CASE STUDY ON THE RENOVATION OF THE ESP UNIT AT GNDTP, BATHINDA

Thesis submitted in partial fulfillment of the requirements for the award of degree of

Master of Engineering
in
Power Systems & Electric Drives

Thapar University, Patiala

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CERTIFICATE

I hereby certify that the work which is being presented in this thesis entitled **"Case Study On The Renovation Of The ESP Unit At GNDTP Bathinda"** in partial fulfillment of the requirements of the award of the degree of master of engineering in **Power Systems & Electric Drives** submitted in Electrical and Instrumentation Engineering Department of Thapar University, Patiala is an authentic record of my own work carried out under the supervision of **Mr. Parag Nijhawan**, Asst. Prof., EIED.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other university.

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ABSTRACT

Most industries have smoke or dust problem of some kind. The smoke can be made up of solid or fluid particles suspended in the gas. For the control of dust, Electrostatic Precipitator is often used. Electrostatic precipitators are used to separate the suspended particles from the flue gases with the help of electric forces. Thesis consists of the complete study of the ESP unit at GNDTP Bathinda. Major problems with the existing system are that in the electronic controllers the current remains very high even when it is not required, causing huge power loss, stack emission level is high (300mg/NM^3) and total plate area is insufficient to cope up with the dust concentration in the flue gases. In my thesis, it is proposed to renovate the existing system by installing Microprocessor based semi pulse controllers (MBSPC). MBSPC can save much more electrical energy than those using Electronic controllers. MBSPC monitors the actual EP current and fires the thyristors at precisely the correct phase angle to maintain the set spark rate or to increase the current to the set current limit if no sparking occurs. Also voltage is monitored. Set points can be adjusted as required and display of data can be seen at the panel. Proposal for the renovation of the existing unit has given by keeping in view the drawbacks in the existing system. Pay back calculations has also been calculated and from this it can be conclude that 72% power can be save and cost of renovation is nearly about 50 lac.With hourly saving of about 130 kwh the cost of modification is recoverable within about two and half years in the form of saving in power.

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CHAPTER-1

INTRODUCTION

1.1 OVERVIEW

The separation of suspended particles from gases is one of the basic scientific and technical problems of the industrial era. Control of these emissions by adequate gas-cleaning processes is essential to prevent heavy, devastating air pollution, and, in many instances, to recover valuable materials, such as copper, lead or gold which otherwise would be carried up the stack and lost by dispersion into the atmosphere. Gas-cleaning processes may be classified broadly as mechanical and electrical. Mechanical processes include all those which depend fundamentally on inertial or mechanical forces, namely, gravity settling, centrifugal or cyclonic separation, gas washing, or scrubbing, filtration through screens, fabric bags, or packed beds, and some agglomeration. The electrical process, commonly referred to as electrostatic precipitation, differs basically from all mechanical methods in that the forces of separation acting on the suspended particles are electrical in nature.

This fundamental difference is reflected in unique advantages both in operation and in application of the electrical method. Separation forces are applied directly to the particles themselves instead of to the entire gas stream, as in most mechanical separation methods. It is limited neither to relatively coarse particles as gravitational and inertial methods are nor by resistance to the motion of the gas as filters and scrubbers are. Even the finest particles in the submicron size range are collected effectively by electrostatic precipitation because of the relatively large electric forces which act on the particles. There is no fundamental limit to the degree of cleaning attainable, and, in practice, most precipitator installations operate in the range of 90% to 99% efficiency, with some as high as 99.99%. The high collection efficiency, the low resistance to gas flow, the ability to treat huge gas quantities at high temperature, and the ability to cope successfully with corrosive atmosphere and particles account for the wide acceptance and diverse applications of the electrical precipitation process.

The process is physical in character and is most accurately classified as electrophysics. Nevertheless, the actual practice of electrical precipitation involves a surprising number of scientific disciplines including physics, chemistry, aerosol technology, chemical engineering, electrical engineering, electronics, aerodynamics, mechanical engineering, and civil engineering.

1.2 LITERATURE REVIEW

The electrostatic attraction of rubbed amber for small particles and fibers was known to the Greeks, probably as early as 600 B.C. The quantitative character of the electrostatic force involved was investigated by Coulomb [1] and published during the period of 1785 through 1789. Coulomb's discovery of the inverse square law forms the basis of the science of electrostatics and also is the starting point for the theory of electrostatic precipitation.

The first recorded reference to the electrical attraction of smoke particles appears in the famous work, *De Magnete*, of the English court physician, William Gilbert [2], in the year 1600. It is also of interest to note that about 1745, Benjamin Franklin began the study of the effect of points "in drawing off and throwing off the electric fire". Franklin's work seems to be the first on what we now refer to as the corona or brush discharge from sharp points. Experimental observations on electric discharges through smoke-filled gases and on the electric wind were also made by Beccaria [3] in 1772.

Hohlfield [4], in 1824, performed the experiment of clearing fog in a jar containing an electrified point, and Guitard [5] repeated the experiment in 1850, using tobacco smoke in a glass cylinder described as being nine inches in diameter and 18 inches long. However, Hohlfeld's and Guitard's experiments did not stimulate any practical study of the electrostatic-precipitation principle and were soon forgotten. They were brought to light again by Sir Oliver Lodge in 1905, many years after he had independently rediscovered the same phenomenon and brought it to public attention [6] in 1884. The work of two other experimenters appearing in the period between Guitard and Lodge also may be noted. In 1862, Gaugain [7] published what are probably the first experiments on the disruptive discharge between concentric-cylinder electrodes. Nahrwold [8], in 1878, experimented with the discharge from a sewing needle point in a tin cylinder, and he noticed that the electric discharge greatly increased the rate of settling or collection of atmospheric dust. He also tried coating the walls of the cylinder with glycerin to make the collected particles adhere; this was probably the first recognition of the difficulty of retaining dry particles on the collecting surface. As the result of Sir Oliver Lodge's researches on the subject, the first attempt to apply electrostatic precipitation commercially was made by Walker and Hutchings [9] at a lead smelting works in Bagillt, North Wales, in 1885.

1.2.1 Cottrell's pioneer developments

Cottrell's interest in gas cleaning seems to have originated not from the scientific aspect, but rather from public demand for control of air pollution caused by smelters. His initial work in this field was not electrical, but, instead, was based on a more prosaic approach using the principle of the ordinary centrifuge. There is no definite record of the events which led Cottrell to the electrical method. However, we can be certain that he was dissatisfied with the gas centrifuge method. Furthermore, Cottrell was working an era of great research activity on electrical discharges in gases and rapid development of high-voltage, alternating-current technology.

Cottrell's first experimental work [10] was on a small laboratory scale. He used a spark coil and a few discharge points in a chamber, an arrangement which worked quite well. In attempting to increase the precipitation capacity by using more discharge points, Cottrell found that the corona, or brush discharge would transfer from point to point but would discharge from only one or two points at a time (because of insufficient power from the spark coil). To correct this, Cottrell, as a result of the partially accidental discovery that a cotton-covered wire gave a continuous glow on its surface, devised the pubescent electrode made of semiconducting fibrous material which in effect provided many small discharge points. The pubescent electrode gave a fairly uniform corona over its whole surface, even at the low power provided by the spark coil, and it functioned where the multiple discharge points failed.

Realizing the need for a better source of high-potential electrical energy, in 1906, Cottrell turned to the newly developed, synchronous-mechanical rectifier [11] and the high-voltage, alternating-current transformer. However, transformer voltages, then readily attainable, were limited to values of about 10 KV to 15 KV, and the pubescent electrode still proved to be an important adjunct in obtaining reasonably uniform corona over extended lengths of discharge electrode.

The first experiments with the synchronous rectifier were made (at the University of California in 1906) to precipitate sulfuric acid fume in a small test precipitator of a few cfm capacity. The choice of sulfuric acid fume for the first experiment was a fortunate one, for this material, although easy to collect by electrostatic precipitation, was frustratingly difficult to collect by the mechanical and wet methods then available. The gratifying success of these experiments soon led to the installation of commercial equipment, first at a powder works at Pinole, a few miles up the bay from Berkeley, and then at the nearby Selby smelter which was at that time embroiled in acute air-pollution difficulties. The essential features of Cottrell's precipitation system are shown in fig1.1 which is reproduced from his first patent [12], issued in 1908.

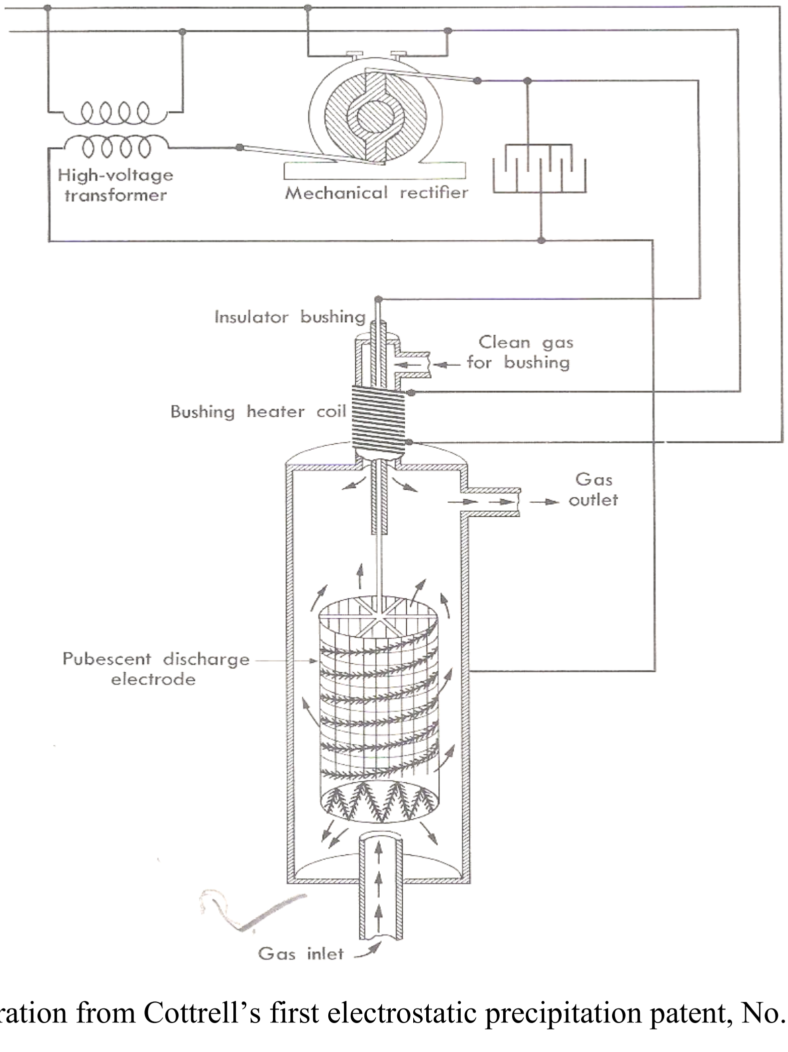

Figure 1.1: Illustration from Cottrell's first electrostatic precipitation patent, No. 895, 729 (1908)

These first commercial precipitators, although crude in construction, were sound in principle. The Selby unit operated satisfactorily for many years. It handled about 5000 cfm of gas from parting kettles for the recovery of precious metal and collected about two gallons per minute of sulfuric acid which previously had been discharged to the atmosphere in the form of a fine mist. Particularly to be noted are the synchronous rectifier and high-voltage step-up transformer, the pubescent discharge electrode, and the heater and ventilating systems for keeping the high-voltage insulator clean and dry. Not indicated in the drawing, but of equal importance, is the use of negative corona which Cottrell showed to be superior to positive corona because of the much higher voltages and currents which could be carried with the negative discharge.

1.2.2 Further advances by W.A. Schmidt

New factors of size and complexity were involved in treating over 1,000,000 cfm of gas carrying 100 tons of dust per day at gas temperatures of 400°C to 500°C. The task of devising and constructing practical electrostatic precipitation equipment to meet these conditions was undertaken in 1910 by W.A. Schmidt [13], a former student of Cottrell's at the University of California. During the course of this work, Schmidt introduced and patented what has since proved to be one of the most fundamental advances in precipitation technology the fine wire corona-discharge electrode. This new concept overcame the limitations and practical difficulties inherent in the pubescent electrode and provided the missing element essential for the large-scale development of the Cottrell process.

1.2.3 Electric Power Production

The continued rapid increase in electric power consumption which, on the average, has doubled every decade since about 1900 has placed ever-increasing emphasis on fuel sources and power generation efficiency. Fossil fuels, comprising coal, oil and natural gas, have been the most important energy sources for many years and by present indication will continue to be for at least several more decades. Hydroelectric power now accounts for only about 20% of the total source, while the outlook for atomic power in a relatively slow long-term growth amounting to possibly 105 to 20% of the total by 1975. Of the fossil fuels, coal is the most important for power production. Early power plants burned coal in stoker-fired boilers, but the drive for higher power-generation efficiency led in 1919 to the successful development of pulverized coal as a basic fuel for the large highly efficient steam-generating units characteristic of modern power plants [14]. In this form of firing, the residual ash from the coal is entrained in the furnace gases in the form of finely divided particles commonly known as fly ash which will be emitted from the stack unless special and effective means are provided for their removal. These minute fly ash particles may constitute ten percent or more of the coal burned and therefore may produce a serious air-pollution problem. Electrostatic precipitators was established early as the standard method for dealing with the fly ash problem; the first full-scaled precipitator [15] for this purpose was installed in Detroit, Michigan, in 1923, only four years after the introduction of pulverized-coal firing in power plants.

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1.2.4 Recent Developments

The collection of low resistive particulate matter (PM) generated from marine and automobile diesel engines have been known to be difficult by conventional electrostatic precipitators (ESPs). The collection efficiency for three types ESPs, namely, the conventional dc-energized ESP, the trapezoidal waveform- energized ESP (TW ESP), and the electrohydrodynamically assisted ESP (EHD ESP) were investigated[16] . Low resistive PMs are detached from the collection plate by the electrostatic repulsion force caused by induction charge resulting in particle reentrainment. The EHD ESP utilizes ionic wind combined with an electrostatic force to transport the charged particles into the zero electric field zone (pocket zone) attached to the collection plate effectively. The conventional dc-energized ESP showed good collection efficiency for particle sizes less than 300 nm where adhesion force was dominated over electrostatic repulsion force but showed a severe reentrainment for particle sizes greater than 1000 nm, while the TWESP suppressed the particle reentrainment for larger particles but still showed negative collection efficiency. On the other hand, the EHD ESP showed excellent collection efficiency for particle sizes up to 1000 nm and significant reentrainment suppression was observed even for particle sizes greater than 2000 nm**.**

Based on the air conductivity theory and the electrostatic precipitation theory, Yan-biao [17] proposes the scheme for ESPs power supply by using the tracking critical spark regulation (no spark) and the three-phase silicon-controlled rectifier (SCR) AC phase-control voltage regulation. It has been verified through industrial test. Compared with the scheme of the single-phase SCR AC phase-control voltage regulation it makes ESPs dust emissions to decrease by

60% approximately and the inherent energy-saving be up to 30% (apparent power), compared with the scheme of the three-phase SCR AC phase-control voltage regulation without using the tracking critical spark point regulation the decrease of ESPs dust emissions is up to 20%.

Zhao Fu [18] proves that electrostatic precipitators using DC power supply can save much more electrical energy than those using rectified AC power supply. The discovery of the mechanism of this energy-saving phenomenon lays a theoretical foundation for the use of DC power supply in electrostatic precipitation and greatly promotes a large-scale energy-saving movement in this field. The adoption of DC power supply and wide pole span structure is beneficial for the sustainable development of de-dusting technology.

Table 1.1 Comparison of Power Consumption between Two Dedusting Electric Fields [18]

Power supply	Dust precepitator	Same pole span mm	valid sectional area m^2	Date of record	Power consumption kW	Power consumption/ sectional area J, kW/m^2	Power consumption multiple k=J2/J1	Saving rate K=1-1/k
DC Power Supply	1	660	80	2001.12.30	4.85	J1=0.0606	8.886	88.7
				2001.12.31	2.84	0.0355	15.169	93.4
				2002.1.31	6.07	0.0759	7.123	86.0
				average value	4.59	0.0573	10.393	89.37
AC Power supply	2	400	130	2002.1.31	71.0	J2=0.5385	1.000	00.0

1.3 OBJECTIVES

1. To study the Electrostatic Precipitation Unit at G.N.D.T.P Bathinda both electrically and mechanically.
2. To calculate the power consumed in the existing ESP Process.
3. To Study the digital semi pulse principle.
4. Keeping in view the various disadvantages in the existing ESP Unit, proposal for the renovation of the existing system by installing new digital semi pulse ESP controllers.
5. Calculations regarding the pay back of the new equipment.

1.4 ORGANIZATION OF THESIS

1. An introduction to the Electrostatic precipitation processes is presented in chapter-1 along with the overview and objectives of the thesis.
2. Chapter-2 involves the elements of Electrical Precipitation Systems
3. Chapter-3 involves the case study of the ESP Unit at G.N.D.T.P Bathinda, complete description of the existing unit (Electrical & Mechanical), power consumption calculations, and the disadvantages of the existing system.
4. Chapter-4 involves the introduction to digital semi pulse principle.
5. Chapter-5 involves the proposal for the renovation of the existing unit, description of material required for renovation, pay back calculations, correction curves and the advantages of the new system.
6. Chapter-6 involves conclusions and recommendations for the future work.

CHAPTER-2

ELEMENTS OF ELECTRICAL PRECIPITATION SYSTEMS

2.1 FUNDAMENTALS

An electrical precipitator may be defined in the broad sense as an apparatus or equipment which utilizes electric forces to separate suspended particles from gases. In practice, electrical precipitators are of many types and configurations, but all are derived from the same underlying principles. Separation of suspended particles from a gas by the electrical precipitation process requires three fundamental steps:

1. Electrical charging of suspended particles,
2. Collection of the charged particles in an electric field, and
3. Removal of the precipitated material from the collecting electrodes to a receptacle external to the precipitator.

Particle charging may occur naturally during the formation or life of a particle, for example, by flame ionization, friction, or even exposure to the cosmic radiation which constantly permeates the earth’s atmosphere. In fact, uncharged or neutral particles are very rare. However, those natural charges on particles, although of scientific interest, are too small for effective precipitation. Field tests on electrostatic precipitators, using only the natural charges on dusts, yield efficiencies of the order of 80%.

Of the several possible artificial methods for charging particles, the high-voltage direct-current corona is by far the most effective and is universally used in electrical precipitation. The corona is usually established between a fine wire, or active electrode, maintained at high voltage and a smooth cylindrical or plate electrode at ground potential. Under these conditions, the corona is manifested by a highly active visible glow in the strong electric field region near the wire’s surface. Large numbers of both positive and negative ions are formed in this active glow zone.

With the wire at negative ions are formed in this active glow zone. With the wire at negative polarity, which is the usual arrangement for industrial precipitators, the positive ions are attracted to the wire, and the negative ions are formed in equal numbers in the corona glow region near the wire, over 99% of the gas space between the wire and ground electrode contains only negative ions. In the precipitation process, the particles in passing through the corona field are subjected to intense bombardment by the negative ions and become highly charged in 0.01 sec or less. Under typical conditions there are about 108 negative ions per cubic centimeter in the corona field.

The separation force acting on a particle is given by Coulomb's law which states that the force is proportional to the product of the particle charge and the intensity of the collecting field. Other minor electric forces, for example, electrostatic image and dipole forces, are sometimes invoked in discussing the electrical precipitation process, but these forces are so small compared with the Coulomb force that they are merely of academic interest. The magnitude of the Coulomb force may be best illustrated by numerical examples. In a typical commercial precipitator, the force turns out to be about 3000 g (g = acceleration of gravity) for a one-micron particle and about 300 g for a 10-μ particle as shown in Fig. 2.3. The great effectiveness and high efficiency of electrical precipitation is ascribable chiefly to the very large Coulomb separation forces which act on each particle.

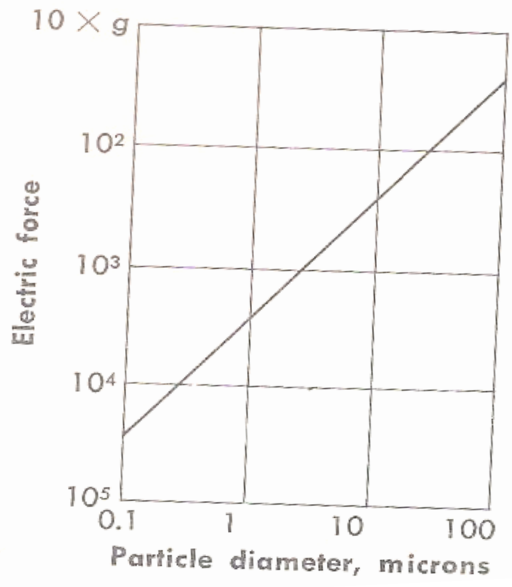


Figure 2.1: Electric separation force acting on suspended particles as a function of particle size under typical conditions

The particles are accelerated toward the collecting electrode by the Coulomb force, but the motion is resisted by inertial and viscous forces. For particles in the size range of interest, it is easily demonstrated that the inertial forces are negligible and that the viscous retarding force of the gas is governed at least approximately by stokes' law. Consequently a particle in the precipitation field attains velocities determined by the equilibrium between the Coulomb and stokes forces. This velocity is conveniently referred to as the migration velocity of the particle and it increases with particle diameter, particle charge and collecting field intensity. For typical precipitator conditions, the migration velocities of suspended particles usually range from about 0.1 ft/sec for very fine particles of one half micron diameter, up to three or four feet per second for 20-µ or 30-µ particles.

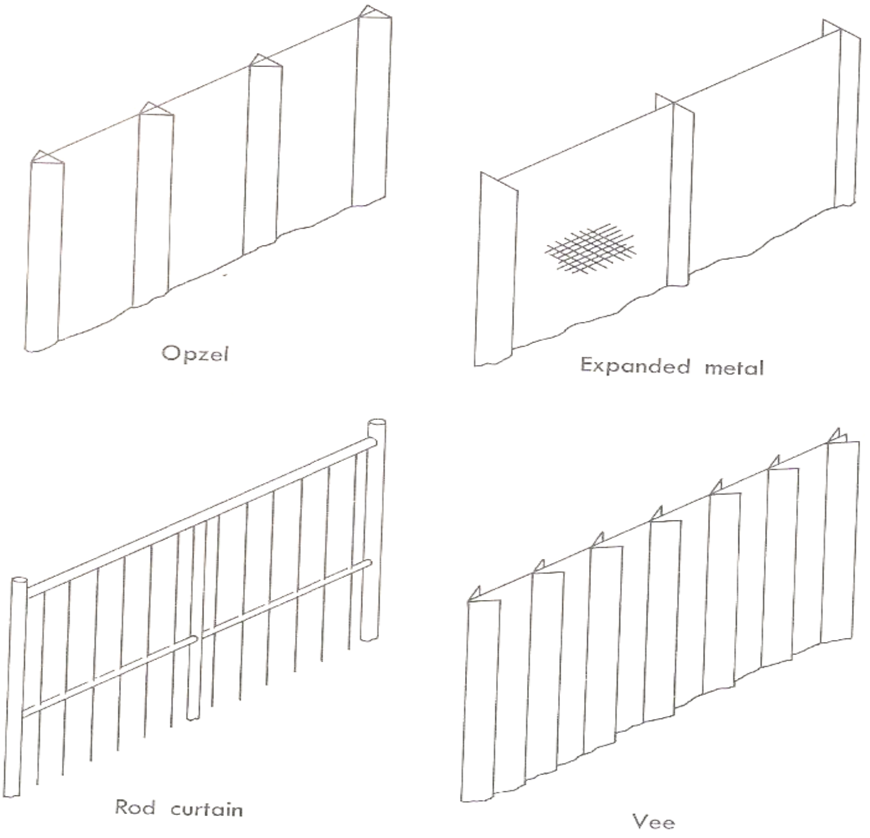
The third fundamental phase of electrical precipitation is removal of material collected on the ground or passive electrodes to an external receptacle. This is fundamental because the collected particles may be lost by reentrainment in the gas stream while still inside the precipitator. Liquid particles such as sulfuric acid mist or tar fog are easy to cope with because they drain from the collecting electrodes and out of the precipitator by gravity. With liquid particles, reentrainment does not occur except at very high gas velocities ordinarily used. On the other hand, with dry collection, which comprises the large majority of cases, particles may be quite easily reentrained and this presents one of the major technical problems of precipitation. Reentrainment may occur by direct scouring of the collecting electrode surfaces by the gas steam, by redispersion of collected particles during a rapping of the electrodes, and by sweepage of collected dust from hoppers. Vulnerability to reentrainment is in part determined by the fundamental characteristics of the particles themselves. For example, metallurgical fumes, such as lead or zinc oxide, are comprised of very fine irregular shaped particles one-micron or less in size and form on the collecting surfaces in loosely-packed, low bulk density layers. These layers are fairly cohesive and under the influence of the gas stream and rapping, they tend to break up into fluffy agglomerates which settle slowly in the gas. In contrast, coarse dust particles of say 50 µ or greater generally lack cohesiveness and do not form agglomerates. These particles will tend to fall into the hoppers if they have high density but will float lazily in the gas if they have low density. Finer dust particles of a few microns size usually agglomerate well, yet they have sufficient bulk density to fall rapidly into the hoppers.

Particle reentrainment is also closely related to gas flow patterns and characteristics. Unbalanced, highly turbulent gas flow, characterized by high gas velocity zones, swirls, jets and eddies is highly potent in scouring and sweeping collected dust from the collecting plates and from the hoppers, and it results in great losses in collection efficiency. It is not uncommon, for example, to raise precipitator efficiency from 85% under poor gas flow conditions to 95% to 98% by correction of the gas flow. Unfortunately, industrial gas flow has received far less attention than the aerodynamics of aircraft or missiles or even of air conditioning and ventilation systems.

2.2 BASIC DESIGN AND COMPONENTS

Type and size of precipitator are determined by the basic properties of the gas and particles handled, by the gas flow, and by the required collection efficiency. Generally pipe-type precipitators are used for small gas flows, for collection of mists and fogs, and frequently for applications requiring water flushed electrodes. Duct type precipitators are used for larger gas flows, dry collection and sometimes also for water flushed service. Collecting electrode size for pipes usually is from about six inches in diameter by six feet long, for small units, up to 12 in. in diameter by 15 ft long for large units. In duct precipitators, the collecting plates vary in size from two or three feet high up to six or eight feet wide by 20 ft 25 ft high. Many designs for collecting plates have been used; several of them are illustrated schematically in Fig. 2.2.

Fundamental requirements for collecting plate design include (a) good corona and high sparking voltage characteristics, (b) shielded or shadow zones for particle collection to keep reentrainment losses at a minimum, (c) good rapping characteristics and (d) high mechanical strength coupled with light weight. Corona electrode design is determined chiefly by application conditions such as gas temperature, nature and concentration of the dispersoid and presence of corrosive gases or particles. Most industrial precipitators use steel or steel alloy corona wires of about 0.1-in diameter. Square wires of 1/8 in. to ¼ in. have advantages in a few applications because of their greater cross section. Lead covered and has talloy wires are used for sulfuric acid mist precipitators. Very fine tungsten wires of 5 mm to 10 mm diameter are used for air cleaning precipitators because of their much lower ozone generation properties. Corona currents usually are in the range of 0.01 ma to 1 ma /ft of discharge wire, with voltages of the order of 30 kv to 100 kv for Cottrell or single stage, precipitators and 10 kv to 15 kv for two stage precipitators.


Opzel

Expanded metal

Rod curtain

Vee

Figure 2.2: Types of Collecting Plates

The basic importance of methods and equipment for supplying electrical energy or corona power to precipitators can scarcely be overemphasized. It is perhaps obvious that since a precipitator functions by electric forces acting on the particles, precipitator performance can be no better than the electrical energization. Nevertheless, this is undoubtedly one of the most misunderstood and frequently overlooked factors of precipitator design and operation. Contrary to initial expectation best precipitator performance is obtained not with steady or so-called pure direct current, but rather with intermittent or pulsating waveforms largely because of the higher voltages and currents that can be maintained with intermittent voltages under the sparking conditions which commonly exist in precipitators. For these reasons most precipitators are powered by high voltage unfiltered rectifier sets, although pulse methods somewhat similar to those used in high power radar equipment may be used with advantage.

The corona electrodes in larger precipitators usually are subdivided into multiple groups or sections frequently referred to as high tension bus sections. These sections are individually powered by separate rectifier sets to reduce the bad effects of precipitator sparking and equipment outages and to provide better matching of corona voltages and currents of the electrical characteristics of the gas and dust. Ideally, best precipitator performance would be obtained by individually energizing each corona wire from a separate rectifier set, an obviously uneconomic arrangement. In practice, the goal is an economic balance among degree of sectionalisation, precipitator size and cost. The effect of high tension sectionlisation or precipitator efficiency is typically very large. For example, a fly ash precipitator designed for a gas flow of 100,000 cfm with just one section typically might produce a collection efficiency of only 60% but the same precipitator with two corona sections might have an efficiency of 90% and with four sections it might be 99% efficient. The much greater efficiency of the four section arrangement basically results from the substantially higher precipitator voltage possible compared with the single large section. Good and poor sectionalization arrangements are shown in Fig. 2.3.

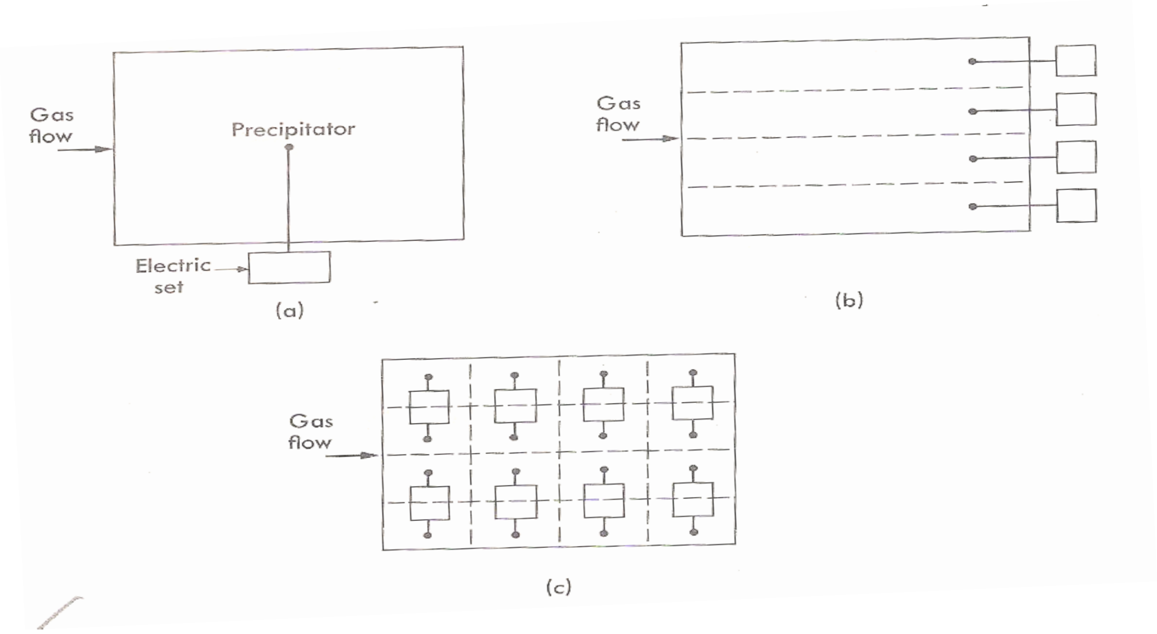


Figure 2.3: Comparisons of good and poor sectionalization arrangements for corona electrodes in dust precipitators to meet high performance requirements. (a) Very Poor; one precipitator

section; one electrode set. (b) Poor; longitudinal sections only. (c) Good; both series and longitudinal sections

2.3 PARAMETERS AFFFECTING PRECIPITATOR

Electrostatic Precipitator is designed for a set of inlet parameters. Variation of one or many of these may lead to unsatisfactory performance of the precipitator. Brief discussions on the effect of such parameters are given below:

- Temperature of gas
- Gas Volume
- Moisture content
- Gas velocity within the ESP
- Inlet dust concentration
- Dust particle size distribution
- Dust resistively
- Dust composition

1. TEMPERATURE OF GAS

Temperature has great influence on the ESP performance either directly or indirectly through resistively. The electrical properties deteriorate with increase in temperature. Flash over limit decreases thereby operating voltage has to be brought down to avoid, back corona. This weakens field strength and consequent force on the particles. *Moreover* gas viscosity increases at higher temperature thereby increasing drag on the particles, which impairs the precipitation rate. Consequent to the above phenomenon particle migration velocity decreases and thus ESP performance deteriorates. An ESP thus designed for a particular temperature may not perform well with higher operating temperature. The strength of ESP structural may not be sufficient enough at higher operating temperature than at which it has been designed. A lower temperature also is detrimental if it falls below acid dew point when corrosion occur giving rise to every possible problem of structural and mechanical aspects of ESP.

2. GAS VOLUME

Increase in gas volume decreases specific collecting area, for which a precipitator is sized. Specific collecting area is the ratio between effective collecting area and the gas volume to be handled. Thus increase in gas volume over the designed value reduces the effective precipitator size, decreasing the ultimate collection efficiency.

3. MOISTURE CONTENT

Moisture content has a large influence on the performance. It directly influences the voltage current characteristics and also indirectly through resistivity. Increase in moisture improves the precipitator performance. It has been seen in number of occasions that lower operating moisture content than at which ESP was designed was the single largest contributor towards the bad performance of ESP.

4. GAS VELOCITY IN THE ESP

Gas velocity within a precipitator is very important factor. It affects the migration velocity on one hand and re-entrapment on the other. Fall of migration velocity at higher gas velocity is due to re-entrapment and that at lower gas velocity is due to gas stratification meaning hot gas passes through the upper zone while the lower zone is relatively cool.

5. INLET DUST CONCENTRATION

Increase in inlet dust burden increases outlet emission level even after maintaining same efficiency.

6. DUST PARTICLE SIZE DISTRIBUTION

Theoretically precipitator performance should increase with increase in particle size for the simple reason that larger particles receive charge more quickly and attains migration velocity which according to Stoke's Law is proportional to the diameter of the particle. Migration velocity is proportional to diameter when d>1pm and is independent when d<1µm. In practical situation precipitator encounters particle size more than 1 pm and thus it may be concluded that more proportion of fineness in the dust will deteriorate the ESP performance.

7. DUST RESISTIVITY

Resistivity is an electrical characteristic of the dust particle which determines the amount of charge, particle may gather under the specific charging condition. Resistivity is very much dependent on the composition and morphology of the dust particles. There are two conduction mechanisms which determine the resistivity of the dust.

- Volume conduction which is related to the composition of the dust.
- Surface conduction, which depends on an absorbed film on the particle surface which, is related to the composition of the gas and dust surface.

The effect of temperature (thermal excitation) on resistivity is worth noting- In absence of moisture {bone dry condition) the resistivity would continue tor increase with decreasing temperature because of less electron excitation. Conversely increase in temperature increases electron flow resulting into lower resistivity. This phenomenon is related to volume conduction, which occurs by means of electron carrier within the material and is dependent on thermal excitation.

At gas temperature below 150°C - 200°C, surface conduction becomes important mode of conduction provided ample moisture and conditioning agents are present in the gas. Surface conduction is dependent on the presence of a conductive film of absorbed material on the surface of the particulate. This film of absorbed material provides the transfer of the electrical charge along the surface. Worst effect of high resistivity is the formation of back corona. When there is dust layer on the collecting electrode a voltage drop occurs across the layer. If the dust resistivity is high voltage drop across the layer becomes so high to cause electrical breakdown of interstitial gas and thus breakdown of the layer and spark over between the discharge electrode and the collecting electrode occur. This phenomenon is called back corona. To prevent such sparking from becoming excessive it is necessary to lower the operating voltage and current with consequent toss in collection efficiency.

8. DUST COMPOSITION

The composition and morphology of the dust largely influence performance of ESP. A brief description of the effect of some of the major components of dust as normally encountered in industries like Cement, Power etc are given as follows:

Oxides of Sulphur

SO_3 produced during a combustion procedure condenses with moisture on the surface of the particles and thus reduces the resistivity. It may be noted that only free SO_3, which combines with water to form H2SO4, has this effect.

- High oxides of sulphur normally produce low resistive dust.
- Sometimes a large portion of sulphur in combustion material, say coal, may occur as $CaSO_4$ which is highly resisitive and so in such case dust may have high resistivity despite high sulphur content.
- Formation of SO_3 from high sulphur content sometimes raises the dew point so high that the dust is wetted by sulphuric acid clogging the entire ESP and hence ESP performance deteriorates despite very low dust resistivity.

Alkali Metals

Sodium, Lithium, Potassium in the heat of firing zone, evaporates and later condense, oxidize and sulphatize absorbing SO_3. So the alkali sulphates thus formed are deposited on the dust and increase the moisture absorption capacity of the dust and thus lower the resistivity. High alkali metal concentration, particularly Sodium, Lithium and Iron reduce the surface resistivity. A reduction in sodium content from 3% to 1%, 50% decrease in effective migration velocity occurs which means fifty percent increase in precipitator size.

Phosphorous

Presence of high level phosphorous in the dust exerts a strong detrimental effect on precipitator electrical operation and plume opacity.

Calcium and Magnesium Oxides

Presence of calcium and magnesium oxides in very high amount results into a possibility of discharge electrode fouling problems, which can suppress corona and thus make precipitator less efficient.

9. OTHER FACTORS INFLUENCING PRECIPITATOR PERFORMANCE

GAS DISTRIBUTION

The purpose of gas distribution is to achieve uniform gas flow and thereby distribute the inlet dust burden evenly over the whole cross section of the field, without under utilising or over burdening a particular zone Also to stop gas sneakage, no gas should by-pass the electrostatic field either in roof or through hopper region. In practice, a perfectly uniform distribution over the whole field is not possible, particularly at the upper and lower extremities.

RAPPING FREQUENCY

Every time the collected dust on electrode surface is subjected to rapping shock, re-entertainment of particles takes place in the main flow path and carried away by the gas. This phenomenon increases the emission level each time the rapping is done. It is necessary to reduce the re-entertainment to a minimum level. Hence, first a layer of dust of significant thickness must be allowed for form so that when it is dislodged by rapping, the layer breaks into agglomerate masses, sufficiently large to fall into the hopper before, being carried out by the moving gas stream into the outlet duct. Secondly rapping frequency is to be set to optimum level for each field in accordance with the concentration and type of dust entering the field to minimize penetration.

CHAPTER-3

EXISTING ESP UNIT (UNIT-4) AT G.N.D.T.P BATHINDA

3.1 INTRODUCTION

Extraction from industrial gases has become necessity for environmental reasons or for improving production. Most of the plants in India use coal as fuel for generating steam. The exhaust gases contain large amount of smoke and dust which are being emitted into the atmosphere. This has posed a real threat to the mankind as a devastating health hazard. Hence it has become necessary to free the exhaust gases from smoke and dust.

There are various ways of extracting dust.

ELECTROSTATIC DUST PRECIPITATION method is most widely used as its efficiency is excellent and it is easier to maintain. Its other advantages are:-

- Ability to treat large volume of gases at high temperature.
- Ability to cope-up with corrosive atmosphere.
- Offer low resistance path for the gas flow.

An ELECTROSTATIC PRECIPITATOR is equipment which utilises an intense electric force to separate suspended particles from the flue gases. The process involves:-

- Electrical charging of suspended particles.
- Collection of charged particles on collecting electrode.
- Removal of particles from collecting electrode.

The flue gases pass between electrodes and are subjected to an intense electric field. The emissive electrodes are connected to the negative polarity of HV power supply while collecting electrodes are connected to positive polarity and grounded.

3.2 DETAILS OF EXISTING ESP UNIT (4)[19]

Table 3.1 DESIGN CONDITION

Gas flow rate	200 m^3 / sec
Temperature	145^0C
Dust concentration	38.9 gms/Nm^3
Type of precipitator	2FAA-5x32-90125-2
Number of precipitator offered per boiler	One
Number of gas path per boiler	2
Number of fields in series in each gas pass	5
Guaranteed collection efficiency for design condition	99.23%
Pressure drop across the precipitator for design conditions	15 mm WC
Velocity of gas at electrode zone on total area	0.889 m/sec
Treatment time	18 sec

Table 3.2 COLLECTING ELECTRODES

No. of rows of collecting electrode per field	31
No. of collecting electrode plates per field	248
Total no. of collecting plates per boiler	2480
Nominal height of collecting plate	12.5 m
Nominal length of collecting plate	400 mm
Specific collecting area	120 m^2/m^3/sec.

Table 3.3 EMITTING ELECTRODES

Type	Spiral with hooks
Size	2.7 mm
No. of electrodes in the frame forming one row	48
No. of electrodes in each field	1440
Total no of electrodes per boiler	14400
Total length of electrodes per field (5.19x1440 = 74736m)	7474metres
Plate/wire spacing	150 mm

Table 3.4 RAPPERS FOR COLLECTING ELECTRODES

No. and type of rappers	One drop hammer per row of collecting electrodes having a collecting surface of 80 m^2
Rapper size	4.9 Kgs.
Frequency of rap	Varying from 12 raps/hr. at the inlet field to 1 rap/hr. at the exit field. The frequency of rapping for the intermediate fields can be adjusted between 12 and 1 per hour according to requirement.
Drive	Geared electric motor controlled by synchronous programmer.
Location	At the bottom of collecting system.

Table 3.5 RAPPERS FOR EMITTING ELECTRODES

No. and type of rappers	Approximately one drop hammer two rows of electrodes.
Rapper size	3.0 Kgs.
Frequency of rap	10 raps/hour
Drive	Geared electric motor controlled by synchronous programmer
Location	On the side of emitting frame middle portion

Table 3.6 HOPPERS

Types	Pyramidal
No. of hoppers	20
Capacity	8 hours storage
Heating	Electrical heating provided for the bottom of hoppers.
Baffling arrangement	2 sets of deflector plates in each row of first and last hopper and one set in each rows of remaining hoppers underneath the collecting plates prevent gas sneakage.

Table 3.7 GAS DISTRIBUTION SYSTEM

Type and quantity	Perforated plate 2 sets
Location	Inlet of precipitator

Table 3.8 ELECTRICAL ITEMS

i. Rectifier	
a. Rating	70 KV (Peak) 800 mA (mean)
b. Number/boiler	10
c. Type	Silicon diode, full wave, bridge connection
d. Location	Mounted on the top of precipitator
ii. Rectifier Control Panel	
a. Type of control	Thristor
b. Number	24
c. Location	In the control room at ground level
iii. Auxiliary control panel	
a. Number	1
b. Equipment controlled	Geared motors of rapping mechanisms of collecting and emitting electrodes, heating elements on hoppers insulator housing and shaft insulators
c. Location	In the control room at the ground level.
iv. Motors	
Rapping of Emitting Electrodes	
a. Quantity	10 Nos.
b. Rating	Geared Motor: 0.33 Hp/2.5 rpm at 3 phase, 415v, 50Hz
c. Location	On top of EP
Rapping of Collecting Electrodes	
a. Quantity	10 Nos.
b. Rating	Geared motor: 0.5 HP/1.1 rpm at 3 phase, 415 Volts, 50 Hz.
c. Location	On the side panels of the casing
v. Heating Elements	
Hoppers	
For 20 hoppers at the rate of 6 KW/hopper	120 KW

Shaft Insulators	
For 10 insulators at the rate of 1 KW	10 KW
Support Insulators	
For 40 insulators at the rate of 1 KW	40W

Table 3.9 RECOMMENDED CURRENT SETTING

Field	1	2	3	4	5	6	7
Current in	230	300	375	450	510	-	-

3.3 HV POWER SUPPLY EQUIPMENT

HV power supply equipment consist of

a. High voltage transformer rectifier (HVR)
b. The electronic controller (EC)

The EC-HVR equipment provides high voltage dc across the precipitator electrodes. The electronic controller provides controlled AC voltage through thyristors (SCR) and associated controls to the primary of step up transformer. The electronic controller has been designed to supply 0 to 415 volts AC to the primary of step up transformer through AC reactor. For its operation it requires a single phase 50 Hz 415V ± 10% AC supply. The equipment operates as constant current controller. The current feedback signal is taken proportional to the AC primary current or actual output d.c. current. Potentiometers are provided to adjust the reference signal, feedback signal spark sensitivity and duration of blocking the supply for achieving optimum performance of the system.

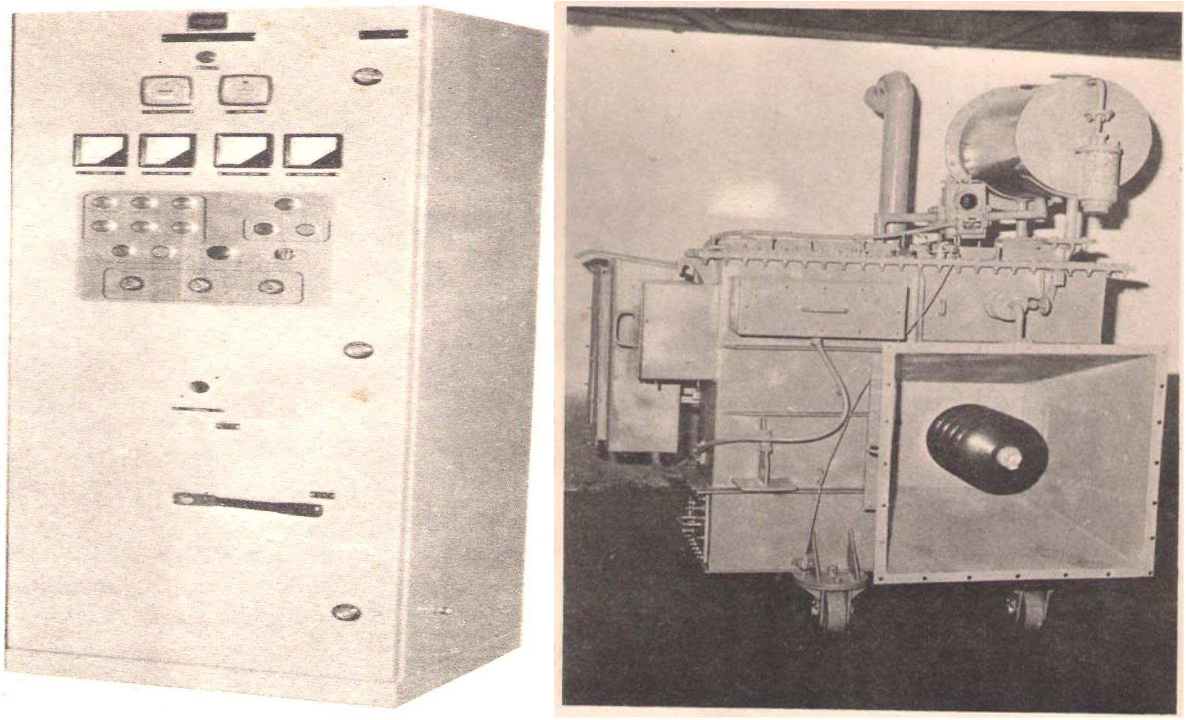


Fig3.1 Electronic controller and High voltage transformer rectifier

3.4 TECHNICAL SPECIFICATIONS OF E.C. - HVR

Table 3.10

Input

Incoming Supply	415, ± 10%, Single phase, 50 Hz. ± 5%.
Current drawn from supply	167 Amps A.C. for 800 mA DC output.
Input Voltage to primary of HV transformer after A.C. Reactor.	0 to 373 Volts A.C. (Designed for rated output at -10% of 415V AC input supply)

Output

Output Voltage from thyristor.	0 to 415 Volts r.m.s. continuously adjustable.
D.C. output of HVR	0 to 70 KV peak continuously adjustable.
D.C. output3 Current	800 milli amps (Maximum AVG)
Maximum arcing current	3 Amps D.C. (Peak)
Form Factor (Current)	1.4 (Maximum)
Current regulation	± 5% (Either within voltage variation or load impedance variation.)

Table 3.11 Ambient Temperature

Electronic Controller (E.C.)	-5° to + 50°C (Minus five to plus fifty)
High Voltage Transformer Rectifier (HVR)	-5° to + 50°C (Minus five to plus fifty)

Table 3.12 Operating Features

Rate of initial current build up to Im set value.	60 ± 10 Sec.
Rate of Current buildup with T/O Control.	10 ± 2 Sec.
Range of Im Control potentiometer.	0 to 100% of rated current.
Range of Is Control Potentiometer (In Manual mode only)	0 to 100% of Im Set value.
Current Detection	
1. Primary feedback	By current transformer
2. Secondary feedback	By shunt resistor.
3. Mode of selection	By selector switch.
Spark Detection	By -ve dv/dt level on primary and secondary sides.

Table 3.13 Protection

Short Circuit Protection	By under voltage relay 10 to 50% of primary volts with time delay from 10 to 80 Sec. adjustable.
Overload protection	By thermal overload relay on primary side.

Degree of Protection

EC	IP 54
HVR	Outdoor

3.5 PRINCIPLE OF OPERATION

A simplified block scheme of electronic controller and high voltage rectiformer is shown in fig3.2

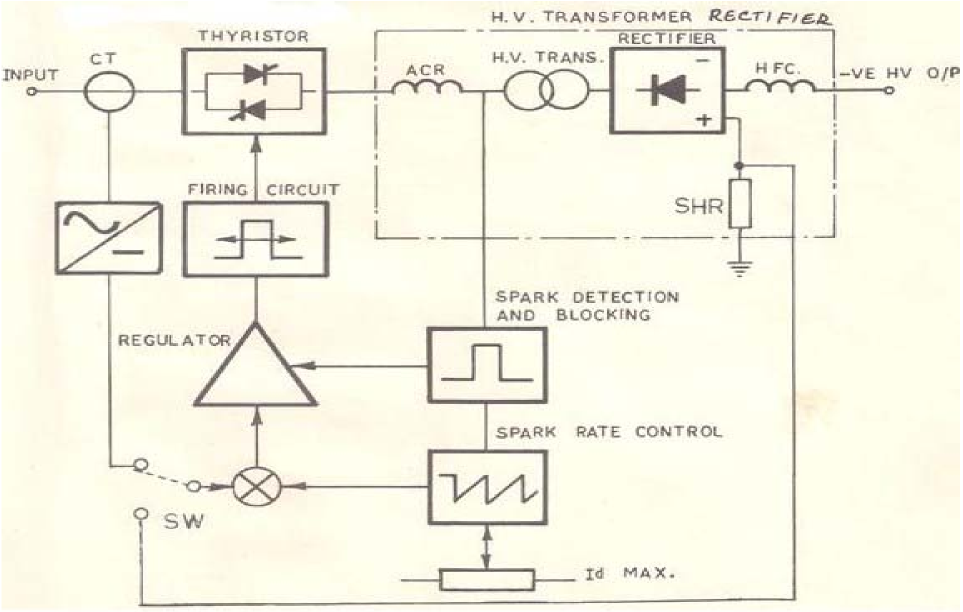


Figure 3.2: Simplified Block Scheme of EC-HVR

The output voltage and current at high voltage d.c. terminals is controlled by controlling the voltage on primary of the transformer. The voltage controls is achieved by two thyristors connected in anti parallel configuration. In normal operation, the output of thyristor is controlled by the gate pulse circuit which in turn gets its control signal from the current regulator output. The output of current regulator adjusts itself such that the actual current is maintained equal to set reference value. In case of occurance of a spark the same is detected by spark detection unit. The detection signal produces a blocking pulse for specific period and the voltage builds up after the blocking period as shown in fig. 3.4.

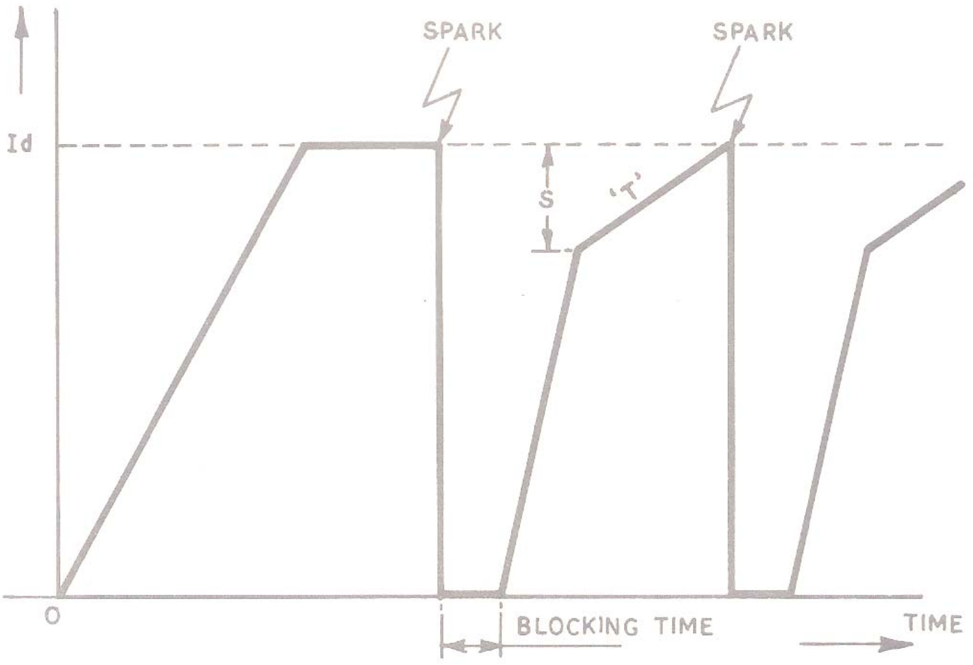


Figure 3.3: Output Characteristics of EC-HVR

3.6 POWER CONSUMED BY EXISTING ESP UNIT

There are 2 paths (A & B) and 5 fields in each path. 1electronic controller for each field, 10 electronic controllers are installed for each unit.

- **Power consumption by field 1A**

Secondary DC Voltage (X) =45 KV

Secondary Avg current (Y) = 230 ma

$$\text{Secondary RMS voltage (V)} = \frac{X \times 1.08}{1.414} = 34.37 \text{ KV}$$

Secondary RMS Current (I) = Y x 1.4

= 0.322 A

Power consumed by field 1A = V x I

= 11.06 KW

- **Power consumption by field 2A**

Secondary DC Voltage (X) =45 KV

Secondary Avg current (Y) = 300 ma

$$\text{Secondary RMS voltage (V)} = \frac{X \times 1.08}{1.414}$$

= 34.37 KV

Secondary RMS Current (I) = Y x 1.4

= 0.42 A

Power consumed by field 1A = V x I

= 14.43 KW

- **Power consumption by field 3A**

Secondary DC Voltage (X) = 45 KV

Secondary Avg current (Y) = 375 ma

$$\text{Secondary RMS voltage (V)} = \frac{X \times 1.08}{1.414}$$

= 34.37 KV

Secondary RMS Current (I) = Y x 1.4

= 0.52 A

Power consumed by field 1A = V x I

= 18.04 KW

- **Power consumption by field 4A**

Secondary DC Voltage (X) =45 KV

Secondary Avg current (Y) = 450 ma

$$\text{Secondary RMS voltage (V)} = \frac{X \times 1.08}{1.414}$$

= 34.37 KV

Secondary RMS Current (I) = Y x 1.4

= 0.63 A

Power consumed by field 1A = V x I

= 21.65 KW

- **Power consumption by field 5A**

Secondary DC Voltage (X) =45 KV

Secondary Avrg current (Y) = 510 ma

$$\text{Secondary RMS voltage (V)} = \frac{X \times 1.08}{1.414} = 34.37 \text{ KV}$$

Secondary RMS Current (I) = Y x 1.4

= 0.71 A

Power consumed by field 1A = V x I

= 24.54 KW

Total power consumption of one path= 1A+2A+3A+4A+5A

= 11.06+14.43+18.04+21.65+24.54

= 89.72kw

There are 2 paths in each ESP unit.

Therefore total power consumption of one ESP unit = 89.72 x 2 = 179.44 kw

3.7 MAJOR DRAWBACKS IN THE EXISTING SYSTEM

1. The basic problem of electronic controllers is that current remains very high even when it is not required, causing huge power loss.
2. The pollution control board of the Punjab govt. has specified an emission level of 90mg/NM^3 from the chimney. But with the existing system, stack emission level is 300mg/NM^3.
3. Total plate area is insufficient to cope up with the dust concentration in the flue gases.
4. In existing system detection of back corona is not possible, which affects the efficiency.
5. As the system is not computerized, control is sluggish.
6. Spark rate control is not effective.
7. Charge ratio selection is not possible.

CHAPTER-4

MICROPROCESSOR BASED SEMI PULSE ESP CONTROLLERS

4.1 OVERVIEW

The prime objective of microprocessor based controllers is to automatically provide optimum precipitator power at all times. The objective is accomplished in the following ways.

- Utilization of state-of-the art microprocessor technology, components, hardware and software.
- Software developed specifically for precipitator operation
- Ability to tailor the electrical operation of the transformer rectifier to actual, real time precipitator operating conditions.
- Fast response to sparks.
- Separate control strategy for operating under severe back corona conditions.

4.2 FEATURES OF MICROPROCESSOR BASED CONTROLLER.

- Effective spark ratio control
- Detection of spark/ arc by di/dt or dv/dt.
- Automatic current control based on step and ramp control settings.
- Intermittent charging technique.
- Measurement of Peak, Mean & Valley of secondary voltage.
- Base charge setting & measurement.
- Automatic selection of charge ratio based on VI characteristics of the ESP.
- Annunciation of warning and trip alarms.
- Facility of REMOTE control through ± 10mA balanced current loop.

4.3 MICROPROCESSOR BASED SEMI PULSE CONTROLLER OPERATION

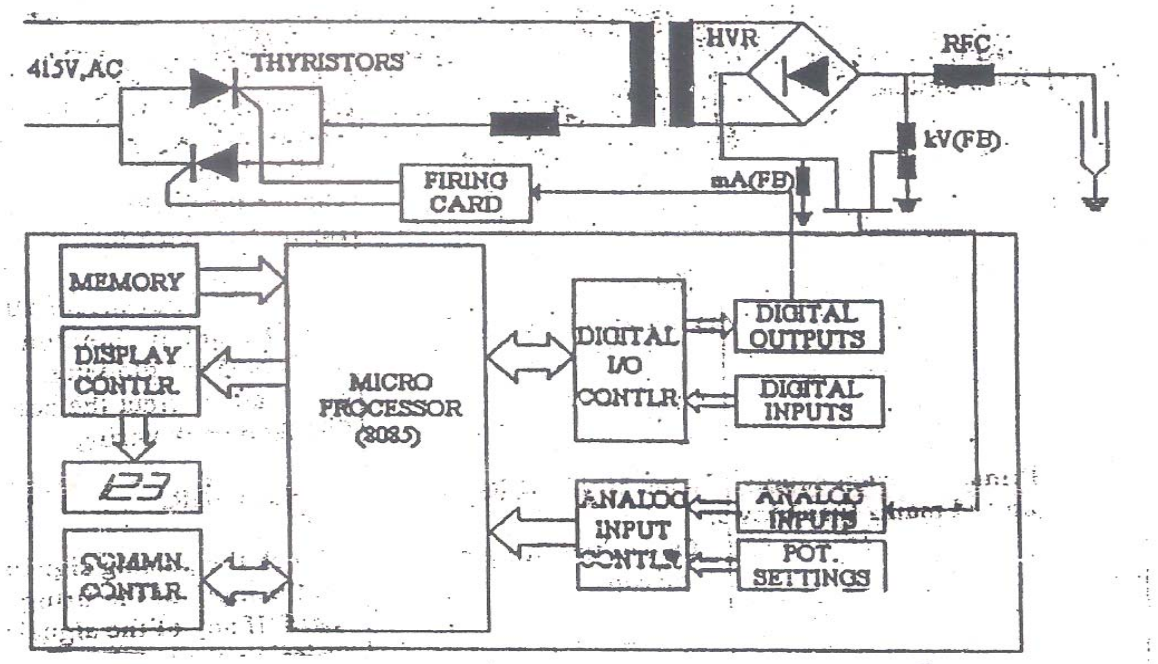


Figure 4.1: Block diagram of microprocessor based semi pulse controller

The ESP is predominantly not a constant load to the thyrister control panel. The electrical field between the electrodes and thereby the ESP current and voltages are influenced by the gas composition, temperature and by the electrical properties of the dust, on the contrary a too low voltage will give a low precipitation. MBSPC controls the precipitator power by changing ignition angle of the thyristor [20]. ESP current, ESP voltage and zero crossing point of the primary voltage are used as input data. On switching ‘ON’ the T/R set, the MBSPC slowly increases the filter current towards the set current limit. The T/O action over rides the start up time slightly at start. When a spark occurs the set current is reduced to zero and the thyristors are blocked for 20ms. After restart of the thyristors, the current quickly increases to a value which is slightly lower than the current at which the spark occurred. This current decrease is called STEP. After that, the current will rise slowly as per the setting in T-control. The values of S-control and T-control will decide the spark rate.[21][22]

4.4 SPARK RATE

The spark rate is determined by the settings of S-control and T-control. Suppose T-Control is set at 20% which corresponds to 2 minutes, the time required by the rectifier to reach the rated current after a spark, from zero current will be 2 minutes. MBSPC will however increase the current very fast upto S-Control level, and thereafter will follow T-Control. Suppose S-Control is set 5% of the rated current, the time from S-Control break point to next spark will then be 5% of the T-Control time (5% of 2 minutes), that is 6 seconds. If we do not account for the thyristor block time (20mS) then 6 seconds is the statistical interval between sparks in the ESP. thus, to summaries. As S-Control & T-Control are affected neither by the absolute value of current nor of the voltage at which a spark occurs, the spark rate is constant.

4.5 INTERMITTENT CHARGING

To get an effective dust collection, a high voltage is required to give an even and dense ion formation at the emitting electrode. Abnormally high electrical field strength in high resistivity dust layers due to high current on collecting electrodes may cause spurious discharges or back corona to occur. This results in decreased voltage between the electrodes, despite a higher current input. To avoid back corona formation in the collecting electrode a low average current is required.

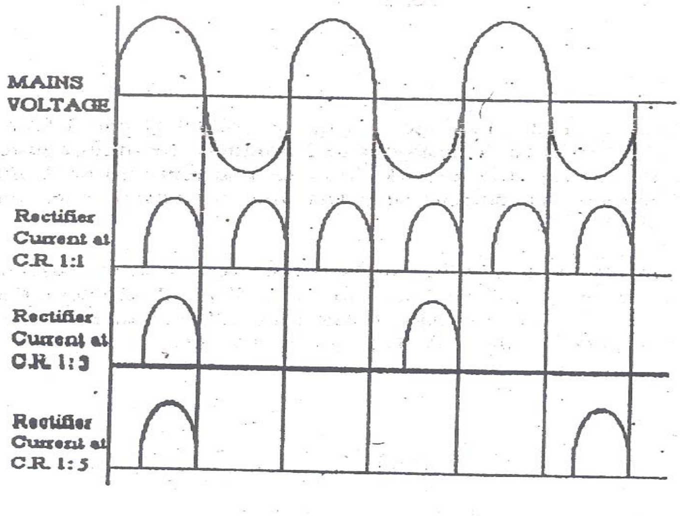


Figure 4.2: Intermittent charging

The intermittent charging mode in the MCB, supplies the current in pulses which provides a dense corona for a short time and at the same time gives a low average current to avoid back corona. Some of half cycles are skipped in the thyristor firing to achieve this. The pulsed current maximum limit is allowed upto 200% of the normal mode current in the ESP, but the average current will be much lower. The longer time between the pulses, the lower the average current.

4.6 CHARGE RATIO OPTIMISATION

With continuously varying conditions of the ESP, it will be very tedious for the operator, to very frequently sot the optimum charge ratio in each field for the entire ESP. The MBSPC does the job systematically & continuously. When optimizer mode is selected, the VI characteristics of the field are studied by the MBSPC and optimum charge ratio is selected automatically. The process is repeated periodically at a preset interval.

4.7 BASE CHARGING

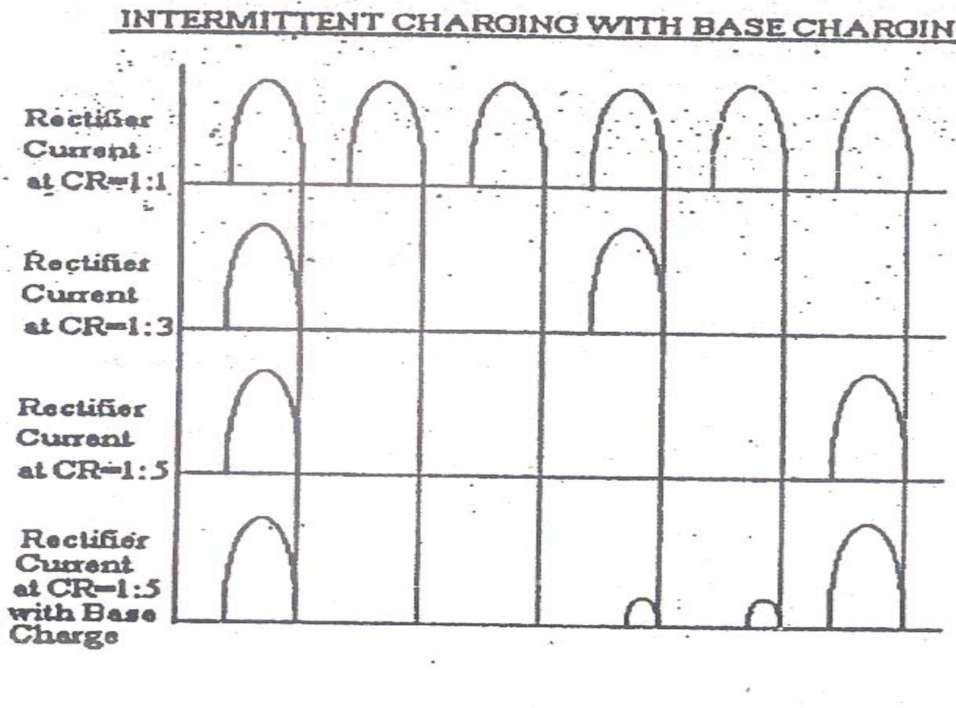


Figure 4.3: Intermittent charging with base charging

In the intermittent charging, the longer the time between each current pulse the lower is the average current as may be required for the high resistive ash. However the ESP valley voltage also reduces pulling down the average voltage. To improve the valley voltage/average voltage small current pulses proportional to operating current pulses are pumped during OFF periods of main current pulses. This maintains the average ESP voltage always near about the best possible voltage, thus the collection efficiency also is further increased. This also protects the T/R set against possible core saturation during higher charge ratios.

CHAPTER-5

PROPOSAL FOR THE RENOVATION OF THE EXISTING ESP UNIT

5.1 WHAT WE REQUIRE TO CHANGE THE EXISTING SYSTEM

5.1.1 FOR ESP (MECHANICAL)

1. Set of casing and hoppers for two numbers extended fields at the front/back of ESP (the extended ESP will become a 7 field ESP in place of 5 field ESP as existing now) with modified inlet/outlet funnel if necessary with 6 mm plate.
2. Set of platforms and staircase for the extended fields of the ESP.
3. Set of insulator housings will insulators (new insulators for new fields) and also replacement of all defective insulators of existing fields.
4. Set of inlet gas distributor (existing ones repaired as required).
5. Set of outlet gas distributor (existing ones repaired as required).
6. Set of emitting system with suspension arrangement, spiral type emitting electrodes, rapping arrangement and geared motor.
7. Set of collecting system with suspension arrangement, collecting electrodes, rapping arrangement and geared motors.
8. Set of outer roof, gas screen for extended field and existing ones repaired as required.
9. Heating elements for shaft insulators.
10. Thermostatically controlled heating elements for support insulators and hoppers.
11. Dust level sensor in each hopper including that of old hoppers.

12. Set of safety interlock (mechanical).
13. 1 lot thermal insulation and cladding for the extended fields.
14. New support columns with structure & foundation bolts for extended fields.
15. New heaters and thermostats for defective ones in all existing hoppers. New heater and thermostat are to be supplied for new hoppers.
16. Replacements for all damaged insulators.

17. Monorail system with handling equipment for TR sets for lowering to ground level. Existing system can be utilized with required modification to make it suit the retrofitted seven filed ESP.

5.1.2 FOR ESP (ELECTRICAL)

Rectification / modification of the existing BHEL make ESP after providing new microprocessor based controller so as to achieve the stack emission level of 90 mg/Nm^3 or less for new design boiler.

1. 14 nos microprocessor based controller to be provided. The existing panel shall be modified / extended as required to accommodate the controllers. Making the system complete in all respects.
2. 4 nos new TR sets compatible with new microprocessor based controller existing 10 nos TR sets are also to be hooked up with new controllers.
3. Modification / extension of the old LT switchgear and panels to suit the new requirement will be also in scope.
4. Control of the rapping motors is to be done from new controller.
5. For extended fields, new cables for TR sets, rapping motors, heaters, thermostat etc and addition / extension of new cable tray to suit the requirement.
6. Necessary amendments / modifications to the existing switchgear
7. And control room building to accommodate the new panels.

5.2 EQUIPMENT DESCRIPTION

System of Power Plant is provided with a horizontal, dry type Electrostatic Precipitator having one steel casing Gases from the system are directed into the ESP through inlet funnels and the cleaned gases at the ESP exit are directed to the ID fans and stack through outlet funnels. Each ESP is equipped with 7 electrical fields lengthwise (effective length and height of each field is 3.75m and 12.5 m respectively) and electrical Bus section widthwise thus providing 7 electrically separated Bus Sections each served by 1 HV Transformer Rectifier Set. An SCA of 66 m^2 /m^3 /s is provided in 400 mm Collecting Electrode spacing for all fields in Guarantee Point condition. Each ESP is provided with 14 Dust Collecting hoppers. A system of platforms and stairs are provided for easy access to all parts of the ESP.

1. Casing

The precipitator casing is designed for horizontal gas flow.The casing is an all-welded steel construction, assembled from pre fabricated waif and roof panels. The Casing walls are made out of 6 mm thick steel plate suitably reinforced with stiffeners. The casing design philosophy ensures that movements caused by gas pressure, temperature and wind load are minimised. Access doors are provided at all strategic locations (suitably protected with a key interlock system) so that all internal parts can be approached for inspection and maintenance.

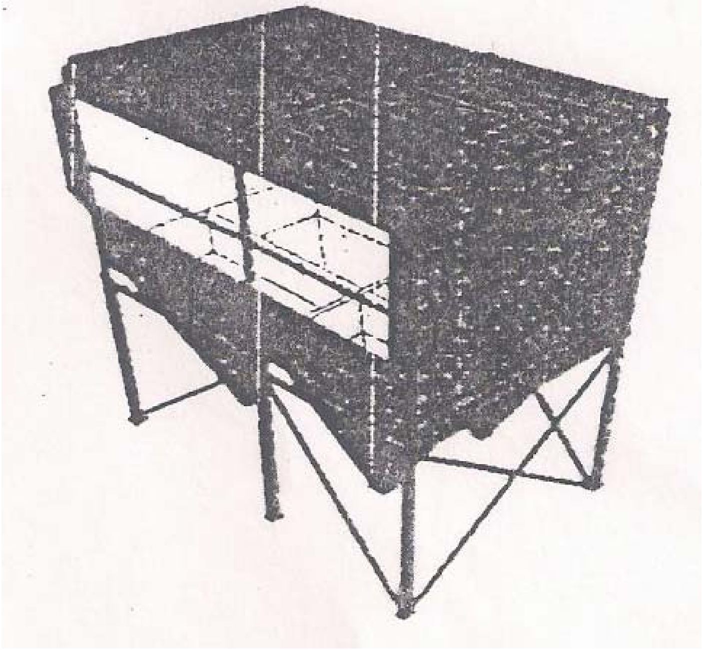


Figure 5.1: The Electrostatic Precipitator Design with support structure

2. ESP Roof

The ESP roof is a double wall construction with an inner roof (hot roof), reinforced design supported by transverse beams. There is also an outer roof (cold roof) covered with MS & chequered plate. Thermal insulation is provided between the inner and outer roof so that maintenance personnel can walk on the outer roof surface.

3. Monorail with Chain Pulley block:

Several equipments such as Transformer Rectifier units, Support Insulators and Insulator Compartment etc. are installed on the ESP roof. Monorail and Chain pulley block is provided to facilitate TR handling from ground level.

4. Slide Bearings

To compensate for expansion of the casing due to heat, the casing is supported by self aligning slide bearings at the point of contact between the casing and ESP Support Structure.

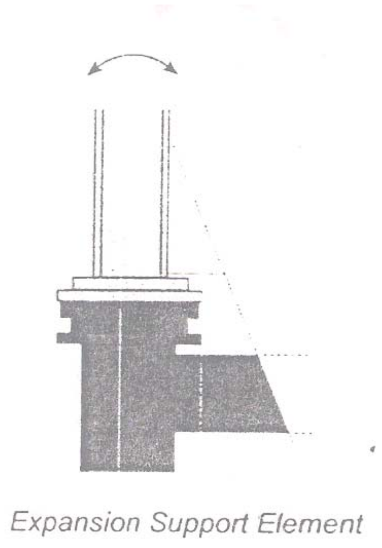


Figure 5.2: Expansion support element

5. Hoppers

Each Electrostatic Precipitator is equipped with 14 nos conical hoppers. The valley angles of the hoppers are maintained to ensure easy flow of dust. The hoppers shall have minimum plate thickness of 6mm and shall be structurally designed to handle the load imposed by dust handling equipment and piping.

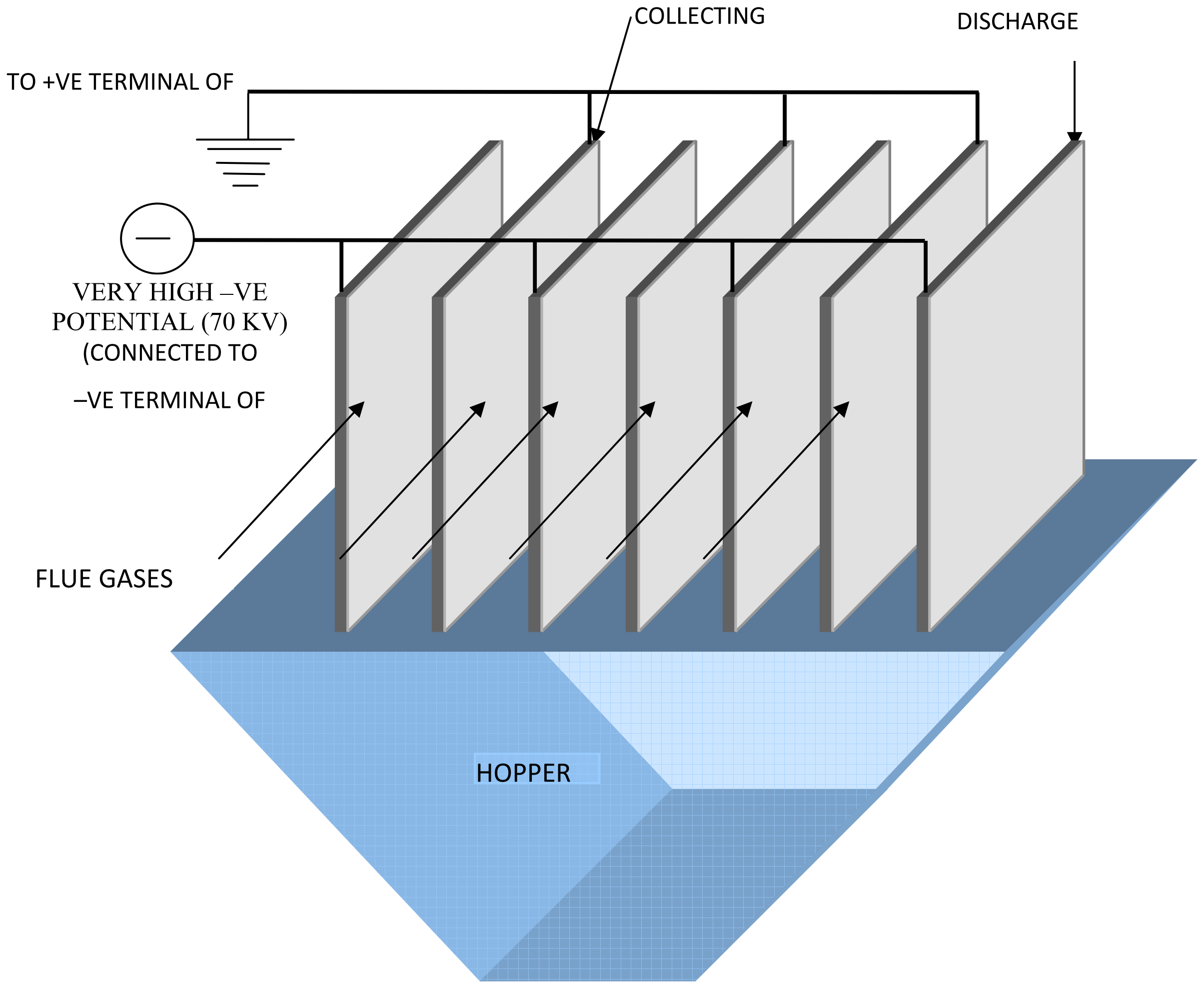


Figure 5.3: Hoppers

To stop gas for bypassing the effective electrical field elaborate covers / baffle plates are arranged on either side of the field with casing wall as well in hopper at the bottom of the field. Hopper being a vast empty area, the possibility of gas leakage through the underside of the field is maximum. To stop the leakage double layer of gas screen plates are provided at the bottom of each field. The upper portion of two adjacent hoppers is suitably reinforced to support adjacent hoppers across the precipitator width. The lower portion of the hoppers are provided with electrical heating system with thermostatic control to prevent bridge formation in the inside face of the hopper plate. Suitable jacketing end insulation is provided to prevent loss of heat in the hoppers. Each dust hopper is provided with high dust level monitoring system operating on Radio frequency principle. The level monitoring system includes its normal accessories like level switch, local & remote signaling lamps.

6. Inlet and Outlet Connections

Each Electrostatic Precipitator is connected to the ducts at inlet and outlet through inlet/outlet funnels made out of 6mm thick steel plates and adequate reinforcements. One inlet/outlet funnels are provided for the precipitator.

7. Insulation & Lagging

The entire outer casing of the ESP including inlet/outlet funnels and hoppers, but excluding the outer roof (steel plate cold roof which has internal insulation) shall be insulated with Mineral Wool and covered with plain Aluminum lagging for personnel protection and to prevent cooling below accepted temperature levels.

8. Platforms and Stairs

Each ESP is provided with access platforms at the rapper and hopper levels to allow easy access to all maintenance areas. Access to the platforms and roof is provided through one common stair case/tower.

9. Gas Distribution Screen

The gas velocity inside the ESP is much less than that in the ducting before the precipitator. It is therefore essential that special arrangement be made to get a uniform velocity distribution over the entire cross section of ESP. A good distribution cannot be obtained solely through the design of the inlet funnel.

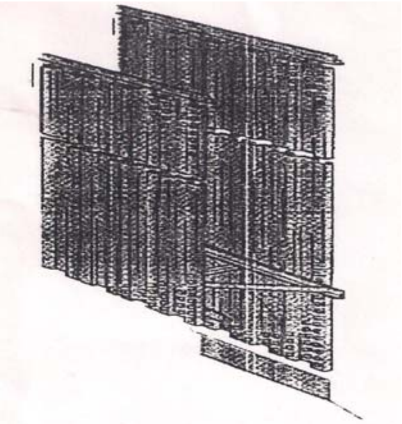


Figure 5.4 : Gas distribution screen

A special gas distribution device is therefore located at the inlet of the precipitator. This device consists of three rows of perforated modular designed screen plates hung within a framework in the casing inlet. The gas flow pattern within the ESP is checked prior to the commissioning and additional deflector added on the screens if required.It may be necessary, depending on the type of dust, to install rapping mechanism for keeping the gas distribution clean.

10. Insulator Housing

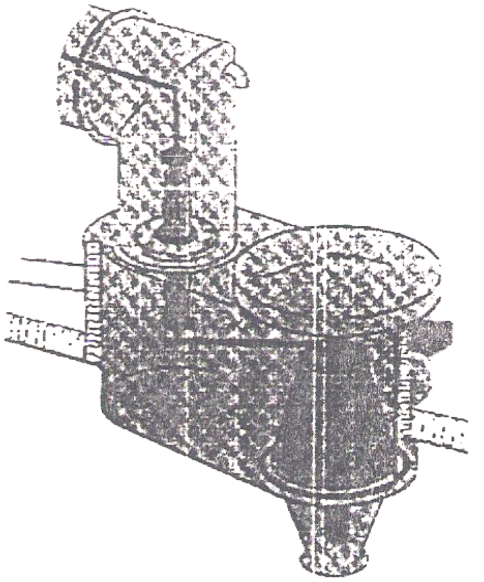


Figure 5.5: Insulator housing

Each electric bus section is supported from insulators located in insulated compartments. The compartments are provided with top opening covers for easy access to the insulators for inspection and service. A special tooling arrangement for each insulator compartment makes it possible to suspend the emitting system from a temporary jacking hook if the insulator must be changed. A screen tube is installed immediately below and in connection with the support insulator, which prevents fouling of the insulator by dust. Each bus section is equipped with four Support Insulators each associated with a 1 KW tubular coil type heating elements. Each heater wraps each insulator to provide uniform heating within the chamber. These heaters heat the air space inside the insulator compartment and in turn prevent condensation and deposition of moisture on the insulator.

11. Emitting & Collecting System Suspension Arrangement

The Emitting and Collecting Electrode System are suspended from roof beams connected to roof panels. A robust suspension system ensures close tolerance to be maintained in the electrode spacing.

12. Emitting System

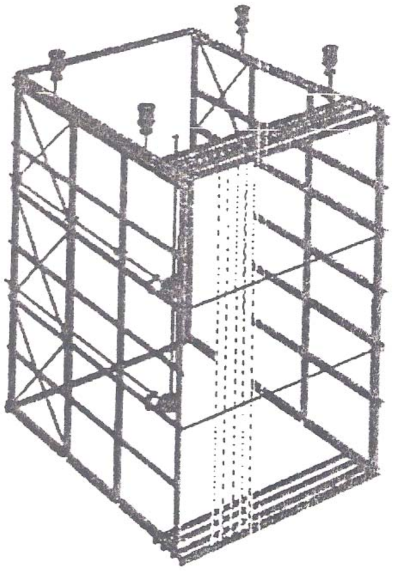


Figure 5.6: Emitting system

The entire emitting system is thoroughly braced and forms a rigid box like structure. The frame is assembled, adjusted and welded to its final position inside the casing, which makes it possible to obtain and maintain highly accurate electrode spacing. The framework has a four point suspension effectively taking care of the expansion due to exposure to hot gases inside the ESP. All sharp edges and ends of frame parts are rounded to maintain electrical clearance.

13. Electrodes

Spiral electrode is used from 1.6-rnm diameter steel wire. The electrodes are held between the-frames. After final erection of frames box structures frame is achieved.

14. Emitting Rapping System

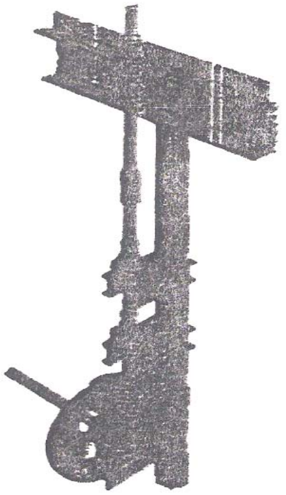


Fig 5.7 Emitting rapping system

During electrostatic precipitation, a fraction of the dust will be collected on the emitting electrodes and the corona will gradually be suppressed as the dust layer grows. The emitting system consisting of tumbling hammers. The hammers hit specially designed shock beams and the vibrations generated are transmitted to the emitting electrodes. One rapping system is provided per electrical bus section.

15. Collecting System

The upper edges of the collecting plates are provided with hooks, which are hung from support angles welded to the roof structure. The collecting plates form a row or curtain for each field. The individual plates are each rigidly connected and secured to a common "shock" bar at the bottom.

16. Collecting Plates

The collecting plates are made out of 1.25 mm thick roiled steel plates.

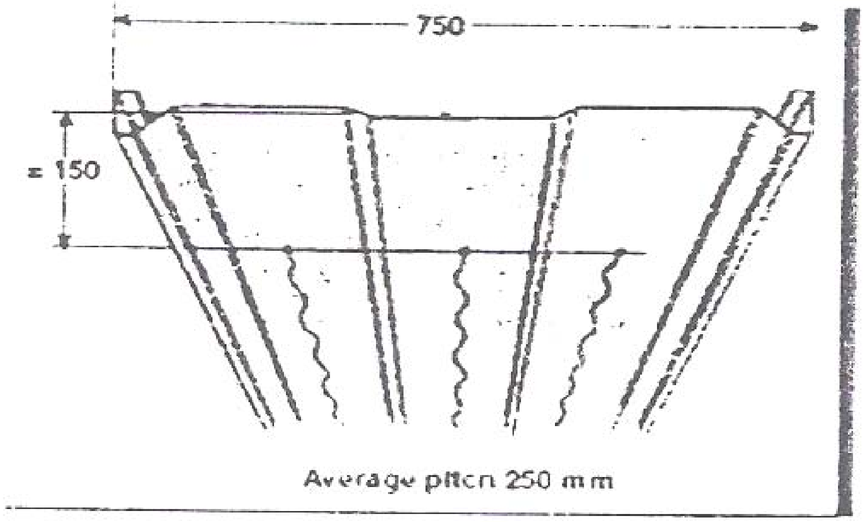


Figure 5.8: Collecting plates

17. Collecting Plate Rapping

A separate hammer of the tumbling type, similar to that used for the discharge electrode rappers each electrode plate. The rapping energy is efficiently distributed to each electrode via the shock bar. The stiffness and the design of the shock bar guarantee that the rapping energy introduced to each electrode row is given the best distribution and without concentration in one singular point. Rapping results into acceleration rather than deflection and therefore the dust cake is not broken, only dislodged and the dust rentrainment is kept low. The rapping frequency should be kept as low as possible in order to minimize the losses from rapping. The frequency of the rapping system is adjustable as the drive units are controlled by MBSPC. One set of rapping mechanism is provided per bus section so that the frequency can be suited to the condition in that individual area. When judging the effectiveness of the collecting system it is also essential to keep in mind the total collecting area being rapped at any one time. The higher the percentage of the total collecting area being rapped at any time, the greater the re-entrainment of dust into the gas. With the design of tumbling rapping mechanism, a very small percentage of the collecting area for each precipitator is rapped at one time. All parts exposed to a rapping and working under extreme conditions i.e. exposed to dynamic loads, high temperatures corrosive environment etc, are considered as critical parts.

18. Power supply to precipitator

A reliable power supply to precipitator is a must for the precipitator to perform at its highest level. This is accomplished through a device called Transformer Rectifier (T / R) unit. The equipment basically consists of a single-phase thyristor AC regulator that controls the primary voltage. The primary low-tension voltage is fed to a high voltage step up single-phase transformer. The secondary AC high voltage of the transformer is rectified by a rectifier to achieve a high voltage DC output. T / R unit is sized to get the required current density to create corona discharge. In order to reach the specified efficiency, precipitator should be operated at an average current density close to the expected average flash over limit. Each T/R set is always sized for higher output than what corresponds to the average. The rectifier is capable of supplying enough voltage for a certain range of operating conditions. Each T/R set has microprocessor based controller called MBSPC. MBSPC monitors the actual EP current and fires the thyristors at precisely the correct phase angle to maintain the set spark rate or to increase the current to the set current limit if no sparking occurs. Also voltage is monitored. Set points can be adjusted as required and display of data can be seen at the panel.

5.3 DESCRIPTION OF ESP UNIT AFTER RENOVATION

Table- 5.1 Description of ESP unit after renovation

S.NO.	Description	Unit	
1.	**GENERAL (Worst Coal)**		
	Gas flow rate at ESP exit.wet	M^3/sec	90.85
	Operating temperature at ESP inlet	Degree C	145
	Dust load (concentration) at ESP inlet wet	Gm/ NM^3	65.95
	Type of precipitator		FAA-7X375H-96-125A2
	No. of ESP offered per boiler	Nos	Two
	No. of gas path per boiler	Nos	Two
	No. of working field (in series in each gas pass)	Nos	Seven

	Collection efficiency at design condition	%	99.8
	Dust load (concentration) at ESP exit, wet	Mg/NM^3	90
	Pressure drop across ESP for design conditions	Mm WC	25
	Gas velocity at electrode zone on total area	M / sec	0.76
	Treatment time	Secs	34.67
2	**COLLECTING ELECTRODE**		
	No. of rows of collecting electrode per field	Nos	33
	No. of rows for collecting electrode plates in each row per field	Nos	5
	Total no. of collecting plates per boiler	Nos	2310
	Nominal plate height of collecting plate	M	12.50
	Nominal length of collecting plate	M	0.75
	Specific collecting area	M^2/m^3/sec	231.9
3	**EMITTING ELECTRODES**		
	Type		Spiral
	Size		2.7 mm dia
	No. of electrodes in the frame forming one row	Nos.	45
	Total no. of electrodes per boiler	Nos.	20160
	Total length of electrodes per field	Mtr	6000
	Plate and wire spacing	Mm	150/225/225/150
4	**RAPPERS FOR COLLECTING ELECTRODES**		
	Rappers for collecting electrodes		
	Type		Tumbling hammers
	No. of Rappers	Sets	Fourteen
	Rapper size		As per AP standard
	Frequency of rapping	Raps/hr	Field adjustable
	Drive		Motor drive
	Location		Outdoor

5	**RAPPERS FOR EMITTING ELECTRODE**		
	Type		Tumbling hammers
	No. of Rappers	Sets	Fourteen
	Rapper size		
	Frequency of rap	Raps/hr	Field adjustable
	Drive		Motor drive
	Location		Outdoor
6	**HOPPERS**		
	Type		Pyramid
	No. of hoppers	Nos.	28
	Storage capacity of each hopper		Approx 8 hours storage
	Heating		Provided
	Baffling arrangement		Provided
7	**GAS DISTRIBUTION SYSTEM**		
I	INLET		
	Type and quantity		Perforated / 2Set
	Location		Inside ESP at inlet
II	OUTLET		
	Type and quantity		Perforated / 1 set
	Location		Inside ESP at outlet
8	**ELECTRICAL ITEMS**		
8.1	Transformer Rectifier		
	Rating		
	No. of TR units provided	Nos	2(New) / 5(existing)
	Location		ESP Roof
	Capacity of each TR set	KW	
	Output voltage(peak)	KV	70
	Current Rating (mean)	Ma	900(New) /800(Existing)
8.2	Rectifier Control Panel		
	Type of control		Microprocessor based

	Number off		Two(new) /five(existing)
	Location		Control room
8.3	Auxiliary control panel		
	No. off (one par pass)		One
	Equipment controlled		TR, RGM, Heaters
	Location		Control room
8.4	Motors		
I	Rapping Of Emitting Electrodes		
	Quantity	Nos	14
	Rating	KW/RPM	037/11
	Location		ESP roof
II	Rapping Of Collecting Electrodes		
	Quantity	Nos	14
	Rating	KW/RPM	0.37/1.1
	Location		ESP Casing side wall
9	**HEATING ELEMENTS**		
9.1	Hoppers		
	No. of heater / hopper	Nos	2
	Capacity of each heater	KW	1.5
	Total KW rating per field	KW	6
9.2	Support Insulator		
	Total no. of support insulator	Nos	56
	Capacity of each heater	KW	1
	Total KW rating	KW	56
9.3	Shaft Insulator		
	Total no. of shaft insulator	Nos.	14
	Capacity of each heater	KW	1
	Total KW rating	Nos	14

5.4 PAY BACK CALCULATIONS

Power consumption of unit-4 (Electronic Controllers) = 180 kw
Power consumption of unit-4 after installing Microprocessor
based semi pulse controllers = 50 kw
Power saved (180 kw – 50kw) = 130 kw
Saving in KWH per year (130 x 24 x 365) x 0.75(PLF) = 854100
In terms of money (854100 x 2) = Rs. 1708200/-
Saving in 3 years (1708200 x 3) = Rs. 5124600/-
Cost of the equipment = Rs. 50 lac
So the cost will be recovered within the period of less then 3 years.

5.5 ADVANTAGES OF THE NEW SYSTEM

1. Auxilary power consumption or power saving to the tune of 72%
2. Efficency shall be much higher.
3. Environment hazard will be reduced.
4. With hourly saving of about 130 kwh the cost of modification is recoverable within about two and half years in the form of saving in power.

CHAPTER-6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

An electrostatic precipitator is electrical equipment where a DC voltage is imparted, through emitting electrode creating an electrical field around it. Dust particles carried by the gas, while passing through the field is charged to saturation and migrate towards the collecting electrode, usually in the form of plate curtain, where they are deposited in layers. By suitable rapping dust is dislodged into the hopper. At present at GNDTP Bathinda, ESP Unit no.4, Electronic controllers are installed. The major drawbacks of existing system are:

1. The basic problem of electronic controllers is that current remains very high even when it is not required, causing huge power loss.
2. The pollution control board of the Punjab govt. has specified an emission level of 90 mg/NM^3 from the chimney. But with the existing system, stack emission level is 300 mg/NM^3.
3. Total plate area is insufficient to cope up with the dust concentration in the flue gases.
4. In existing system detection of back corona is not possible, which affects the efficiency.
5. As the system is not computerized, control is sluggish.
6. Spark rate control is not effective.
7. Charge ratio selection is not possible.

Keeping in view the above mentioned drawbacks, renovation of existing ESP unit is proposed by replacing electronic controllers with microprocessor based semi pulse controllers. MBSPC monitors the actual EP current and fires the thyristors at precisely the correct phase angle to maintain the set spark rate or to increase the current to the set current limit if no sparking occurs. Also voltage is monitored. Set points can be adjusted as required and display of data can be seen at the panel.

Advantages of MBSPC are described below:

1. Auxilary power consumption or power saving to the tune of 72%
2. Efficency shall be much higher.
3. Environment hazard will be reduced.
4. Cost of renovation is nearly about Rs. 50 lac.With hourly saving of about 130 kwh the cost of modification is recoverable within about two and half years in the form of saving in power.

6.2 FUTURE SCOPE

Zhao Fu [18] proves that electrostatic precipitators using DC power supply can save much more electrical energy than those using rectified AC power supply. For future work, we can use pure DC supply in place of rectified AC supply, for more power saving. We can also improve the efficiency of the electrostatic precipitators by using IGBT inverter technology [23].

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