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Application of High Voltage Engineering for Air Pollution Control: ESP

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ABSTRACT

The fastest growing Industrialization in today's world of has resulted into degradation of environmental in terms of air pollution. It is not possible physically to achieve a 100 per cent pollution-free environment with industries operating. Considering the hazardous effects due to air pollution it is important to make sure that, the least pollution caused by industrial units. To achieve this effective and adequate pollution control techniques are required to implement, so that effects on the environment are minimized. The electrostatic precipitator is one of the major applications of high voltage engineering for air pollution control. It became one of the key control in get rid of harmful particulates coming out and mixing in environment from different industries. Already various research and invetstments in the area of Electro Static Precipitator is growing by looking at the key benefits resulting through the use of it. As numerous projects are in working even at this very moment all over the world, this paper a comprehensive review is attempted to focus on elements of ESP.

KEYWORDS: *Electro Static Precipitator, Ionization, Rapping Mechanism, Electro-magnetic Rapper, Mechanical Hammer*

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1. INTRODUCTION

The development in Economic for any area is mainly to give jobs to people and in-tern provide opportunities for improved living. Where industrial development plays a major role to creates more jobs in any region. On the other hand due to industrialization the environment may face adverse effects and if due care is not taken to reduce adverse effects, major consequences has to face.

Though, it is very difficult to restrict the industrial units to cause the least pollution. But we can always work on implementing sufficient and effective pollution control methods, in order to minimize adverse effects on the environment. For doing so we have, required technological expertise and institutional back up for support in this regard.

The major manufacturing industry like thermal power plants, coal mines, cement, sponge iron, steel & ferroalloys, petroleum and chemicals cause dust, smoke, fumes and toxic gas emissions occur as a result of highly-pollution. In industry-specific clusters, these industries have not only become hazardous, but also cause irreparable damage to our ecology and environment.

2. ELECTROSTATIC SMOKE PRECIPITATOR

The dirty flue gas (the gas released from smokestack) is forced to pass through Electrostatic smoke precipitators. The ESP consists of electrodes which are termed as electrical terminals is in the form of metal spiked bars, suspended wires, or thin plates inside a pipe or smokestack along with grounded plate.

A very high negative voltage is used to charge the electrode initialy. The dust particles will be negatively charged when the particles move past it. There is metal plates installed in same smokestack which is refered as a second electrode to which a high positive voltage in range of 50KV–100KV is applied.

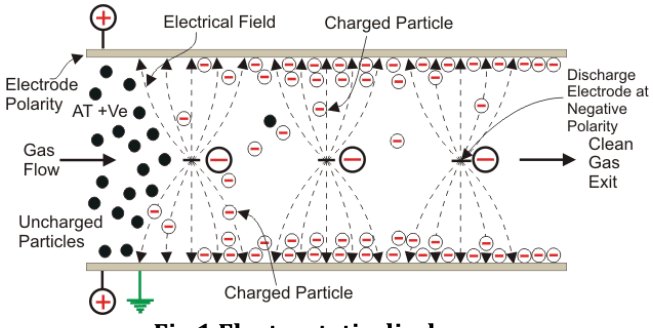


Fig.1 Electrostatic discharge

As per the property of charged particles, the unlike charges attracts, hence the dust particles which are negatively

charged attracted to the positively charged plates which is second electrode and get deposited thereon plate. Once sufficient amount of dust particles are collected at the plate, a mechanism will come into the picture by which the deposited particles will be collected by shaking the plates; this mechanism can be either manual or automated by someone brushing them clean with the help of automated shaking or brushing, this process is called as rapping.

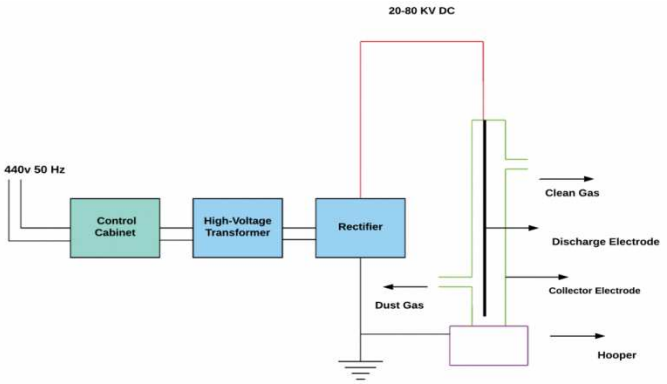


Fig.2 the Block Diagram of ESP

2.1. Various process stages in ESP

In general there are two to six types of zones in Industrial side electrostatic Precipitators. In the inlet zone which is called as raw gas zone, the huge amounts of dust particles are splitted. For this purpose, heavy electrical current is applied to the circulating particles and so it is collected in collecting electrode. In the last stage of zone, the fine particulates are electrically charged with the help of power system. The ESP efficiency is enhanced with short pulse in microsecond duration time period. With the dominance of electric field strength, the dust molecules are electrically charged in Electrostatic precipitation process and the suspended molecules are directed to accumulated surface area. Then it is disembodied from the flue gas. The precipitation mechanism involves various procedures such as

1. Molecules charging through ionization rendered during corona discharge
2. Disentangling the charged particulates from the gas stream in an enforced electrictricity field.
3. Aggregating the ionized particles on a grounded area and abolishing the accumulated molecules by striking them off.

2.2. Working Principle

The electrostatic precipitator's working principle is very simple. It consists of two pair of electrodes in which one is positive, and another is negative. The state of negative electrodes are generaly of spike rod or wire mesh form, while the positive electrodes are in the form of plates. Both these positive plates and negative electrodes are placed vertically in the electrostatic precipitator in alternative fashion i.e. one after another.

A high voltage DC source is mounted at the top of ESP and the negative terminal of DC source connected to the negative electrodes, and positive terminal of the DC source connected to positive plates. In many cases the positive terminal of the DC source is grounded in order to get stronger negativity in the negative electrodes. For working of ESP the ionization of dust particle is very important and for that a very high voltage gradient is required between negative electrode and positive plate. In order to maintain voltage gradient the distance between each negative electrode and positive plate and the DC voltage applied across them are so adjusted.

The flue gas which is released from various industries like, thermal power station, sponge iron etc. has dust particles present in considerable amount. These flue gases are made to pass through the ESP chamber which contains electrodes. When air act as medium between the electrodes, and as the electrodes are highly negativitely charged, there result a corona discharge surround the negative electrode rods or wire mesh.

The corona effect causes air molecules in the field between the electrodes become ionized. Once the air is ionized, plenty of free electrons and ions will be availble in the space. The structure of ESP is such that, both positive and negative electrodes are enclosed in a metallic structure. There is a provision for inlet and outlet for flue gas to pass into the structure and pass out as well. when the flue gases containing dust particles enter into the ESP chamber, dust particles in the gases collide with the free electrons available in the medium which is ionized earlier due to high charge present between the electrodes. The free electrons will then attach to the dust particles and as a result, the dust particles aquires negative charge. These negatively charged dust particles will be attracted to the positive plate due to electrostatic force.

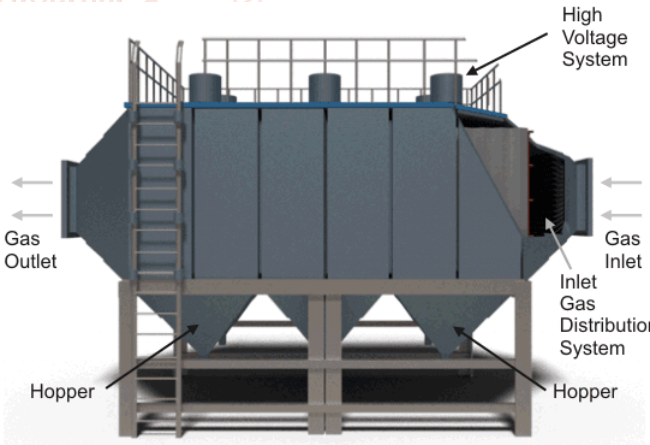


Fig.3. The Structure of ESP

As a result of the process, the dust particles will be charged and move towards the positive plates and deposited there, therefore the positively charged plate is called as collecting plate. The dust particles then fall due to gravitational force when the extra electron from the dust particles will be removed on positive plates. After the entire process, the flue gases after passing through the ESP chamber become almost free from ash particles and then it made to discharge through chimney into the atmosphere. Though there is no direct contribution from ESP to produce electricity at thermal power station, but it's contribution to keep atmosphere clean is very important for human beings. The unite named, 'Hopper' is planned below the ESP chamber for collecting dust particles. The various rapping mechanism used from side of chamber or from top to accelerate the removal of the dust from the collecting plates.

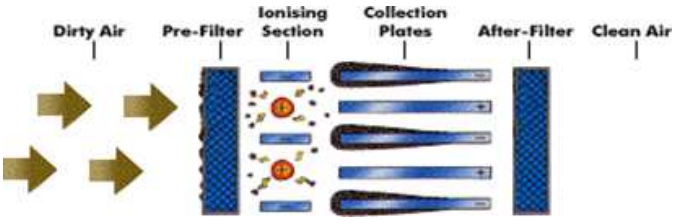


Fig.4 Working Principle of ESP

3. HIGH VOLTAGE SUPPLY

To generate a very high negative DC supply required by ESP chamber for ionization of air and then the collection of dust particles present in flue gasses we need to use the TR set. The TR set consists of a high voltage transformer along with rectifier stack array. The role of TR set to converts single phase or three phase AC power to single-phase DC power with almost 30 % ripple which need to feed to ESP electrodes.

The amount of dust particles the passing through chamber can be deposited on positively charged plates and then collected in hopper is totally depend on range of voltage applied between the electrodes. The efficiency of ESP i.e. removal of dust particles form flue gases is totally depend on voltage differential between electrodes Eo i.e. discharge electrode and collection plate Ep. The ESP nowadays are of various ratings depend on nature and amount of flue works but still a general ESP is works at a range of 50 k to 150 k volts.

An ESP has designed with multiple discharge electrodes (to which common negative charge is applied) between each set of collecting plates (which are charged with positive supply/grounded), along with multiple sets of collecting plates in a single "field" which are oriented in the direction of gas flow. With such arrangement of structure, each field acts as an independent precipitator. In many plants, to improve the efficiency, multiple fields are be added in series. Mostly using three or more fields many ESP's are working in various plants nowadays. Some plants which required to follows very strong rules of environment pollution control, use up to 12 fields in order to achieve collection efficiencies greater than 99 percent. While designing the multiple field ESP structure, temperature of the flue gasses and flow rate one of the key parameters considered. In such utility applications, each field is electrically divided into separate compartments to achieve higher degree of optimization for removal efficiency.

There are three major areas on which the particle removal effectiveness of an ESP is based,

A. The ability of a particle to hold a charge i.e. resistivity of the particles
B. The gas flow properties, and
C. The quality and strength of the electric field produced

In industry mainly, the thermal power generation, the resistivity of dust particle in flue gas changes with change in fuel. Therefore various government agencies has designed standeards to put limits on mercury and acid gas. These limits may require the addition of activated carbon injection for mercury removal and/or dry sorbent injection for removal of acid gases. Adding activated carbon or dry sorbent to the gas stream may change the particle resistivity and, therefore, the efficiency of ESP operation. Apart from these major parameters, there are some other parameters as well which can affect the collection efficiency of ESP like,

A. The volumetric flow rate,
B. Moisture content,
C. Chemical composition, and
D. Temperature

If further improvement in collection efficiency of existing structure of ESP is desired by the end users, then by making sum physical changes in ESP like increasing collecting surface area, improving flow distribution of flue gas entering into the ESP, or upgrading or replacing the collection plates or discharge electrodes, it can be achieved. But every change suggested in these options requires extensive physical changes not only to each stage of the ESP but also in extended unit outage which will demand a significant cost.

A typical power supply system for an ESP consists of the transformer-rectifier (TR) set, control panel consisting of silicone controlled rectifier (SCR). Depend upon the need of power based on output load i.e. amount of flue gas, the desired corona needs to be set up inside ESP chamber which is set by TR set but controlled by the control panel. A single or three phase supply is fed to the control panel consist of SCR used as AC controller, this controlled AC power is given to TR set, which produces DC power output as per AC input it get from the control panel. To summarize, the controlled AC power fed to the TR set decide the high voltage DC supply desired by the ESP for ionization

4. RAPPING MECHANISM

When the flue gas made to pass through the ESP chamber, the corona effect causes the ionization of air and thereafter dust particles will get negative charged and stick to the positively charged/grounded plate. The dust particles are need to be separted out from the plate in order to get collected at hopper. The process of detaching the dust particle from collecting electrode and to get collected at hopper is known as rapping mechanism. The mechanism for rapping, to release deposited dust particles strong shearing forces are transmitted to collecting plates. Rapping in other word is the process by which electrodes and particles are broken apart by vibrations from the rappers. Depending upon the specific characteristics of the dust being collected, there are various parameters like, number, size, and frequency of the rappers vary from system to system.

There are two major types of rappers available,

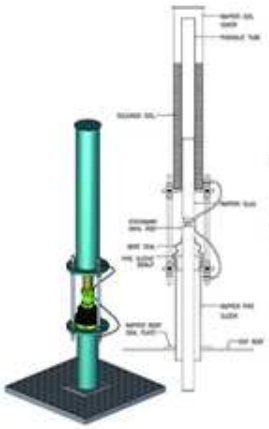
A. Mechanical Hammer
B. Electromagnetic impulse units

4.1. Electromagnetic impulse units

The electromagnetic vibrator are mounted on the top of ESP structure which works on simple principle of electromagnetic theory. It consists of a coil which is energized by alternating current. The energy creates a vibrations which are transmitted through a rod to the electrodes or collecting plates.

Now a days in many designs of ESP's magnetic-impulse rapper (MIGI rapper) are installed for the rapping of the Collecting Electrode and Discharge Electrode. Whenever a current pulse is provided to coil, due to electromagnetic effect the heavy steel plunger raises inside the MIGI rappers. When we cut the current pulse to the coil, then by the effect

of gravity, the heavy plunger drops down and strike a frame which is connected to many plates inside the ESP. An electrical controlling system is used to decide the frequency and intensity of the rapper.



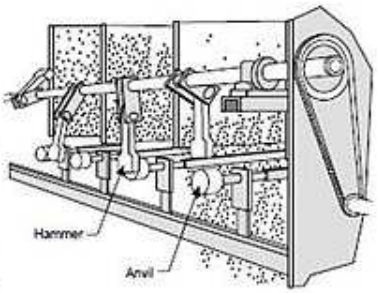


Fig.5 Electromagnetic Rapper Fig. 6 Mechanical Hammer

In order to have ease of maintainance and gravitation effect the rapper assembly for both the electrodes are mounted on the ESP structure roof. Generally, the rappers for collecting plate are mounted at the leading and trailing edge of the collecting plates. A typical rapper asstmbly consists of a 2" diameter solid rod stainless stell tip plunger, which can easily move within a smooth guide tube. The guide tube is surrounded by a copper solenoid type coil. In order to protects all the components a weatherproof metal casing is used.

4.2. Mechanical Hammer

A Mechanical hammer consist of a large weight which is connected to a shaft positioned in array of discharge electrodes and collecting plates. The shaft is connected to a motor which is placed sideways to the ESP chamber. When the motor starts, the shaft rotate and the weight is lifted to gain potential energy and then released. This weight position is placed such that it allows to fall and collide with an anvil and create a shock to dislodge caked-on dust.

As shown in fig 6 it has an electrically driven rapping carriage moves on along the rams while it is guided by two running rails.

5. CONCLUSION

The world is moving fast towards industrialization which is essential to keep up with pace of growth but the adverse effect on environment should also be taken into the consideration by industries. Serveral industries are producing particulate matter during their manufacturing of products. These industries then release these tiny size matter throught flue gasses in the environment. These tiny particles are when particulate in environment cause various deseases like lung infection and bronchitis. The other problems to environment like reduction of visibility and climate change also occure due to these particles. In order to get rid of all above mentioned and many more problems caused by dust particles in flue gas the device named Electrostatic Precipitator is used which helps to get the flue gases filtered and free from the dust particles.

When it comes to cleaning the dust particles from flue gases, Electrostatic precipitators are proved to be a important tools. Over the years ESP are proved to be highly effective at reducing particle pollution, including those particles whose sizes approximate 1 micron (0.00004 inch) in diameter, and some precipitators can remove particles of 0.01 micron in diameter.

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