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Pollution Control in Coal Fired Thermal Power Plant Flue Gas Desulfrisation System Technology Analyis and Selection

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Abstract--- *The Fossil fuels (Coal) used in thermal power plants contain significant amounts of sulfur. At burning, about 95% of the sulfur is converted to sulfur dioxide (SO2), which reacts with the particles of water in the atmosphere, forming acid rain under normal conditions of temperature and pressure. Sulfur dioxide, through its annual emissions, is the main gas pollutant. The flue gas desulphurization can be done both by wet or dry process. The most used process is wet desulphurization of limestone or lime, accounting for about 80% of all desulphurization processes. The paper presents the current Norms technology in FGD for SOX in the world, their advantages and disadvantages analysis, as well as the future trends and selection of optimal technology.*

Keywords--- *Pollution Control, System Technology, Plant Flue Gas, Analyis and Selection.*

I. INTRODUCTION

Combustion of fossil fuels leads to discharging into the atmosphere significant volumes of gaseous sulphur oxides. Sulphur dioxide is a major pollutant and have a significant impact on human health. High concentrations of sulphur dioxide in atmosphere can influence the flora and fauna. Moreover, SO2 emissions represent a precursor for acid rain. As the flue gas desulphurization (FGD) technology advanced in time, some processes were removed from the market because of economic and technical others developed, becoming more mature, fact proven through a higher efficiency rate of desulphurization, the use on a large scale and a simplified technological process reasons, while some others developed, becoming more mature, fact proven through: a higher efficiency rate of desulphurization, the use on a large scale and a simplified technological process. If the beginnings of desulphurization found in the first development line countries like USA, UK, Germany, Japan, after the 90's a lot of developing countries (especially Asian ones) started research and application on desulphurization processes.

Analysis and study of Emission Norms and FGD Technologies

The Indian Government (MOEF &CC) prescribed new norms 2015 for Thermal power plant units before installed December 2003 are presented in table 1.

Table 1

Sl.No.	Parameters	Standards less than
1	Particulate Matter (PM)	100 mg/ Nm^3
2	Sulphur Dioxide ($SO_{2)}$	600 mg/ Nm^3
3.	Nitrogen Oxides(Nox)	600 mg/ Nm^3

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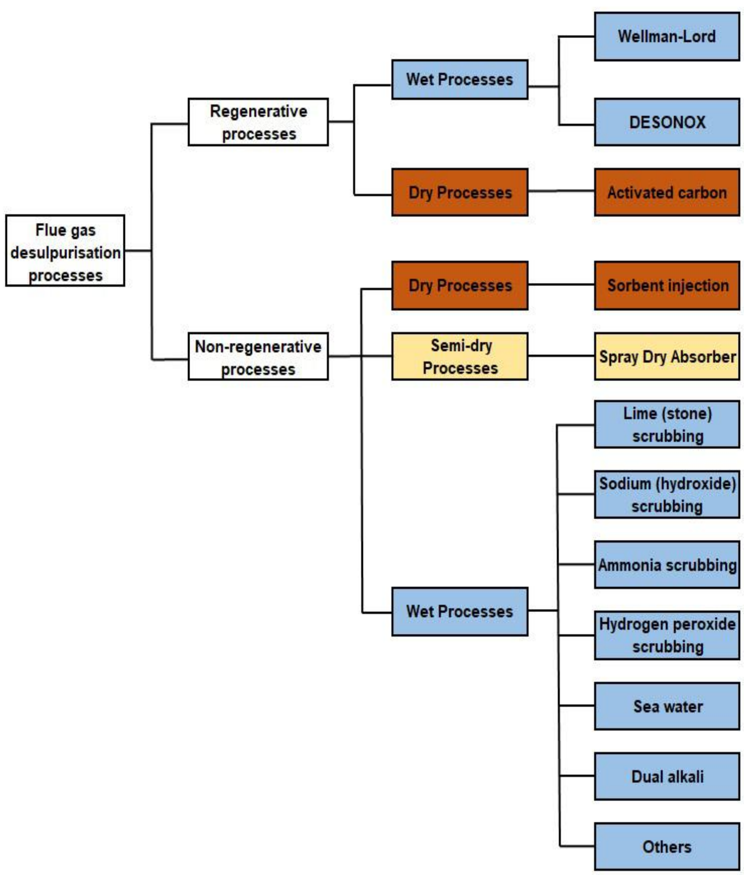
Desulphurization process removes sulphur or sulphur based components from solids, liquids and gases. Most of all, desulphurization refers to removing sulphur oxides from flue gas. Desulphurization is necessary because of environmental regulations regarding SO2 emissions. Depending on the final co-product, FGD processes are divided into those whose co-product is disposed on landfill, and those with a commercially useful co-product. Environmental requirements imposed by the current legislation led to research regarding valorisation of waste from thermal power plants (synthetic gypsum and ash). A field with large valorisation possibilities of these waste is represented by the construction materials. In almost all FGD systems, SO2 is extracted from flue gas through a reaction with an alkaline substance to produce sulphite or sulphate. FGD process is based on the contact of the flue gas with an absorbing substance (absorbent/reactive) that reacts and/or absorbs SO2 and other acid gases (SO3, HCl, HF). Based on the scientific literature, FGD technologies can be classified in regenerative and non-regenerative (one pass). Regenerative processes – the used absorbent is recycled after thermal or chemical treatment generating concentrated SO2, that is further transformed, usually, in elementary sulphur. These complex processes need high investment costs and a higher energy consumption during exploitation. These processes are not used on a large scale for FGD mainly because of the costs and very low commercial value of sulphur.

Non-regenerative processes (one pass) – the absorbent is not recycled. During time these were and are the most used FGD technologies at industrial scale. Depending on the aggregation state of the used absorbent, FGD technologies can be classified as:



- Wet processes (suspension or solution; the discharged gases are water saturated);
- Semi-dry processes (controlled humidification, the wet absorbent becomes solid in SO2 absorption process);
- Dry processes (water is not used at all, zero humidification).

A classification of desulphurization processes can be seen in Figure 1, being based on the most common processes used on industrial scale.

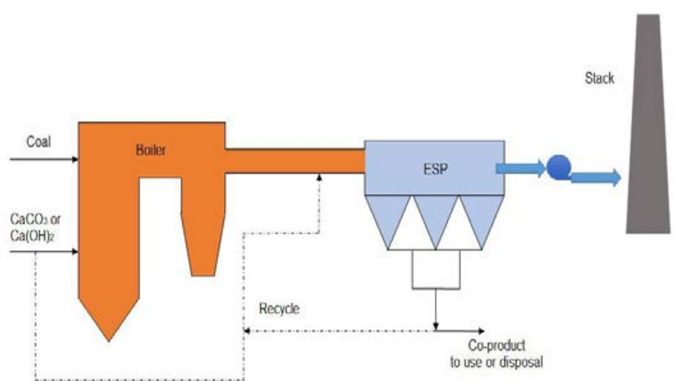
Dry process

Sorbent Injection (SI). In the case of dry systems (Fig. 2) with alkaline absorbent compounds, these are either injected in the gas flow, or the gas flow is passed through an absorbent layer. Typical sorbents include sprayed calcium carbonate ($CaCO_3$) and dolomite ($CaCO_3 \cdot MgCO_3$). In the burning point, heat addition determines the generation reactive particles of CaO through sorbent calcination. The surface of these particles reacts with SO_2 in the gas flow to form calcium sulphite ($CaSO_3$) and calcium sulphate ($CaSO_4$). Reaction products are further retained together with the flying ash by the control device of micro particles, usually an an electrostatic precipitator (ESP) or a fabric filter (FF). The dry system] depends mostly on the adsorbent that can be very fine or very porous. The reactions of SO_2 removal through sorbent injection in the burning point are as follows:

$CaCO_3$ + heat → CaO + CO_2 or $Ca(OH)_2$ + heat →CaO + H_2O

CaO + SO_2 +½ O_2 → $CaSO_3$ + heat

Taking into consideration the characteristics of this process, industrial use of dry technology is not very widespread and its applications are limited. Depending on the supply point of alkaline substance, different types of reagents can be used (limestone, lime or hydrated lime). As it was shown in , lime/gypsum (L/G) molar ratios are higher, fact that leads to a low desulphurization efficiency. That is why desulphurization installations through dry process are decreasing, especially because of worldwide stricter environmental legislation.



Typical dry FGD process.

However, lately dry process developed as reduction process for multiple pollutants (SO_3, HCl, HF and Hg), thus becoming an alternative to the wet process for thermal power plants and other steel and iron manufacturing plants.

Semi-dry processes are similar to the dry ones , except that water is added to create a thin liquid layer on the adsorbent particles, in which SO_2 is dissolved, thus enhancing the reaction with the solid. Solid product is collected

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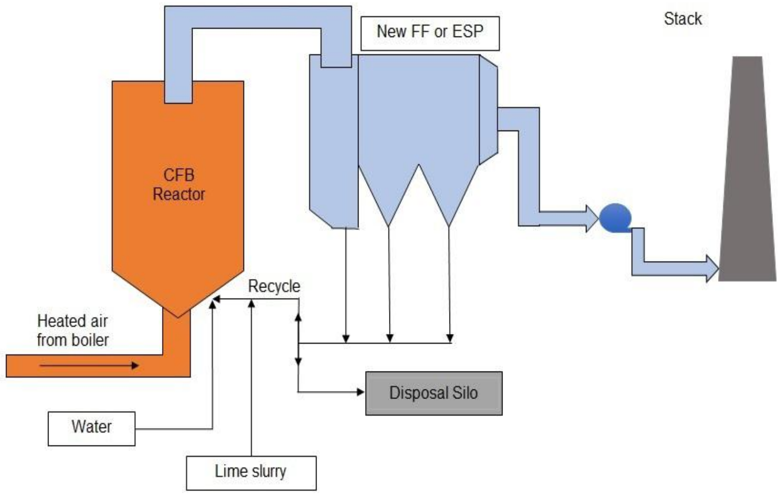
in dust collection equipment in order to be sold or stored. The most known semi-dry processes are CDS (Circulating Dry Scrubber, also known as CFB - Circulating Fluidized Bed) and SDA (Spray Dry Abortion).



CDS Process (Circulating Dry Scrubber)

CFB (Circulating Fluidized Bed). CDS is a semi-dry FGD process in which flue gas is passed through a mixture of lime(stone), products of reaction and fly ash (depending on the location of the filling) on a CFB (Fig. 3). SO2 is extracted in a proportion of up to 99%, all SO3 and HCl being also extracted. CFB semi-dry process is a relatively simple technology, limestone or hydrated lime being usually used as adsorbent in CFB process and injected at the reactor base. Water is also added to moist the flue gas, thus improving SO2 and macro particles extraction. The reactions that take place in the CFB process when limestone is used are presented as follows.

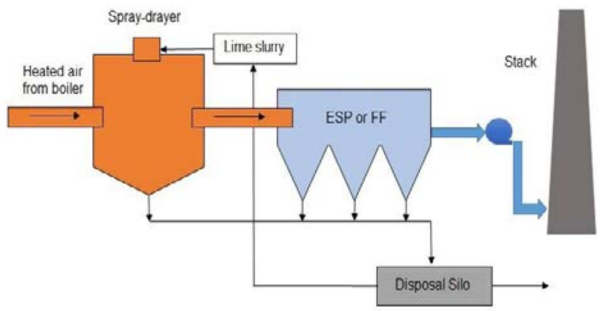
$$CaCO3 \rightarrow CaO + CO2$$

$$CaO+ \frac{1}{2}O2 + SO2 \rightarrow CaSO4$$

CFB semi-dry process has almost unlimited turndown capability and is flexible regarding rapid changes in inlet SO2 concentrations. Operational costs of CFB process are relatively high Compared with wet LSFO (forced oxidation of limestone) process, CFB process has lower investment costs, and compared with semi-dry SDA process, investment costs are approximately at the same level.

The flue gas enters through the bottom of the venturi shaped absorber and the acid gases such as SO3, SO2, HCl, HF and partially CO2 are removed by hydrated lime. The optimal reaction temperature, which is 20 to 30 °C above the wet bulb temperature, is achieved by water injection directly into the bottom of the fluidized bed. The reaction products are entrained to the top of the absorber and collected in the downstream precipitator, which may be a fabric filter (FF) or an electrostatic precipitator (ESP) without any difference in desulphurization efficiency. The characteristic of this process is represented by the venturi section, where the flue gas acceleration takes place. In the last years design changes have been successfully implemented for the venturi section and water injection system , for significantly decreasing consumption of lime suspension.

SDA process - Spray dry absorption. Concentrated lime paste is injected in flue gases in order to extract SO2, SO3 and HCl. The chemical reactions that take place in the semi-drying process with spraying are similar with the ones from the CFB process and the final product is a dry dusty mixture of calcium components that needs storage (Fig. 4).



Low use of SDA process, compared with CFB process, is due to higher operational costs because of higher use of adsorbent and of product storage costs.

Although semi dry process are less used compared to the wet ones, SDA and CDS processes present many advantages than LSFO wet process: consumption with approximately 60% less water, lower space for installation, lower auxiliary energy consumption, lower investment costs, higher efficiency of SO3, HCl, Hg and other acid gases removal. Regarding the disadvantages of semi-dry processes, we observe: lower efficiency of removal SO2 emissions, although modern CDS systems can reach a 98% efficiency ; lack of a selling co-product; higher operation costs because of reagents used and maintenance costs for dust removal equipment.

Wet process

General technologies of FGD using wet processes need an alkaline reaction agent (limestone, lime, caustic soda, ammonia, sea water). The most known wet desulphurization processes are: forced oxidation of limestone - LSFO (L/G), (W-L), (MEL) process, seawater FGD and ammonia process.

Limestone forced oxidation (LSFO or L/G – Limestone/gypsum process). Even from the ’80s, LSFO is the top technology in flue gas desulphurization through wet process , as well as in general. In LSFO process (Fig. 5), known as L/G process limestone/gypsum), flue gases pass through a heat exchanger and enter in FGD scrubber where SO2 is removed through direct contact with a dense aqueous limestone suspension, in which limestone must contain more than 95% CaCO3. In the absorption installation fresh limestone suspension is continuously introduced. Moreover, at this process all HCl that exists in flue gas is extracted. Clean gas leaves the absorbent layer through moist eliminator and then is discharged through the stack. For a higher efficiency of mist removal, good washing techniques are needed and a lower flue gas speed than their critical speed. The reaction products are extracted from the absorption installation and transferred for dehydration and further processing. Residence time of limestone solution in the scrubber tower is generally 3-5 min.

A basic process and possible alternative in selecting the technological process is the oxidation of calcium sulphite or bisulphite (generated in SO2 reaction with limestone/limestone). This can be produced through forced

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oxidation or through natural oxidation. Oxidation conditions have an important influence on the quality of resulted co-product.

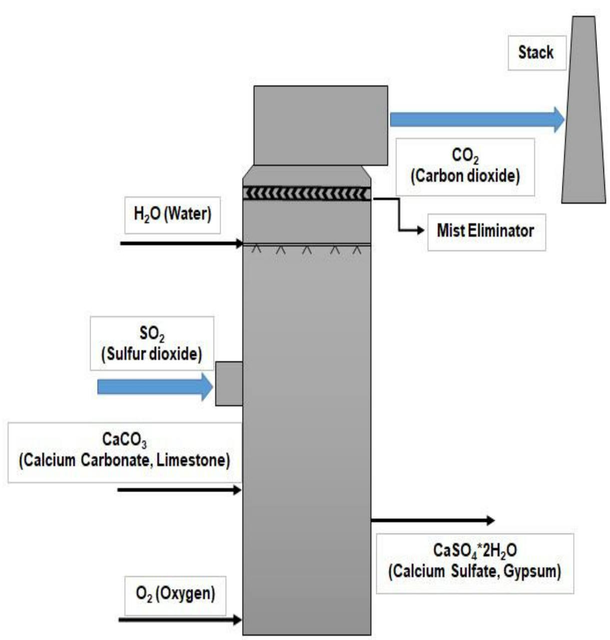
The most used absorbent is limestone because of its wide availability and low price. Limestone properties have an important influence on the efficiency of FGD system in general and on the scrubber performance in particular: high content of calcium carbonate; low content of Al, F and Cl; reactivity (dolomite fraction); size distribution. Lime can also be used (MEL process), but it presents the risk of carbonation. Adsorption yield of SO2 is the same. From the wet technology, gypsum sludge or calcium sulphate /sulphite mixture and flying ash (from thermal power plant) results.

The quality of co-product depends on the type of oxidation. Wet scrubber technology with lime/limestone needs big land surfaces for disposal of sludge. If the quality of the gypsum is good, then the co-product is marketable. If the gypsum contains big quantities of fly ash or sulphite, it cannot be used and it must be disposed at an appropriate (non-hazardous waste) landfill.

Calcium sulphite is oxidized by the air injected in the scrubber, dehydration is easy because the gypsum crystals are relatively big. Primary dehydration is done usually in hydro cyclones being followed by a secondary dehydration in filters or centrifuge. The final product, that contains approximately 90% solids, is easy to handle and easy to sell especially like gypsum for plaster, cement, gypsum-board manufacturing, replacing natural gypsum. Basic chemical reactions in case of this process are presented below.

$$CaCO3 + SO2 \rightarrow CaSO3 + CO2$$

$$CaSO3+O2+2H2O\rightarrow aSO4*2H2O$$



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Efficiency and co-products

Efficiency of SO2 removal in a FGD installation can be characterized through “desulphurization rate” (or “desulphurization efficiency”) that means ratio between sulphur amount that is no longer generated (as SO2) into the atmosphere by a combustion installation in a certain period of time and the sulphur amount contained in the solid fuel introduced in the combustion installation and that is used in the installation in the same period of time. When choosing a desulphurization technology, it is necessary to take into consideration technical (desulphurization efficiency and reliability).

	Dry	Semi-Dry	Wet
Characteristics	Dry powder-Reactor-Dry powder	Slurry or solution-Reactor-Dry Powder	Slurry or solution-Reactor-Slurry or solution
Main reactor	Dry Injector	Semi Dry Reactor	Wet Scrubber
Application		Small / Medium scale	Large scale
Agents		Mg, Ca, Na compounds	Ca, Mg, Na compounds
Coal % Sulfur preference		<3%	>3%
Removal efficiency	up to 95%	up to 98%	up to 99%
Water usage	Minimum	Medium	High
Waste water treatment		Unnecessary	Necessary
Byproduct	Calcium sulfite and sulfate		Gypsum, Ammonium Sulfate, Sodium Bisulfite
Operation cost	High	Medium	Low

The quality of FGD co-products (Table 2) is heavily correlated with coal quality and with desulphurization techniques used. The co-products from dry or semi-dry desulphurization process are in majority of cases dry, meaning easier to handle and store compared to the ones that are generated by the wet process. Most often we can encounter these co-products in construction materials manufacturing, mine applications, highway building or agriculture.

Desulphurization installations with seawater have the same efficiency as LSFO.

II. THE FUTURE TREND AND SELECTION OFFGD SYSTEM

A new development in FGD technology for power plants located along the coast has been the utilization of seawater from the plant’s cooling system to scrub SO2 from flue gas. Dating back to the early 1970s, research conducted at the University of California, Berkeley, showed the feasibility of using seawater to absorb SO2 from stack gas . In Japan, the seawater FGD process was first installed in 1978 at a chemicals-processing plant. This plant reused seawater from the production line of a factory. The effluent was neutral-ized with magnesium hydroxide prior to its discharge. A seawater FGD system was also utilized at a refinery plant in Norway in 1988.

Despite being a promising technology, the U.S. Envi-ronmental Protection Agency (EPA) reported that, in 1998, seawater FGD systems installed worldwide accounted for only 0.6% of the total systems in use . Current development of seawater FGD is still focused on maximizing its performance as well as minimizing its costs. Basically, this development involves simpler design and improved operation. Major constituents of seawater (salinity » 3.5%).

Constituent (as Dissolved Ion)	Conc. in Seawater (g/kg)
Chloride	19.35
Sodium	10.76
Sulfate	2.71
Magnesium	1.29
Calcium	0.411
Potassium	0.399
Bicarbonate	0.142
Bromide	0.067
Strontium	0.008
Boron	0.0045
Fluoride	0.0013

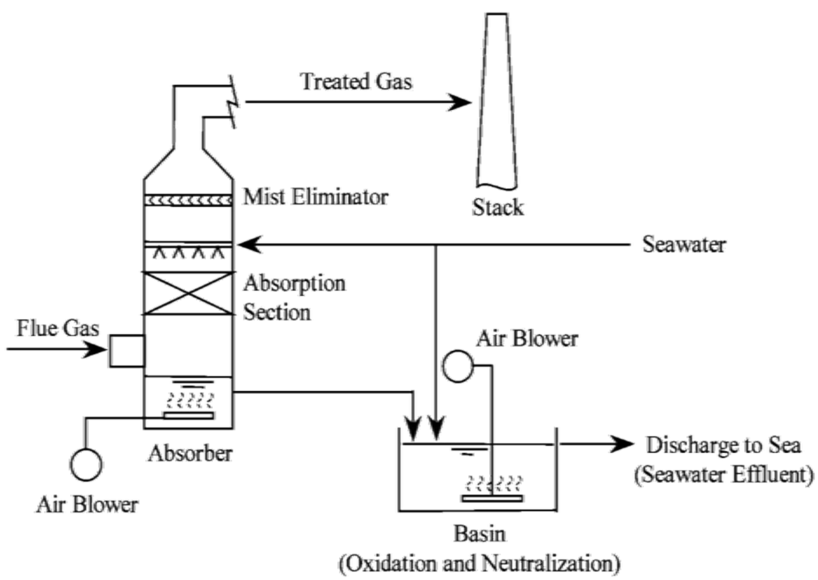

Figure 1: Sea Water Based Flue Gas De Sulfrisation System

Seawater is normally used as a medium in the cool-ing systems of power plants located along the coast. It has a typical pH of 7.6 to 8.4, with an alkalinity of approximately 100-110 mg/l as CaCO3. The natural alkalinity of seawater, in terms of carbonate ions (CO3) and bicarbonate ions (HCO3), can be employed to neutralize acidified seawater resulting from scrubbing flue gas. The major constituents of sea-water are shown in Table 1. Every ton of seawater con-tains approximately 0.9 kg of sulfur, which is an essen-tial substance to the marine environment.

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Figure 1 shows a simplified schematic diagram of a seawater FGD system. Flue gas is introduced to an absorber and contacted with seawater. The most com-monly employed flow regime of flue gas and seawater is countercurrent. Scrubbed flue gas then passes through a mist eliminator to prevent carryover of droplets before being released to a stack. The SO2 in flue gas reacts with seawater in the absorption section, which contains either perforated plates or packings to promote vigorous gas-liquid transfer and larger gas-liquid interfacial area, depending on its design.

Figure 2 depicts the chemistry of a seawater FGD system. The chemistry mainly consists of the sulfur-related system (Equations 1 and 2) and the carbonate-related system (Equations 3 and 4). The SO2 in flue gasis absorbed in water to form bisulfite (HSO3), as described in Equation

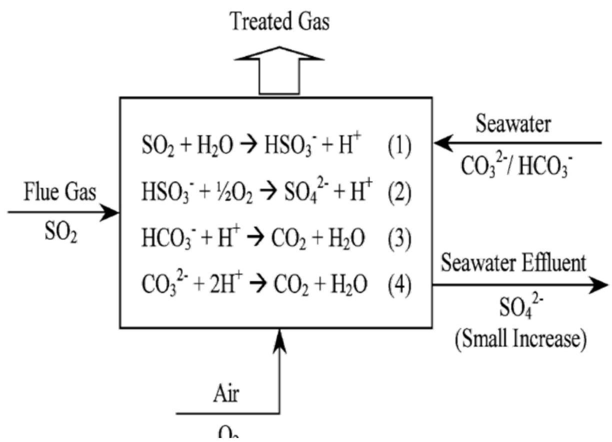

Figure 2

As an alternative for power plants located along the coast, the seawater FGD system offers a simpler alterna-tive to the conventional system, wet limestone processes, in process, design, and operation since it requires no addition of chemicals.

***Implementations and Expected results*.**

North Chennai Thermal Power station is located in Thiruvallur district in Tamil Nadu. The plant is about 25km away from Chennai in the northern side coastal area . There are three units each having a Maximum Continuous Rating of 210MW. So the total capacity of the plant is 3x210MW = 630MW.

The salient features of the project are:

- Date of commissioning : Unit 1- 25/10/94

Unit 2- 27/3/95.

Unit 3- 24/2/96.

- Annual generation : At 80% PLF: 4415MU.

  : At 85% PLF: 4690MU.

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FUEL COAL

- Type: Bituminous coal.
- Linked coalmines: Kalinga mines and Talcher coal mines.
- Gross calorific value: 3855 kcal/kg.
- Quantity required: 2.52 million tones per year.

The average coal consumption of coal per hour is 130 T/Hr (Approx).

Proximate Analysis of Coal on the day of samplingDecember 2018.

Total moisture %	Inherent Moisture	Ash(%)	Volatile matter(%)	Fixed carbon (%)	Gross calorific value(Kcal/Kg)
14.9	6	42.7	22.6	28.7	3664

Flue gas measurements at Unit-I

Load (MW)	Stack temp ·c	Velocity (m/s0	Volumetric flow (Nm3/Hr)	PM mg/Nm3	OO2 mmg/Nm3	Nox mg/Nm3	Oxygen (%)	CCO ppm	CO2(%)
185	130	28	1055199	200	870	890	10.5	95	8.95

It is observed that values of SO2 exceeding the norms. Hence it is necessary to implement the FGD systems to reduce sox level as prescribed level below 600 mg/Nm3.

it is obvious that the seawater FGD system is technically and economically better than the wet limestone system. When planning power plants, site-specific conditions must be taken into account in the selection of the FGD systems. For exam-ple, in terms of the operations, management of very large amount of generated gypsum can be considered a limit-ing factor for the wet limestone FGD system, whereas availability of seawater is a limitation for the seawater FGD system.

Feasibility study and Expected results in North Chennai thermal power plant

The sea water already used in our plant to condensation of stem in to water in condenser in the stem generating cycle.

The condition of Sea water from Condenser Unit-I

Sl.No	Description	Unit	Actual
1.	Sea water from condenser outlet	M 3 /Hr r	33000
2	pH		8.5-8.6
3	Alkalinity	Mg/l as CaCo3	134
4	SS	Mg/l	18-24
5	Temp at condenser outlet	Deg c	36

Sea Water required for FGD Sea water based for unit Unit-I is 9900 M 3 /Hr expected results are tableted below.

Sl.No	Description	Unit	Expected results
1.	Boiler Load	MW	210
2	Type of fuel		Coal
3	Ambient Conditions		
	a.Temp	Deg c	30-45
	b. Relative Humidity	%	90-100
4.	Coal flow	T/Hr	125-170
5	Gas flow at FGD inlet	Nm^3/s	217.5-260
6.	Gas temp at FGD inlet	Deg c	130-145
	Flue gas Composition at FGD inlet		
7.	O2(% Wet)	%	4-4 to 58
8.	Co2	%	13-13.25
9.	H2O	%	8.-8.879
10	SO2	%	0.06-.061
11	N2	%	73-73.24
12	NOX	mg/Nm^3	≤510
13.	Inlet So^2concentration wet	mg/Nm^3	1749
14.	Outlet So^2 concentration dry	mg/Nm^3	≤600

III. CONCLUSIONS

The most of the thermal power plants are situated near the coastal area in TAMILNADU and the availability of lime stone comparatively lesser than the otherstates of INDIA. Hence Utilization of seawater to remove sulfur dioxide from flue gas has technically and economically proven to be a promising alternative to alkaline chemicals for power plants located along the coast.

The seawater FGD systemoffers a number of remarkable advantages, such as the simplicity of the process, design, and operation because no additional chemicals are needed, and no solid wastes are produced. The quality of the seawater effluent can be controlled through the oxidation and neutralization processes.

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