A Review on Emission of NOx and SOx in Thermal Power Plant

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Abstract - Coal combustion in coal-fired power plants is one of the important anthropogenic NOx sources, especially in any country. Many policies and methods aiming at reducing pollutants, such as increasing installed capacity and installing air pollution control devices (APCDs), especially selective catalytic reduction (SCR) units, could alter NOx emission characteristics (NOx concentration, NO2/NOx ratio, and NOx emission factor). Emissions of nitrogen oxides (NOx) contribute to formation of particulate matter and ozone, and also to acidification of the environment. Here it is introduced the related research background of the technology of SCR denitrification which was as the symbol of the technology of the catalytic denitrification and discussed the reaction principles of the SCR denitrification and frequently used catalysts, the process of the technology, and the configuration. In the end, we pointed the way of the future research of the technology of the SCR denitrification.

Keywords - SCR denitrification, NOx, Flue gasses Coal Combustion, APCDs. Air Pollution etc.

I. INTRODUCTION

Emissions of nitrogen oxides (NOx) are precursors to secondary pollutants, including particulate matter and ozone, and contribute to nitrogen deposition and thus to environmental problems including acidification of ecosystems. Particulate matter is associated with both morbidity and mortality. Ozone has a widely recognized effect on human morbidity and potentially on mortality, although the latter effect is not firmly established. NOx is also associated with other environmental problems such as reduced visibility. Ozone is primarily a summertime problem, which is attributable to the photochemical process that leads to its formation. Both particulate matter and ozone pollution are widespread problems in the United States, and many metropolitan areas are not in compliance with the National Ambient Air Quality Standards (NAAQS) for these pollutants.

A. THERMAL POWER PLANT COMPONENT AND ITS AUXILIARIES

1) FUEL PREPARATION SYSTEM:

In coal-fired power stations, the raw feed coal from the coal storage area is first crushed into small pieces and then conveyed to the coal feed hoppers at the boilers. The coal is next pulverized into a very fine powder, so that coal will undergo complete combustion during combustion process. Pulveriser is a mechanical device for the grinding of many different types of materials. For example, they are used to pulverize coal for combustion in the steam-generating furnaces of fossil fuel power plants.

2) TYPES OF PULVERISERS:

Ball and Tube mills; Ring and Ball mills; MPS; Ball mill; Demolition.

a) DRYERS: they are used in order to remove the excess moisture from coal mainly wetted during transport. As the presence of moisture will result in fall in efficiency due to incomplete combustion and also result in CO emission.

b) MAGNETIC SEPARATORS: coal which is brought may contain iron particles. These iron particles may result in wear and tear. The iron particles may include bolts, nuts wire fish plates etc. so these are unwanted and so are removed with the help of magnetic separators.

The coal we finally get after these above process are transferred to the storage site.

3) PURPOSE OF FUEL STORAGE

Fuel storage is insurance from failure of normal operating supplies to arrive. Storage permits some choice of the date of purchase, allowing the purchaser to take advantage of seasonal market conditions. Storage of coal is primarily a matter of protection against the coal strikes, failure of the transportation system & general coal shortages.

a) TYPES OF STORAGE

- Live Storage (boiler room storage): storage from which coal may be withdrawn to supply combustion equipment with little or no remanding is live storage. This storage consists of about 24 to 30 hrs. Of coal requirements of the plant and is usually a covered storage in the plant near the boiler furnace. The live storage can be provided with bunkers & coal bins. Bunkers are enough capacity to store the requisite of coal. From bunkers coal is transferred to the boiler grates.
- Dead storage- stored for future use. Mainly it is for longer period of time, and it is also mandatory to keep a backup of fuel for specified amount of days depending on the reputation of the company and its connectivity. There are many forms of storage some of which are stacking the coal in heaps over available open ground areas. But placed under cover or alternatively in bunkers. Allocating special areas & surrounding these with high reinforced concerted retaking walls.

B. 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:-

- To convert chemical energy of the fuel into heat energy
- To transfer this heat energy to water for evaporation as well to steam for superheating.

1) COMPONENTS OF BOILER

1. Furnace and Burners
2. Steam and Superheating

a. Low temperature super-heater.
b. Platen super-heater
c. Final super-heater

C. ASH HANDLING SYSTEM

The disposal of ash from a large capacity power station is of same importance as ash is produced in large quantities. Ash handling is a major problem.

- Manual handling: While barrows are used for this. The ash is collected directly through the ash outlet door from the boiler into the container from manually.
- Mechanical handling: Mechanical equipment is used for ash disposal, mainly bucket elevator, belt conveyer. Ash generated is 20% in the form of bottom ash and next 80% through flue gases, so called Fly ash and collected in ESP.
- Electrostatic precipitator: From air preheater this flue gases (mixed with ash) goes to ESP. The precipitator has plate banks (A-F) which are insulated from each other between which the flue gases are made to pass. The dust particles are ionized and attracted by charged electrodes. The electrodes are maintained at 60KV.Hammering is done to the plates so that fly ash comes down and collect at the bottom. The fly ash is dry form is used in cement manufacture.

D. ADVANTAGES OF THERMAL POWER PLANT

These are the following advantages of thermal power plant:

1. The fuel (i.e. coal) is used is quite cheap.
2. Less initial cost as compared to the other generating stations of the same capacity.
3. It requires less space as compared to the hydro-electric power station.
4. The cost of generation is lesser than the Diesel power station.
5. According to the demand, the load can be changed frequently without any difficulty.
6. Thermal Power plant can be installed anywhere irrespective of the availability of fuels. Fuel can be transferred to the site of the plant by rail, road etc.
7. This type of plants is installed near load center.
8. Thermal Power plant can be run with overload condition (around 25%).

E. DISADVANTAGES OF THERMAL POWER PLANT:

The disadvantages of thermal power plant are:

1. It pollutes the atmosphere due to the production of a large amount of smoke.
2. Maintenance cost and operating cost is high.
3. A Huge amount of water is required.
4. Running cost is high as compared to the diesel power plant.
5. Coal handling and ash disposal is quite difficult.

II. LITERATURE REVIEW

Mohaddeseh Azimi et al 2018 [1] investigates inequality in SO_2 and NO_X 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 SO_2 emission: SO_2 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 NO_X emission: NO_X 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 (SO_2) and nitrogen oxides (NO_x) 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 SO_2 into solid $CaSO_4$ while selective catalytic reduction (SCR) reduces gaseous NO_x by NH_3 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 CO2 are determined for each case. For the pressures between 3 to 5 bar in the pressure swing adsorption process, the net adsorbed CO2 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 SO2 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 SO2 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+NO2) from satellite observations of tropospheric NO2 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 NO2 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 NO2 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 NO2 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. OBJECTIVE

This paper surveys the important NOx programs affecting the electricity sector. These programs have followed a path beginning with traditional command-and-control regulations leading to expanded use of flexible market-based approaches. Today both approaches play an important role. Here it is provided a description of these programs and measures of their effectiveness. And pay particular attention to the effect of these policies on those coal-fired boilers subject to Title IV of the 1990 Clean Air Act Amendments (CAAA)

IV. EXPECTED METHODOLOGY

A. The technical principle of SCR denitrification technology

There are many chemical reactions during the SCR denitrification technology. And the main chemical reaction of the denitrification is the oxidation-reduction reaction whose reductant is usually ammonia.

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$6NO + 4NH_3 \rightarrow 5N + 6H_2 O$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H O$$

$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2 O$$

The main reaction always accompanying with three side reactions which will have negative influence on the main reaction: the oxidation of ammonia, the oxidation of sulfur dioxide, the formation of the ammonium salt.

B. The catalysts of the SCR denitrification technology

The precious metal and the non-precious metal are always used in the SCR denitrification technology. The precious metal catalyst is platinum, palladium, rubidium and other precious metals that are all carried by the Al2O3 and other integral ceramics. However, For the low selectivity, these catalysts are not widely used before.

The non-precious metal catalyst occupies the major part of the catalyst of the denitrification technology and consists of the metal oxide catalyst and the zeolite catalyst.

The transition metal catalysts are V2O5 (WO3), Fe2O3, CuO etc., the main group metal catalysts are MgO, Al2O3 etc. and composite metal catalysts are Cu-Mg-Al, Cu-Co-Mg-Al etc. And TiO2, Al2O3, ZrO2, SiO2 and the active carbon are the main supports of all these catalysts.

The zeolite catalyst is that molecular sieve which is a kind of solid acid catalyst with plenty of microporous and has the advantages of good absorbability, reproducibility and heat stability. Hence, it takes an important role in the developing catalyst.

C. The systematic constitution of the technology of SCR denitrification

1) The main process of the technology of SCR denitrification

The liquid form of the reductant (ammonia as an example) is transported by ammonia-carrying truck and then is stored in the anhydrous ammonia tank. Before injected into the flue gas of the SCR denitrification system, the reductant must be evaporated by the ammonia evaporator. The next step is that the ammonia is mixed with the air in the ammonia and air mixer. After mixed, the mixed flue is injected into the flue gas of the upstream device by ammonia injection grid. At last, the reductant reacts with the flue gas in the SCR reactor catalyzed by the catalyst to remove the NOX in the flue gas. The progress is shown in Figure 1.

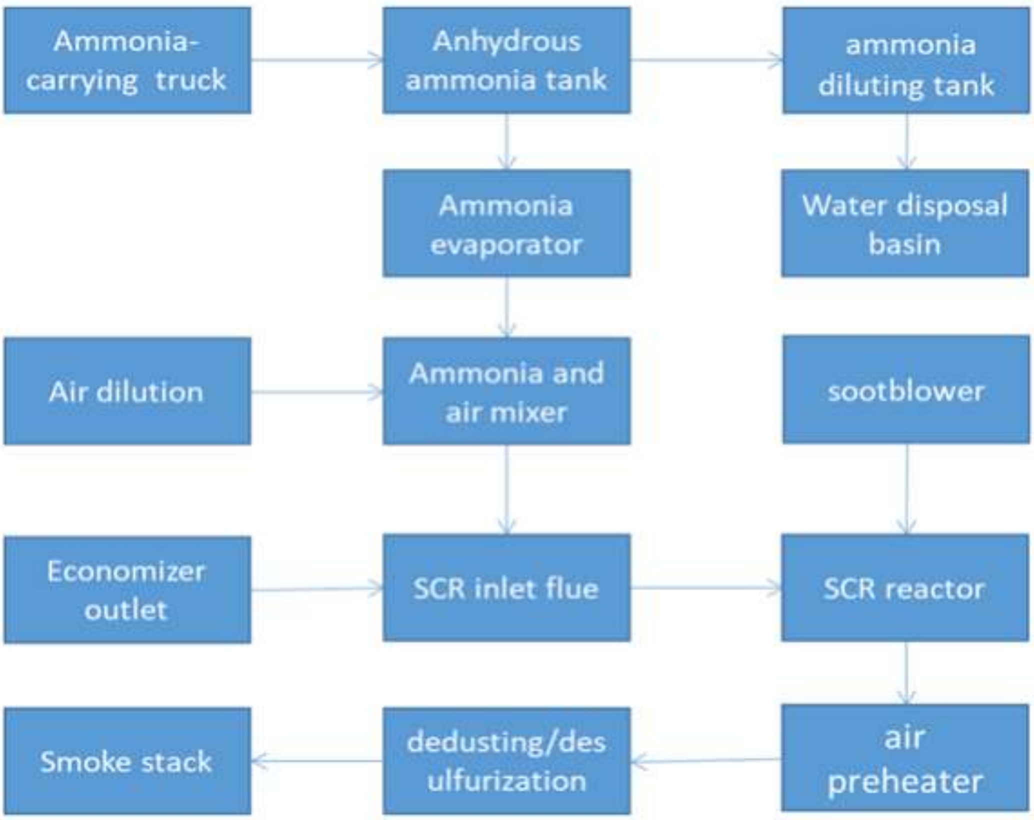

Fig: 1 The flowchart of the main process of the technology of SCR denitrification

2) The concrete systematic constitution of the technology of SCR denitrification

The systematic constitution of the technology of SCR denitrification is consist of the flue gas system, the storage and supply system of the ammonia, the ammonia and air mixer system, the ammonia injection system, the SCR reactor system, soot blower system and other systems. The Figure 2. is the diagram of the systematic constitution of the technology of SCR denitrification.

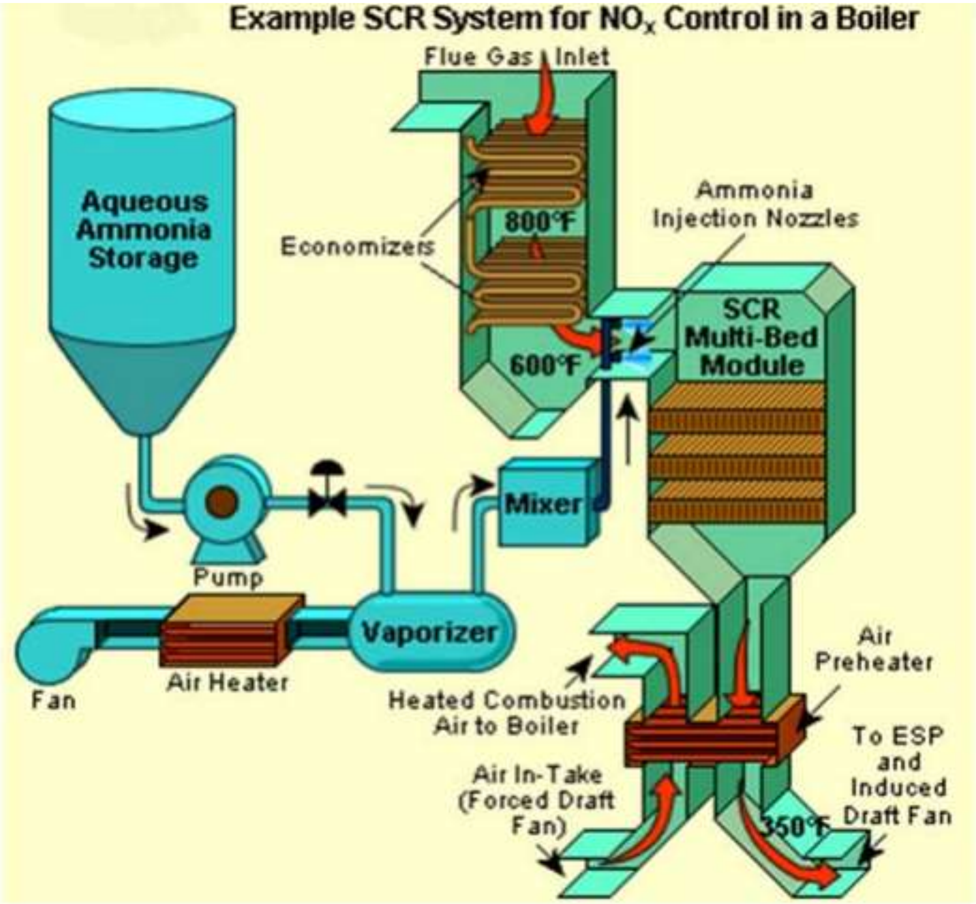

Fig: 2 The diagram of the systematic constitution of the technology of SCR denitrification

3) SCR reactor system

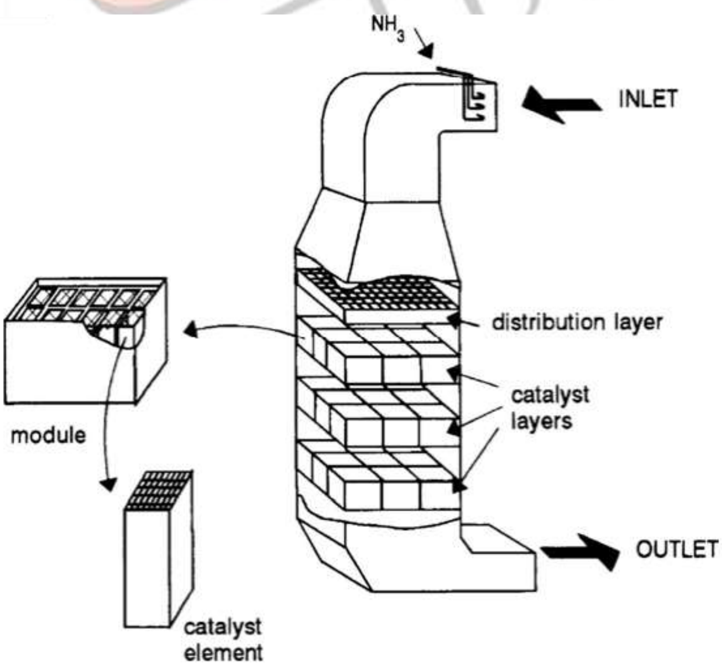

Fig: 3 The diagram of the SCR reactor system

The diagram of the SCR reactor system is shown in Figure 3. The SCR denitrification reactor is the most vital part of the SCR denitrification, which is the place for the ammonia and NOX to react with each other under the catalysis of the catalyst. The approximate progress is that the flue contains the nitrogen oxides flow in the reactor from the inlet, and the ammonia is injected into the SCR reactor from another pipe simultaneously, then the mixed gas reacts with each other during passing through the catalyst that be set layer by layer. Eventually, the gas that has react completely and incompletely is exhausted from the outlet. It is notable that in the reactor, the new catalyst is always set on the place that the reserved catalyst should place. By using this method, not only can we decrease the replacement of the catalyst but also trim the cost of the replacement of the catalyst.

V. CONCLUSION

In order to check the effectiveness of SCR technique in thermal power plant to predict the control of NOx and SOx emission a monitoring can be performed for a number of days and at different time period in a day so as to have the overall knowledge of effecting parameters like temperature, climate and environment on SCR implementation in thermal power plant. With the implementation of this procedure further changes and improvements can be suggested to improve the prevailing conditions of thermal power plants.

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