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Research on Electrostatic Precipitation used in 300 MW Thermal Power Plant in Viet Nam

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A B S T R A C T

Nowadays, environmental requirements are increasingly demands, so even though it have completely been eliminated dust as well as SOx and NOx emissions in the thermal power plants, we are still looking for solutions to improve filtration efficiency as well as finding other methods to handle dust and these emissions. Electrostatic Precipitators (ESP) are used to control fly ash from the boilers of the power plants and to avoid harmful effects of dust and smoke in thermal power plants. Characteristics of coal-fired thermal power plant emissions mainly depend on the composition and properties of the coal. The main source of raw materials used for the production process is anthracite coal. That is a type of coal with high ash content. It creates a large amount of gas, emissions from coal-fired thermal power plants. The product of coal combustion emits mainly fly ash, CO2, CO, SO2, SO3 and NOx created during the burning process. The sulfur content in coal is $\cong$ 0.5%, so the exhaust gas has a high rate of SO2. The paper describes the structure of the plant's Electrostatic Precipitators (ESP) and studies the operating parameters of one Thermal power plant. So that, the results obtained will be analyzed for providing some solutions to improve the ability to treat incoming gas in thermal power plants.

Keywords: Electrostatic Precipitators (ESP), thermal power plants, coal, NOx, SOx…

Introduction

The production of coal in electricity generation in developing countries is quite big around 50 % at present. Viet Nam has large plants of expanding coal-based power plants with the total capacity of coal-fired power plants in the system is currently 27531 MW nearly 32.4% of the entire system.

Currently, this environmental requirement is increasing for Vietnamese power plants, it is extremely urgent and necessary for improving the dust filtering efficiency of ESPs.

In this paper, the ESP will be described in details and the product of combustion of boiler will be eliminated and discussed to provide solutions for improving the efficiency of Electrostatic Precipitators (ESP) and for reducing the pollutions in and around the power plants.

Influence research of the coal-fired thermal power plant emissions

Thermal power plant dust is fine dust particles with extremely small sizes from a few nanometers to a few micrometers, originating during the process of producing electricity using heat from burning coal or oil to generate energy, fly ash and smoke emissions containing dust are released into the air.

Thermal power plant emissions cause many negative impacts on the environment and humans such as:

• *Air pollution:* Thermal power plant dust increases the level of air pollution in the area surrounding the plant. Fine dust particles can be breathed into the lungs and cause respiratory and health problems.

• *Impact on flora*: Dust can affect trees and soil around the factory area, causing deterioration of soil quality and affecting tree growth.

• *Impact on fauna:* Thermal power plant dust pollution can affect fauna in the surrounding area. Fine dust particles can impact the respiratory system and skin of animals causing biological imbalance.

• *Greenhouse effect:* Some dust particles could absorb heat and cause a greenhouse effect, contributing to climate change and increasing global temperature.

It is necessary to have knowledge of the properties of fly ash, sizing and operation of ESP for fulfill strict emission levels from power plants.

The Advantage of Electrostatic Precipitators (ESP) is:

- High dust removal efficiency: Can be more than 98%
- Small pressure loss
- Can filter very small dust: 0.1µm
- Low power consumption
- The incoming gas passing through the device is large
- Horizontal and Vertical Flow Precipitators
- Dry type design for big gas volumes
- Wet type design for maximum particulate removal
- Resistant for operation at gas temperatures around 450°C
- Expertise of top as well as bottom rapping
- Diverse applications like corrosive gas, many types of dusts, tar, etc

Disadvantages

- ESPs are constant efficiency devices. When the inlet dust load even slightly increases, the outlet emissions may increase.
- High Foot-print area
- ESPs have comparatively higher capital investments

Electrostatic dust filtration system

The structure of a ESP depends mainly on its working conditions, the composition and properties of the gas to be filtered etc. Zone dust filter equipment is often used in ventilation systems, while other zone is often widely applied to filter dust in most industrial fields. Electrostatic precipitator (ESP) in figure 1 is a device that filters dust using the electrostatic method. Therefore, electrostatic precipitator technology is put into use as the option that brings the highest efficiency of up to more than 98%. It is a filtration system capable of removing small-sized dust particles from the air flowing through the filter chamber, based on the principle of ionization and separation of dust from the air as it passes through. areas with large electric fields.

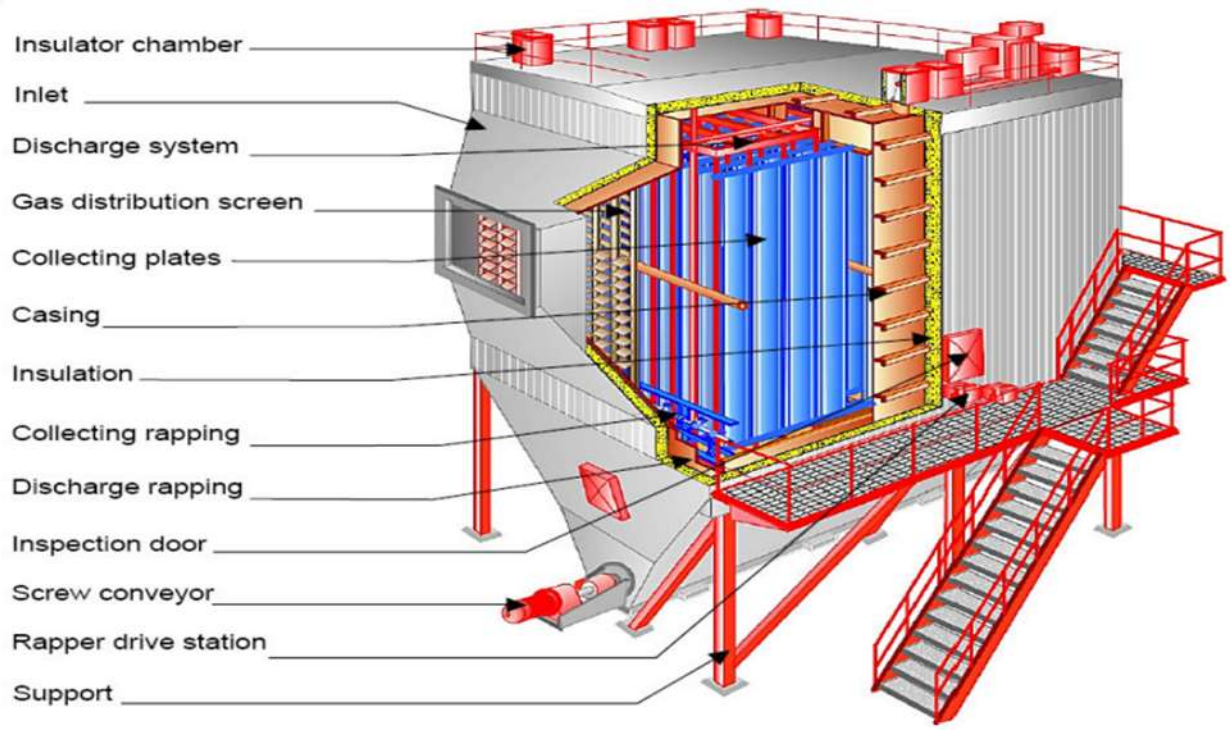


Fig. 1 - Diagram of electrostatic precipitator (ESP)

They can also distinguish the following other types of electric dust filter devices:

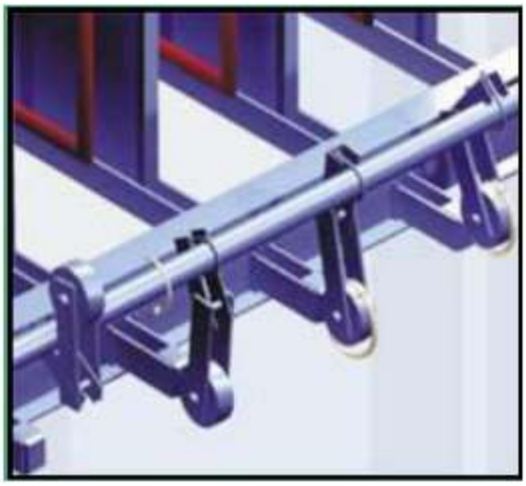
+ Depending on the direction of air flow passing through the device, we have vertical type horizontal filter devices.

+ Regarding cleaning and removing dust from the device, it is divided into dry type and wet type. In the dry filter device, dust on the electrodes is cleaned by methods such as vibration and impact to remove dust. falls into the funnel and then carried away and for the wet electric filter device, dust on the electrode is cleaned by spraying water, dust on the electrode is washed away by the water membrane into the container.

In fact, the Electrostatic Precipitators have two mainly types:

- Dry ESP: used on hot process exhaust (50 – 450˚C) that operate above the dew point of gas stream.
- Wet ESP: used for special applications that require filtering wet, sticky, tarry and oily particulate matter.

Dust in smoke when passing through the electric field is also electrified. The electrified dust particles will be attracted to opposite electrodes and stick to the surface of the electrodes. After a period, the dust on the electrode surface will have a certain thickness and will be separated by a system of hammers and vibrators and sent to the collection funnel.



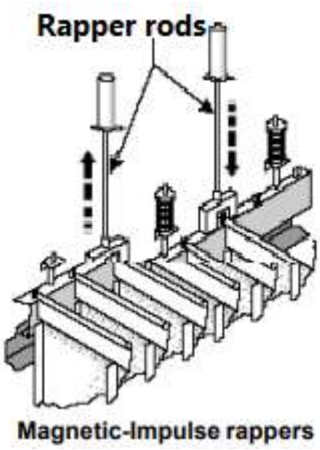


Fig. 2 - (a) hammer system (left) –(b) Magnetic-impulse rappers

The principle of ESP is described in the figure 3. The incoming gas passes through an electric field (created by a high voltage), the incoming gas will be electrolyzed to form electrons, negative ions and positive ions. Dust in smoke when passing through the electric field is also electrified. The electrified dust particles will be attracted to opposite electrodes and stick to the surface of the electrodes. After that, the dust on the electrode surface will have a certain thickness and will be separated by a system of hammers (Figure 2) and vibrators to separate the dust particles and return them to the collection hopper.

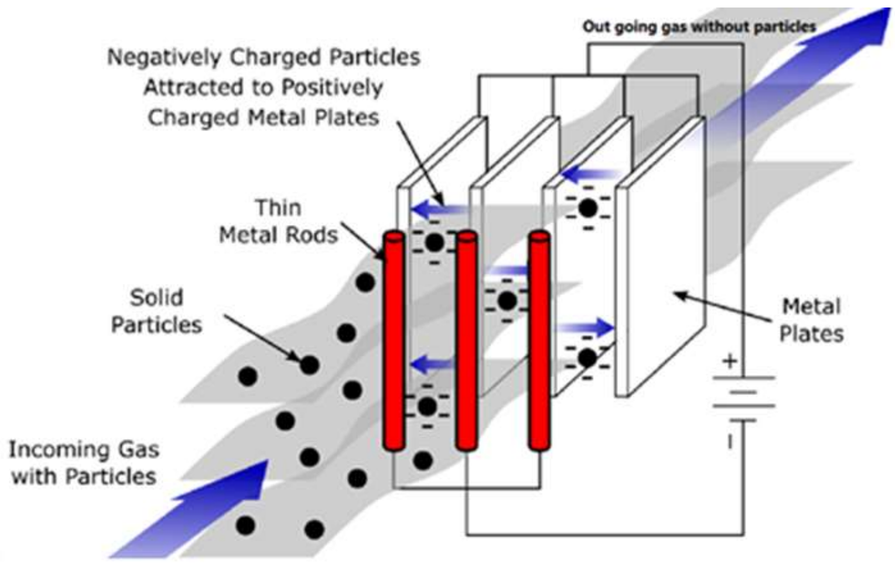


Fig. 3 - The process of charging and moving dust particles in the device's electric field

Different types of electrodes:

Discharge Electrode: They are typically supported from the upper discharge frame as a line from upper to lower discharge frames. The roof of the precipitator casing play role the upper discharge frame that is incorporated the high-voltage insulators.

Collecting Electrodes: They are where that the precipitated particles will be attached on the surfaces and then these particles are removed into the hopper. The electrical power circuit of ESPs including of the collecting plates. The smooth surface of the collector electrodes ensures strong electric field intensity, is easy to manufacture and easy to shake off dust but it has a major disadvantage that the dust is easily thrown back into the vibrating air stream to shake off the dust. For this reason, smooth surface particles collectors are often applied when the air flow velocity does not exceed 1m/s.

Jibao discussed that the charging process of dust particles occurs very quickly due to the dense number of ions and their size is many times smaller than even sub-micrometer dust particles. Indeed, most dust is charged right from the inlet cross-section. of equipment. The amount of charge that a dust particle can hold is proportional to the square of the particle diameter

K.Parker et al assume that the ESP performance depends on the following most important dirqensional variables:

1. Electrical field strength $E\left(\frac{v}{m}\right)$ $[LMT^{-3}I^{-1}]$
2. Current I (A) $[I]$
3. Gas velocity U$\left(\frac{m}{s}\right)$ $[LT^{-1}]$
4. Gas viscosity $\mu\left(\frac{kg}{m.s}\right)$ $[ML^{-1}T^{-1}]$

The three following variables with independent dimensions will be selected: electrical field strength, current and gas velocity.

In case of the Pi Theorem, the nondimensional ESP similarity number is:

$$N_{ESP} = \left(\frac{EI}{\mu U^2}\right)$$

Using the similarity theory, we have the nondimensional drift velocity W/U for two ESP'S with different field strength, currents, sizes, gas velocity, etc. is equal to:

$$\left(\frac{W}{U}\right)_1 = \left(\frac{W}{U}\right)_2$$

$$\left(\frac{EI}{\mu U^2}\right)_1 = \left(\frac{EI}{\mu U^2}\right)_2$$

The figure the experimental values of the drift velocity have been plotted EI against the ESP similarity number $N_{ESP} = \left(\frac{EI}{\mu U^2}\right)$. All the data was obtained under different test conditions, i.e., varying the field strength at the edge of the corona, the electric current, gas velocity, number of energization sharp edges, the shape and size of the collection tube cross section and the discharge electrode, it can be seen in Figure 1 that a unique relationship exists between the relative drift velocity of Darticulates and the discovered ESP similarity number:

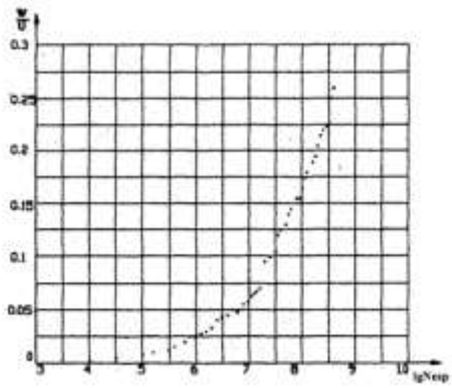


Fig. 3 Drift velocity versus ESP similarity number.

Study the ESPs of Nghi Son coal-fired thermal power plant

Description of the ESPs of Nghi Son coal-fired thermal power plant

Each boiler of Nghi Son Thermal Power Plant (300 MW) has 2 electrostatic precipitators, dry electrostatic precipitators type manufactured by KC Cottrell (Korea). Each unit is installed after the heat recovery air dryer on a branch of the boiler system.

An electrostatic precipitator includes casing, collector, discharge, smoke distribution device, impact hammer for collector and discharge (DE&CE), high voltage ceramic insulator, ceramic drying system, control system and ash hopper. The discharge electrode is connected to the cathode (negative potential), the collector electrode is connected to the anode (positive potential). At the inlet of each dust filter there is a perforated plate made of steel to distribute the gas flow into the dust filter fields evenly. On each field there are receiver and discharge hammers. Insulated discharge electrode with ceramic insulating shell, ceramic insulating ceramic with heating device. Below the dust filter field are ash funnels used to collect fly ash separated from going out gas. The ash hoppers have steam heaters and hot air nozzles to prevent clogging and make ash disposal easy.

Fig. 4 ESP of Nghi Son thermal power plant.

When fly ash passes through the electrodes, negatively charged ash particles are attracted to the collector, a few particles stick to the discharge electrode due to positive charge. Ash stuck on the poles is periodically tapped by hammers and falls into the ash hopper and is sucked into the silos.

Table 1 Main technical specifications of Nghi Son ESP

No	name	unit	value
1	Largest incoming gas flow	m3/h	2*787102
2	Total collector area	m2	2*21168
3	Voltage supply	mA/kV	2150/72
4	Dust concentration remaining after ESP	mg/Nm^3	≤ 98,90
5	ESP performance	%	98,787

Some solutions to increase the efficiency of Nghi Son ESP

ESP Performance Improvements by changing Resistivity Dust

The most important consideration in ESP for coal-fired boiler applications is to maintain and increase the dust collecting performance of high-resistivity dust. Several improvements to counter high-resistivity dust have been established based on the investigation into the mechanism of back corona phenomenon.

Our technologies are shown in the following table. We can offer suitable technologies for plant applications and operations and can realize both compact.

Our accumulated know-how in evaluating characteristic assessments on various dust properties and flue gas conditions, together with extensive field experience, are reflected in the ESP design

Table 2 Summary table of technology and methods

	Method	Our Technologies
(1) Dust layer Removal	Removing Dust on Electrode Completely	Moving Electrode Type ESP
		Wet ESP
(2) Resistivity Decreasing	Decreasing Gas Temperature	High Efficiency AQCS (Low Low Temp. ESP)
(3) Current Control of Dust layer	Electrical Energization Control	Intermittent Energization
		Pulse Energization
		Pulse Energization

In the high resistivity region, some negative effects on dust filtration performance will occur. First, the voltage between the two electrodes of the dust filter decreases due to the high voltage drop across the dust, thereby reducing the magnetic force used to collect the ionized dust. If the electrical resistivity is too high, back corona can occur. This is an electrical discharge phenomenon in air bubbles covered by dust on the settling plate. This phenomenon can significantly reduce the performance of electrostatic precipitators.

Figure 5 shows the relationship between dust resistivity and the performance of the electrostatic dust filtration system. We can see that outside the low resistivity region, when the resistivity is reduced, the dust filtration efficiency will increase, especially in the high resistivity region. Therefore, in some cases people can spray additional moisture into the exhaust gas to reduce resistivity, thereby increasing dust filtration efficiency

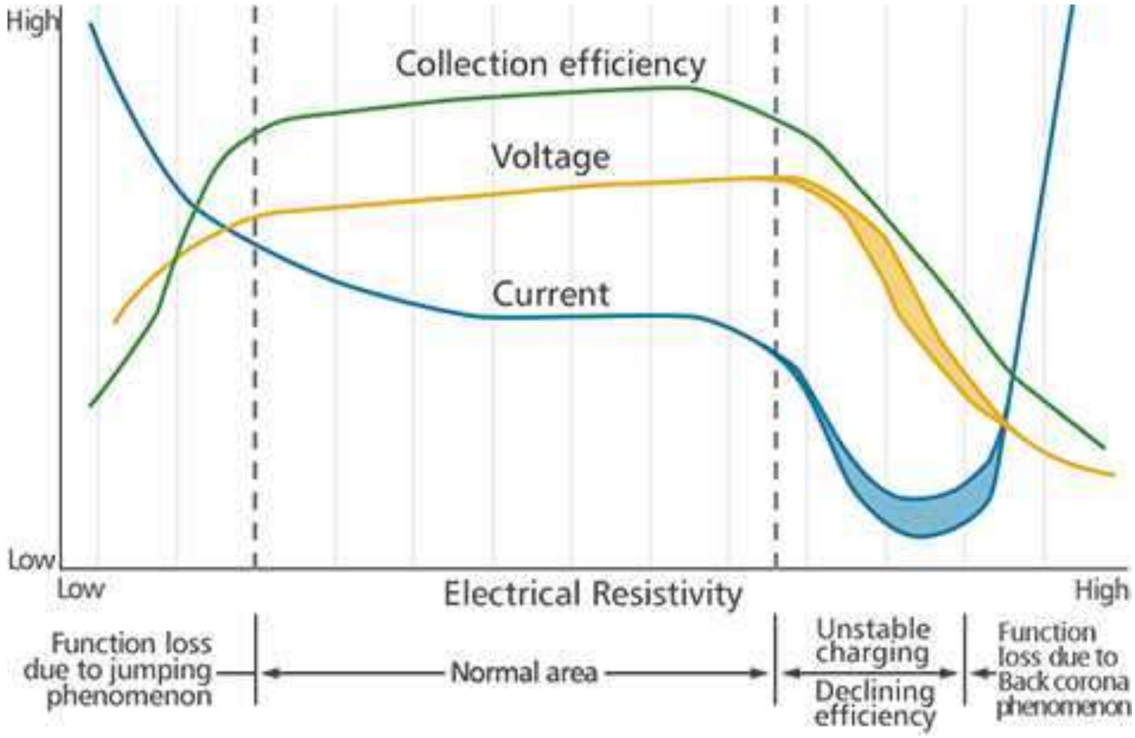


Fig. 5 Graph of evolution current and voltage into resistivity

ESP Performance Improvements depends on the particle size

Figure 6 shows the effects of the power sources supplied for EPS on the grade collection efficiencies. In this case, both single and three-phase TRs will be discussed, the efficiency h(r) always rises with increasing the applied voltage. With the single-phase TR at its maximum operation voltage of 55 kV, it is around 83-88%. With three-phase TR at 69 kV, it can obtain about 92-98%.

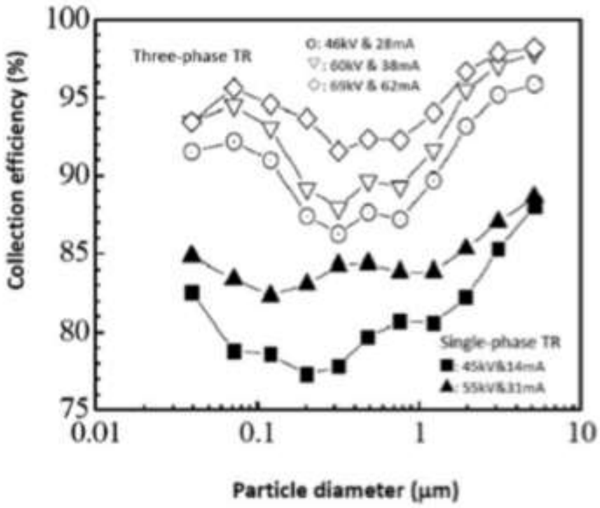


Fig. 6 Grade collection efficiency versus particle diameter and power sources under a gas low rate of 40,000 m3/h and an initial mass concentration of 15 g/Nm3 at 110C.

ESP Performance Improvements depends on the humidity

Humidity plays an important role in affecting the resistivity of dust. Because moisture is absorbed on the surface of the dust creating a conductive layer, the resistivity of the dust decreases sharply as the humidity increases. In fact, at a certain gas temperature, the resistivity decreases as the humidity increases. Therefore, the humidity of outgoing smoke is an important factor to adjust dust resistivity as well as dust collection efficiency. The humidity of exhaust smoke depends on many factors such as coal humidity and air humidity. In case the dust resistivity is too high, affecting the dust filtration efficiency as presented, we can spray more moisture into the exhaust smoke to increase dust conductivity, increasing dust collection efficiency. If the smoke temperature is fixed, when we increase the humidity to a certain level, the percentage of dust loss decreases or the dust collection efficiency increases.

Conclusion

By studying the structure and the parameters of operations of ESP to reduce the emission from the existing ESP by adopting either or any one of the following methods

- water fogging
- Intermittent charging
- Ammonia dosing of flue gases
- Sodium conditioning of flue before feeding to boiler.
- Diminution of resistivity

From the above analysis, several conclusions can be drawn: The phenomenon of flashover and back corona occurs when the dust resistivity is high, or the dust resistance is low. This can be prevented by reducing the resistivity of dust through humidification. The phenomenon of dust accumulation on the plates occurs when the resistivity of the dust is high, making it difficult for the dust to lose its charge, increasing the binding force between the plate and the dust. The humidity does not increase the thickness of the dust layer, but it also reduces dust accumulation on the electrode plate thanks to reduced resistivity. However, when the humidity increases too high, causing water vapor to appear in the outgoing gas. There is a possibility that dust will stick to the plates, so maintaining a slightly superheated condition in the gas is necessary.

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