Enhancement of ESP performance of Thermal Power Plant : a controlling measure towards Environmental Sustainability.

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Abstract

Thermal Power plants emit fly ash as well as other gases like Carbon dioxide(CO_2), Carbon Monoxide (CO), Sodium Oxides(NO_x) , Sulpher oxides(SO_x) ,etc. to the atmosphere and, in turn, the atmosphere gets polluted. The pollution to this effect is dangerous to our living society as well as to the plant life. The reason is the use of fossil fuel like coal to run the thermal power plants. Now-a-days. more numbers of old coal based power plants, are still in existence with high emission. High ash content or deterioration in quality of coal reserve is the major focus for our environmental sustainability. Around 70% of power generation is from coal based thermal power plant. Alternative power generation technologies have also been adopted to reduce emission as a major towards environmental care.

Air pollution control equipment for today's need are Electrostatic Precipitator (ESP) , Fabric Filter (FF) etc. are in greater use. But, **Electrostatic Precipitators(ESP)** are widely used all over the world for better performance and better dust collection efficiency. It is a reliable and proven technology which Can effectively handle large quantities of abrasive type fly ash without any operating problems. Energy saving aspect on this controlling measures is really challenging. For enhancement of ESP performance, promotion of new technology and development of electronics & materials are in continuous process of improvement.. This paper presents the basic technological and operational concept of ESP and performance enhancement programs/activities being taken in Thermal power generation plants, which are in accordance with the Environmental Regulations of today's world.

Introduction to Electrostatic Precipitators

An electrostatic precipitator is a large, industrial emission-control unit. It supersedes in many way to the previously used bag filter system and is designed to trap and remove dust particles efficiently and effectively from the exhaust gas stream of an industrial process. Precipitators are used in these industries:

- Power/Electric
- Cement
- Chemicals
- Metals
- Paper

In many thermal power plant plants, fly ash generated in the coal combustion process is carried as dust in the hot exhaust gases. These dust-laden gases are allowed to pass through an electrostatic precipitator that collects most of the dust. Cleaned gas then passes out of the precipitator and then through a stack to the atmosphere. Precipitators typically collect 99.9% or more of the dust from the gas stream.

Precipitators function by electro-statically charging the dust particles in the gas stream coming out of the boiler after coal combustion. The charged particles are then attracted to and deposited on the collector plates. When enough dust has accumulated, the collectors are hammered to dislodge the dust, causing it to fall with the force of gravity to hoppers below. The dust is then removed by a conveyor, slurry form, vacuum trapped system etc. for disposal or recycling.

Depending upon dust characteristics, coal composition (primarily ash content) and the gas volume to be treated, there are many different sizes, types and designs of electrostatic precipitators. Very large power plants may actually have multiple precipitators for each unit

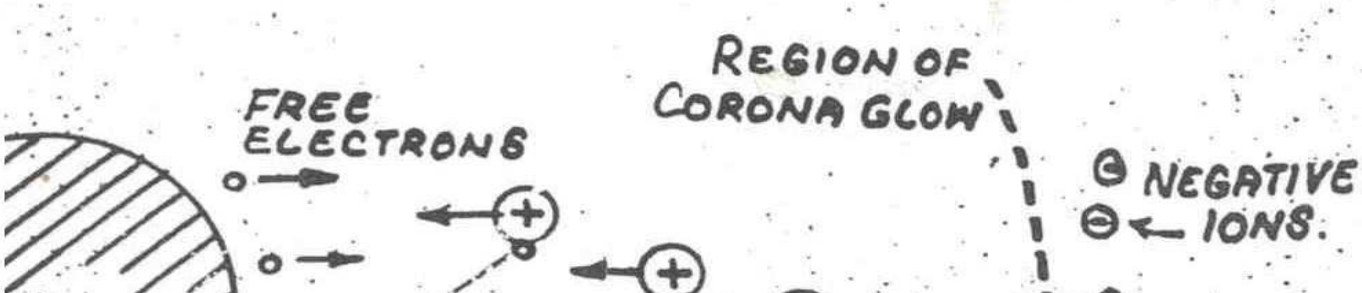
Basic Principles

Electrostatic precipitation removes particles from the exhaust gas stream of an thermal power plant. Often the process involves combustion, but it can be any industrial process that would otherwise emit particles to the atmosphere. The following processes are being carried out inside ESP:

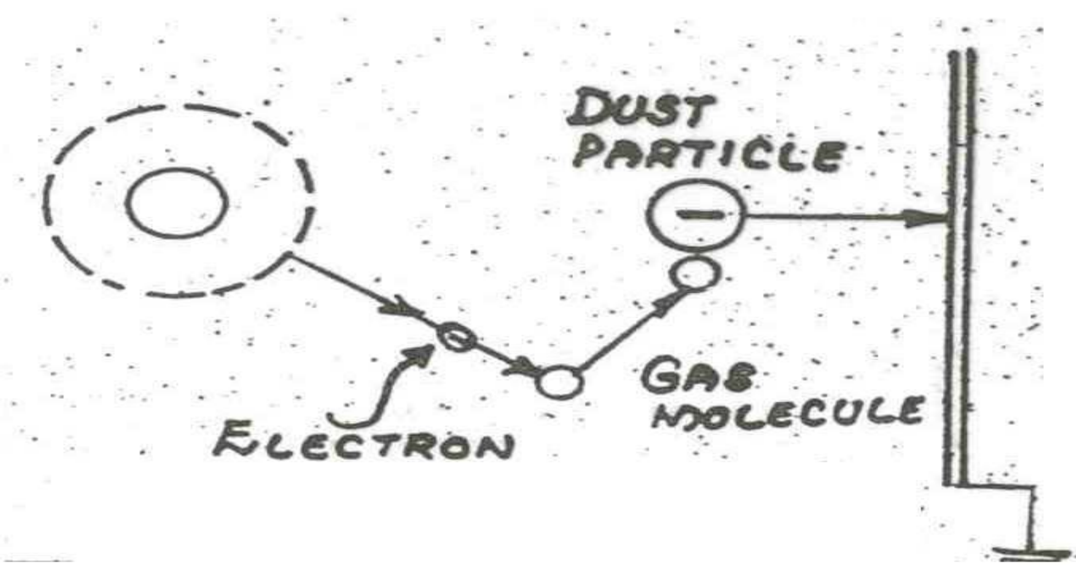
- Gas distribution – Uniformly distributing the gas inside ESP
- Ionization - Charging of particles by corona power
- Migration - Transporting the charged particles to the collecting surfaces
- Collection - Precipitation of the charged particles onto the collecting surfaces
- Charge Dissipation - Neutralizing the charged particles on the collecting surfaces
- Particle Dislodging - Removing the particles from the collecting surface to the hopper
- Particle Removal - Conveying the particles from the hopper to a disposal point

The major precipitator components that accomplish these activities are as follows:

- Flue Gas Conditioning
- Discharge/ emitting Electrodes
- Collecting electrodes/ plates
- Power Components
- Precipitator Controls / electronic controller
- Rapping Systems
- Purge Air Systems



The above figure shows the process of ionization of ash particles inside the ESP fields. The figure below shows the condition of particle charging and collection at the collecting plate.



DEUTSCH - ANDERSON EQUATION

Collection Efficiency = $1 - e^{-w \cdot SCA}$

where,

w = Migration velocity

SCA = Specific Collecting Area

- Migration Velocity
  - The velocity with which the dust particle travel towards the collecting electrode under the influence of electric field. Unit is m/sec
- Specific collecting area
  - Amount of collecting area required to be provided to collect dust in gas flow rate of 1 m3/s. Unit : m2/m3/sec

Operation

To maximize electrostatic precipitator efficiency a voltage controller usually attempts to increase the electrical power delivered to the field. However in some conditions a voltage controller must just maintain power at a constant level. Increased electrical power into the electrostatic precipitator directly correlates with better precipitator performance, but there is a limit. If too much voltages is applied for a given condition, a spark over will occur. During a spark over, precipitator performance in that field will drop to zero, rendering that field temporarily ineffective.

To overcome the crippling effect that spark over has to increasing the electrical power in the precipitator field, spark response algorithms have been developed that will interrupt power upon detection of a spark, then ramp power back up to a high level. These response algorithms can greatly influence overall precipitator performance

The transformer-rectifier rating should be matched to the load imposed by the electrical field or bus section. The power supply will perform best when the transformer-rectifiers operate at 70 - 90% of the rated capacity, without excessive sparking. This reduces the maximum continuous-load voltage and corona power inputs. Practical operating voltages for transformer-rectifiers depend on:

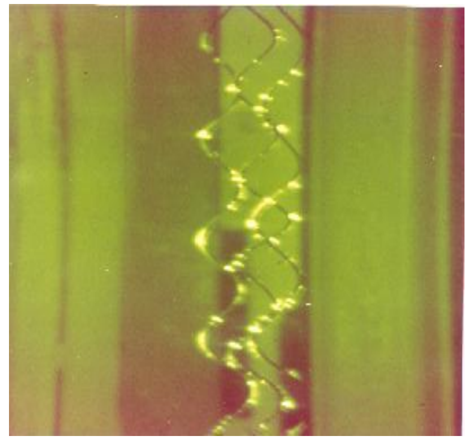
- Collecting plate spacing
- Gas and dust conditions
- Collecting plate and discharge electrode geometry

Similarly, Corona current density should be in the range of 10 - 100 mA/1000 ft2 of plate area. (Calculate this using secondary current divided by collecting area of the electrical field or bus section.) The actual level depends upon:

- Location of electrical field or bus section to be energized
- Collecting plate area
- Gas and dust conditions
- Collecting electrode and discharge wire geometry

The right side figure is condition of corona discharge inside the

field. Precipitator corona power is the useful electrical power applied to the flue gas stream to precipitate particles.
Either precipitator collecting efficiency or outlet residual can be expressed as a function of corona power in Watts/1000 acfm of flue gas, or in Watts/1000 ft of collection area

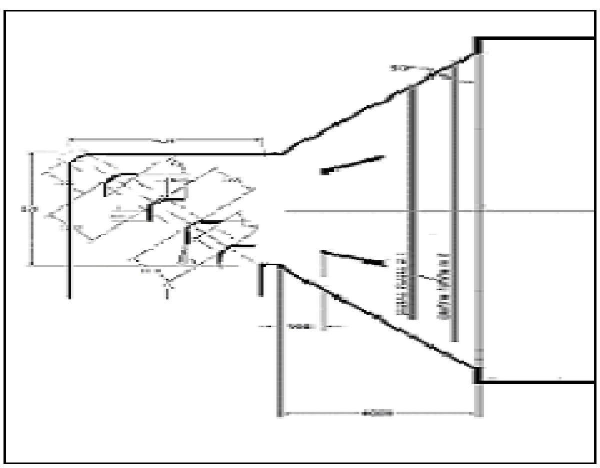


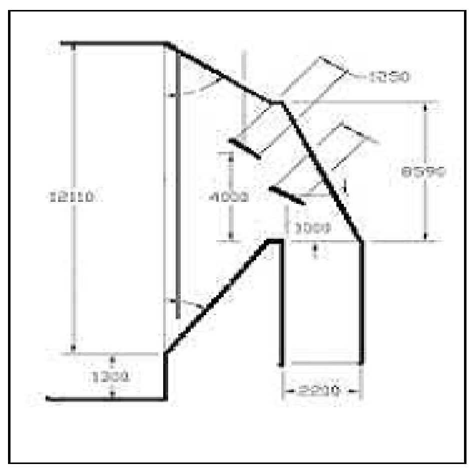
Performance Improvements:

For improving ESP performance, the following major aspects are to be looked into for corrective action.

Optimizing Gas Velocity Distribution

Efficient precipitator performance depends heavily upon having similar gas conditions at the inlet of each electrical field and at the inlet of each gas passage of the electrical field. Uniformity of gas velocity is also desirable to have a good gas velocity distribution throughout the precipitator. Gas Velocity Distribution in a precipitator can be customized according to the design of the precipitator and the characteristics of the dust particles. Traditionally, precipitators have been designed with uniform gas velocity distribution through the electrical fields, to avoid high-velocity areas that would cause re-entrainment. While this is still a recommended practice, there is an advantage in some cases to developing a velocity profile that brings more particles closer to the hopper.





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Gas distribution arrangement at the inlet of electrostatic precipitator.

The worn-out screen used for uniform gas distribution

For improving the uniform distribution of flue gas inside the ESP field, the following aspects are to be emphasized.

- Adding/improving gas flow control devices in the inlet ductwork
- Adding/improving flow control devices in the inlet of the precipitator
- Adding/improving flow control devices in the outlet of the precipitator
- Adding a rapping system to the flow control devices (where applicable)
- Adding/improving hopper baffles
- Eliminating air leakages into the precipitator

Optimizing Corona Power

Precipitator corona power is the useful electrical power applied to the flue gas stream to precipitate particles. Either precipitator collecting efficiency or outlet residual can be expressed as a function of corona power. The separation of particles from the gas flow in an electrostatic precipitator depends on the applied corona power. Corona power is the product of corona current and voltage. Current is needed to charge the particles. Voltage is needed to support an electrical field, which in turn transports the particles to the collecting plates.

In the lower range of collecting efficiencies, relatively small increases in corona power result in substantial increases in collecting efficiency..

Optimum conditions depend upon the location of the field (inlet, center and outlet), fly ash characteristics and composition and physical conditions (collecting plates and discharge wires). Corona power levels can be optimized by adjusting or optimizing the field voltage. This field voltages are automatically determined by the intelligent electronic controller by properly studying the field status such as gas volume, gas temperature, gas velocity etc. while in operation. Accordingly, appropriate corona power is being delivered in the field to ionize the ash particles which need to be collected before going to stack.

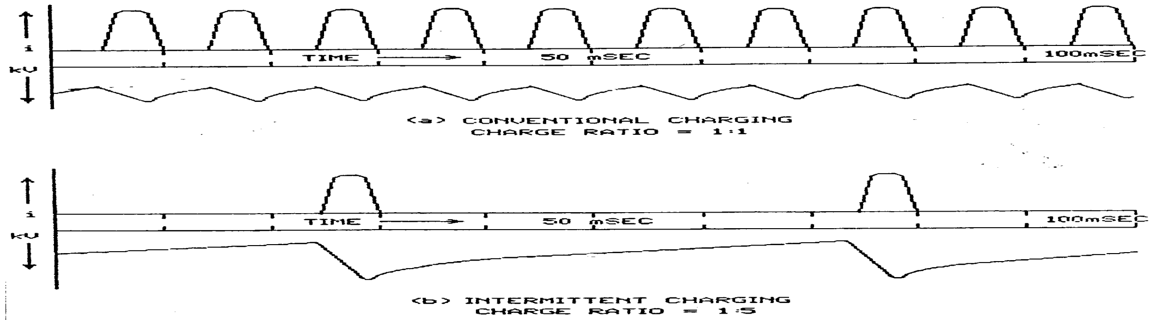
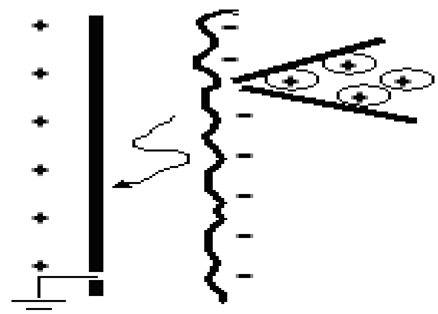


Fig.9 CURRENT AND VOLTAGE WAVEFORMS WITH DIFFERENT CHARGE RATIOS

The above figure shows the intermittent charging of ESP field for better performance.

Intermittent charging the ESP field is the best practice for improving the collection efficiency as well as the energy saving. It also helps the equipment damage against spark initiated inside the field. The above figure shows the current and voltage pattern at different charge ratio in the ESP field.



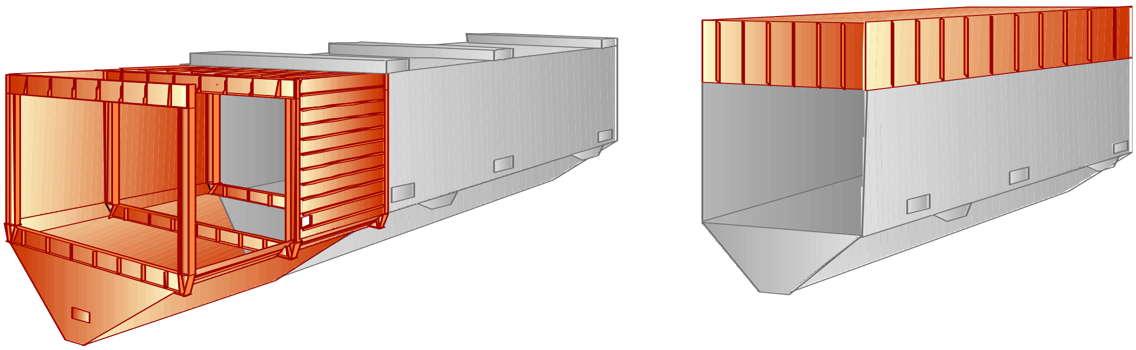
The above figure shows the effect of back corona which deteriorates the ESP performance. So, correct intermittent charging reduces the formation of back corona.

Optimal Designing of ESP Equipments:

The objectives of equipment improvements are to optimize corona power, reduce re-entrainment, and optimize gas velocity distribution inside the precipitator. Some important topics to consider when planning equipment improvements include:

1. **Precipitator Size :**

   When sizing the precipitator, it is important to provide a cross-section that will maintain an acceptable gas velocity. It is also important to provide for enough total discharge wire length and collecting plate area, so that the desired specific corona current and electrical field can be applied.



Horizontal and vertical design consideration of ESP to meet the required efficiency

2. **Minimizing Spark**

When the voltage applied to the electrostatic precipitator field is too high for the conditions at the time, a spark over (or will occur. Detrimentally high amounts of current can occur during a spark over if not properly controlled, which could damage the fields. A voltage controller will monitor the primary and secondary voltage and current of the circuit, and detect a spark over condition. Once detected, the power applied to the field will be immediately cut off or reduced, which will stop the spark. After a short amount of time the power will be ramped back up, and the process will start over. Hence the space between electrodes is to be optimally designed and to be closely monitored while opening the field for inspection and maintenance.

3 **Minimizing Particle Re-entrainment:**

Minimizing re-entrainment of dust particles is important aspect for improvement of precipitator efficiency. Most precipitator equipment affects the re-entrainment level. The deflecting plates to be placed properly in the path of gas stream to divert it uniformly inside the field . Consequently gas velocity remains uniform throughout the ESP field.

Combustion Process Improvements for Power Plants

Combustion process conditions mainly affect the corona power level. The primary contributors to combustion process conditions and their effects include:

Fly Ash and Flue Gas Conditioning

Flue gas and fly ash characteristics at the inlet define precipitator operation. The combination of flue gas analysis, flue gas temperature and fly ash chemistry provides the base for fly ash resistivity. Typically, fly ash resistivity involves both surface and volume resistivity. As gas temperature increases, surface conductivity decreases and volume resistivity increases.

In lower gas temperature ranges, surface conductivity predominates. The current passing through the precipitated fly ash layer is conducted in a film of weak sulfuric acid on the surface of the particles. Formation of the acid film (from SO_3 and H_2O) is influenced by the surface chemistry of the fly ash particles.

In higher gas temperature ranges, volume conductivity predominates. Current conduction through the bodies (volume) of the precipitated fly ash particles is governed by the total chemistry of the particles.

Fly ash resistivity can be modified (generally with the intent to reduce it) by injecting one or more of the following upstream of the precipitator:

- Sulfur trioxide (SO_3)
- Ammonia (NH_3)

Sulfur Trioxide and Ammonia Conditioning Systems

In most cases, a sulfur trioxide conditioning system is sufficient to reduce fly ash resistivity to an acceptable level. The source of sulfur trioxide can be liquid sulfur dioxide, molten elemental sulfur, or granulated sulfur. It is also possible to convert native flue gas SO_2 to SO_3.

In some instances, ammonia alone has been proven a suitable conditioning agent. It forms an ammonia-based particulate to increase the space charge. The source of ammonia may be liquid anhydrous or aqueous ammonia, or solid urea.

Finally, sulfur trioxide and ammonia may be used in combination. This solution has been successful because it can lower fly ash resistivity and also form ammonia bisulfate. The latter increases the adhesion of particles, and thus reduces re-entrainment losses.

Many of the precipitators in operation today were sized and designed to meet performance requirements that are far below current requirements. Time has also taken its toll on the robust machines built many years ago. Most units can be upgraded, repaired or rebuilt to extend their life and improve their performance. Many design experiences are there to insure the modifications to meet the objectives of today's precipitator performance. Varieties of precipitators have been modified to meet more stringent performance requirements.

Rapping Systems

Rappers are time-controlled systems provided for removing dust from the collecting plates and the discharge electrodes as well as for gas distribution devices (optional) and for hopper walls (optional). Checking the rapping frequency and correct operation of each rappers including in time maintenance enhances the value addition to the ESP performance

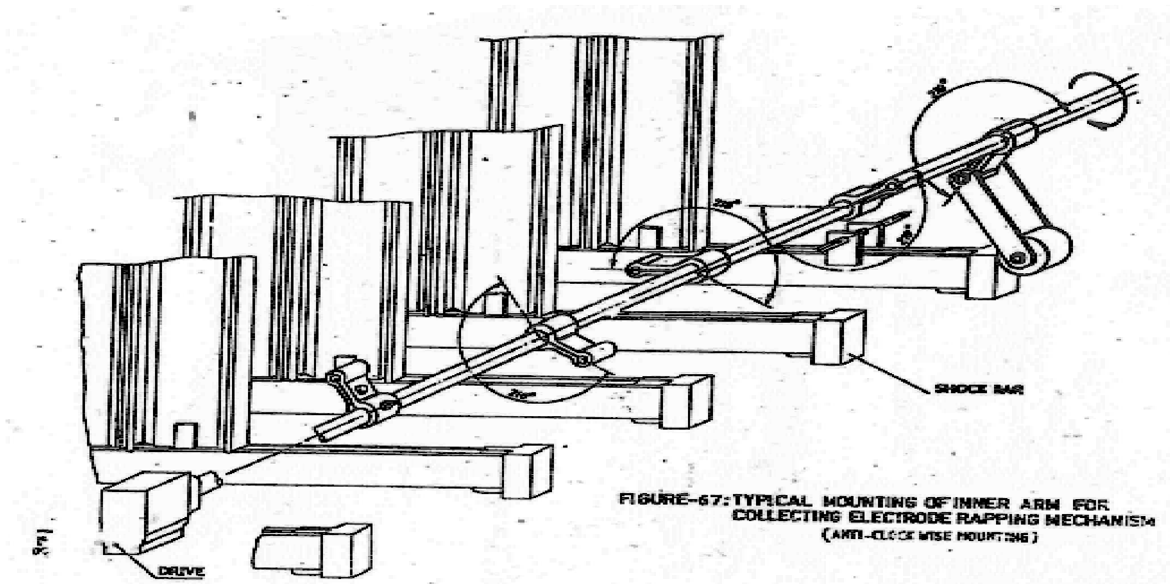


FIGURE-67: TYPICAL MOUNTING OF INNER ARM FOR COLLECTING ELECTRODE RAPPING MECHANISM (ANTI-CLOCK WISE MOUNTING)

Conclusion

Many of the precipitators in operation today were sized and designed to meet performance requirements that are far below current requirements. Time has also taken its toll on the robust machines built many years ago. Most units can be upgraded, repaired or rebuilt to extend their life and improve their performance. It has the design experience to insure that modifications meet the objectives of today's precipitator operators. Hundreds of precipitators have been modified to meet more stringent performance requirements. Units built in the 1960s and 70s can often be modified to provide 15% to 20% more collecting surface without increasing the footprint of the unit. The size of European design precipitators can be increased 30% and more.

In energy saving point of view, the response time of a typical SCR controlled transformer rectifier can be no faster than 8.33 milliseconds. However, at the higher frequency operating level of SMPS controller, the response time can be as quick as 100 microseconds, an order of magnitude quicker.

This quicker response time allows the control to reduce the short circuit inrush current created by arcing in the precipitator. Short circuits created by arcs simply send current to ground and waste power. By reducing these arcs, power is conserved.

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Shared Experience of operation and maintenance of ESP.