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Analysis of the Effect of Inlet Compressor Temperature on the Thermal Efficiency of PLTG Unit 3.2 in Grati*

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Abstrak
PLTGU Grati blok 3 memiliki dua turbin gas, yaitu unit 3.1 dan unit 3.2, dengan Kapasitas Bersih masing-masing 145 MW untuk setiap turbin gas. Pada unit PLTG 3.2 Grati, terdapat masalah terkait perbedaan nilai efisiensi termal yang disebabkan oleh perubahan suhu inlet kompresor. Nilai efisiensi termal pada unit PLTG 3.2 Grati lebih tinggi ketika suhu inlet kompresor rendah. Oleh karena itu, untuk mengetahui pengaruh suhu inlet kompresor terhadap nilai efisiensi termal unit PLTG 3.2, dilakukan proses perhitungan parameter-parameter yang mempengaruhi nilai efisiensi termal untuk tujuan analisis. Dalam penelitian ini, perhitungan dilakukan pada tiga titik data suhu inlet kompresor, yaitu pada suhu 296,69 K, 299,49 K, dan 304,11 K, yang menghasilkan nilai efisiensi termal turbin gas sebesar 32,17%, 31,84%, dan 31,79%, masing-masing. Berdasarkan hasil perhitungan tersebut, menunjukkan bahwa seiring dengan meningkatnya suhu inlet kompresor, nilai efisiensi termal cenderung menurun.

Kata kunci : Suhu, PLTG, Efisiensi

Abstract
PLTGU Grati block 3 has two gas turbines, namely unit 3.1 and unit 3.2, with a Net Capacity of 145 MW for each gas turbine. In PLTG unit 3.2 Grati, there is an issue related to differences in thermal efficiency values caused by changes in the inlet compressor temperature. The thermal efficiency value of PLTG unit 3.2 Grati is high when the compressor's inlet temperature is low. Therefore, to determine the effect of the compressor's inlet temperature on the thermal efficiency value of PLTG unit 3.2, a calculation process of parameters affecting thermal efficiency values is conducted for analysis purposes. In this research, calculations were performed for three compressor inlet temperature data points, namely at temperatures of 296.69 K, 299.49 K, and 304.11 K, resulting in gas turbine thermal efficiency values of 32.17%, 31.84%, and 31.79%, respectively. Based on the calculation results, it is shown that as the compressor's inlet temperature increases, the thermal efficiency value decreases.

Keywords: Temperature, PLTG, Efficiency

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1. INTRODUCTION

A. Background

This The core issue under investigation in this research pertains to the variability of the compressor inlet temperature, which leads to disparities in the thermal efficiency values of Gas Turbine Power Plant (PLTG) Unit 3.2 at the Grati site. Notably, the thermal efficiency of PLTG Unit 3.2 is peak values during scenarios characterized by lower compressor inlet temperatures. This phenomenon is substantiated by data extracted from the Performance Management System (PMS), as illustrated in Figure 1.

LID	NAME	UNIT	29.07/2020 06:00 45	29.07/2020 12:00 20	29.07/2020 18:00 30
LG30131	G132 Compressor efficiency	%	92.6553	92.5811	92.6401
LG30132	G132 Compressor inlet air temperature	degC	23.5421	30.9644	26.3356
LG30133	G132 Compressor outlet air temperature	degC	341.8192	357.5382	348.8771
LG30134	G132 Compressor outlet air pressure	Bar	11.1110	11.1420	11.1892
LG30135	G132 Compresssor inlet pressure	Mbar	992.5281	994.9108	992.9541
LG30136	Specific heat ratio (K 1,4 constant)	-	1.41000	1.4000	1.4000
LG30137	G132 Compressor efficiency expected	%	0.2656	0.2782	0.2720
LG30138	G132 Compressor efficiency deviation	%	92.3097	92.3030	92.3681
LG30139	SPARE		0.0000	0.0000	0.0000
LG30140	SPARE		0.0000	0.0000	0.0000
LG30141	G131 gross efficiency	%	0.0000	0.0000	0.0000
LG30142	G131 net efficiency	%	0.0000	0.0000	0.0000
LG30143	G132 gross efficiency	%	30.9289	30.5616	30.6040

Figure 1. PMS Data for GT AE94.2 (Source: PMS Blok 3 PLTGU Grati PGU)

A prior study was conducted by Yolanda Imelda Putri in 2020 at Block 1 Unit 2 of the Gas Turbine Combined Cycle Power Plant (PLTGU) in Muara Karang, operated by PT. Pembangkitan Jawa Bali (PJB). Based on the outcomes of this research, it was indicated that the efficiency of the Gas Turbine Power Plant (PLTG) is affected by the inlet compressor temperature (Putri, 2020).

Based on the background above, the author aims to conduct a research study titled "Analysis of the Effect of Compressor Inlet Temperature on the Thermal Efficiency of Gas Turbine Power Plant (PLTG) Unit 3.2 in Grati.

B. Problem Formulation

Can the parameter of compressor inlet temperature affecting the thermal efficiency value of Gas Turbine Power Plant (PLTG) Unit 3.2 in Grati?

C. Objectives

1. Inlet temperature of the compressor versus mass flow rate of fuel, heat input, and heat rate.
2. Inlet temperature of the compressor in relation to air- fuel ratio and air mass flow rate.
3. Inlet temperature of the compressor affecting compressor efficiency, combustion chamber, and turbine efficiency.
4. Inlet temperature of the compressor and its impact on the thermal efficiency of the Gas Turbine Power Plant (PLTG)

D. Benefits

Based on this research, the expected benefits are as follows:

1. Theoretically
   This research can contribute to the field of electrical power engineering by analyzing the effect of gas turbine compressor inlet temperature parameters on the thermal efficiency of Gas Turbine Power Plants (PLTG).
2. Practically
   This research can provide practical insights by preparing an action plan for companies to maintain a stable gas turbine compressor inlet temperature based on the analysis results.

E. Literature Review

Based In a gas turbine, kinetic energy is converted into mechanical energy to rotate the turbine. The gas turbine consists of rotating components called the rotor and stationary components known as the stator. The generator load and compressor are driven by the rotor shaft of the gas turbine (Gusnita and Saputra, 2017).

In our previous review the gas turbine was viewed as a black box and the first law of thermodynamics applied. We will continue to use energy concepts; however, now we will begin analyzing the individual gas turbine components (compressor, combustor, turbine), rather than the system as a whole.

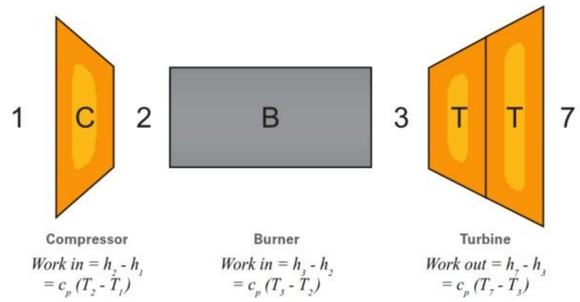


Figure 2. Compressor, Combustor and Turbine

Analyze the ideal simple Brayton cycle graphically, this time plotting temperature versus entropy (Figure 3). Note that the temperature (T) on this diagram can be exchanged with enthalpy (h) since they are related by:

$$h = CP \cdot T$$

The specific heat, CP, is assumed to stay constant throughout the process

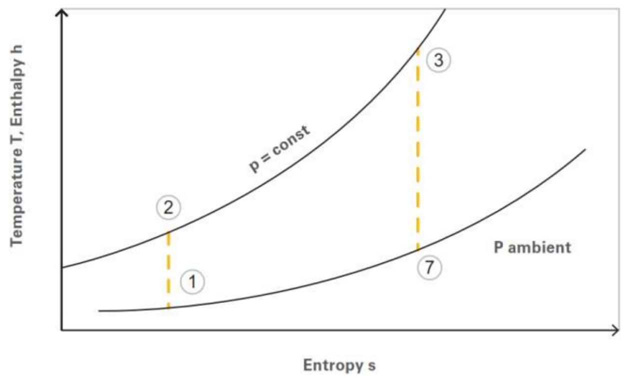
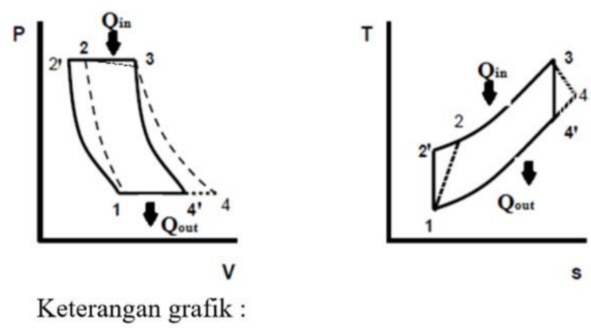


Figure 3. Temperature vs Entropy Process Diagram

In the Brayton cycle, the relationship between pressure- volume and temperature entropy is depicted throughout the compression, combustion, expansion, and exhaust phases, as shown in Figure 2.



Keterangan grafik :
Grafik no. 1-2'-3-4'= Proses ideal
Grafik no. 1-2-3-4 = Proses aktual

Figure 4. P-V and T-S Diagram (Faizal *et al*, 2017)

Here is the Brayton Cycle process :

1. Compression

   On the graph, the process from point 1 to point 2 represents isentropic compression. In this process, atmospheric air is compressed in an adiabatic manner. Adiabatic conditions involve perfect heat insulation, meaning there is no heat entering or leaving the system. The ideal gas equation shows that the temperature of air affects the density of air/gas:

$$\frac{P.v}{T} = constant \qquad (1)$$

Explanation:
P = pressure
υ = specific volume, υ = 1/ϱ, ϱ = density of air/gas
T = temperature (Cengel *et al*, 2019)
If the pressure of air/gas is constant, the equation becomes as follows:

$$\frac{p1}{p2} = \frac{T2}{T1} \qquad (2)$$

$$\frac{Pr2}{Pr1} = \frac{P2}{P1} \qquad (3)$$

Explanation:
Pr1 = Relative pressure of air entering the gas turbine compressor
Pr2 = Relative pressure of air exiting the gas turbine compressor
P1 = Pressure of air entering the gas turbine compressor (kg/cm2)
P2 = Pressure of air exiting the gas turbine compressor (kg/cm2)

$$\frac{Pr3}{Pr4} = \frac{P3}{P4} \qquad (4)$$

Explanation:
Pr3 = Relative pressure of gas entering the turbine Pr4 = Relative pressure of gas exiting the turbine P3 = Pressure of gas entering the turbine (kg/cm2) P4 = Pressure of gas exiting the turbine (kg/cm2)

$$rp = \frac{P2}{P1} \qquad (5)$$

Explanation:
rp = Pressure ratio
P1 = Pressure of air entering the compressor (kg/cm2) P2 = Pressure of air exiting the compressor (kg/cm^2)

$$rp = \frac{Pr2}{Pr1} = \frac{Pr3}{Pr4} \qquad (6)$$

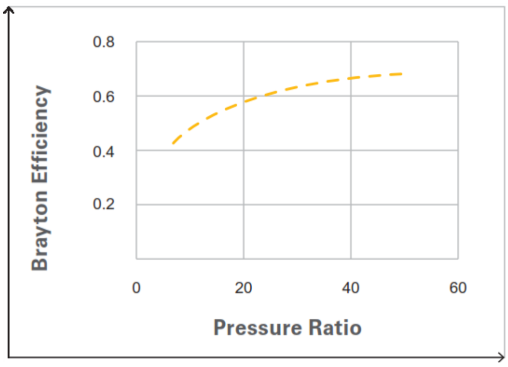


Figure 5. Brayton Cycle Maximum Theoretical Efficiency (Brun and Kurz, 2019)

Explanation:
rp = Pressure ratio
Pr1 = Relative pressure of air entering the compressor
Pr2 = Relative pressure of air exiting the compressor
Pr3 = Relative pressure of gas entering the turbine
Pr4 = Relative pressure of gas leaving the turbine (Rahman *et al*, 2011)

$$Pr4 = \frac{(T4 - T\ bawah)(\Pr atas - \Pr bawah)}{(T\ atas - T\ bawah)} + \Pr bawah \qquad (7)$$

$$T2' = T1 \times rp^{(k-1)/1,4} \qquad (8)$$

Explanation:
T1 = Temperature of air entering the compressor (K)
rp = Pressure ratio
bawah = lower
atas = upper

$$T4' = T4 \times \frac{1}{\frac{rp(k-1)}{1{,}4}} bawah \quad (9)$$

Explanation:
T3 = Temperature of air entering the turbine (K)
rp = Pressure ratio(Mubarrok, 2021)

$$h1 = \frac{(T1 - T\ bawah)(h\ atas - h\ bawah)}{(T\ atas - T\ bawah)} + h\ bawah\ bawah \quad (10)$$

$$m_{bb} = \frac{V\ bb \times Sg\ bb \times \rho\ udara}{3600} \quad (11)$$

Explanation:
ṁ bb = Mass flow rate of fuel (kg/s)
V bb = Volume flow rate of fuel (Nm³/h)
Sg bb = Specific gravity of fuel ϱ Air = Air density (kg/m3
The calculation of the air-fuel ratio $\left(\frac{A}{F}\right)$ is determined using the formula provided below :

$$\left(\frac{A}{F}\right) = \frac{\frac{wgen}{\eta\ gen} - m\ bb(h3 - h4)}{m\ bb(h3 - H4) - m\ bb(h2 - h1)} \quad (12)$$

Explanation:
(A/F) = Air-fuel ratio
m ḃ b = Mass flow rate of fuel (kg/s) m u = Mass flow rate of air (kg/s)
h1 = Enthalpy of air at compressor inlet (kJ/kg) h2 = Enthalpy of air at compressor exit (kJ/kg)
h3 = Enthalpy of gas from combustion to turbine inlet (kJ/kg)
h4 = Enthalpy of gas at turbine exit (kJ/kg) Wgen = Generator work (kW)
η gen = Generator efficiency (%)
The calculation of the mass flow rate of air is based on the formula provided below

$$\dot{m}\ udara = \dot{m}\ bb \times \frac{A}{F} \quad (13)$$

Explanation:
ṁ udara = Mass flow rate of air (kg/s)
ṁ bb = Mass flow rate of fuel (kg/s)
$\frac{A}{F}$ =Air fuel ratio

$$\dot{m}\ Gas = \dot{m}\ air + \dot{m}\ bb \quad (14)$$

Explanation:
ṁ Gas = Mass flow rate of gas (kg/s)
ṁ air = Mass flow rate of air (kg/s)
ṁ bb = Mass flow rate of fuel (kg/s) (Nugraha, 2020)
The calculation of compressor efficiency using the formula provided below :

$$\eta\ Compressor = \frac{h2^{F-h1}}{h2 - h1} \times 100\% \qquad b \quad (15)$$

Explanation:
$\eta\ Compresor$ = Compressor efficiency (%)
h1 = Enthalpy of air entering the compressor (kJ/kg)
h2 = Enthalpy of actual air leaving the compressor (kJ/kg)
h2' = Enthalpy of ideal air leaving the compressor (kJ/kg)

$$\dot{W}\ c = \dot{m}\ air\ \times (h2 - h1) \quad (16)$$

Explanation:
W c = Compressor work (kJ/s)
$\dot{m}$ udara = Mass flow rate of air (kg/s)
h1 = Enthalpy of air entering the compressor (kJ/kg)
h2 = Enthalpy of air exiting the compressor (kJ/kg)

2. Combustion

In the graph from point 2 to point 3, the combustion process occurs in the combustion chambers at constant pressure. The combustion process involves adding heat, leading to a change in gas temperature.

The calculation of the mass flow rate of fuel is based on the following formula:

$$\dot{m}bb = \frac{V\ bb \times Sg\ bb \times \rho\ udara}{3600} \quad (17)$$

Explanation:
$\dot{m}$ bb = Mass flow rate of fuel (kg/s)
V̇ bb = Volumetric flow rate of fuel (Nm^3/h)
Sg bb = Specific gravity of the fuel
ρ Udara = Air density (kg/m3)
The calculation of heat input is based on the formula below

$$Q\ in = \dot{m}\ bb \times LHV \quad (18)$$

Explanation:
$Q\ in$ = Heat input in the combustion chamber (kJ/s)
ṁ bb = Mass flow rate of fuel (kg/s) LHV = Low heating value (kJ/kg)
The calculation of combustion chamber efficiency (ηcombution chamber) is based on the formula

$$\eta\ combution\ chamber = \frac{T2 - T3}{T2 - T3} \times 100\% \quad (19)$$

Explanation:
T2 = Actual air temperature leaving the compressor (K)
T2’ = Ideal air temperature leaving the compressor (K)
T3 = Gas temperature entering the turbine (K)

3. Expansion

In the graph from point 3 to point 4, expansion occurs in the gas turbine in an isentropic manner. This expansion in the gas turbine involves decreasing gas pressure and temperature to drive the turbine. The high-temperature and high-pressure combustion gases are transformed into a high-speed fluid that rotates the turbine.

Calculation of turbine work based on the formula below

$$W\ T = \dot{m}\ Gas \times (h3 - h4) \quad (20)$$

Explanation:
W T = Turbine work (kJ/s)
$\dot{m}$ Gas = = Mass flow rate of gas (kg/s)
h3 = Enthalpy of gas entering the turbine (kJ/kg)
h4 = Enthalpy of gas exiting the turbine (kJ/kg)

The calculation of turbine efficiency is based on the formula :

$$\eta\ Turbine = \frac{h3 - h4}{h3 - h4} \times 100\% \quad (21)$$

Explanation:
η Turbine = Turbine efficiency (%)
h3 = Enthalpy of gas entering the turbine (kJ/kg) h4 = Enthalpy of gas exiting the turbine (kJ/kg)
h4’ = Enthalpy of ideal gas exiting the turbine (kJ/kg) (Yogaswara *et al*, 2020)

4. Exhaust

In the graph, the process from point 4 to point 1 represents the gas disposal process at constant pressure. This process begins with the combustion gases that have been utilized by the turbine and are then directed into the exhaust duct. In the exhaust process, there is heat released into the atmosphere.

The thermal efficiency of a Gas Turbine Power Plant (PLTG) is a measure to determine how efficiently the gas turbine unit generates energy. The calculation of thermal efficiency for a PLTG is based on the formula provided below :

$$\eta\, Thermal\ PLTG = \frac{W^{T-WC}}{Qin} \times 100\% \qquad (22)$$

In addition to the calculation method mentioned above, the efficiency value is the ratio between the output (energy production in kWh) and input (fuel consumption). The calculation is based on the formula provided below :

$$\eta\, Thermal\ PLTG = \frac{Prod\ (kWh \times 860^{(Kcal)})}{Fuel\ Volume\ (kg{:}\ ltr) \times Caloricvalue^{\left(\frac{Kcal}{kg:ltr}\right)}} \times 100\% \qquad (23)$$

$$\eta\, Thermal\ PLTG = \frac{P}{Qm} \times 100\% \qquad (24)$$

Explanation:
η Thermal PLTG = Thermal efficiency (%)
W T = Work from the turbine (kJ/s)
W C = Work from the compressor (kJ/s)
Q in = Heat input (kJ/s)
P = Power generator (kJ/s)

Heat Rate is the amount of energy from fuel utilized to produce 1 kWh of electrical energy. The calculation of the heat rate is based on the formula provided below :

$$Heat\ Rate = \frac{Q\ m}{W1 - Wc} \qquad (25)$$

Explanation:
Heat Rate = Fuel energy used (kJ/kWh)
Q in = Heat input (kJ/s)
W C = Work from the compressor (kJ/s)
W T = Work from the turbine (kJ/s) (Setiawan *et al*, 2019)

2. METHODOLOGY

Data Collection Method

A. Direct Observation Method

Conducting field studies, collecting operational data of the Gas Turbine (GT) through log sheet records of operational parameters in Table 1 and the Central Control Room (CCR) Planned Maintenance System (PMS) of Block 3 at Grati Combined Cycle Power Plant (PLTGU Grati). In Figure 3, several data collection points for gas turbine operation are depicted, including various sensors for temperature, pressure, flow, and more.

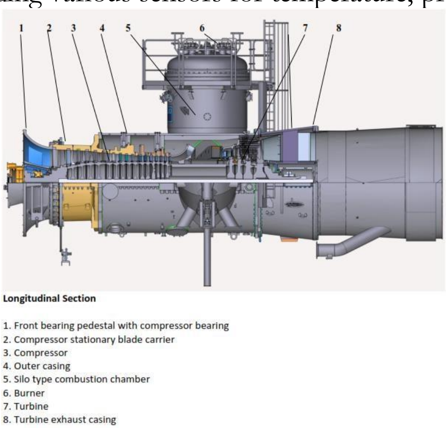


Figure 6. Data Collection Points for GT Operation (Energia , 2017)

Table 1. Log Sheet Record of GT Operational Parameters

No	Parameter	Symbol	Unit	Gas Turbine Compressor Inlet Temperature 296,69 K	Gas Turbine Compressor Inlet Temperature 299,49 K	Gas Turbine Compressor Inlet Temperature 304,11 K
1	GT 3.2 Compressor Inlet Temperature	T1	degC	23,54	26,34	30,96
2	GT 3.2 Compressor Inlet Pressure	P1	degC	992,53	992,95	994,91
3	GT 3.2 Compressor Outlet Air Temperature	T2	degC	341,82	348,88	357,54
4	GT 3.2 Compressor Outlate Air Pressure	P2	Bar	11,11	11,19	11,14
5	GT 3.2 Exhaust Gas Duet Temp (ave)	T4	degC	555,58	556,86	566,89
6	GT 3.2 Exhaust Gas Duct Press	P4	mbar	19,35	19,54	18,70
7	Block Active Power (gross MW)	P	MW	146	146	146
8	Gas Volumetric calorific value of fuel		Gj/Nm	35,31	35,31	35,31
9	Fuel gas metering flowrate energy		Gj/h	1701,45	1718,32	1719,37
10	Volume bahan bakar	LHV	Nm^3/h	48186,07	48663,75	48693,66
11	Gas lower heating value		kJ/kg	45269,23	45269,23	45269,23
12	Density of fuel gas		Kg/Nm^3	0,78	0,78	0,78
13	Spesific gravity bahan bakar	Sg bb		0,63	0,63	0,63

B. Indirect Observation Method

The literature review conducted is based on the gas turbine AE94.2 manual book and research journals on enhancing gas turbine efficiency.

C. Research Stage Design

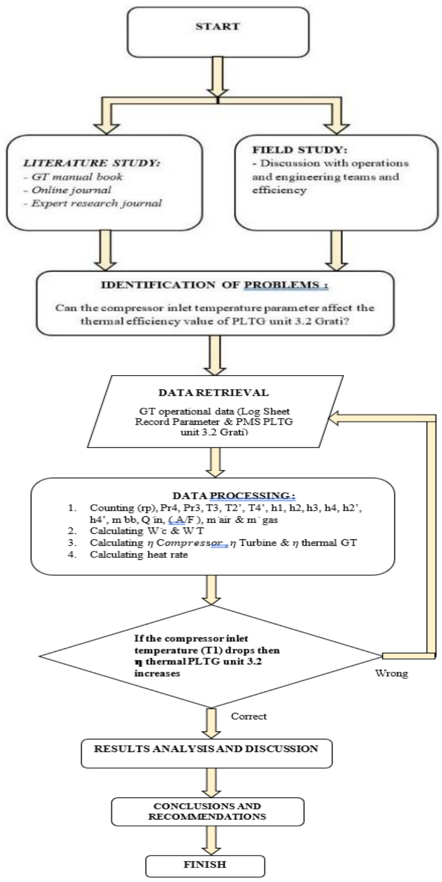


Figure 7. Research Methodology Flowchart

D. Calculation Method or Data Processing

a. Calculate the compression ratio (rp) using equation (5).
b. Calculate the relative pressure of the gas exiting the turbine (Pr4) using equation (7), calculate the relative pressure of the gas entering the turbine (Pr3), and calculate the gas inlet temperature to the turbine (T3).
c. Calculate the ideal temperature of air exiting the compressor (T2') using equation (8) and the ideal temperature of gas exiting the turbine (T4') using equation (9).
d. Calculate enthalpy using interpolation method based on the ideal-gas properties of air table at each gas turbine cycle, starting from the enthalpy entering the compressor (h1) using equation (10), enthalpy exiting the compressor (h2), enthalpy entering the turbine (h3), enthalpy exiting the turbine (h4), ideal enthalpy exiting the compressor (h2'), and ideal enthalpy exiting the turbine (h4').
e. Calculate the mass flow rate of fuel ($\dot{m}$ bb) using equation (17).
f. Calculate the heat input ($Q\ in$) using equation (18).
g. Calculate the air-fuel ratio (A/F) using equation (12).
h. Calculate the mass flow rate of air ($\dot{m}$ air) using equation (13).
i. Calculate the gas flow rate ($\dot{m}$ Gas) using equation (14).
j. Calculate the compressor efficiency (ηCompressor) using equation (15).
k. Calculate the compressor power (W c) using equation (16).
l. Calculate the turbine efficiency (ηTurbin) using equation (21).
m. Calculate the turbine power (W T) using equation (20).
n. Calculate the η thermal PLTG unit 3.2 (calculated output power) using equation (22).
o. Calculate the η thermal PLTG unit 3.2 using the input- output method (measured output power) using equation (23/24).
p. Calculate the heat rate using equation (25).

3. RESULT & DISCUSSION

A. Comparison of Pressure Ratio and Brayton Efficiency

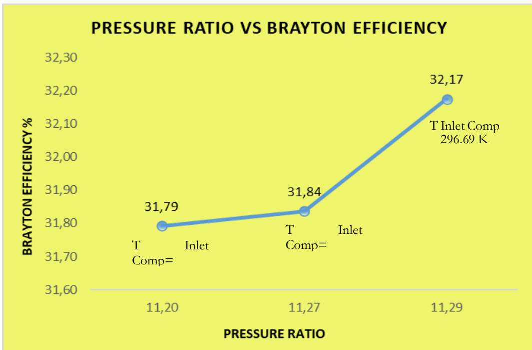


Figure 8. Comparison of Pressure Ratio and Brayton Efficiency

The temperature versus entropy (T-s) diagram allows us to quantitatively assess the efficiency of a thermodynamic process, since an entropy increase indicates thermodynamic nonrecoverable energy losses. Thus, following the air as it passes through the previously defined states of a simple Brayton cycle. Results comparison of pressure ratio and brayton efficiency matching with figure 5. simple brayton cycle maximum theoretical efficiency. The research results show that with increasing pressure ratio, Brayton efficiency also increases. The highest Brayton efficiency value is at a pressure ratio of 11.29, namely 32.17% at a compressor inlet temperature of 296.69 K, and the lowest Brayton efficiency value is at a pressure ratio of 11.20, namely 31.17% at a compressor inlet temperature of 304.11 K.

B. Comparison of Fuel Mass Flow Rate

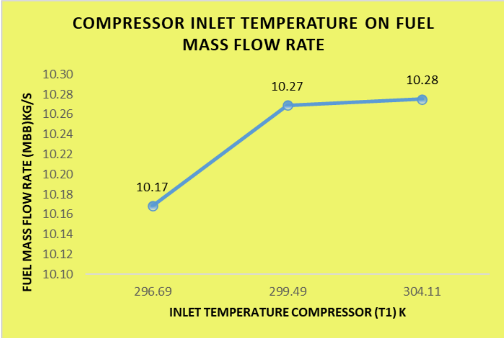


Figure 9. Comparison of Fuel Mass Flow Rate

The results of this research showed the highest value of fuel mass flow rate at an inlet compressor temperature of 304.11 K, which was 10.28 kg/s, and the lowest at 296.69 K, which was 10.17 kg/s.

C. Comparison of Heat Input

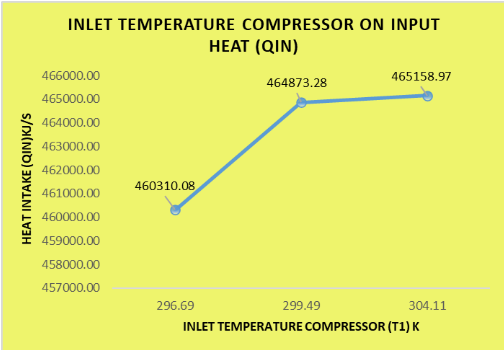


Figure 10. Comparison of Heat Input

The research results showed that the highest heat input value was obtained at an inlet compressor temperature of 304.11 K, amounting to 465,158.97 kJ/s, while the lowest was at 296.69 K, amounting to 460,310.08 kJ/s

D. Comparison of Combustion Chamber Efficiency

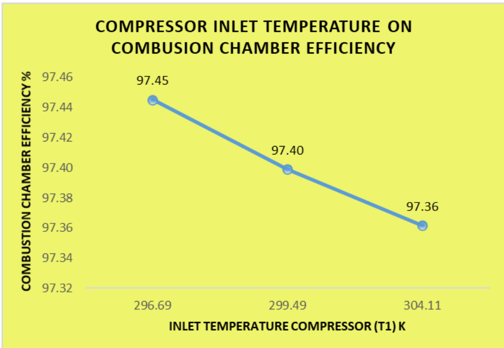


Figure 11. Comparison of Combustion Chamber Efficiency

The research results revealed that the highest combustion chamber efficiency value was achieved at an inlet compressor temperature of 296.69 K, which was 97.45%, and the lowest was at 304.11 K, which was 97.36%.

E. Comparison of Air-Fuel Ratio

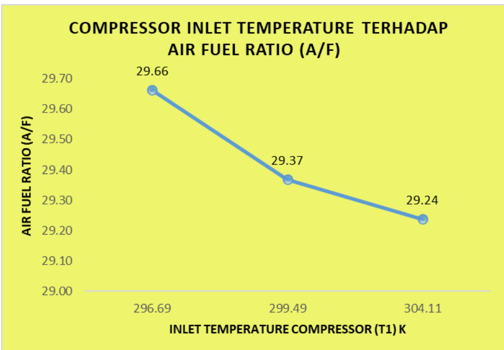


Figure 12. Comparison of Air-Fuel Ratio

The research results showed that the highest air-fuel ratio value was obtained at an inlet compressor temperature of 296.69 K, which was 29.66, while the lowest was at 304.11 K, which was 29.24.

F. Comparison of Air Mass Flow Rate

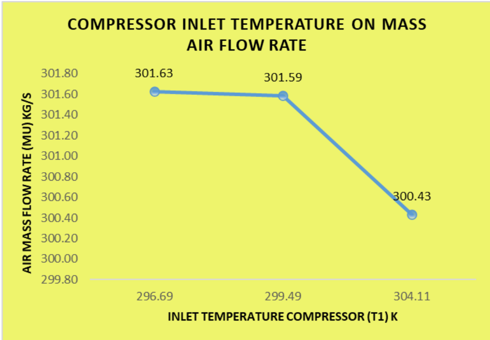


Figure 13. Comparison of Air Mass Flow Rate

The research results showed that the highest value of air mass flow rate was obtained at an inlet compressor temperature of 296.69 K, amounting to 301.63 kg/s, while the lowest was at 304.11 K, amounting to 300.43 kg/s.

G. Comparison of Compressor Efficiency

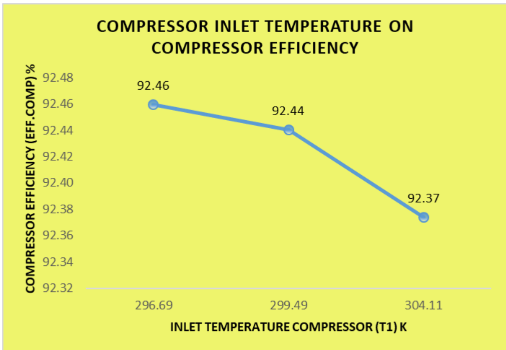


Figure 14. Comparison of Compressor Efficiency

The comparison of compressor efficiency in PLTG Unit 3.2 indicated that the higher the inlet compressor temperature, the lower the compressor efficiency. The compressor efficiency equation is affected by several factors, including the enthalpy entering the compressor, the enthalpy leaving the compressor, and the ideal enthalpy leaving the compressor. The research results showed that the highest compressor efficiency value occurred at an inlet compressor temperature of 296.69 K, which was 92.46%, and the lowest was at 304.11 K, which was 92.37%.

H. Comparison of Turbine Efficiency

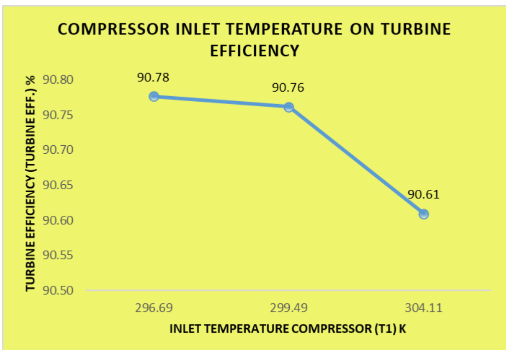


Figure 15. Comparison of Turbine Efficiency

The comparison of turbine efficiency in GTPP Unit 3.2 showed that the higher the inlet compressor temperature, the lower the turbine efficiency. The turbine efficiency is determined by the values of enthalpy entering the turbine, enthalpy leaving the turbine, and the ideal enthalpy leaving the turbine. The research results showed that the highest turbine efficiency value occurred at an inlet compressor temperature of 296.69 K, which was 90.78%, and the lowest was at 304.11 K, which was 90.61%.

I. Comparison of Thermal Efficiency of PLTG

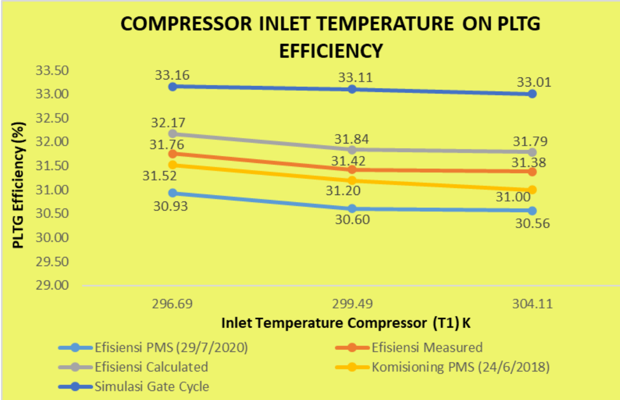


Figure 16. Comparison graph of thermal efficiency of PLTG

Table 2. Comparison of Thermal Efficiency for PLTG Unit 3.2

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	
[illegible]		

Based on all the methods used for calculating thermal efficiency, it is evident that there is an effect of the inlet compressor temperature on the thermal efficiency of PLTG Unit 3.2. Specifically, as the inlet compressor temperature increases, the thermal efficiency of PLTG Unit 3.2 decreases. This effect is attributed to a decrease in compressor efficiency, contributing to the overall thermal efficiency reduction. The decrease in compressor efficiency is due to the increasing workload of the compressor when the inlet compressor temperature rises. The heavier workload on the compressor results from changes in the density of the incoming air. Lower air density reduces the mass flow rate of air. As the mass flow rate of air decreases, the mass flow rate of fuel increases, along with the heat input, due to the constant generator output setting. These factors lead to the low thermal efficiency of PLTG Unit 3.2. To address this issue, the addition of a cooling system to the GT compressor's inlet air filter is necessary. The purpose of this cooling system is to maintain a low inlet compressor temperature, around 296.69 K, which can result in improved thermal efficiency for PLTG Unit 3.2

J. Comparison of Heat Rate

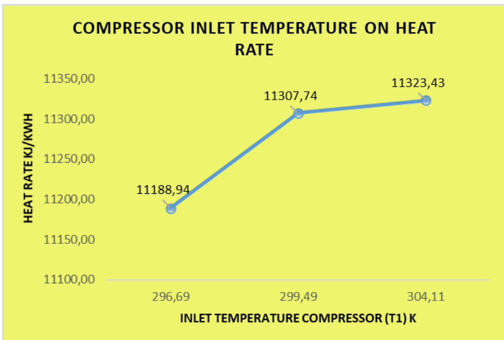


Figure 17. Comparison of Heat Rate

The research results showed that the highest heat rate value was obtained at an inlet compressor temperature of 304.11 K, amounting to 11,323.43 kJ/kWh, while the lowest was at 296.69 K, amounting to 11,188.94 kJ/kWh.

K. Analysis of the Influence of Inlet Compressor Temperature on the Thermal Efficiency of PLTG Unit 3.2 Grati

Table 3. Inlet Compressor Temperature Data on Efficiency

Increase in temperature K	Increase in temperature C	Air mass flow rate (mu) kg/s	Compressor efficiency (Eff.Comp)	Thermal Efficiency of PLTG (Eff. PLTG) %
299.15	26	301.60	92.43	31.85
301.15	28	301.30	92.41	31.73

From the analysis data of the inlet compressor temperature's effect on the thermal efficiency of PLTG Unit 3.2 Grati, it was found that an increase of 2°C (275.15 K) in the inlet compressor temperature resulted in a decrease of 0.29 kg/s in the air mass flow rate and a decrease of 0.02% in compressor efficiency, leading to a decrease of 0.12% in the thermal efficiency of the PLTG.

4. CONCLUSION AND RECOMMENDATION

A. Conclusion

Based on the analysis of the research above, the following conclusions can be drawn:

1. When the inlet compressor temperature increased by 2°C (275.15 K), it caused a decrease of 0.29 kg/s in the air mass flow rate and a decrease of 0.02% in compressor efficiency, resulting in a 0.12% decrease in the thermal efficiency of the PLTG.
2. The inlet compressor temperature affects the fuel mass flow rate,heat input,heat rate,air-fuel ratio, air mass flow rate,efficiency of the compressor, combustion chamber, and turbine.
3. The inlet compressor temperature affects the thermal efficiency value of PLTG Unit 3.2 in Grati. Specifically, as the inlet compressor temperature increases, the thermal efficiency of PLTG Unit 3.2 Grati decreases. This effect is evident when the inlet compressor temperature increases, specifically at 296.69 K, 299.49 K, and 304.11 K, resulting in a decrease in the thermal efficiency value of PLTG Unit 3.2 Grati to 32.17%, 31.84%, and 31.79%.

B. Recommendation

1. Further studies are recommended regarding the addition of a cooling system to the inlet air filter of the GT compressor to maintain a low inlet compressor temperature
2. Considering the lowland location of the Grati Gas Turbine Power Plant (PLTG), reforestation efforts should be conducted by planting trees in the vicinity of the power plant to enhance the thermal efficiency of the PLTG.

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