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Environment Impact Assessment of Thermal Power Plant for Sustainable Development

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Abstract— Thermal Power plants are the major source of generation of electricity for any developing country. Around 61.8% of electricity generation in our country is met by thermal power plants. Fuel is blown into the combustible chamber of the boiler where it is burnt at high temperature where Heat energy converts water into steam. High energy steam is passed through the turbine and the steam creates force on the turbine causing the shaft to rotate at high speed. A generator is coupled at one end of the turbine shaft which generates power. The thermal power plant has serious impacts on land, soil, air and various social impacts. The thermal power plants are also said to emit large amount of mercury and generate large quantity of fly ash which destroys the surrounding environment. These plants also consume a large amount of water. Due to these problems, they require a proper Environmental impact assessment before commencement of the project. Various mitigation measures for the control of pollution caused by thermal power plants along with some new technologies are discussed

Index Terms— Desulphurization, Electrostatic precipitator, Environmental impact assessment, Fly ash, Mercury emission, Particulate matter, Selective Catalytic Reduction, Selective Non-Catalytic Reduction.

1 INTRODUCTION

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle. The greatest variation in the design of thermal power stations is due to the different fossil fuel resources generally used to heat the water. Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally, fossil fueled thermal power plants produce a large part of man-made CO2 emissions to the atmosphere, and efforts to reduce these are varied and widespread. The energy efficiency of a conventional thermal power station, considered commercial energy produced as a percent of the heating value of the fuel consumed, is typically 33% to 48%.

As of July 2020, India has a total Thermal installed capacity of 231.45 GW. Almost 86% of the thermal power is obtained from coal and the rest from Lignite, Diesel and Gas. The private sector generates 46.9% of India's thermal power whereas States and Centre generate 27.9% and 25.3% respectively.

Sustainability plays a major role in the electrical generation industry as the latter contributes approximately 37% of the global Greenhouse gas emissions. Whenever there is growth in the energy sector, care should be taken to ensure that the ill effects caused to the surroundings and living beings should be minimum. The growth of energy on this principle is sustainable growth.

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2 WHAT IS EIA

The International Association for Impact Assessment (IAIA) defines an environmental impact assessment as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made. The purpose of the assessment is to ensure that decision makers consider the environmental impacts when deciding whether or not to proceed with a project. EIAs are unique in that they do not require adherence to a predetermined environmental outcome, but rather they require decision makers to account for environmental values in their decisions and to justify those decisions in light of detailed environmental studies and public comments on the potential environmental impacts.

3 ENVIRONMENTAL IMPACT

Environmental impact caused by Thermal Power Plant can categorized into three phases:

1. Pre-operation:
   - During manufacturing of products required for installation of the plants.
   - During the construction and installation of the plants
   - During transportation
2. During operation:
   - Air pollution – SO_x, NO_x, Fly ash, CO, CO_2 etc.
3. Post operation:
   - Dumping of untreated water
   - Dumping of fly ash slurry
   - Dust pollution

3.1 Environmental issues during constructionphase

Use of land at the proposed site of a thermal power plant is a prime concern to communities living in the vicinity and the project proponent. Optimal use of land should be considered in order to ensure operation and maintenance flexibility. Hence, for efficient use of land and other resources (water, coal, and vegetation), proper and prior field and technical study should be done. Land required for a power plant depends on factors like:

- Type of coal (indigenous or imported)
- Location of the plant (pithead or coastal)
- Coal storage capacity
- Mode of coal transportation
- Water storage capacity planned depending on the source of water and its availability
- Type of condenser cooling system
- Greenbelt required
- Capacities of water and wastewater treatment plants

Impacts:

1. Land Degradation:
   - Erosion
   - Loss or change of soil quality and quantity
   - Loss of biodiversity: Untreated air and water pollutants from coal power plants affect the water and the flora and fauna of adjoining areas making them unfit for living or livelihood activities.
2. Civil works such as earth moving and building of structures causes dust pollution.
3. Huge diversion and acquisition of land in case of power plant with captive mine.
4. Noise Pollution: Regular exposure to such high noise levels emanating from power plants from

3.2 Environmental impact during operational phase

Among thermal based power generation, coal-based power plants are highest in: Air pollution, Waste generation, Water consumption, Emission of mercury, Greenhouse emission.

3.2.1 Impact of Thermal power plant on water source

Water Intensive: Power plant of 500 MW installed capacity requires around 14 million m^3 of water per annum

- **Sources of water pollution:**
  - Cooling Tower Blow Down
  - Boiler Blow Down,
  - Demineralization (DM) Plant Effluent,
  - Coal Handling Plant Dust Suppression
  - Ash handling (Leachate of heavy metal (ash pond) contaminate groundwater)
  - Effluent from oil handling and transformer areas
  - Power House and Turbine Area Effluent
  - Domestic waste water

- **Impact:**
  - High impact on river & ground water due to seeping or direct dumping of hazardous chemicals.
  - Limits crop cultivation due to increase in alkalinity of soil and reduction of land available for agriculture
  - Limits crop cultivation as water demand for the once-through system is 30 to 50 times that of a closed cycle system.
  - Open cycle cooling system water sourced from fresh water like a river or lake has a direct effect by restricting the availability of water for human and agricultural consumption.
  - In an open cycle system, the most important environmental effect is the discharge temperature. As the cooling water passes through the condenser, it picks up heat. The amount of temperature rise depends on the amount of water flow.
  - A higher discharge temperature is detrimental to the aquatic life, especially the smaller species and fish eggs. This in turn has a snowball effect on the entire ecosystem.
  - Seawater open Cycle Systems use Sodium hypochlorite produced by electrolysis from the seawater itself. This is very cost effective since only the conversion cost is required. Higher amounts of this chemical will change the pH of the discharge water which is again detrimental to aquatic life.

3.2.2 Thermal power plant: Largest emitter of mercury

- Typical power plant emits 90% of its mercury into the air and 10% on land.
- The contribution of coal fired thermal power plant for mercury emissions works out to 70.7 % of total emission from coal combustion
- **Health Hazard of Mercury**: Exposure to mercury even in small amounts is a great danger to humans & wild life. When mercury enters the body, it acts as a small neurotoxin, which means it harms our brain & nervous system.

4 AIR POLLUTION DUE TO THERMAL POWER PLANTS

4.1 Air Pollution from point source:

- Particulates matter, Gaseous emission - Sulphur dioxide, oxides of nitrogen, carbon monoxide, carbon dioxide, Hydrocarbon.
- Particulate Matter (PM):
  - → Coarse Particulates (PM10)
  - → Fine Particulates (PM2.5)

- **Heath Hazards**

i. Particulate Matter (PM):
- Causes asthma
- Causes Chronic Obstructive Pulmonary Disease
- Stunt's lung growth
- Causes lung cancer
- Causes cardiac disease
- Causes congestive heart failure

ii. Sulphur Dioxide:
- Affects respiratory system and lung functions
- Causes asthma and chronic bronchitis
- Causes eye irritation
- Causes cardiac disease

iii. Nitrous Oxides:
- Causes asthma
- Causes Chronic Obstructive Pulmonary Disease
- Stunt's lung growth
- Causes cardiac disease

iv. Polycyclic Aromatic Hydrocarbons:
- Adversely affects the liver, kidney and testes
- May damage sperm cells and impair reproduction
- May attach to small particulate matter and be deposited in the lungs

4.2 Air Pollution from non-point source:
- Transportation of coal, Loading/unloading of fuel, coal storage yard, Fly ash handling & transportation.
- Fly ash have high surface concentrations of several toxic elements, have high atmospheric mobility and are deposited over a large area around coal fired power plants. These fly ashes enter the terrestrial or aquatic environment by wet or dry deposition

5 Remedial measures to curb pollution

5.1 Air pollution control

- **Point source**
  - For boiler stacks – Electrostatic precipitator/Bag house.
  - Coal crusher – Bag filter.
  - Coal mill – Bag filter.

- **Removal of SO_X**

1. Flue Gas Desulfurization (FGD) systems:

Flue-gas desulfurization (FGD) is one of the most popular set of technologies used to remove Sulphur dioxide (SO_2) content from the exhaust flue gases of coal fired power plants. The FGD system is essentially installed between the boiler/furnace and the stack. The flue gases are desulfurized by chemical scrubbing action. Some of the common methods used are:

1. Wet scrubbing using a slurry of alkaline sorbent, usually limestone or lime, or seawater to scrub gases.
2. Spray-dry scrubbing using similar sorbent slurries.
3. Wet sulphuric acid process recovering sulphur in the form of commercial quality sulphuric acid.
4. SNOX Flue gas desulfurization removes sulphur dioxide, nitrogen oxides and particulates from flue gases.
5. Dry sorbent injection systems.

For at typical coal-fired power station, flue-gas desulfurization (FGD) will remove 95% or more of the SO_2 in the flue gases. Most FGD systems employ two stages: one for fly ash removal and the other for SO_2 removal.

2. Use of low Sulphur containing fuel

3. High stack

- **Removal of NO_X**

1. COMBUSTION NOx CONTROL PROCESSES

i. Low-Excess Air (LEA): firings an efficient & practical operational control strategy since high excess air causes high NO x emissions.

ii. Over Fire Air (OFA): allows fuel to burn initially with minimal air and sometimes at a deficiency of air (sub-stoichiometrically) with additional air introduced as over fire air. Over fire air ports are located above the highest elevation of burners.

iii. Low-NO x Burners (LNB): reduce NO x emissions by reducing the formation of thermal & fuel NO x in the combustion area. This is accomplished by reducing flame temperatures by staging & controlling secondary air.

2. POST-COMBUSTION NO x CONTROL PROCESSES

i. Selective Non-Catalytic Reduction (SNCR) reduces NOx via injection of ammonia or a urea-based reagent into the upper furnace and/or convection section (1500 -2200 ^{0}F) of the boiler.

ii. Reaction with Urea:

$$CO(NH_2)_2 + 2NO + \frac{1}{2}O_2 = 2N_2 + CO_2 + 2H_2O$$

Possible byproducts due to poor process conditions (improper mixing, low residence time, lack of proper temperature etc.) are CO, high NH_3, and N_2O. There is no urea emission.

iii. Reaction with Ammonia:

$$6NO + 4NH_3 = 5N_2 + 6H_2O$$

For temperature >1750 ^{0}F

$$4NH_3 + 5O_2 = 4NO + 6H_2O$$

The reaction between NO_2 & NH_3 is not known for certain. However, field observations & calculations indicate that flue gas NO_2 concentrations are typically less than 5% of the total NOx. Therefore, NO_2 is not a major concern based on NOx reduction levels.

iv. Selective Catalytic Reduction (SCR): It uses a catalyst to increase the rate of selective chemical reactions between NOx & NH_3 to produce N_2 & H_2O. This process has the highest NOx reduction capability (>90%) and is the most widely commercialized post-combustion control technology today.

Chemical Reactions are as following:

$$4NO + 4NH_3 + O_2 = 4N_2 + 6H_2O$$
$$2NO_2 + 4NH_3 + O_2 = 3N_2 + 6H_2O$$
$$6NO + 4NH_3 = 5N_2 + 6H_2O$$
$$6NO_2 + 8NH_3 = 7N_2 + 12H_2O$$

Reaction Temp: 500 – 750 ^{0}F

5.2 **Fugitive Dust Control**

- Covered storage yard for coal
- Closed unloading of coal with adequate dust suction device
- Closed conveyor belt for transportation of raw
- Material with bag filter at every transfer points

5.3 **Fly Ash Management**

After the combustion of the coal in the boiler, 20% of the ash is collected at the bottom of the boiler called bottom ash and 80% is carried along with flue gases called fly ash. Bottom ash is mixed with water and made into sludge form and sent through pumps into the ash ponds. The Electro Static Precipitator is used to collect the ash particles in the flue gases.

- Ash disposal site shall be lined to prevent metal contamination.
- Construction of green barrier all around the ash pond.
- Piezometric hole shall be constructed upside and downside of the ash pond.
- Recycling of ash pond effluents.
- Switching from medium concentration slurry disposal system (MCSD) with ash concentration in slurry 40-45% to high concentration slurry disposal systems (HCSD) with ash concentration in slurry 65-72%

Innovative use of fly ash:

- **Fly ash bricks: The** Central Fuel Research Institute, Dhanbad has developed a technology for the utilization of fly ash for the manufacture of building bricks. Fly ash bricks have a number of advantages over the conventional burnt clay bricks. Unglazed tiles for use on footpaths can also be made from it
- **Fly ash in manufacture of cement:** A cement technologist observed that the reactive elements present in fly ash convert the problematic free lime into durable concrete
- **Fly ash as fertilizer:** Fly ash provides the uptake of vital nutrients/minerals (Ca, Mg, Fe, Zn, Mo, S and Se) by crops and vegetation, and can be considered as a potential growth improver
- **Fly ash-based polymer products:** Fly ashes are also being used as wood substitutes.
- **Fly ash in road construction**

5.4 **Mercury abatement**

- Mercury exists in three forms in coal fired thermal power plants flue gas:

(i) Elemental (HgO): Hg(O) is difficult to capture, since it is insoluble in water.

(ii) Oxidized Hg (2+): Increasing the emission of Hg (2+) allows for high Hg emission reduction because Hg (2+) or Hg (2+) derived species such as $HgCl_2$ can be removed in downstream equipment such as ESP and Wet FGD systems. Washing is one of the main methods, with traditional coal mercury removal efficiencies to the extent of20 to 30 %.

(iii) Particle bound Hg (2+) & Hg (P): are relatively easy to remove from flue gas using typical air pollution control devices such as electrostatic precipitator (ESP) &wet- Flue gas Desulphuriser (FGD).

5.5 **Super Critical Technology**

- Larger unit size (more than 500 MW) Higher thermal efficiency (of 5% and above)
- Low gaseous & soot emissions

5.6 **Circulating Fluidized Bed Combustion (CFBC/PFBC)**

Design pressure & temperature: Up to 150 kg/cm2 (g) & 545^{o}C

- Can burn wide range of coals and other fuels such as high sulphur, high ash and high moisture fuels, pet-coke, sludge, washery rejects, lignite, biomass
- Higher thermal efficiency (>40%)

5.7 **Water Conservation Techniques**

Big power plant - Closed loop instead of open loop, Small power plant - Air cooling instead of water cooling, Recycle and reuse of process and effluent water, zero discharge in case of small plant, Demineralized backwash water shall be treated with RO and reuse in process, Collection of rain water which can be used for many purposes Reducing leaks and over flow

5.8 **Practices to Reduce Transportation Impact**

Encourage bulk transportation by train, only pollution certified vehicles should be engaged in transportation, Appropriate infrastructure for vehicles such as concrete or pitched road, Separate approach road for transportation of raw materials such as coal, diesel, caustic etc.

5.9 **Practices for Soil Management**

Provision for topsoil storage and reuse, Separate stacking of topsoil with adequate collection rain all around, Topsoil storage heap should be covered with grasses and bushes to avoid erosion, removing vegetative cover only from the specific site on which construction has to take place.

5.10 Practices for Reducing Noise Pollution

Design of equipment, Acoustic enclosures / barrier shields, Construction of sound barrier in the form structure, Personal protective equipment i.e., ear plug & ear muffs, more than 33 % of total area under green cover Recommendation of dust scavenging plant (reduce 5 to 6 dB noise)

6 Conclusion

After studying thoroughly and understanding the whole thermal power plant, it is essential to curb adverse impact on environment during various phases of thermal power plant. Thus, various problems were identified and their impact on society were noted. The impact was associated with health hazards, deterioration of flora and fauna, degradation of land and economical. Therefore, technologies and effective steps were discussed to avoid exacerbation of adverse repercussions and improving the efficiency of power plant.

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