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# Study and Analysis on Emissions of NOx and SOx in Thermal Power Plant

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***Abstract: The présent study deals with the emissions of oxide of nitrogen and sulphur in a thermal power plant at. NTPC, Simhadri Visakhapatnam as these power plant are based on combustion of raw materials for the generation of electricity hence it produces large amount of harmful toxics that are suspended freely into the atmosphere. These fumes contain oxide of Nitrogen and Sulphur (NOx and SOx) which are harmful for the ecosystem and environment.***

***The study included monitoring of pilot Project installed at NTPC Simhadri Visakhapatnam thermal power plant. The detail of SCR model installed at selected power plant where continuous monitoring for 15 days was performed are mentioned in different sections of this research paper. From the experiment the maximum efficiency and the minimum efficiency are depicted in the work also the efficiencies with respect to the temperature fields were also recorded and it was found that the complete setup experiment did not have any effect on sulphur oxides and only the oxide of nitrogen was calibrated hence other techniques can also be further implemented other than SCR technique.***

***Keywords : NOx, SOx, SCR technique, Harmful Toxic, Fumes,Thermal Power Plant etc.***

## I. INTRODUCTION

Thermal power plant or steam power plant is a generating station which converts heat energy of fossil fuels into electrical energy. Generally bituminous, brown or peat type coal are used as the fuel of coal based thermal power plant.

In a thermal power plant, coal is burnt in a big boiler which produces steam at high pressure and temperature. This steam is passed through a steam turbine which converts steam's heat energy into mechanical energy. The steam turbine acts as a prime mover and it is coupled to an alternator. Now alternator collects the mechanical energy from the steam turbine and converts into electrical energy. In this power plant, steam turbine sometimes acts as auxiliary equipment's like pumps, strokes etc.

Though thermal efficiency and overall efficiency of thermal power plant is comparatively less than other power plant like nuclear power plant but still it is very popular. The only reason behind that, is coal. It is very cheap and easily available as well. Still, now maximum energy is supplied by the coal-based thermal power plant.

Fig: 1 Thermal Power Plant (Source: NTPC)

### *A. Boiler And Auxiliaries*

A Boiler or steam generator essentially is a container into which water can be fed and steam can be taken out at desired pressure, temperature and flow. This calls for application of heat on the container. For that the boiler should have a facility to burn a fuel and release the heat. The functions of a boiler thus can be stated as:-

1) To convert chemical energy of the fuel into heat energy
2) To transfer this heat energy to water for evaporation as well to steam for superheating
3) Components Of Boiler
a) Furnace and Burners
b) Steam and Superheating
c) Low temperature super-heater.
d) Platen super-heater
e) Final super-heater

### B. Economiser

It is located below the LPSH in the boiler and above pre heater. It is there to improve the efficiency of boiler by extracting heat from flue gases to heat water and send it to boiler drum.

*1) Advantages of Economiser include*

a) *Fuel economy:* used to save fuel and increase overall efficiency of boiler plant.
b) *Reducing size of boiler:* as the feed water is preheated in the economiser and enter boiler tube at elevated temperature. The heat transfer area required for evaporation reduced considerably.

### C. Air Preheater

The heat carried out with the flue gases coming out of economiser are further utilized for preheating the air before supplying to the combustion chamber. It is necessary equipment for supply of hot air for drying the coal in pulverized fuel systems to facilitate grinding and satisfactory combustion of fuel in the furnace

### D. Reheater

Power plant furnaces may have a reheater section containing tubes heated by hot flue gases outside the tubes. Exhaust steam from the high pressure turbine is rerouted to go inside the reheater tubes to pick up more energy to go drive intermediate or lower pressure turbines.

### E. Steam Turbines

Steam turbines have been used predominantly as prime mover in all thermal power stations. The steam turbines are mainly divided into two groups: -

1) Impulse turbine
2) Impulse-reaction turbine

The turbine generator consists of a series of steam turbines interconnected to each other and a generator on a common shaft. There is a high pressure turbine at one end, followed by an intermediate pressure turbine, two low pressure turbines, and the generator. The steam at high temperature (536 ‘c to 540 ‘c) and pressure (140 to 170 kg/cm2) is expanded in the turbine.

### F. Condenser

The condenser condenses the steam from the exhaust of the turbine into liquid to allow it to be pumped. If the condenser can be made cooler, the pressure of the exhaust steam is reduced and efficiency of the cycle increases. The functions of a condenser are:-

1) To provide lowest economic heat rejection temperature for steam.
2) To convert exhaust steam to water for reserve thus saving on feed water requirement.
3) To introduce make up water.

### G. Boiler Feed Pump

Boiler feed pump is a multi-stage pump provided for pumping feed water to economiser. BFP is the biggest auxiliary equipment after Boiler and Turbine. It consumes about 4 to 5 % of total electricity generation.

### H. Cooling Tower

The cooling tower is a semi-enclosed device for evaporative cooling of water by contact with air. The hot water coming out from the condenser is fed to the tower on the top and allowed to tickle in form of thin sheets or drops. The air flows from bottom of the tower or perpendicular to the direction of water flow and then exhausts to the atmosphere after effective cooling.

The cooling towers are of four types

1) Natural Draft cooling tower

2) Forced Draft cooling tower
3) Induced Draft cooling tower
4) Balanced Draft cooling tower

## II. LITERATURE REVIEW

Mohaddeseh Azimi et al 2018 [1] investigates inequality in SO2 and NOX emissions, by observing their extraordinary levels and uneven distribution in China during the period of the 11th and 12th Five-Year Plans (FYPs, 2006–2015). This provincial and regional analysis utilizing the Theil index and Kaya factors help us to find the trajectory of inequality and its primary sources. Based on our analysis, we conclude the driving factors behind emissions inequalities are as follows. There are four economic factors of per capita SO2 emission: SO2 emission intensity of coal consumption, coal intensity of power generation, power intensity of GDP, and per capita GDP. Additionally, there are four urban development factors of per capita NOX emission: NOX emission intensity of gasoline consumption, proportion of gasoline vehicles, vehicle use in urban population, and urbanization rate.

Xiang GAO et al 2018 [2] explained the case of combustion, where several toxic substance emissions such as sulfur dioxide (SO2) and nitrogen oxides (NOx) have been severely limited to very small values. To protect the environment from the adverse effects of emissions, many countries worldwide have adopted legislation to regulate various types of pollution as well as to alleviate their adverse effects. Both combustion modifications and after-treatment strategies have been employed to achieve the goal of emission control. During this process, various innovative methods have been invented and put into practice. For example, wet flue gas desulfurization (WFGD) can convert over 98% gaseous SO2 into solid CaSO4 while selective catalytic reduction (SCR) reduces gaseous NOx by NH3 to form water and nitrogen. Author in his work sincerely hope the most up-to-date view and outlook of the field that is shared in this special issue will move the research frontier forward, improve the understanding of air pollutant control technologies and strategies, as well as preserve existing know-how.

Muhammad Ehsan 2017 [3] revealed that due to high energy generation potential, coal is widely used in power generation in different countries. Although, the presence of carbon, hydrogen and sulfur in coal facilitates the energy generation in coal combustion, some pollutants including COx, SOx, NOx, particulate matter (PM) and heavy metals are accumulated in air and water and lead to severe environmental and health impacts as a result of leaching, volatilization, melting, decomposition, oxidation, hydration and other chemical reactions. In addition, fly ash, in both wet and dry forms, is mobilized and induces severe impacts including bone deformities and kidney dysfunction, particularly with exposure of radionuclides. This review will cover the impact of these major pollutants (including COx, SOx, NOx, PM, and heavy metals (traces)) on human health and the environment. Given the lack of adequate data about the cumulative health based impacts of these pollutants from coal combustion, this review can be used as a significant tool to further explore disease-association risks and design standard management protocols to overcome coal associated health and environmental assaults.

Shahzad Baig et. al 2017 [4] Most of the people in this world are concerned about the environmental impacts of coal based power plants. Coal fired power plants are one of the sources of SOx, NOx and mercury emissions. These emissions have serious impact on the health of neighbouring people such as increased rates of premature death, to the exacerbation of chronic respiratory diseases. The decided objectives by the author in this work were to identify the issues of air pollution and the environmental impact of coal fired power plants and to discuss techniques and equipment that can contribute to improve the environmental sustainability. The objectives were tackled by going through extensive literature review, field observations, and attending the applicable meetings and conferences. The research outcomes show that coal will continue to be the key energy source in some countries in the next 20 years, because the reserves of coal with them are relatively high. Such countries have to undertake special considerations to minimize the bad impact on the local and global environment. The most important problem to be solved is to limit the emissions (particulate matter, nitrogen oxides, sulfur oxides, carbon oxides, etc.). In order to achieve reduction in the emissions it is necessary to apply advanced and efficient technologies. Author in this article presents functioning of a coal fired power plant, discuss environmental impacts and recommend technologies to make coal fired power plants environmentally sustainable.

Fatemeh Rostami et al 2017 [5] explained that high dependence on fossil fuels has led to increment of the atmospheric carbon dioxide emissions. Minimization of energy demand and relevant avoided CO2 emission improves the technology diffusion of carbon capturing and utilization and helps the economy of the process. In the pressure swing adsorption as a promising carbon capturing technology, increasing pressure leads to more adsorbed amount of carbon dioxide and also more energy consumption of compressor which is a source for carbon dioxide emission. Thus, the optimum value of the pressure is found to minimize the total energy demand using experimental data in this paper. Also, CO2 utilization in the aerogel production, as a nano-based thermal insulator, is applied in this work. Comparing the aerogel and other building insulators, the energy consumption and cost of avoided

$CO_2$ are determined for each case. For the pressures between 3 to 5 bar in the pressure swing adsorption process, the net adsorbed $CO_2$ is maximum.

Fateme Rezaei et al 2015 [6] worked on one of the main challenges in the power and chemical industries is to remove generated toxic or environmentally harmful gases before atmospheric emission. To comply with stringent environmental and pollutant emissions control regulations, coal-fired power plants must be equipped with new technologies that are efficient and less energy-intensive than status quo technologies for flue gas cleanup. While conventional sulfur oxide (SOx) and nitrogen oxide (NOx) removal technologies benefit from their large-scale implementation and maturity, they are quite energy-intensive. In view of this, the development of lower cost, less energy-intensive technologies could offer an advantage. Significant energy and cost savings can potentially be realized by using advanced adsorbent materials. One of the major barriers to the development of such technologies remains the development of materials that are efficient and productive in removing flue gas contaminants. In this review, adsorption-based removal of SOx/NOx impurities from flue gas is discussed, with a focus on important attributes of the solid adsorbent materials as well as implementation of the materials in conventional and emerging acid gas removal technologies.

Haitao Zhao et al 2013 [7] explains to their significant impacts on the environment and health, there has been a growing environmental concern on sulfur oxide (SOx), nitrogen oxides (NOx) emissions to the atmosphere in the past two decades. Flue gas at coal-fired power stations is one of the main sources for the emissions of SOx and NOx. More and more stringent regulations on the emission of these pollutants come in force, which have put a high pressure on coal-fired power generators. Cost-effective and sustainable technologies for the reduction of such pollutants from flue gas have become increasingly important nowadays. However, even though numerous attempts have been made aiming at developing technologies for the removal of SOx and NOx, not much effort has been made on the simultaneous conversion of NOx and SOx in flue gas via selective catalytic reduction This paper presents the study of simultaneous removal of $SO_2$ and NO over a synthesized Cu/Na-13X zeolite catalyst using carbon monoxide as a reducing agent. The characterization of fresh and spent catalysts was carried out using X-Ray Diffraction (XRD) and Brunauer-Emmett-Teller (BET) Surface Area Analyser. The experiments on the selective reduction of $SO_2$ and NO were carried out using a multi-functional catalyst testing rig with an online flue gas analyser..

L. C. Valin et al 2011 [8] Inference of NOx emissions (NO+$NO_2$) from satellite observations of tropospheric $NO_2$ column requires knowledge of NOx lifetime, usually provided by chemical transport models (CTMs). However, it is known that species subject to non-linear sources or sinks, such as ozone, are susceptible to biases in coarse-resolution CTMs. Here we compute the resolution-dependent bias in predicted $NO_2$ column, a quantity relevant to the interpretation of space-based observations. We use 1-D and 2-D models to illustrate the mechanisms responsible for these biases over a range of $NO_2$ concentrations and model resolutions. We find that predicted biases are largest at coarsest model resolutions with negative biases predicted over large sources and positive biases predicted over small sources. As an example, we use WRFCHEM to illustrate the resolution necessary to predict 10AM and 1 PM $NO_2$ column to 10 and 25% accuracy over three large sources, the Four Corners power plants in NW New Mexico, Los Angeles, and the San Joaquin Valley in California for a week-long simulation in July 2006.

## III. AIM & OBJECTIVE

Despite this heavy load of pollutants and the fact that two years were given to the industry to comply with the new emission standards, the industry has done nothing, according to CSE. The government is, in fact, are making it easier for the industry to flout the norms. Instead of pushing the industries to comply, the Ministry of Power (MoP) and Central Electricity Authority (that also acts as the technical advisor to the power ministry) are trying to push the deadline by five years (from 2017 to 2022) in a country which is grappling with the issue of intense air pollution. This Study aims at studying the NTPC Simhadri Visakhapatnam thermal power plant.

*A.* To Study the NTPC Simhadri Visakhapatnam thermal power plant and its operating conditions.
*B.* To Study and monitor the emission of NOx and SOx in the NTPC Simhadri Visakhapatnam thermal power plant.
*C.* To suggest the further options to control the emission of pollutants released from the NTPC Simhadri Visakhapatnam thermal power plant.

## IV. METHODOLOGY

Current Study deals with the study and monitoring of Pilot Project installed at NTPC Simhadri Visakhapatnam thermal power plant. The below methodology contains the detail of SCR model installed at selected power plant where continuous monitoring for 15 days was performed

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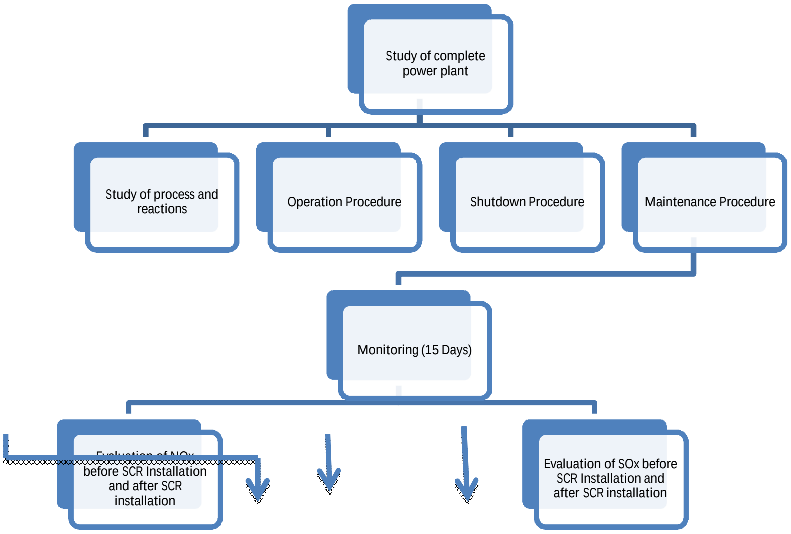


Fig : 2 Flow of Methodology

### *A. Process Description*

The SCR model is a steady-state model to remove nitric oxide (NO) and nitrogen dioxide (NO2) from the flue gas to a certain specification level of NOx or with a certain efficiency.

The model estimates the reagent stream requirements that can be in the form of Anhydrous Ammonia, Aqueous Ammonia or Urea, and are always diluted with air. The SCR process chemically reduces the NOx formed during combustion into molecular nitrogen and water Vapour.

$$4\ NO + 4\ NH_3 + 0_2 = 4N_2 + 6H_2O$$

$$2NO_2 + 4\ NH_3 + O_2 = 3N_2 + 6H_2O$$

1500Nm 3/hr of flue gas will be extracted from the economizer outlet as a slip stream for the SCR testing. Anhydrous Ammonia is diluted with air and injected through the Ammonia Injection Nozzle into the flue gas stream. Static mixer provided in the flue gas line ensures thorough mixing of ammonia with the flue gas. The flue gas then enters-the SCR reactor and comes into contact with catalyst layers, where NOx reduction takes place. The NOx, SOx, 02 concentration in the flue gas entering and leaving the SCR reactor will be measured. Based on the NOx measurement at inlet and outlet of SCR reactor, the NOx reduction achieved will be determined.

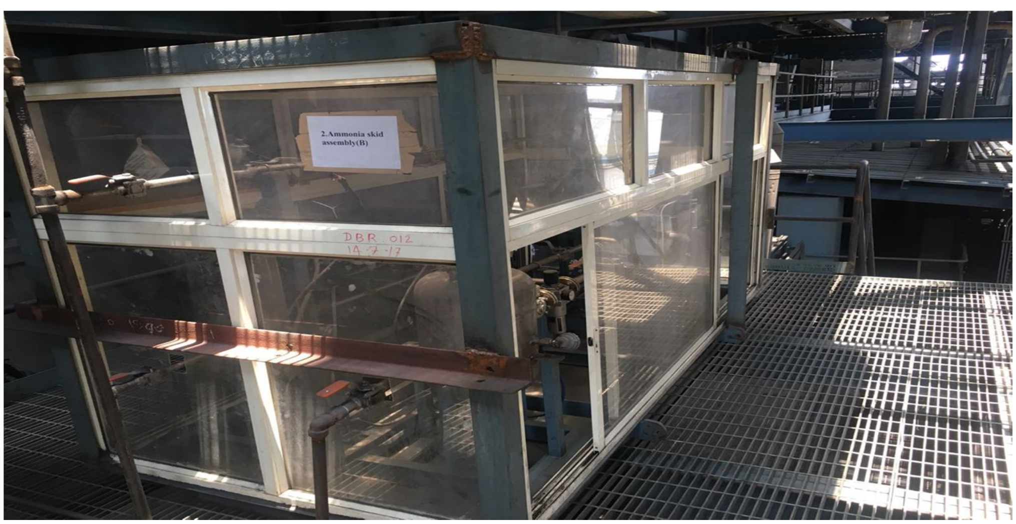

Fig: 3 AMMONIA and AIR mixture assembly

A flue gas cooler and stationary pi lot APH is installed downstream of the SCR reactor to study the effect of ABS (Ammonium Bi Sulphate) fort nation. The flue gas cooler will reduce the temperature of flue gas to ABS deposition temperature (- l 90°C).

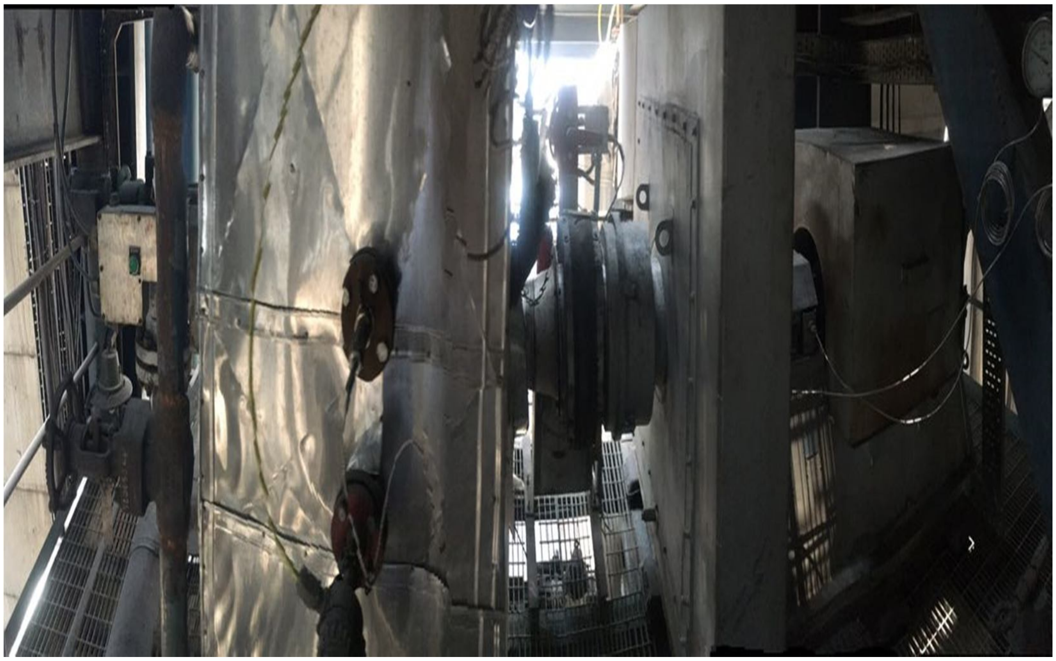

Fig: 4 PILOT APH Assembly

Fig: 5 Catalyst at thermal power plant

The key performance parameters for the SCR test are

1) De-NOx efficiency - Should be greater than 80o/o

2) Ammonia slip - Should be less than 2ppm Vd (6% 02 on dry basis)
3) S02 to S03 oxidation rate - Should be less than 1%
4) Catalytic activity ratio - Should be greater than 0.85

Since S02 to S03 oxidation rate and catalytic activity ratio depend on the catalytic composition as well as other inherent properties of the catalyst, it may not be possible to regulate it by controlling any of the process/operating variable. However, De-NOx efficiency and ammonia slip can be regulated by controlling the ammonia injection.

### *B. Flue Gas Analyser*

1) Check The zero and span calibration once in a month. Calibration gas ranges are recommended to be between 80% and 100% of the full range of the analyser.

The mirrors inside the analysis cells have to be cleaned frequently. At times, the mirror inside the cells may get contaminated by the ash particles in the flue gas being sampled. Mirrors can be cleaned with either methanol or IPA solution. Before removing the mirror, the pressure in the cell must be brought to atmospheric.

Fig: 6 flue gas sample outlet from economizer

### *C. Ammonia Slip Analyser*

1) Observe the power bar (S) in the scope display or the bar at the bottom of the "Main Running" display on the analyzer. In the host trend display it should be green. If it is yellow, it indicates the power is low. If it is purple the power is very low and the instrument will have stopped recording data. On the analyzer the bar is normally between 25% - 75%. You may also check the P(percent) values on the analyzer display by cycling to the "Species Information Screen". It should be greater than 5% for proper operation. Low power generally indicates a need for maintenance such as cleaning the optics or a problem with the process that is releasing dust into the duct and cutting down the power.
2) Check laser temperature and current values. They should agree with those listed in the equipment specification sheet
3) To clean the window, open the NEMA enclosure door to expose the optical window. Unscrew the window holder from the flange mount. Squirt a liberal amount of isopropyl (rubbing) alcohol on the window and wipe carefully with a soft cotton cloth. The window should not be wiped when dry, as this can cause scratches. Similarly, paper towels, kim-wipes, and lens tissue are not recommended. This procedure can be used for both launch and receiver window elements.

## V. RESULT

Further the reading for 15 days continuous monitoring was performed to check the reduction in values of NOx and SOx.

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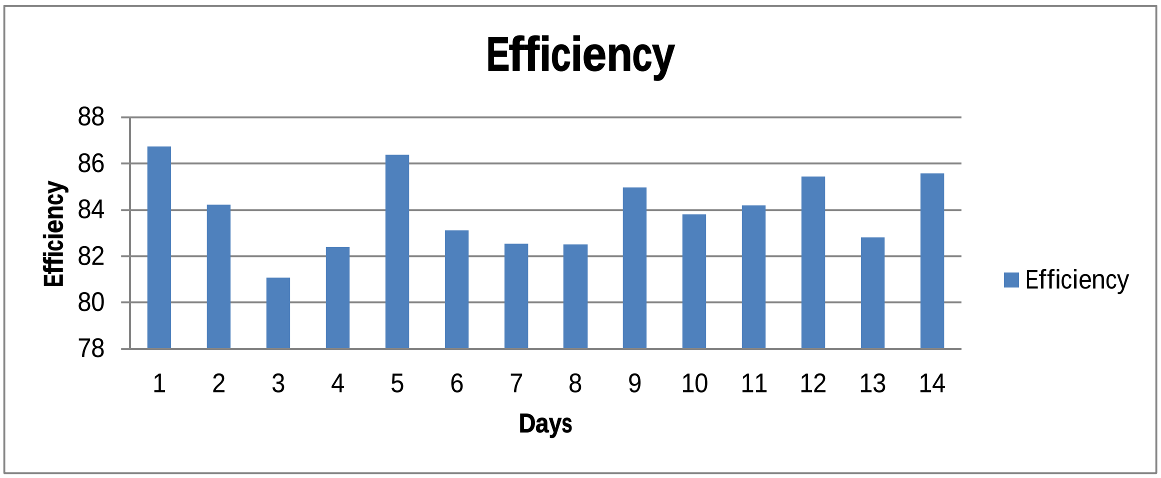
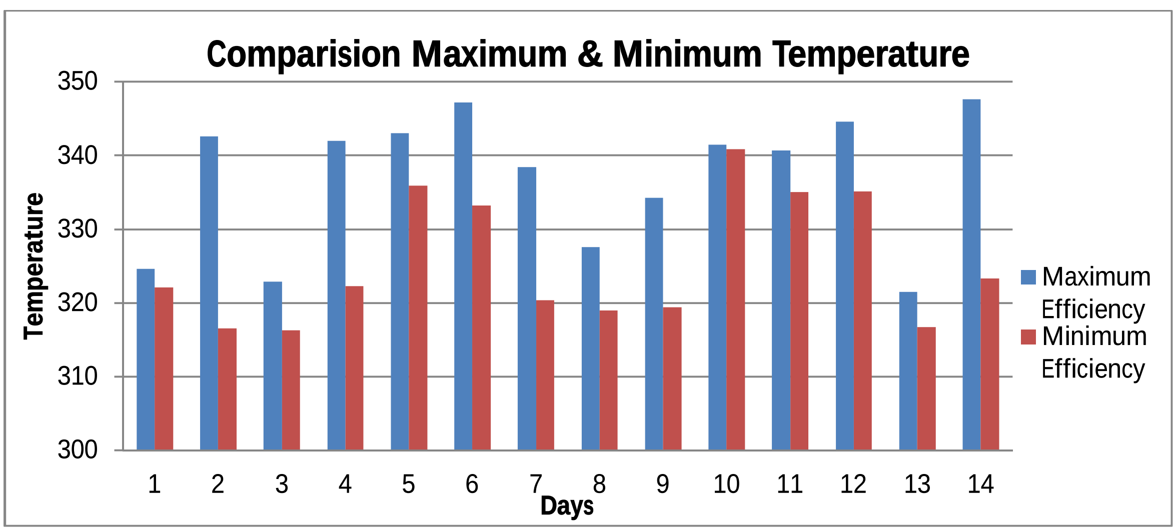
Table: 1 All Day Means efficiency

| Days | Mean Efficiency (%) | Maximum temperature ($^0$c) | Minimum Temperature ($^0$c) |
|---|---|---|---|
| 1 | 86.7433 | 324.6 | 322.1 |
| 2 | 84.2233 | 342.6 | 316.5 |
| 3 | 81.0617 | 322.9 | 316.3 |
| 4 | 82.4067 | 342 | 322.3 |
| 5 | 86.385 | 343 | 335.9 |
| 6 | 83.1267 | 347.2 | 333.2 |
| 7 | 82.55 | 338.4 | 320.4 |
| 8 | 82.4983 | 327.6 | 319 |
| 9 | 84.9833 | 334.3 | 319.4 |
| 10 | 83.8083 | 341.5 | 340.9 |
| 11 | 84.2067 | 340.7 | 335 |
| 12 | 85.4317 | 344.6 | 335.1 |
| 13 | 82.8217 | 321.5 | 316.7 |
| 14 | 85.565 | 347.6 | 323.3 |




Graph: 1 Days by efficiency graph




Graph: 2 Comparison per day maximum and minimum efficiency with respect in temperature

## VI. CONCLUSION

Thermal power plants use boilers to generate steam for steam turbines. A significant part of the world energy consumption is found to be used for operating boilers to facilitate the heating process or power generation. The design of the boiler, internal combustion engine, or gas turbine has a major effect on the operation. NOx formation tends to increase with an increase in boiler capacity, because larger boilers tend to have more intense combustion with higher combustion temperatures and longer residence time for flue gases. The same appears to be true in case of engines and turbines.

From the above experiment the process was carried out for fifteen days and the reading was recorded with respect to time intervals each days.

The following experiment was carried out to study the effect NOx and Sox during the fifteen days. The following conclusions were drawn.

*A.* The maximum was obtained on day-1 of about 86.7433%. This efficiency depicts the lowering of NOx
*B.* The minimum efficiency was on day-3 of about 76.0617%.
*C.* The maximum efficiency in terms of temperature was recorded on day-14 at temperature 347.6 $^0$C at 11:00PM of the day.
*D.* The minimum efficiency in terms of temperature was recorded on day-03 at temperature 316.3 $^0$C at 11:00PM of the day.

So from the above conclusion it is clear that with the increase in temperature with the efficiency of the system also increases and with decreases in temperature the efficiency of the system decreases. It is concluding that the emission of NOx is dependent on input temperature of the system hence it can be replaced by other techniques rather than SCR technique.

The major disadvantage of SCR technique is that, they can only control the NOx but they cannot reduce other gases like Sox and Ox; so it is necessary to adapt new technology by replacing this conventional technique.

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