# The Heat Rate of Thermal Power Plants

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Rapid industrialization and the increased use of consumer electronic goods have increased the demand for energy. To meet the increasing energy demand, global nations are looking for energy from renewable sources rather than non-renewable sources, to adhere with the sustainability principle. As energy from renewable sources is still in the experimental stage, there is a need to use available energy sources optimally.

Keywords: thermal power plant ; renewable energy source ; sustainability

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## 1. Coal Thermal Power Plants in India

Following China, with 285 coal-fired thermal power plants, India is the second country to have a large number of coal-fired thermal power plants. Accordingly, India is the second largest coal polluter in the world [1]. The abundance and combustion properties of coal favor the preference for meeting energy demands. However, the poor functioning of the CBTPP has often been cited as the reason for the environmental pollution caused by the thermal power plant. The heat rate of CBTPPs is an important criterion to define the plant's efficiency. The studies that improve the performance of thermal power plants also help to save the environment by contributing to reduced GHG emissions and carbon footprints [2]. Despite the advances made in CBTPPs, the research is still insufficient concerning conventional fueled boilers with minimal thermal operating loads [3]. Many studies specific to the Indian region have shown interest in increasing the performance of Indian thermal power plants. Sahoo et al. [4] studied 71 Indian power plants to determine their efficiency and energy-saving potential, Singh and Bajpai [5] used data from 23 state-run power plants in India to arrive at an average efficiency level, and Malik et al. [6] assessed the data of 83 state- and central-run power plants in India to find evidence to improve the thermal efficiency of a power plant.

According to Guttikunda and Jawahar [7], India annually consumes 503 million tons of coal and generates 580 ktons of particulates with a diameter of 2.5 μm. This leads to 80,000 to 115,000 premature deaths and 20 million asthma cases. Another recent study [8] suggests that 32% of global chronic respiratory disease occurs in India. The disposal of coal ash into the environment exposes the communities to heavy metals and particulate matter waste. Fly ash produced during coal combustion contains toxic heavy metals, such lead (Pb), zinc (Zn), and nickel (Ni) [9]. As the fly ash is disposed directly into the water bodies, it causes water pollution. Studies on the environmental impact of the coal-fired thermal power plants indicate that the partial burning of the coal as the main cause of the increased emissions of carbon monoxide and other particulates. The thermal power plants are also facing many challenges in relation to coal combustion. The subsequent section explains the challenges affecting the heat rate performance of thermal power plants.

## 2. The Challenges Affecting the Heat Rate of Thermal Power Plants

To identify the challenges of improving the thermal power plant's heat rate, scholarly articles were searched from the databases, such as Science Direct, Google Scholar, and Web of Science. To collect the articles, the following keywords and Boolean operators were used: "challenges in thermal power plant OR problems faced by the thermal power plant", "thermal power plant in India", "difficulties faced by the thermal power plant AND challenges faced by thermal power plant", and "coal-fired power plant AND thermal power plant". From this, initially, 60 articles were collected. Then, the articles were checked for the nature of work. Here, 15 articles were found to be duplicate or replicate works. After rejecting the duplicated works, the challenges of improving the boiler's heat rate were identified from the remaining articles.

Since, usually, the coal in the thermal power plants is not burned properly, this leads to the formation of fly ash. These fly ash wastes are not handled effectively and are often disposed of into the environment. The fly ash from the thermal power plants is a rich source of carbon content and it increases the global warming effect [10]. Likewise, the maintenance activities are not carried out properly in the thermal power plants, and this resulted in the damage to some of the critical components. Damage to the boilers and ducts may result in the trapping of incoming air, which leads to low pressure. At a low pressure condition, the fly ash generated during the combustion of coal may settle in the tube pathway [11]. This affects the heat rate performance of the thermal power plants. Talapatra et al. [12] state that moisture content present in the coal affects the combustion process and reduces the efficiency of coal. The identified challenges with descriptions and the relevant references are provided in **Table 1**.

**Table 1.** The challenges affecting the heat rate improvements of a boiler system.

| Challenges | Brief Description | References |
|---|---|---|
| Fly ash unburned carbon content (B1). | The pulverized coal supplied to the boiler for burning is not completely burned inside the furnace and comes out with flue gas as unburnt. | [10][13] |
| Bottom ash unburned carbon content (B2). | The heavy pulverized coal comes out through the boiler bottom ash hopper with heavy ash particles. | [10] |
| Boiler and duct work air-in leakage (B3). | Any leakage in the ducts affects the draft pressure, leading to incomplete combustion and results in fuel loss and the increasing consumption of auxiliaries. | [11][14] |
| Optimizing pulverizer (B4). | Supplying the correct quantity of required air based on the quantity of coal fed into the boiler is called optimizing, which reduces heat loss due to excess air carryover and reduces the auxiliary consumption. | [15] |
| Pulverizer throat size and geometry optimization to reduce coal rejects (B5). | Pulverizer throat size and geometry optimization reduces the coal mill rejects. | [15] |
| Pulverizer fineness, mechanical tolerance, and tuning optimization (B6). | Optimize coal size based on the retention time in the furnace and required correct air flow. | [11] |
| Balanced fuel and air distribution into the burner belt (B7). | Measuring coal flow rating and supplying correct quantity of air leads to efficient firing. | [10] |
| $NO_X$ reduction by burner adjustment (B8). | Coal distributor insertion depth in the coal burner plays a main role in the $NO_X$ reduction in boiler. | [16] |
| Coal flow balancing (B9). | Balancing the coal flow among the burners in the boiler results in more efficient combustion. | [6] |
| Super heater de-super heating spray water flow (B10). | Heat in the superheated region of the main stream is wasted by utilizing this heat to heat the water sprayed into it. | [2] |
| Re-heater de-super heating spray water flow (B11). | Heat in a superheated region of hot reheat steam is wasted by utilizing this heat to heat the water sprayed into it. | [5] |
| Air pre-heater leakage (B12). | Air pre-heater leakage reduces the heat gain of primary and secondary air from flue gas. | [17] |
| Auxiliary consumption from non-optimized combustion (B13). | The boiler draft system and mill fans are excessively loaded due to non-optimized combustion, thus increasing the auxiliary consumption. | [3] |
| Super heater outlet steam temperature (B14). | Air heater leakage, un-optimized combustion, and poor quality coal. Improper soot blowing is the main cause of low super heater outlet steam temperature. | [4] |
| Re-heater outlet steam temperature (B15). | Reduction in re-heater outlet steam temperature reduces the reheat cycle efficiency, reduces the boiler efficiency, and leads to low-pressure turbine final stage corrosion. | [6] |
| Air heater air outlet temperature (B16). | The high air outlet temperature increases the boiler efficiency, reduces the flue gas outlet temperature, and increases the boiler efficiency. | [16] |
| Air pre-heater exit gas temperature (B17). | Lowered exit flue gas temperature is the indicator of heat absorbed in the boiler if the air pre-heater is leak proof. | [3] |
| Boiler exit excess air (B18). | A high loss of heat energy is carried away by the excess air flow through the boiler. | [18] |
| Boiler vent and drain valve leakages (B19). | These are heat and high-cost demineralized water-loss points. They reduce plant efficiency. | [4] |
| Optimized soot blower operation (B20). | Soot blowers are used to remove the ash deposited in tube surfaces. Soot blower operations are programed with some periodicity, regardless of whether there is or is not an ash deposit. | [3][19] |
| Pulverizer coal spillage and rejects (B21). | Reducing coal spillage and rejects directly saves coal, thus reducing coal cost and auxiliary consumption. | [5][20] |

| Challenges | Brief Description | References |
|---|---|---|
| **Continuous monitoring (B22).** | **Operating the power plant with designed parameters helps to achieve the designed heat rate.** | **[10][21]** |

## 3. The Existing MCDM Methods

Since the performance of the thermal power plants is affected by multiple factors, MCDM techniques are widely used. Patel and Dwivedi [22] used AHP methodology to find the preventive maintenance ace of the critical components in thermal power plants. Li et al. [23] evaluated the competition criteria of thermal power plant generation by using a hybrid MCDM methodology. Yuan et al. [24] utilized ANP methodology to study the challenges of using CBTPPs in various countries. Mittal et al. [25] used the AHP methodology to evaluate the challenges of thermal power plants. Pradhan and Ghose [26] provided an analysis of the key factors of thermal power plants in the state of Tamil Nadu in India. Wu et al. [27] provided an analysis of the sustainable challengers for evaluating the thermal power plants. Most existing literature uses AHP methodologies, whereas this proposed research uses the DEMATEL methodology to rank the challengers of thermal power plants in India. Most of the existing literature on thermal power plants in India concentrate on improving the performance and generation capacity of boilers. Studies devoted to finding the challengers to improve the heat rate performance of CBTPPs are rare.

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