adhesiveness helps the particle to stick with the plate while cohesiveness helps them to remain held to each other.
- Particle removal (Rapping): In this process the collected layer of dust is removed by process depending on the type of collection electrode i.e. tube type cleaned by spraying water vapour and plates type of collection electrode by water spraying or rapping. Rapping is a process in which the deposited dry particles are dislodged from the collection plates by sending mechanical vibrations or impulses to it. Plates are rapped when the accumulated dust layer is relatively thick i.e. 0.08 to 1.27 cm.
- Damping: In this process the collected dust is sent to damping according the nature of ash or plant location. If the ash is less acidic then it can be dumped to nearby location or can be send to other location through water channels. If there is any cement industry then it can send to them directly as a raw material.

IV. COMMON PROBLEMS DURING THE OPERATION OF DRY ESP

Following problems are commonly seen during the operation of dry ESP:

- Variation in resistivity of dust particles: It is the measure of particle’s resistance to transferring charge. It is an important phenomenon in the inner electrode region where most particles charging takes place. So common problem arises that the collection of dust particle is not efficiently, there is more particles.
- Electrical Sectionalisation: An ESP is divided into series/parallel of independently energised bus fields. Each field has individual T-R sets, voltage-stabilisation controls, and high-voltage conductors those energies the discharge electrodes within the field. In an ESP, electrical sectionalisation is to manage the varying level of flue gas temperature, dust concentration, and problems with gas flow distribution.
- Specific Collection Area of a section: It is the ratio of collection surface area to the gas flow rate in to the collector region. More the area tends to more collection and vice-versa.
- Aspect ratio:It is the ratio of the effective length to the effective height of the collector surface. It is an important factor in reducing the rapping loss, i.e. large amount of collected dust can be re-entrained in the gas flow and carried out of the ESP if the aspect ratio is smaller. Generally it is

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kept between 0.5 to 2.0, for greater efficiency the efficiency must always greater than 1.0.

- Gas Flow Distribution: It plays a vital role in collection of dust particles as ESP will perform best at optimum gas velocity due to more time in the precipitator. At low gas flow the dust will settle to the bottom of inlet duct, causing the problem of mal-distribution of flue gas in the ESP.
- Corona Power: In an ESP a strong electric field is required to achieve high collection efficiency of dust particles. The corona power is the power that energises the discharge electrodes and thus creates the strong electric field to charge the dust particles. Corona power increases as the voltage and / or current increases.
- Dust Accumulation: There are some main causes of this are as follows: (i) Inadequate rapping (ii) sticky dust (iii) operation at temperature below of its dew point.
- Wire Breakage: As the discharge electrodes is in the form of wire, and it may fall in one of the three regions: top, bottom, misalignment. Weakening of wire is happened due to electrical erosion, mechanical erosion, corrosion, or some combination of these.
- Hopper Pluggage: Hopper pluggage can be caused by the factors as mentioned: (i) obstructions due to fallen wires (ii) inadequate size of solid removal equipment (iii) using hoppers for storing (iv) inadequate insulation and hopper heating

V. SOLUTIONS

Following are the solutions to the common probles during the operation:

- Aspect Ratio: An ESP must be well-designed with aspect ratio greater than 1.0 for greater collection efficiency i.e. increasing its height or reducing its width.
- Gas Velocity: It must be kept as that the dust particle may exhibit their maximum time for charging and the collection efficiency will increase.
- Specific Collection Area:It must be kept the adequate surface area of collecting plates so the collection efficiency of an ESP must be maximum.
- Electrical Sectionalisation: Install the high frequency transformer rectifier for the initial fields and for remaining upgrade the overall voltage so the corona power will increase and the collection efficiency will increase.
- Reducing the distance between the electrodes: The passage between the electrodes is the area for charging the dust particle and the effect of electric field is more at discharge electrodes and weaker near the collection electrodes, so it is beneficial for to reduce the distance between the electrodes.
- Reducing the resistivity by adding some agents:For different resistivity level we can use different agent to neutralise its effect on collection efficiency. For particles with high resistivity we can use sulphuric acid, ammonia, sodium chloride, etc. For particles with low resistivity we can use NH_3.
- Reducing the temperature of flue gas:At high temperature the dust particles doesn't get charged easily so the temperature of flue gas must be kept optimal.
- Adding perforated filter behind collecting electrodes of each field:When the flue gas leaves the ESP there may be chances of dust particles going with exhaust gas so it is beneficiary to add a perforated filter to entrap the dust particle which didn't get charged.
- Increasing the temperature of hopper: For reducing the chances of hopper pluggage, we could increase the temperature so the dust particles don't stick in the hopper or eaily remove when the ash removal happens.

VI. CONCLUSION

An ESP is device which removes the particle from dust particle. The factors that influence the performance of an ESP are gas velocity, electrical sectionalisation, up gradation of voltage, temperature of flue gas, and distance between the electrodes. It is good to reduce the distance between the electrodes and increase the voltage supply, so the corona charge will increase that all particles get charged and accumulated.

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