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ALGORITHMS UTILIZING AI FOR LOAD PREDICTION IN INTELLIGENT POWER GRIDS

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Abstract
This in-depth research investigation explores the application of fundamental energy and exergy principles to evaluate the performance of a gas-fired steam power plant boiler located in Bangladesh. The power plant has a total installed capacity of 210 MW and comprises two generation units. The study focuses on comprehending the energy and exergy dynamics within the boiler to gain insights into its operational effectiveness. Throughout the research, a thorough analysis of both energy and exergy efficiencies of the boiler has been conducted. Additionally, the assessment quantifies the overall irreversibility within the boiler under various load conditions. The findings show that the energy efficiency of the boiler fluctuates in the range of 75% to 80% across different load conditions. Simultaneously, the exergy efficiency experiences variations, ranging from 41.4% to 43%, as load conditions change. Significantly, the outcomes of the irreversibility analysis reveal a direct relationship between exergy destruction and the load magnitude. This analysis suggests that exergy destruction increases proportionally with the load, reaching its peak under full-load conditions.
In summary, this research provides valuable insights into the energetic and energetic aspects of a gas-fired steam power plant boiler in Bangladesh, fostering a nuanced understanding of its efficiency and performance across diverse load conditions. These findings can lay the groundwork for further enhancements and optimizations in power generation and energy utilization within the region. This comprehensive research endeavour delves into the practical application of fundamental energy and exergy principles to assess the operational efficiency of a gas-fired steam power plant boiler situated in Bangladesh. This power plant boasts a total installed capacity of 210 MW, comprising two generation units. The core objective of this study is to unravel the intricate interplay of energy and exergy dynamics within the boiler, providing valuable insights into its overall effectiveness.

Throughout this investigation, we conducted a meticulous examination of both energy and exergy efficiencies associated with the boiler. Furthermore, we quantified the overall irreversibility within the boiler across varying load conditions. The research outcomes elucidate that the energy efficiency of the boiler demonstrates fluctuations within the range of 75% to 80% across diverse load conditions. Concurrently, exergy efficiency exhibits variations spanning from 41.4% to 43%

as the load conditions undergo changes. Notably, our irreversibility analysis highlights a direct correlation between exergy destruction and the load magnitude, with exergy destruction reaching its zenith under full-load conditions. To summarize, this study furnishes invaluable insights into the energetic and exegetics facets of a gas-fired steam power plant boiler in Bangladesh, contributing to a nuanced comprehension of its efficiency and performance across diverse load conditions. These revelations can serve as the foundation for subsequent enhancements and refinements in power generation and energy utilization within the region.

Key Words: Power plant, energy flow, exergy, exergy destruction and exergy efficiency

1. Introduction

In spite of the global economic challenges, Bangladesh, a nation with promising potential, maintains a consistent GDP growth rate that surpasses 7%. To support its national economic development, the country requires substantial growth in electricity production to meet the growing demand. Presently, approximately 90% of the population has access to electricity, with each person's electricity generation averaging 382 kWh, inclusive of captive power. The total designed capacity, which includes captive power and renewable energy facilities, stands at 20,775 MW. Natural gas serves as the primary source of fuel, constituting roughly 53.9% of the total installed capacity. The government has set ambitious objectives, aiming to provide electricity to all citizens by 2021 while ensuring that power supply remains reliable and affordable. The majority of power plants in Bangladesh are of the steam power plant variety. This underscores the importance of conducting comprehensive investigations to optimize their efficiency. Traditionally, the performance of these power plants is evaluated using the principle of energy conservation. This approach offers insights into the transformation and processing of energy but can sometimes lead to misconceptions. To address this, researchers have introduced the second law of thermodynamics, which introduces the concept of "Exergy." Exergy takes into consideration the quality of energy, entropy generation, and irreversibility throughout a process, offering ample opportunities for enhancement. Irreversibility analysis emerges as a valuable method for improving complex thermodynamic systems. This approach has been observed in numerous studies on power plants worldwide. These investigations have employed the concept of exergy to assess the overall performance of power stations. They aim to identify areas for improvement and optimize various components, such as combustion chambers, heat recovery systems, and gas turbines. The ultimate goal of these endeavours is to elevate energy efficiency and diminish the destruction of exergy, thus contributing to more effective power generation. In summary, Bangladesh's sustained economic growth hinges on its ability to meet the burgeoning demand for electricity. By applying advanced thermodynamic principles, researchers strive to boost the efficiency of power plants, making significant contributions to the nation's development and the sustainable management of its energy resources. The author's research was dedicated to examining how adjustments in unit load and variations in ambient temperature influence the overall cycle performance. Notably, preheating the air entering the boiler was identified as a highly effective method for enhancing efficiency, especially when the power plant operates at its marginal load. Elsafi's work centred on conducting an exergy and exergoeconomic assessment of solar power plants, involving the development of formulas based on fuel contents for various components of the plant. Zhai and colleagues applied a systemic thermo-economic approach to a coal-fired power plant, evaluating performance from the perspectives of both fuel conservation and energy generation. In the fuel-saving approach, they recorded a substantial 15.04 g/kWh reduction in fuel consumption, while the energy-increasing approach resulted in a notable 57.2 MW increase in energy output.

Li's investigation explored sub-critical, supercritical, and ultra-supercritical steam conditions in power systems, providing a comprehensive comparison of energy and exergy. Parikhani's research involved a thorough energy, exergy, and exergoeconomic analysis of a 2.33 MW geothermal plant incorporating both cooling and power cycles. This study aimed to assess the energy and exergy performance of the plant's cogeneration system. Mitrović's assessment delved into the energy and exergy aspects of a 348.5 MW steam-driven power plant in Kostolac, Serbia, revealing higher irreversibility in the boiler when compared to other plant modules. Hagi addressed the performance evaluation of first-generation oxy coal power plants, utilizing exergetic techniques for process unification.

Rosen and Dincer conducted an exergoeconomic analysis of diverse fuel power plants, scrutinizing the intricate relationship between capital costs and thermodynamic deficits. Gonca's study reported on an energy and exergy analysis of single and double reheat irreversible Rankine cycles, forecasting thermal efficiency, exergy destruction, exergy efficiency, and net specific work output. Erdem's comprehensive research revolved around the energy and exergy performance analysis of nine coal-fired thermal power plants, which helped identify inefficiencies and prompted recommendations for necessary modifications.

Ehyaei's research had a broader focus, encompassing exergy, environmental, and economic evaluations to gauge the impact of inlet fogging on the efficiency of a conventional gas turbine power plant. In particular, this article homed in on the energy and exergy analysis of a 210 MW gas-fired thermal power plant boiler owned and maintained by the Bangladesh Power Development Board (BPDB). The study involved an in-depth examination of the boiler's energy efficiency, exergy efficiency, and the rate of exergy destruction within the power plant, all based on the principles of the first and second laws of thermodynamics.

2.Power Plant Description

The power plant under examination in this study is the oldest one in Bangladesh, known as the Chittagong Power Station. The focus of this study is the Chittagong Power Station, which holds the distinction of being the oldest power plant in Bangladesh. Situated approximately 16 miles from Chittagong town on the northeast side of the city, this government-owned facility operates as a gas-fired thermal power plant with a total installed capacity of 210 MW. It consists of two steam turbine units, collectively providing a full-load capacity of 420 MW. This power station operates on a Rankine cycle and boasts an approximate cycle efficiency of 32%, using an air-fuel ratio of 10:1 for efficient combustion. It is situated approximately 16 miles away from the city of Chittagong, to the northeast. This government-owned facility operates as a gas-fired thermal power plant, boasting an installed capacity of 210 MW. It consists of two steam turbine units, providing a combined capacity of 420 MW at full load. Both steam turbine units, each with a capacity of 210 MW, operate at 100% load capacity. The power station operates on a Rankine cycle, and you can find an operational flow diagram in Figure 1. The approximate cycle efficiency of this power plant is estimated to be 32%. Within the combustion chamber, an air-fuel ratio of 10:1 is utilized to ensure complete combustion. The focus of our study lies on the Chittagong Power Station, which holds the distinction of being the oldest power plant in Bangladesh. This power station operates based on a Rankine cycle, a thermodynamic process that is commonly used in power generation. The Rankine cycle is represented in Figure 1, providing a visual depiction of the plant's operational flow. It's worth noting that the approximate cycle efficiency of this power plant is estimated to be around 32%, reflecting the plant's effectiveness in converting heat into mechanical work.

To achieve complete combustion, the combustion chamber within this power station employs an air-fuel ratio of 10:1. This precise ratio ensures that the air and fuel mixture is optimized for combustion, resulting in the efficient release of energy for power generation. In essence, this power plant embodies both a historical legacy and a commitment to operational efficiency in Bangladesh's power generation landscape.

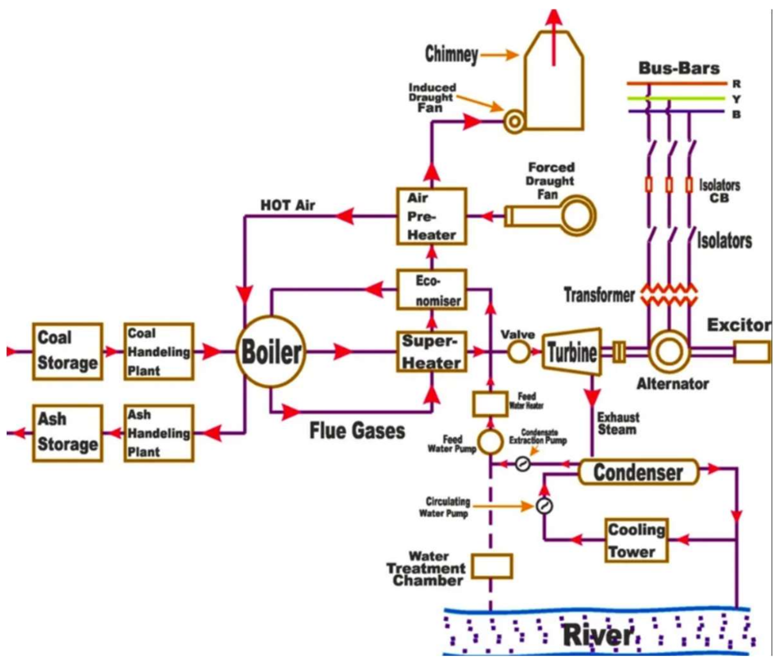

Figure 1. Process flow diagram of the power plant

3. DATA Analysis and Modelling

A. Analysis of Energy and Exergy in the Boiler

To scrutinize the energy and exergy aspects within the power plant cycle, we rely on the data available in the power plant repository to assess the thermodynamic parameters essential for all

cycle points under the specified design conditions. The values of unknown variables are determined by applying the principles of energy conservation and utilizing exergy equations.
Exergy analysis plays a crucial role in identifying the maximum available work potential of energy and is established with reference to specific ambient conditions. When conducting exergy analysis for the boiler, we make the assumption that there is no change in exergy rate. This simplification allows us to focus on the combustion of methane in the combustion chamber, where methane serves as the primary fuel, and the associated chemical reactions take place.

B. Gathering Data

We accumulated data on the mass flow rate, temperature, and pressure at various positions within the boiler by consulting the power plant's extensive records. This data serves as the foundation for computing the energy and exergy parameters. The thermodynamic properties of the refrigerant were ascertained using REFPROP 7 software package. The information in Table 2 presents the data we collected from the records and the calculated thermal properties under different load conditions.

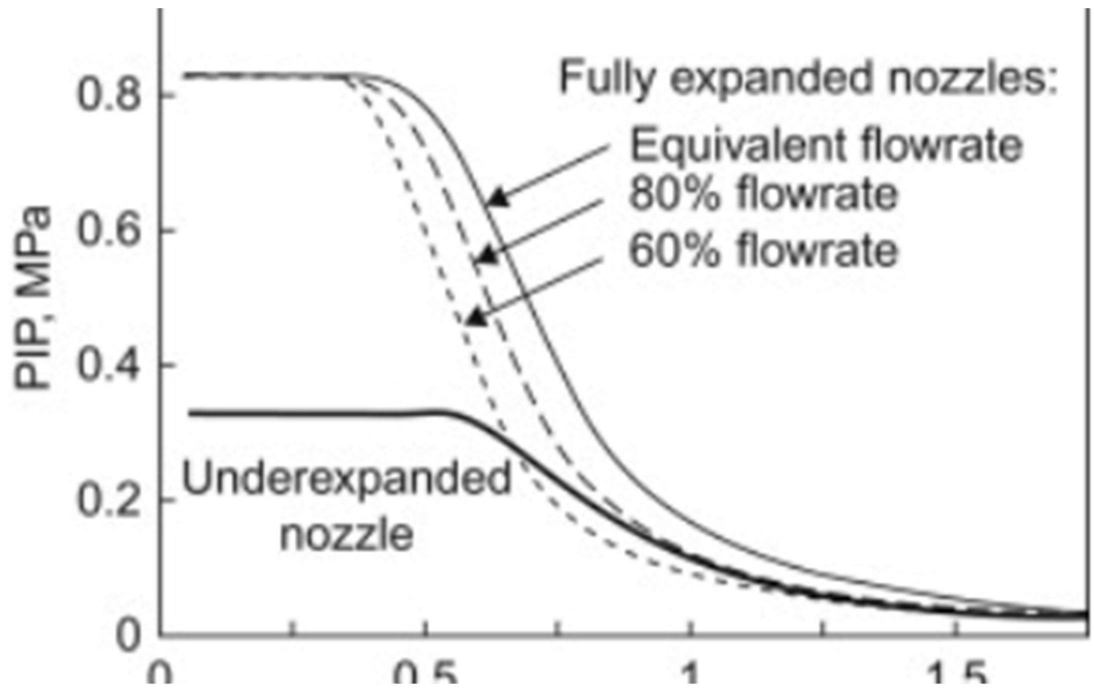

Figure 2. Graphical representation

4.Conclusion

Throughout this study, we thoroughly examined the energy and exergy efficiency of a steam power station boiler. Our investigation entailed a comprehensive analysis of the fuel's energy contribution and the efficiency of combustion energy. Additionally, we delved into the exergy domain, exploring elements such as exergy destruction and the efficiency of the combustor's exergy. In this research, we delved into the energy and exergy efficiency of a steam power station boiler. We closely examined the energy derived from the fuel and assessed the efficiency of combustion energy. Our investigation also extended to the realm of exergy, where we explored factors such as exergy destruction and the combustor's exergy efficiency.To conduct this analysis, we gathered data from the steam power plant and applied Equations 2-13 to compute various energy and exergy parameters for the boiler. Figure 3 provides a visual representation of the boiler's energy efficiency across different load conditions. Notably, this figure illustrates variations in the thermal efficiency of the boiler corresponding to changes in the load condition, with the highest thermal efficiency observed at a load of 160 MW. It's worth mentioning that the designed energy efficiency of the boiler was calculated to be 87.16%.

In summary, our research delved into the intricacies of energy and exergy efficiency within a steam power station boiler, shedding light on the boiler's performance under different load conditions. These insights contribute to our understanding of how the boiler operates efficiently, particularly when it's operating at a load of 160 MW, where it achieves its peak thermal efficiency.

To conduct this analysis, we collected crucial data from the steam power plant, forming the basis for our computations using Equations 2-13 to derive various energy and exergy parameters associated with the boiler's operational performance.

Figure 3 illustrates the energy efficiency of the boiler across different load conditions. Notably, this figure highlights fluctuations in the boiler's thermal efficiency corresponding to changes in the load condition, with the highest efficiency recorded at a load of 160 MW. Calculations revealed the designed energy efficiency of the boiler to be 87.16%. Meanwhile, Figure 4 effectively depicts the variations in exergy gain as the load condition alters, indicating an upsurge in exergy gain with increasing load, primarily attributed to fluctuations in the mass flow of steam under different load conditions. Figure 5 provides valuable insights into the exergy supplied by the fuel at distinct load conditions.

Our study focused on scrutinizing the energy and exergy aspects of a 420 MW steam power plant in Bangladesh. We conducted meticulous examinations of energy efficiency, exergy efficiency, exergy gain, and exergy destruction under varying load conditions. Our findings led us to several important conclusions. The overall energy efficiencies of the boiler fluctuated between 75% and 80%, while exergy efficiencies varied within the range of 41.4% to 43%. Moreover, we observed that the peak energy and exergy efficiencies were achieved during the 160 MW load condition. Conversely, the rate of exergy destruction within the boiler peaked at a load of 180 MW, with this rate consistently increasing with higher load conditions.

References

[1] (2018) BPDB. Present Installed Generation Capacity (MW) [Online]. Available at: http://www.bpdb.gov.bd/bpdb_new/index.php/site/page/13e9-2cc0-ce41-9c09-088d-94d5-f546-04a6-b4fa-1d18.

[2] Ahmadi GR, Toghraie D. "Energy and exergy analysis of Montazeri Steam Power Plant in Iran,' Renew Sustain Energy Rev, vol. 56, pp. 454–63, 2016.

[3] Cengel Y., Boles M. Thermodynamics: An Engineering Approach. 5th ed. New York: McGraw-Hill Education; 2006.

[4] Utlu Z, Hepbasli A. A review on analyzing and evaluating the energy utilization efficiency of countries. Renew Sustain Energy Rev, Vol. 11, pp. 1–29, 2007.
[5] Wall G. “Exergy flows in industrial processes,” Energy, vol. 13, pp. 197–208, 1988. [6] Rosen MA. “Energy- and exergy-based comparison of coal-fired and nuclear steam power plants,” Exergy, An Int J, vol. 1:pp. 180–92, 2001.
[6] Rosen MA. “Energy- and exergy-based comparison of coal-fired and nuclear steam power plants,” Exergy, An Int J, vol. 1:pp. 180–92, 2001.
[7] Habib MA, Zubair S. “Second-law-based thermodynamic analysis of regenerative-reheat Rankine-cycle power plants,”Energy, vol. 17: pp. 295–301, 1992.
[8] Amir V. “Improving Steam Power Plant Efficiency through Exergy Analysis : Ambient Temperature,”In: 2nd Int. Conf. Mech. Prod. Automob. Eng., p. 209–12; 2012.
[9] Kaviri AG, Jaafar MNM, Lazim TM, Barzegaravval H. “Exergoenvironmental optimization of Heat Recovery Steam
Generators in combined cycle power plant through energy and exergy analysis,” Energy Convers Manag, vol. 67, pp 27–33, 2013.
[10] Wang L, Yang Y, Dong C, Xu G, Wu L. “Exergoeconomic Evaluation of a Modern Ultra-Supercritical Power Plant,” Energies, vol. 5, pp 3381–97, 2012.