THERMODYNAMIC PERFORMANCE ANALYSIS OF SELECTED GAS TURBINE POWER PLANTS IN NIGERIA

BY

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DECLARATION

I hereby declare that I carried out the work reported in this thesis in the Department of Mechanical Engineering, School of Engineering and Technology, College of Science and Technology, Covenant University, Ota, Nigeria under the supervision of Prof. R.O. Fagbenle and Prof. S.S. Adefila.

I also solemnly declare that no part of this report has been submitted here or elsewhere in a previous application for award of a degree. All sources of knowledge used have been duly acknowledged.

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CERTIFICATION

This is to certify that this thesis is an original research work undertaken by **Sunday Olayinka OYEDEPO** and approved by:

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Signature: …………………… Date:

2. Name: **Prof. S.S Adefila**

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DEDICATION

This Thesis is dedicated to:

The All Seeing

The All Knowing

The All in All

The All Sufficient

The Almighty God

The Source of all knowledge!

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ABSTRACT

In the last two decades, electricity generating plants in Nigeria have been operating below their capacity with available capacity barely surpassing half the installed capacity which is short of international standards of over 95% installed capacity. Due to this low availability, other key performance indicators such as capacity factor and load factor have also been relatively low. This research work therefore aims at evaluating the performance of selected gas turbine power plants in Nigeria thermodynamically with a view of providing possible ways of improving the performance thus meeting the international standards. A thermodynamic analysis of the design and performance of eleven selected gas turbine power plants was carried out using the first and second laws of thermodynamics. Energy, exergy, exergo-economic and exergo-environmental analyses were conducted using operating data collected from the power plants to determine the energy loss and exergy destruction of each major component of the gas turbine in each plant. The carbon dioxide (CO_2) emission and cost of environmental impact were determined for each plant. Energy analysis result shows that the turbine has the highest proportion of energy loss in the plants. The exergy analysis revealed that the combustion chamber is the most exergy destructive component compared to other cycle components. Also, its exergy efficiency is less than that of other components studied, which is due to the high temperature difference between working fluid and burner temperature. In addition, it was found that by increasing gas turbine inlet temperature (GTIT), the exergy destruction of this component can be reduced. Exergo-economic analysis shows that the cost of exergy destruction is high for the combustion chamber. Increasing the GTIT effectively decreases the cost associated with exergy destruction in combustion chamber. The exergy costing analysis revealed that the unit cost of electricity produced in the plants varies from cents 1.88/kWh (₦2.99/kWh) to cents 5.65 /kWh (₦8.98/kWh). Exergo-environmental analysis shows that the CO_2 emissions vary from 100.18 to 408.78 kgCO_2/MWh while cost rate of environmental impact varies from $40.18 /hour (₦6, 388.62/hour) to $276.97 /hour (₦44, 038. 23/hour). The results show that CO_2 emissions and cost of environmental impact decrease with increasing GTIT. The effects of design parameters on exergy efficiency showed that an increase in the pressure ratio and GTIT increases the total exergy efficiency of the cycle. These results imply that increase in gas turbine efficiency can be achieved by improving the performance of the most inefficient component of the system. The statistical analysis result of plant availability showed significant difference ($p>0.05$) in the availability of the selected power plants. The research work has established the possibility of increasing power generation efficiency, strategies of reducing fuel consumption and CO_2 emissions in the selected gas turbine power plants in Nigeria, thus meeting the required international standards. It has also provided a suitable methodology for relatively quick identification of the key items requiring performance improvement in a gas turbine power plant.