



KAPS INITIATIVE

Thermodynamic performance analysis of retrofitted simple cycle gas turbine power plant

¹Isah, I., ²Ishaq, J. A., ³Aisha, S., ⁴Muhammad, M. M. and ⁵Bonet, M. U.

¹Centre for Atmospheric Research-National Space Research and Development Agency, Prince Abubakar Audu University, Campus Ayingba, Kogi State Nigeria

²Department of Mechanical Engineering, Kaduna State University Kaduna Nigeria

³Department of Mechanical Engineering, Nigerian Defence Academy Kaduna Nigeria

⁴Department of Mechanical Engineering, Federal University of Technology Minna Nigeria

⁵Department of Aerospace Engineering, Air Force Institute of Technology Kaduna Nigeria

abjumare@gmail.com, a.saad@nda.edu.ng, masin.muhammad@futminna.edu.ng, mubonet@nda.edu.ng

Paper History

Received: 11th Jan, 2026

Accepted: 26th Jan, 2026

Published: January, 2026

Abstract:

The combined cycle power plant (CCPP) utilizes both gas and steam turbines to generate more than 50% electricity using the same fuel than the conventional simple cycle gas turbine power plant. The waste heat from the gas turbine is harnessed by the steam turbine utilizing the heat recovery steam generator (HRSG) to generate additional electricity, increase efficiency and reducing emission. Thermodynamic performance analysis of a retrofitted simple cycle gas turbine power plant was carried out. The studied gas turbine unit is the Siemens SGT5-2000E (3 units) gas turbine model with an installed capacity of 145 MW each located at the Geregu gas turbine power plant in Ajaokuta Kogi State. A one-year data covering March, 2018 to February, 2019 was used for the study in order to investigate the effect of ambient temperature on the performance parameters such as compressor work, turbine work, pump work, steam turbine work, power output and efficiency of the combined cycle power plant. The different control volumes of gas and steam turbines were subjected to thermodynamic study, and comparisons between simple and combined cycles were made. The analysis's predicted findings indicate that a drop in ambient temperature will boost power output, improve efficiency, and reduce emissions. Similar to this, a combined cycle power plant would produce more electricity and have a higher efficiency than a simple cycle gas turbine power plant.

Corresponding author

Isah, I.

informisah@yahoo.com

Keywords: Efficiency, Gas turbine, Power plant, Steam, Temperature, Waste heat

1. Introduction

A gas turbine engine is a type of internal combustion engine that can be considered as an energy conversion device that converts the energy stored in the fuel into useful mechanical energy in the form of rotational power [1]. The term "gas" refers to ambient air that is absorbed by the engine and used as a working fluid in the energy conversion process. Gas turbines operate on the Brayton thermodynamic cycle either in open or closed cycle configuration. However, despite the numerous benefits of the closed cycle, its application remains very rare because of the inability to run it at very high turbine inlet temperature like the open cycle. The open cycle gas turbine in its basic term consists of the compressor, the combustion chamber, and the turbine [1]. A gas turbine works through some thermodynamic processes in series. Fresh atmospheric air is first drawn into the circuit continuously and energy is added in the combustion chamber by fuel addition and the products of combustion are expanded through the turbine which produces the work and finally discharges to the atmosphere [2]. The turbine

gases which expanded and emitted into the atmosphere contain very high energy content with temperature range of between 500-600°C. This waste heat can therefore be used to produce additional power through generation of steam which is used in rotating steam turbine. A heat recovery steam generator (HRSG) is used to produce steam which is then used in steam turbine to drive a generator. Combined cycle and cogeneration can be achieved if gas turbine is modified with HRSG. Combined cycle power plant is when two plants (gas and steam) are combined to operate as single plant with the sole aim of achieving more efficiency, generating more power and reduction in emission of pollutant. Cogeneration, also known as combined heat and power (CHP) is a process whereby process heat and power are produced from a single source simultaneously. However, the emphasis of this present work is on retrofitting of simple cycle power plant into combined cycle power plant (combined cycle power plant) [2].

There have been various studies conducted by different researchers which are related to performance

analysis of simple cycle gas turbine and combined cycle power plants. The study on the effective parameter of gas turbine model with intercooled compression process was carried out by Ibrahim, *et al.* [3]. The study proposed parametric study of a gas turbine cycle modeled with intercooler compression process. The results show that increasing turbine inlet temperature and pressure ratio can improve the performance of the intercooled cycle. Influence of operation conditions and ambient temperature on performance of gas turbine power plant was presented by Rahman, *et al.* [4]. The effect of ambient temperature and operation conditions such as compression ratio, turbine inlet temperature, air to fuel ratio and efficiency of compressor and turbine on the performance of gas turbine power plant was presented and computational model developed using the MATLAB codes. The results obtained show the thermal efficiency increases linearly with increases in compression ratio and decreases in ambient temperature. Also, the specific fuel consumption increases with increases in ambient temperature and lower turbine inlet temperature [5]. Also, investigation of the SGT5-2000E gas turbine power plant performance in Benin City based on energy analysis using MATLAB software showed the average net thermal efficiency of the SGT5-2000E was 30.21 % when the ambient air temperature ranges from 21 to 35 °C, the compressor pressure ratio of 10.73 to 10.96, the net power output of 148.92 MW to 160.70 MW, and 60.16 % of the fuel energy input was lost to the power plant surroundings as waste heat [5].

Thermodynamic analysis of gas turbine was analyzed by Ibrahim and Mohammed [6]. The project was intended to analyze the performance of a gas turbine engine using operating factors such as pressure ratio, turbine inlet and exhaust temperatures, fuel to air ratio, isentropic compressor and turbine efficiencies and ambient temperature. The simulation result from mathematical equation using Microsoft Office Excel software could be used to suggest the optimum cycle operating condition. Parametric study of a two-shaft gas turbine cycle model of power plant was proposed by Ibrahim, *et al.* [7]. The parametric study of a two shafts gas turbine cycle model of the power plant was proposed and the power output, compression work, specific fuel consumption and thermal efficiency are evaluated with respect to the cycle temperature and compression ratio for a typical set of operating conditions. Two shafts gas turbine cycle with realistic parameters was modeled using the MATLAB codes. The results obtained show that the turbine work is found to decrease as ambient temperature increases as well as the thermal efficiency decreases with the thermal efficiency, power output increases linearly with increases of compression ratio while decreases of ambient temperature and the simulated power of the two shafts gas turbine can reach to 135 MW, which is higher than the Bajji gas turbine power plant with less than 131 MW.

A technical review of the study of the performance of the gas turbine power plants from simple to complex cycle was carried out by Ighodaro and Egbon [8]. The study conducted review on various gas turbine power plants. The review focused on a simple cycle GT power plant (GTPP) with a 2-shaft, regenerative, reheat, intercooler, complex

cycle GT with effective intercooler, regenerative and reheat. Further reviews/technical focused on the effect of operating conditions and improvement on the performance of GTPP. Performance analysis of Delta III GT9 Transcorp gas turbine power plant, Ughelli in Nigeria was conducted by William [9]. The power plant was analyzed and evaluated using thermodynamic principles and technical data obtained from the plant. The results of the analysis covering one year show that 92% of the expected capacity was available in the period under study. Comparative performance assessment of different gas turbine configurations of a local power station in Nigeria was carried out by Mohan, *et al.* [10]. A comparative assessment of gas turbine options for power generation was conducted on Omotosho power station based on the simple cycle and its retrofitted modified cycles were used for the investigation. Thermal efficiency, specific fuel consumption and power output were used for investigation and the DWSIM, multiplatform open-cape software was used for simulations. The percentage changes in performance of these cycles over the simple cycle was evaluated and found to exhibit better performances in terms of thermal efficiency, specific fuel consumption and power output than the conventional simple cycle achieving up to 68% increment in some cases. In this current work, parametric analysis of retrofitted simple cycle gas turbine power plant is carried out.

2. Methodology

2.1 Thermodynamic analysis of Geregu gas turbine power plant

The Geregu Gas Turbine Power Plant was modeled using the schematic diagram of simple open cycle gas turbine having its control volumes as the compressor, the combustion chamber and the turbine shown in Figure 1.

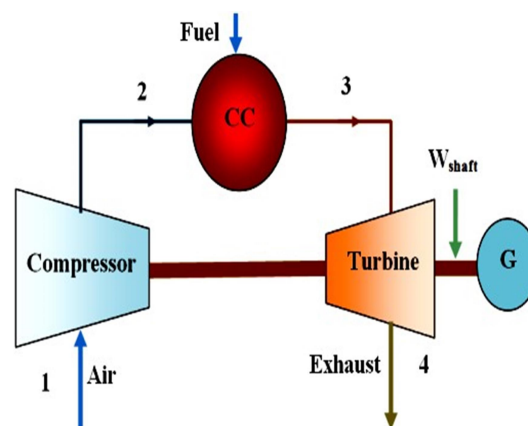


Figure 1: Schematic Diagram of Simple Open Cycle Gas Turbine Showing the Basic Components [11]

The compressor takes in atmospheric air from the environment and compresses it to increase the temperature and pressure before delivering it into the combustion chamber, where fuel is added for combustion to take place. The product of this combustion is thereafter expanded in the turbine where work is developed. Part of

the work developed is used to rotate the compressor which is on a common shaft with the turbine and the remaining is used to generate electricity and the rest emitted into the environment in form of pollutant. The temperature-entropy diagram of the simple open gas turbine cycle is shown in Figure 2.

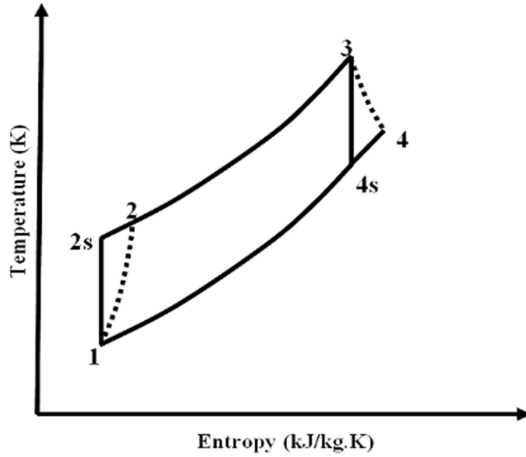


Figure 2: Temperature-entropy diagram for simple GT cycle [11]

According to Brayton thermodynamic principle, in a control volume, heat transfer minus shaft work equals the difference between the energy carried by the fluid streams leaving and entering the system as given in equation 1 [12].

$$Q - W_{SHAFT} = \sum m \left[h + \left(\frac{v^2}{2} \right) + gz \right]_{in} - \sum m \left[h + \left(\frac{v^2}{2} \right) + gz \right]_{out} \quad (1)$$

Where; Q = heat transfer rate into the system (W), W_{SHAFT} = shaft work rate out of the system (W), m = rate of mass flow into or out of the system (kg/s), h = specific enthalpy (J/kg), $\frac{v^2}{2}$ = kinetic energy per unit mass (J/kg) and gz = gravitational potential energy (J/kg).

Neglecting the kinetic energy $\left(\frac{v^2}{2}\right)$ and the gravitational potential energy (gz) therefore the first law of thermodynamic is given by equation 2 [13].

$$0 = Q - W_{SHAFT} + m (h_{in} - h_{out}) \quad (2)$$

Where h_{in} = specific enthalpy into the system and h_{out} = specific enthalpy out of the system

2.1.1 The compressor model

The compressor work rate is a critical component in gas turbine power plant and can be modeled using the equation 3 [13].

$$W_c = \dot{m}_a c_{pa} (T_2 - T_1) \quad (3)$$

Where; W_c = compressor work, \dot{m}_a = mass flow rate of air, c_{pa} = specific heat capacity of air, T_2 = compressor exit temperature, and T_1 = compressor inlet temperature.

2.1.2 The combustion chamber model

The combustion chamber is where fuel is burned to add energy to the working fluid. The quantity of heat added into the combustion chamber is given by the equation 4 [3].

$$q_{in} = h_3 - h_2 = \dot{m}_a c_{pg} (T_3 - T_2) \quad (4)$$

Where; q_{in} = heat added, h_3 = enthalpy specific to state 3, h_2 = enthalpy specific to state 2, c_{pg} = specific heat capacity of combustion gas, T_3 = turbine inlet temperature and T_2 = compressor outlet temperature.

2.1.3 The turbine model

The turbine in a gas turbine expands hot gases to produce work and is modeled using the equation 5 [3].

$$W_t = \dot{m}_g c_{pg} (T_3 - T_4) \quad (5)$$

Where; W_t = turbine work, \dot{m}_g = mass flow rate of combustion gas, c_{pg} = specific heat capacity of combustion gas, T_3 = turbine inlet temperature, and T_4 = turbine exit temperature.

Network of gas turbine (W_{net}):

$$W_{net} = W_t - W_c \quad (6)$$

Where W_t = turbine work and W_c = compressor work

Therefore, the energy balance in the combustion chamber is expressed in equation 7 [3].

$$\dot{m}_a c_{pa} T_2 + \dot{m}_f \times \text{LHV} + \dot{m}_f c_{pf} T_f = (\dot{m}_a + \dot{m}_f) c_{pg} T_3 \quad (7)$$

Where; LHV is low heating value = 47,976.5 kJ/kg [3] where \dot{m}_a = mass flow rate of air, c_{pa} = specific heat capacity of air, T_2 = compressor exit temperature, \dot{m}_f = mass flow rate of fuel, c_{pf} = specific heat capacity of fuel, T_f = temperature of fuel and T_3 = turbine inlet temperature

Meanwhile, the isentropic efficiency of the turbine is given in equation 8:

$$\eta_{ts} = \frac{\text{Actual Work}}{\text{Isentropic Work}} = \frac{T_3 - T_4}{T_3 - T_{4s}} \quad (8)$$

Where T_4 = turbine outlet temperature and T_{4s} = isentropic outlet temperature

Therefore, T_{4s} can be defined as in equation 9:

$$T_{4s} = \frac{T_3}{\left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}} \quad (9)$$

Where P_1 = compressor inlet pressure, P_2 = compressor outlet pressure and γ = specific heat ratio. Turbine Pressure Ratio = $\frac{P_3}{P_4}$ and the Compressor Pressure Ratio = $\frac{P_2}{P_1}$.

Thermal efficiency of a gas turbine (η_{th}) is given in equation 10:

$$\eta_{th} = \frac{\text{Net Work}}{\text{Total Heat Supplied}} = \frac{W_{net}}{Q_{adde}} \quad (10)$$

Where W_{net} = network and Q_{adde} = Energy supply

Specific fuel consumption (SFC) was obtained using equation 11 [3, 16]

$$SFC = \frac{(3600 \times f)}{W_{Net}} \quad (11)$$

Where; f = fuel air ratio and W_{net} = network Heat Rate (HR) was obtained using equation 12 [3]

$$HR = \frac{Kg \text{ of air mass}}{Power \text{ Generated}} = \frac{1}{\eta t} \quad (12)$$

Air fuel ratio (AFR) was obtained using equation 13:

$$AFR = \frac{LHV}{Q_{Addd}} \quad (13)$$

Where LHV = lower heating value and Q_{Added} = energy supply

2.2 Thermodynamic analysis of combined cycle power plant

Combined cycle power plants integrate gas and steam turbines for efficient power generation. Thermodynamic analysis of these plants involves evaluating energy balances, efficiencies and losses across components like compressors, combustion chambers, turbines and heat recovery steam generators (HRSG) [13]. The combined cycle power plant is shown schematically in Figure 3 while its temperature-entropy diagram is shown in Figure 4.

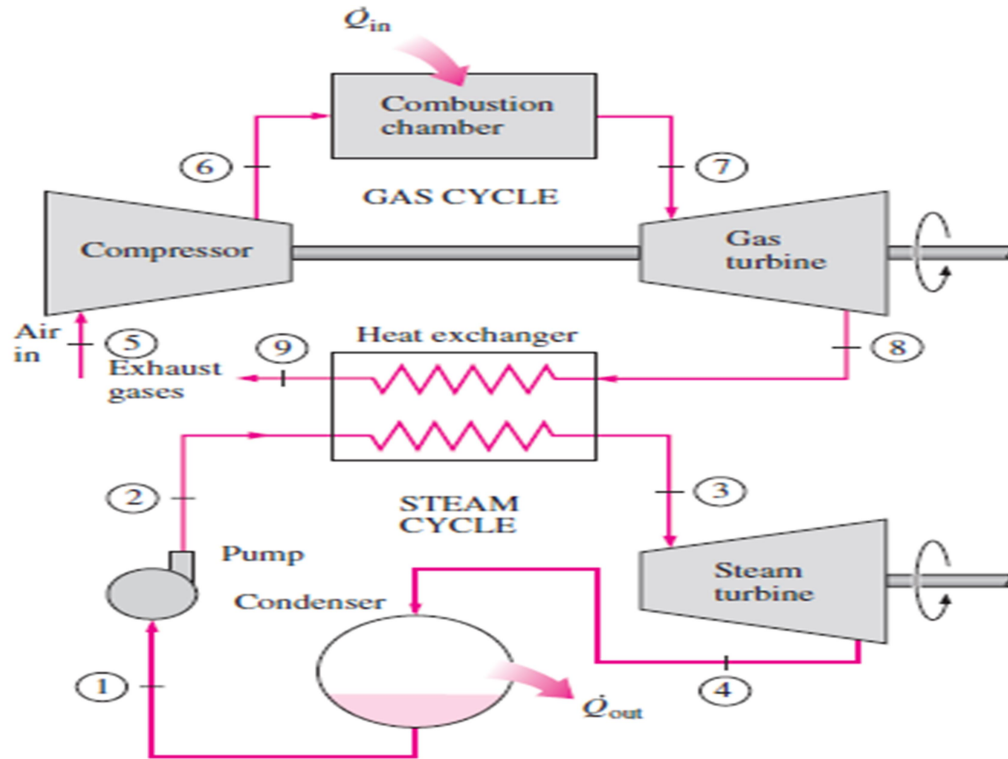


Figure 3: Combined Cycle Power Plant [13]

2.2.1 The steam turbine cycle work, W_{ts}

The steam turbine cycle work, W_{ts} is given by equation 14 [14]:

$$W_{ts} = \dot{m}_s (h_5 - h_6) \quad (14)$$

Where \dot{m}_s = mass flow rate of steam, h_5 = enthalpy of superheated steam inlet to the turbine and h_6 = enthalpy of steam outlet from the turbine (low pressure steam).

2.2.2 The pump work, W_{ps}

The pump work, W_{ps} in steam cycle turbine is given by equation 15 [14].

$$W_{ps} = V_f (P_2 - P_1) \quad (15)$$

Where V_f = specific volume of saturated liquid, P_1 = pressure of condensate liquid and P_2 = pressure of saturated vapor.

2.2.3 The network output

The network output (W_{nets}) of the steam turbine cycle is given by equation 16 [14]:

$$W_{nets} = W_{ts} - W_{ps} \quad (16)$$

Where W_{ts} = steam turbine cycle work and W_{ps} = pump work

2.2.4 The energy efficiency

The energy efficiency of the steam turbine cycle is given by equation 17 [14]:

$$\eta_{st} = \frac{W_{nets}}{Q_{added}} \quad (17)$$

Where η_{st} = energy efficiency of steam turbine, W_{nets} = network of steam turbine and Q_{added} = energy supply

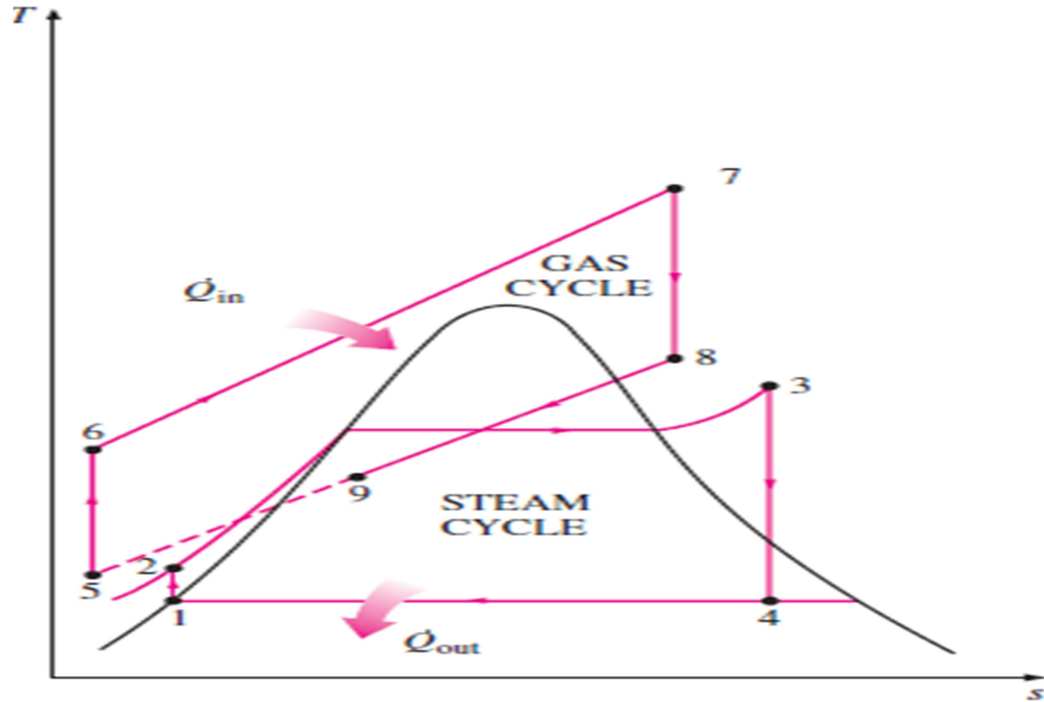


Figure 4: Temperature-entropy diagram for simple GT cycle [13]

2.3 Thermodynamic analysis of retrofitted combined cycle

Combined cycle power plant is a combination of both simple cycle gas turbine (topping cycle) and steam cycle turbine (bottoming cycle) power plants shown in Figure. 3. The combination of these two cycles increases both the thermal efficiency and power output of the cycle.

2.3.1 The network of the combined cycle

The network of the combined cycle power plant is modeled using equation 18 [15].

$$W_{netc} = W_{netg} + W_{nets} \quad (18)$$

However, heat inputs from gas turbine still remain constant.

Where W_{netc} = network of combined cycle, W_{netg} = network of gas turbine and W_{nets} = network of steam turbine

2.3.2 The overall efficiency

The overall efficiency (η) of combined cycle power plant is modeled using equation 19 [15].

$$\eta = \frac{(W_{gt} + W_{st})}{Q} \quad (19)$$

Where W_{gt} = gas turbine work, W_{st} = steam turbine work and Q = energy supply

3. Results and Discussion

The Table 1 and Figures 5 to 10 present the design data of SGT5-2000E gas turbine model obtained from the Geregu II Gas Turbine Power Plant located in Ajaokuta Kogi State North Central of Nigeria and results obtained.

The Figure 5 presents yearly ambient temperature distribution running through March 2018 – February 2019. From the Figure, it can be seen that the highest ambient temperature was in March 2018 while the lowest temperature was in December 2019. Similarly, the highest ambient condition was influenced by dry season harmattan wind from the Sahara in December to March while the corresponding low ambient temperature was due to rainy season spanning from April through September [19].

Figure 6 presents effect of ambient temperature on gas turbine power output. The Figure shows increase in ambient temperature lead to decrease in gas turbine output and vice versa. The decrease in gas turbine power output with increasing ambient temperature is due to reduced air density, leading to lower mass flow rates of air. This is critical because gas turbine power output is directly proportional to mass flow rate of air. Higher ambient temperatures reduce air density, decreasing the air mass flow into the compressor, which in turn reduces the power output. This trend aligns with findings in [17].

The Figure 7 presents effect of ambient temperature on specific fuel consumption. Specific fuel consumption is the quantity of fuel an engine burns per hour. The specific fuel consumption (SFC) increases with rising ambient temperature because the gas turbine's efficiency drops at higher temperatures. As ambient temperature increases, air density decreases with reducing mass flow rate, compressor work increase relative to turbine output and the turbine produces less power, but still needs to maintain operation, burning more fuel per unit of power output. Thus, SFC (fuel used per power output rises. This result aligns with the finding in [18].

Table 1: Design Data of SGT5-2000E Gas Turbine at Geregu II Gas Turbine Power Plant

S/N	Parameter	Symbol	Unit	Value
1	Ambient temperature	T_1	°C	15
2	Compressor outlet temperature	T_2	°C	350
3	Turbine inlet temperature	T_3	°C	1060
4	Turbine exit temperature	T_4	°C	540
5	Compressor inlet temperature	P_1	Bar	1
6	Compressor outlet pressure	P_2	Bar	11
7	Compressor pressure ratio	r_p		11:1
8	Turbine pressure ratio	r_p		1:11
9	Power output	P_{out}	MW	145
10	Mass flow of air in gas turbine	\dot{m}_a	kg/s	500
11	Mass flow of fuel in gas turbine	\dot{m}_f	kg/s	8
12	Specific heat ratio			1.4
13	Specific heat of air	c_{pa}	kJ/kg	1.005
14	Specific heat of gas	c_{pg}	kJ/kg	1.14
Assumptions				
15	Isentropic efficiency of compressor and turbine	η	%	90[4]
16	Mass flow rate of steam	\dot{m}_s	kg/s	0.136
17	Stack temperature	T_{stack}	°C	140
18	Steam pressure		Bar	50
19	Condensate pressure		Bar	5
20	Enthalpy of superheated steam	h_5	kJ/kg	3556.07
21	Enthalpy of low pressure steam	h_6	kJ/kg	2974.60

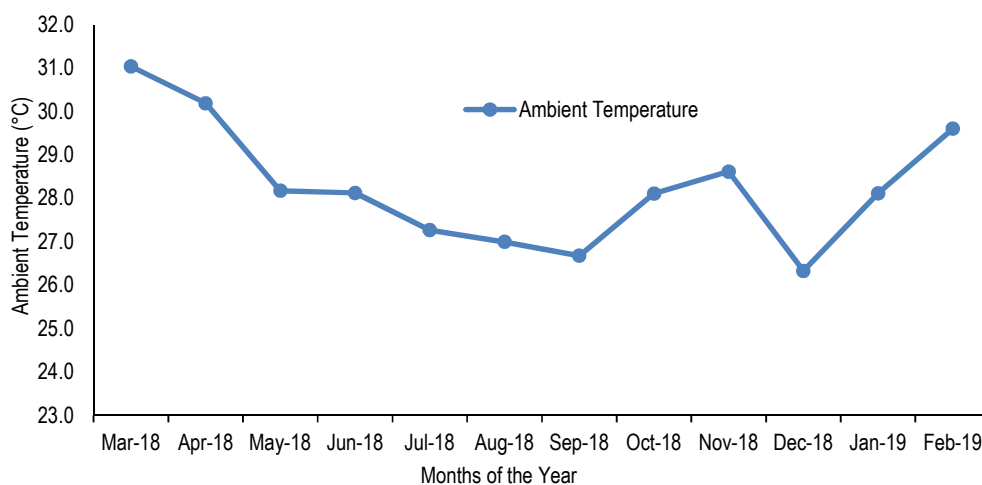


Figure 5: Yearly Ambient Temperature Distribution (March 2018-February 2019)

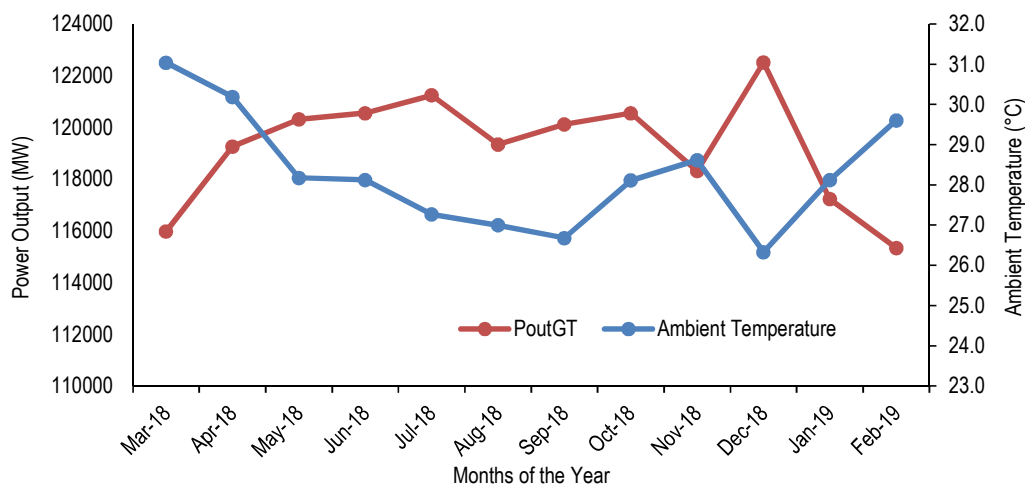


Figure 6: Effect of Ambient Temperature on Power Output

The Figure 8 presents effect of ambient temperature on thermal efficiency of the gas turbine power plant. The Figure illustrates the significant impact of ambient temperature on the thermal efficiency of the gas turbine power plant, revealing an inverse relationship between the two. As the ambient temperature increases, thermal efficiency decreases, primarily due to reduced power output and increased specific fuel consumption. This decrease in power output can be attributed to the reduction in air density at higher temperatures, resulting in lower mass flow rates and subsequently lower power generation. Furthermore, the increases specific fuel consumption is a

direct consequence of gas turbine's compressor requiring more energy to compress the less dense air, thereby reducing overall efficiency. This interplay highlights the challenges of operating gas turbine power plants in high-temperature environments, where efficiency and power output are compromised. The observed decrease in thermal efficiency with increasing ambient temperature aligns with finding from similar study in [19].

The Figure 9 presents combined cycle thermal efficiencies and when the plants are operating individually. Finally, Figure 10 presents combined cycle power output and when the plants are operating individually.

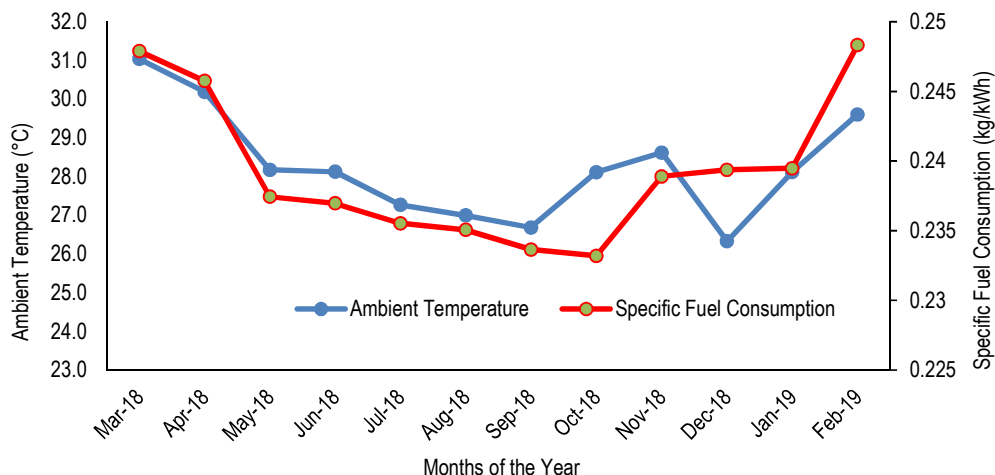


Figure 7: Effect of Ambient Temperature on Specific Fuel Consumption

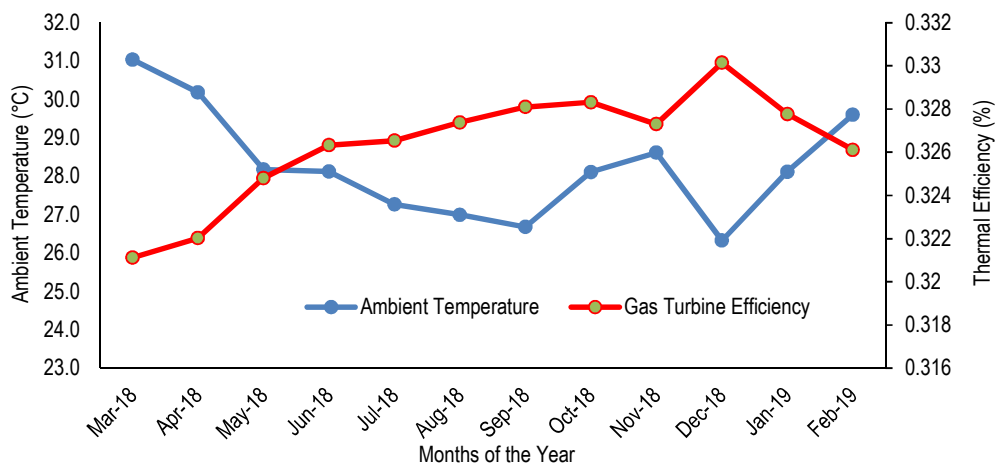


Figure 8: Effect of Ambient Temperature on Thermal Efficiency

The installation of combined cycle arrangement, as shown in Figure 9, leads to a significant improvement in thermal efficiency, achieving an overall efficiency of 55% in December 2018. This is a notable increase, with the gas turbine cycle contributing 33% and the steam cycle plant adding 22%. This combined cycle configuration outperforms individual gas and steam power plants, highlighting the benefits of harnessing waste heat from the gas turbine to generate additional power through the steam cycle. This approach maximizes fuel consumption,

ultimately leading to improves thermal efficiency. This result aligns with findings from a study by [20].

The installation of a combined cycle arrangement, as depicted in Figure 10, leads to a substantial increase in power output compared to individual gas and steam power plants. Notably, in December 2018, the combined cycle configuration achieves a total power output of 163.3 MW, comprising 122.2 MW from the gas turbine and 41.1 MW from the steam plants. This represents a significant enhancement in power generation capacity. Similar studies which have reported comparable findings are [21, 22].

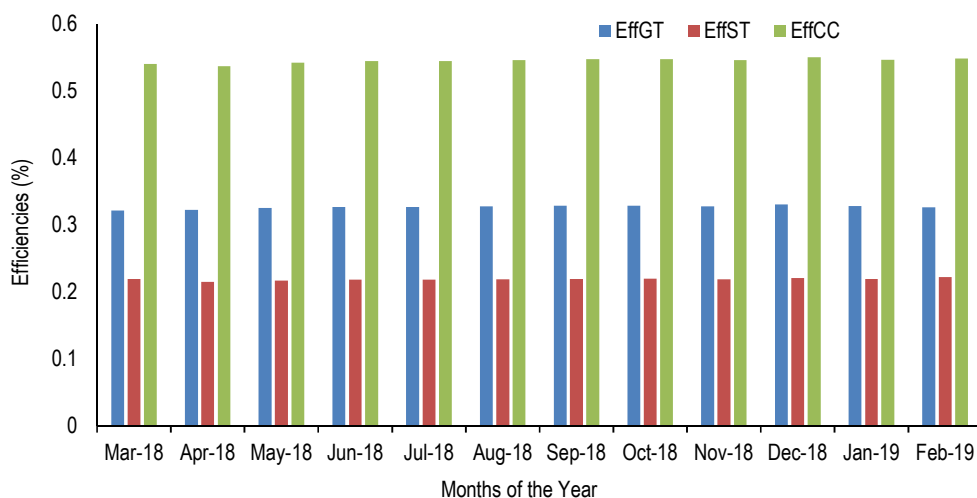


Figure 9: Combined Cycle Power Plant Efficiencies

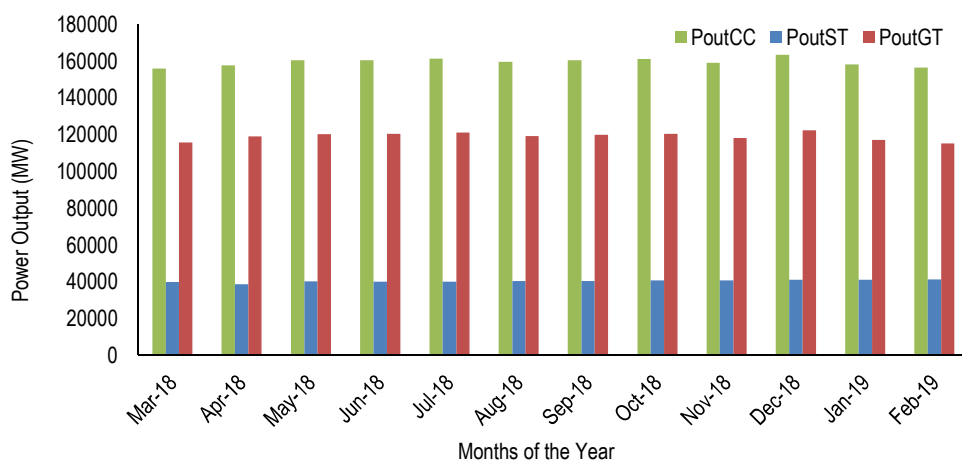


Figure 10: Combined Cycle Power Plant Power Output

3. Conclusion

The study concludes that retrofitting a simple cycle gas turbine power plant to a combined cycle power plant is an effective way to improve its performance. The results show that the combined cycle power plant achieves a higher thermal efficiency and power output of 55 % and 164 MW in December 2018. Therefore, retrofitting the existing simple cycle gas turbine power plant to combined cycle power plant can help improve its efficiency and reduce environmental impact. Similarly, in comparing the simple and combined cycles, there is an increase in both power output and thermal efficiency of the combined cycle power plant as against individual cycles.

Recommendations

- a. It is therefore recommended that future study should consider modifying the simple cycle gas turbine using steam injection, inlet air cooling, and incorporation of HRSG for combined heat and power and combined cycle power plant for increase in overall cycle efficiency, reduction of exhaust waste heat into the environment and improvement in power generation.

- b. Retrofitting the existing simple cycle gas turbine power plant to combined cycle power plant should be considered to improve efficiency and reduce its environmental impact.
- c. Further research should be conducted to investigate the economic feasibility and technical viability of retrofitting simple cycle gas turbine power plant to combined cycle power plant.

Acknowledgement

The authors appreciate the management of Geregu Gas Turbine Power Plant for providing data for the study.

References

- [1]. Cengel, Y. A. and Boles, M. A., (2006). *Thermodynamics: An engineering approach*, McGraw- Hill, New York, 6th edition, pp. 500-520.
- [2]. Egware, H. O. and Obonor, A. I., (2022). The investigation of an SGT5-2000E gas turbine power plant performance in Benin City based on energy analysis, *Energy Conversion and Management*, 16(October), 100316. <https://doi.org/10.1016/j.ecmx.2022.100316>

- [3]. Eke, M. N., Okoroigwe, E. C., Umeh, S. I. and Okonkwo, P., (2020). Performance improvement of a gas turbine power plant in Nigeria by exergy analysis: A case of Geregu 1, *Open Access Library Journal* 1(7), 1–20. <https://doi.org/10.4236/oalib.1106617>
- [4]. Raman, M. M., Thamir, K. I. and Abdalla, A. N., (2011). Thermodynamic performance analysis of gas-turbine power plant, *International Journal of the Physical Sciences*, 6(14), 3539-3550, <https://doi.org/10.5897/IJPS11.272>
- [5]. Ibrahim, T. K., Mohammed, M. K., Hussein, W., Al, A., Al-sammarraie, A. T. and Basrawi, F., (2019). Study of the performance of the gas turbine power plants from the simple to complex cycle: A technical review, *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 2(2), 228–250.
- [6]. Ibrahim, T. K. and Mohammed, M. N., (2015). Thermodynamic evaluation of the performance of a combined cycle power plant, *International Journal of Energy Science and Engineering*, 1(2), 60–70.
- [7]. Ibrahim, T. K., Rahman, M. M. and Alla, A. N. A., (2010). Study on the Effective Parameter of Gas Turbine Model with Intercooled Compression Process, *Scientific Research and Essays*, 5(23), 3760–3770.
- [8]. Ighodaro, O. O. and Egbon, O. C., (2021). Comparative Performance Assessment of different Gas Turbine Configurations: A study of a local power station in Nigeria, *Nigerian Journal of Engineering*, 28(2), 22–31.
- [9]. William, O. E. (2018). Performance analysis of gas turbine power (A case study of Delta III GT9 Transcorp gas turbine power plant , Ughelli , Nigeria), *Global Scientific Journals*, 6(6), 1-12.
- [10]. Mohan, G., Dahal, S., Kumar, U., Martin, A. and Kayal, H., (2014). Development of natural gas fired combined cycle plant for tri-generation of power, cooling and clean water using waste heat recovery: Techno-economic analysis, *Energies*, 7, 6358-6381. <https://doi.org/10.3390/en7106358>
- [11]. Nuraizat, A. and Sulaiman, B. I. N., (2012). *Thermodynamic Analysis of Gas Turbine by the Requirements for the Bachelor Of Engineering (Hons) (Mechanical Engineering)*. Department Of Mechanical Engineering, Universiti Teknologi Petronas Bandar Seri Iskandar 31750 Tronoh Perak Darul Ridzuan.
- [12]. Rahman, M. M., Ibrahim, T. K., Kadirgama, K., Mamat, R. and Bakar, R. A., (2011). Influence of Operation Conditions and Ambient Temperature on Performance of Gas Turbine Power Plant, *Advanced Materials Research: Trans Tech Publ*, 193, 3007–3013. <https://doi.org/10.4028/www.scientific.net/AMR.189-193.3007>
- [13]. Mustafa, A., Ahmad, S., Ali, A. and Ahmad, A., (2020). Thermal Analysis of a Combined Cycle Power Plant under Varying Operating Conditions, *Jordan Journal of Mechanical and Industrial Engineering*, 14(4), 387 - 392.
- [14]. Çengel, A. Y. and Boles, M. A., (2015). *Thermodynamics: An Engineering Approach*, 8th Edition, pp 99 - 105, McGraw-Hill Education, United States
- [15]. Charles, M., Abeeku, B., and Seth, P. A., (2010). Thermodynamic Analysis of the Gas and Steam Turbines at Takoradi Thermal Power Station, *European Journal of Technology and Advanced Engineering Research*, 1(2010), 62-72. <http://www.eurojournals.com/EJTAER.htm>
- [16]. Rahman, M. M. and Thamir, K. I., (2012). Parametric Study of a Two-Shaft Gas Turbine Cycle Model of Power Plant, *IOP Conference Series: Materials Science and Engineering* 36(2012), 1-14. <https://doi.org/10.1088/1757-899X/36/1/012024>
- [17]. Al-Hashimi, S., (2011). Impact of Ambient Temperature on the Performance of Gas Turbines. *International Journal of Engineering Research and Applications*, 1(4), 1657-1663
- [18]. Boyce, M. P. (2012). *Gas Turbine Engineering Handbook* (4th Ed.) Butterworth-Heinemann (An imprint of Elsevier) Oxford, UKr.
- [19]. Khalil, A. E. and El-Sharkawi, A. M., (2020). Ambient Temperature Effects on Gas Turbine Power Plant Performance. *International Journal of Ambient Energy*, 41(10), 1125-1134.
- [20]. Poullikkas, A., (2005). An Overview of Current and Future Sustainable Gas Turbine Technologies, *Renewable and Sustainable Energy Reviews*, 9(5), 409-443.
- [21]. Kaushik, S. C. and Singh, O., (2011). Gas Turbine Performance Enhancement Through Integrated Gas-Steam Cycle, *International Journal of Energy Research*, 35(10), 931-942.
- [22]. Srinivasan, P. and Kumar, N., (2019). Performance Analysis of Combined Cycle Power Plant, *Journal of Thermal Science and Engineering Applications*, 11(3), 031008.