Electrostatic Precipitator in Ash Removal System: A Comprphensive Review

M.Karunakaran, P.Sivakumar, N. Chira

Abstract: Electrostatic precipitator became one of the key spot in removing harmful particulates coming out from various industries. Since the potential benefits are resulting through the use of electro static precipitator, investigation in this area is growing continuously and there are numerous projects in this moment all over the world. Hence in this paper a comprehensive review is attempted to focus the various issues in implementing precipitator. Furthermore, the detailed investigations towards the enhancement of collection efficiency of precipitator are also addressed in this work.

Keywords: Electrostatic precipitator, collection efficiency, power converter, high pulse, single stage and two stage precipitators.

I. INTRODUCTION

The recent study predicts that the utilization of coal for the power production will rise up in following two decades. The combustion of these coal releases most harmful gases, and sulphur compounds to the atmosphere.[1]. Further carbon monoxide, black and unburned hydrocarbons come out in the atmosphere if the combustion process is half-finished. Besides nitrogen oxides such as nitric oxide, di nitrogen monoxide and nitrogen dioxide can also be generated on account of oxidation. Relying upon the nature of coal, the following plenty of minute particles exhaust out after the combustion process: one eighth of the compounds are aluminum oxide, one fourth are ferric oxide whereas approximately half of the fly ash density contains Silicon dioxide. Besides less than 1 milli gram amount of calcium chloride, sodium chloride, magnesium oxide, potassium chloride and titanium dioxide are present.[2-3] Despite that, minute particle less than 2.5 micrometer contains dangerous contaminants such as toxics and black carbon.[4-7]

By considering all the above said issues, it is very challenging and in research for the expulsion of PM 2.5

particles. So for many traditional cleaning appliances are in practice such as bag filters, cyclones, scrubbers, bed filters and electro static precipitators. These devices remove the particles of size greater than 2.5 micrometer with good efficiency. At the same time, the collection efficiency gradually decreases with increase in the size of the particle. Via bag filters it is possible to remove PM 2.5 particles with efficiency around 98%, but at the same time , around 2 Kpa pressure drops across the filter, as a consequence operating efficiency of the equipment increases.[8-10]

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M.Karunakaran, Research Scholar, Assistant Professor / EEE, SKP Engineering College, Thiruvannamalai, Tamil Nadu, India.

P.Sivakumar, Professor, Department of ECE, Karpagam College of Engineering, Coimbatore, Tamil Nadu, India

N. Chira, Professor,Department of EEE,SKP Engineering College, Thiruvannamalai,Tamil Nadu, India.

With the usage of electrostatic precipitator, the fractional efficiency of the particle diminishes with the decrease in size of the particle less than 2.5 micrometer. We all know that many harmful particulates are coming out from several industrial sectors such as Coal based thermal power plants, sintering plant , cement kilns ., etc. [11].One of the effacious method of controlling the ejaculation of these particulates is using ESP. The potency of ESP depends upon various parameters like geometric properties of ESP, supply voltage magnitude and polarity, electrode configuration, air flow velocity, temperature of the air, humidity of the air[1-8], size of the dust particles and conductivity also.

Addressing the above said problems, this paper concentrates on various methodologies for the precipitation of dust particles. The remaining section of the paper is organized as follows. Section 2 presents general guidelines about ESP and the processes stages. Section 3 discuss about the two stage ESP process. Section 4 gives about high voltage high power supply in ESP. Section 5 highlights about resonant converter in ESP. Section 6 outlines conclusion.

II.ELECTRO STATIC PRECIPITATOR

An Electro static precipitator , in recent years a significant filtration equipment that filters various particulates such as smoke, dust , pollution particles and some more poisonous things from the flowing gases[20]. The gases coming out from the coal power plants, cement industries, furnaces are very harmful and toxic in nature. As per the environmental standardasitaion, particles of size less than 10μm in diameter are identified as hazardous in nature and the chances are there to settle down in lungs. It may lead to severe health issues when sincere care has not been considered [21].

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[22]. 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

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1. Molecules charging through ionization rendered during corona discharge
2. Disentangling the charged particulates from the gas stream in an enforced electrictricity field.

Aggregating the ionized particles on a grounded area and

3. Abolishing the accumulated molecules by striking them off.

Working Principle of ESP

A Precipitator works by electro statically charging the cinders in the gas steam. Customary precipitators adjust a number of discharge electrodes that flap upwardly between grounded parallel plates as shown in figure 2.1. Corona formation occurs when the negative voltage is enforced to the discharge electrode and charge discharges via the gas space to the grounded plate electrodes. Once the particulates flow into the precipitator, they are negatively charged by mobile ions, which then collaborate with electrostatic field minimizing a force, which incitements them to wander to the ground plates and there they are amassed. In order to remove the layer formed by the dust, the plates are babbled and so the dust descent into hoppers localized below the plates.

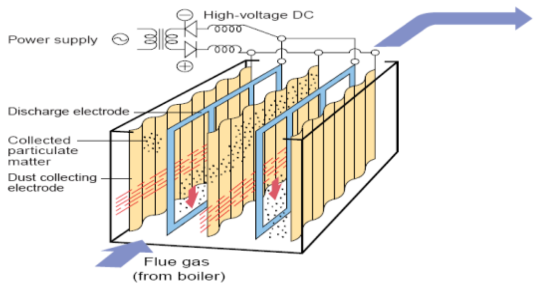

Fig. 2.1 Principle of Operation

The operating principles of electrostatic precipitators are shown in figure 2.2. The charged particles are then captivated to and consigned on collecting plates or alternative compilation equipments. When sufficient dust has accrued, the collectors are flustered to extricate the dust, inducing it to decline with the force of gravity to hoppers underneath.

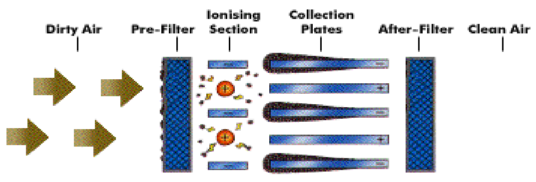

Fig. 2.2 Working of ESP

For the need of recycling, the dust is evacuated with the conveyor system. The flue gas loaded with fly ash is circulated via pipes having negatively charged plates which give the molecules a negative charge. The particles are then expelled past positively charged plates, or grounded plates, which attract the now negatively-charged ash particles. The particles adhere to the positive plates up till then they are gathered. The air that leaves the plates is then clean from harmful pollutants [23].

Electro Static Dust Collectors

In this subdivision, the duty of dust collector is discussed. It utilises electrostatic charges to isolate dust from the dirty air stream. A number of high voltage, direct current electrodes (carrying negative charge) are implanted between grounded electrodes (importing positive charge). The dust borne air stream is crossed through the segment among the discharging (negative) electrodes and collecting (positive) electrodes. Dust particles acquire a negative charge from the discharging electrodes (ionizing section) and are enticed to the positively charged grounded electrode (collection plates) and fasten on to it. Purification is done by discoursing or pulsating the collecting electrode where in dust particles fall away. Cleansing can be accomplished without disrupting the flow. The assembly of electrostatic dust collectors are represented in figure 2.3.

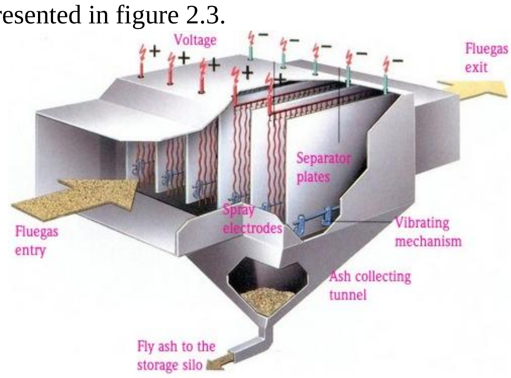

Fig. 2.3 Electrostatic Dust Collectors

Types of ESP

ESPs are composed in different approaches. These approaches are established for distinctive control action, and remaining varieties have evoked for cost beneficiary.The different categories are (1) the plate-wire precipitator, the prevailing conventional type; (2) the flat plate precipitator, (3) the tubular precipitator; (4) the wet precipitator, and (5) the two-stage precipitator.

Soft Switching Techniques

The power electronics converters are the crucial in ESP. Power electronics converters are executed with switching equipments that turn on and off, at the same time power is being transformed from one model to another. They work with high switching frequencies to diminish the size of the converters' inductors, transformers and capacitors. Such high switching frequency operation, however, improves the measure of power that is lost due to switching losses and hence minimizes the efficiency of the power converter.

The following section describes in detail about the various articles that are worked in ESP are discussed in detail.

III.TWO STAGE ESP

This subsection gives guidelines about the research article that are implemented with two stage ESP. In general there are two possible ways to enhance the performance of collection efficiency of ESP i) separation of charging (ii) precipitation process. The equipment which involves these two stages are called two stage ESP. [24]

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The author [24] proposed a new methodology for a two stage ESP with needle electrode. This method overcomes the drawback of the conventional method where long wire is utilized. Through this methodology, collection efficiency is enhanced by improving the particle charging .The results are compared with single stage. Experimental setup with COMPSOL package is also implemented in this work. In the paper [25]the author proposed a two stage ESP with pre charging and agglomeration stages[25]

IV.HIGH VOLTAGE PULSE SUPPLY WITH PULSE TRANSFORMER

In general there are two pulsed power supplies with respect to high and low potential for ESP. High voltage semiconductor switches and high voltage pulse transformer are used for generating pulse at high and low potential[26-30].The voltage stress will be high at high potential switching compared to the low potential switching. On the other side by using a HV pulse transformer on the primary side of the transformer, pulses are applied. The author in [31]and [32] used a high voltage ESP methodology where IGBTs are employed to regulate the high pulse voltage. But the problem faced in this work is designing aspects of HV pulse transformer in addition to handle high amplitude of current. To overcome the above said problem, the author [33] designed a HV pulse transformer with narrow pulse lasting for 85 microseconds. It is designed for industrial applications. Here 1200 A/ 1700 V IGBTs are utilized in the economic aspect whereas [32] 1200 A/3300 V are employed, as a result the cost increases.

V.HIGH VOLTAGE HIGH POWER DC SUPPLY WITH IMPROVED TRANSFORMER BASED RESONANT CONVERTER

The usage of HV high power supply provides the following benefits such as reduction in size and as well as weight with enhanced efficiency, low switching losses. controlled stress and rapid reaction towards flashover. In general ESP utilizes HVDC converters to cater a pair of parallel plates. In earlier thyristors family devices played the role. But it has some drawbacks like high ripple constant and low power factor. [34-35].

Hence it is necessary to regulate the voltage rapidly. This is possible with IGBT devices with low switching frequency with 500 HZ[36].Even though the increase in switching frequency minimises the size of the transformer, it induces dv/dt stress and frequency losses .All things considered , it is an opt choice in introducing a new topology based on resonant converters. Volt ampere ratings and outcomes amongst the passive components decide the size, weight and losses. The LC tank approach towards the HVDC has been highlighted in many works. [37-44].With the given output power, it is preferable to minimize the sum of VA. In the LC circuit, the inductance Ls is recouped with leakage inductance.

VI.CONCLUSION

As we know that the removal of dust particle from various industries and power plants are very harmful to atmosphere, it is very significant to remove these particles. Hence in this paper a brief survey about various methodologies of electrostatic precipitation in removing harmful particulates are discussed. Utilization of two stages ESP, high voltage high power supply and resonant converter are also addressed.

Associating different categories of high voltage power supplies and harnessing their rewards can enhance the interpretation of electrostatic precipitators. Addressing on the dust and gas equities on individual field of a precipitator the approach of the high voltage generation system can now be designated. The initiation of high frequency high voltage power supplies for the use on electrostatic precipitators will have a number of consequences over the industry:

- ✓ Enhanced collection performance
- ✓ New opportunity for detecting and establishing power supplies
- ✓ Disparate methodologies to maintenance and assistance.
- ✓ Fluctuations to power supply purchasing strategies

Each of these determinants attempts potential cost savings for both latest and retrofit accessions. Less power consumption ascribed by the augmented power factor will result in direct cost savings. The full impact of all the potential savings has not yet been defined. We are still in the early stages of apprehension how to best apply HVHF units to ESP applications. The systems commercially available today are comparatively unproven and afford limited power and voltage options. But as with all recent technology, the systems will continue to embellish. Higher power and voltage ratings and more features and options will soon be acquirable. There is little doubt that switch mode power supply technology will eventually become the standard proposal for ESP power supplies. Participants at all levels of the ESP market-new system suppliers, rebuild and repair firms, consultants, and users—should commence the process of understanding the impact these new power supplies will have on their businesses.

Even for previously existing precipitators the efficiency can be enhanced in many cases. Furthermore the energy consumption of electrostatic precipitators can be optimized. Further investigations will follow regarding the several parameters of high voltage high frequency (HVHF) power supplies used in order to further increase precipitator efficiency.

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