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Analysis of Gas Turbine Performance Based on Variation of Operating Load at PLTGU Panaran 1 Unit 1 PT.Mitra Energi Batam

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ABSTRACT

Gas and steam power generation units often experience changes in load according to the requested electricity needs. Changes in generator workload will also affect the efficiency of the generator. The different efficiency in each workload will have an effect on the amount of heat rate production produced when compared. By calculating the efficiency at each load, it will be useful to find out the workload with the best performance. From the results of the enthalpy calculation process based on the temperature of each gas turbine process, in this study the gas turbine performance is calculated, and then it compares the turbine performance with variations in operating load. The turbine performance that will be calculated includes compressor power, turbine power, net power, thermal efficiency, compressor efficiency, combustion chamber efficiency, turbine efficiency, heat input, and heat rate. The results of the calculation of the highest average thermal efficiency at 27 MW load were 35.18%; the average compressor efficiency experienced the highest increase at 25 MW load of 83.24%, followed by an average increase in combustion chamber efficiency and an average decrease in turbine efficiency at each increase in load, as well as experiencing the lowest decrease in heat rate at 27 MW load conditions of 2,842 kJ/kWh.

Keywords: *Load Variation, Gas turbine, Efficiency, Performance.*

Introduction

Electrical Energy is the main source of energy that is widely used and needed in the development of a country. This can be seen from the increasing growth in industry, education and the economy which has resulted in an increase in the rate of electricity consumption [1]. Therefore, increasing efficiency in the operation of generating units is very important as a provider of electrical energy in the present and in the future.

Gas and Steam Power Plant (PLTGU) is a type of power plant in Indonesia that is chosen to meet the demand for electricity which in operation experiences load changes every time, depending on consumer demand. The PLTGU load that changes every time will affect the gas turbine which is a constituent component of gas and steam power plants [2].

Gas turbine is an internal combustion engine that utilizes air and gas as the fluid. Gas turbines that experience variations in loading will affect the performance of each of its components such as the compressor, combustion chamber and gas turbine [3]. When a load change occurs, the combustion air, fuel supply, and exhaust gas that will be processed into the HRSG will also change[4].

Research conducted by Budiono,Lukman (2013) analysis of the efficiency of the gas turbine against the operating load of PLTGU Muara Tawar Block 1. The results obtained for unit 1 are efficiency values with variations in load of 90 MW, 100 MW, 110 MW, 125 MW, and 136 MW in gas turbines with Maximum Capacity Rate or installed capacity of 145 MW. The resulting thermal efficiency values are 34.25%, 34.79%, 35.21%, 36.09% and 36.35%. In this study it is known that the greater the loading process, the greater the efficiency. If the efficiency decreases as the load increases, the gas turbine components that are damaged and fail must be maintained or even overhauled [5].

Research conducted by Muhammad Nafi Annur (2017) The Effect of Load Variation on Gas Turbine Performance in PLTGU Block GT 1.3 PT. Indonesia Power Grati, Pasuruan. In this study it was concluded that there was an increase in temperature from the start of the compressor discharge temperature to the end of each process which determines the enthalpy for each load and affects the performance of each gas turbine component [6].

PT Mitra Energi Batam's Panaran 1 gas and steam power plant (PLTGU) has 2 power units with a 2-2-1 configuration, including MEB 1 and MEB 2 with a capacity of 82.1 MW. In the PLTGU MEB 1 unit, the gas turbine operates at a fairly high temperature and works for a long time at variations in operating load. Under these conditions, over time the performance of the gas turbine will decrease[7] . To monitor the performance of the gas turbine, it is necessary to analyze the performance of the gas turbine related to the factors of safety, efficiency and reliability as a determinant of maintenance and overhaul of gas turbines [8]

Research Methods

The data collection used for this study was obtained from several related sections, namely the CCR (Central Control Room) PLTGU and the Engineering Team. In addition, data and information were obtained from literature studies obtained from manual books, scientific journals [9]. The theory of gas turbine performance calculations uses a thermodynamic formula that works with the Brayton cycle [10][11]. This cycle is an ideal cycle for a simple gas turbine system with an open cycle. The ideal cycle is a cycle that is built based on the following assumptions [12][13].

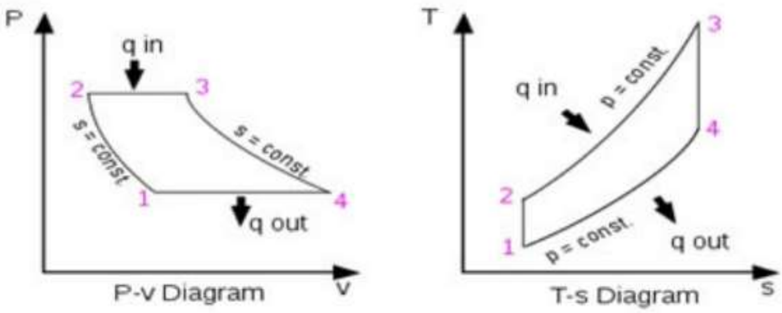

Figure 1. Siklus Ideal brayton

Cycle process as follows

a. The process of compression and expansion takes place reversibly adiabatic (isentropic).
b. The change in kinetic energy of the working fluid between the inlet and outlet sides of each compressor is ignored.
c. There is no pressure loss at the inlet and outlet of the gas.
d. The working fluid is considered an ideal gas with a constant specific heat[14].

The data processing technique was carried out to find out the comparison of changes in the load variations of the PLTGU MEB 1 gas turbine which describes the data processing as follows.

1. Process gas turbine performance data, such as temperature and pressure for each load variation. The processed data will be used to determine the enthalpy in each work cycle of the gas turbine which is then used to calculate the efficiency of the Panaran 1 Unit 1 PLTGU MEB 1 gas turbine.
2. The pressure data obtained will be processed to determine the pressure ratio which is specifically used to determine the ideal gas turbine cycle work and is also used to assist actual calculations.
3. Process data related to load variations carried out on the compressor, combustion chamber and turbine sides at Panaran 1 Unit 1 PLTGU MEB 1
4. Quantitative methods are used in calculating existing data and parameters at PLTGU MEB unit 1, then using formulas related to gas turbine efficiency.

Results and Discussion

Panaran Operation Performance Test Data 1 Unit 1

After observing at PT Mitra Energi Batam, obtained data from the Panaran 1 Unit 1 PLTGU gas turbine for each load variation that has been converted, as follows.

Table 1. Operation Performance Test Data 1 Unit 1

Load (MW)	T1 (K)	P1 (bar)	T2 (K)	P2 (bar)	T4 (K)	Wgen (MW)	mf (kg/s)	LHV (kJ/kg)
22,21	299,28	1	728,25	16,6	1011,35	22,21	1,505	44193,85
22,84	299,23	1	729,75	16,7	1016,45	22,84	1,547	44193,85
23,17	299,3	1	730,55	16,8	1018,75	23,17	1,555	44193,85
23,77	299,39	1	736,95	17,2	1028,65	23,77	1,609	44193,85
24,1	299,43	1	737,25	17,3	1030,85	24,1	1,615	44193,85
24,7	299,87	1	739,05	17,4	1035,65	24,7	1,637	44193,85
25,02	299,26	1	738,55	17,5	1035,35	25,02	1,648	44193,85
25,35	299,56	1	743,35	17,9	1044,95	25,35	1,691	44193,85
26,01	299,54	1	743,95	17,9	1047,15	26,01	1,713	44193,85
26,6	299,42	1	748,95	18,3	1056,05	26,6	1,749	44193,85
27,55	299,67	1	752,65	18,6	1064,05	27,55	1,779	44193,85
27,75	299,98	1	754,75	18,8	1068,65	27,75	1,815	44193,85

Performance Calculation of PLTGU Panaran 1 Unit 1 Gas Turbine PT Mitra Energi Batam with different load variations

This sub-chapter will describe how to calculate the performance of the Panaran 1 Unit 1 gas turbine PLTGU PT Mitra Energi Batam. The data used in the calculation example is PLTGU Panaran 1 Unit 1 operational data, in October 2022 at a load variation of 22.21 MW.

Calculation of Gas Turbine Performance at a Load of 22.21 MW

In calculating the thermal efficiency of a gas turbine at a load of 22.1 MW, before using the formula with the Brayton cycle in determining thermal efficiency, first find the heat entering the turbine which is obtained as follows:

Defined for Heat Entering the Turbine

Finding the amount of heat that enters the turbine can be obtained in the following way:

$$Qin = \dot{m}f \times LHV \quad (1)$$

Qin = 1,659 Kg/s × 44193,85 kJ/kg

= 66511,744 kJ/s

Determining the Air Flow Rate

Determine the air flow rate, while for this calculation the Air Fuel Ratio value is needed, then the calculation A/F is obtained by the equation:

$$\left(\frac{A}{F}\right) = \frac{\frac{\dot{w}gen}{\eta gen} - \dot{m}f\,(h3 - h4)}{\dot{m}f\,(h3 - h4) - \dot{m}f\,(h2 - h1)} \quad (2)$$

$$\left(\frac{A}{F}\right) = \frac{\frac{22210\ KW}{0,9876} - 1,505\,\frac{Kg}{s}\left(2226,950\frac{kJ}{kg} - 1059,007\,\frac{kJ}{kg}\right)}{1,505\,\frac{Kg}{s}\left(2226,950\frac{kJ}{kg} - 1059,007\,\frac{kJ}{kg}\right) - 1,505\,\frac{Kg}{s}\left(743,73\ \frac{kJ}{kg} - 299,467\ \frac{kJ}{kg}\right)}$$

$\left(\frac{A}{F}\right)$ = 19,034

After obtaining the results of the calculation of the Air Fuel Ratio, it is possible to find the air flow rate with the following equation:

$$\dot{m}a = \frac{A}{F} \times \dot{m}f \quad (3)$$

$\dot{m}a$ = 19,034 × 1,505 Kg/s

$\dot{m}a$ = 28,646 Kg/s

Determine Compressor Working Value

The value of the air flow rate has been obtained, then to find the compressor work with the equation:

$$\dot{w}compressor = \dot{m}a \times (h2 - h1) \quad (4)$$

$\dot{w}compressor$ = 28,646 Kg/s × (743,73 kJ/kg - 299,467 kJ/kg)

$\dot{w}compressor$ = 12726,654 kJ/s

Determine Turbine Working Value
Then to find the turbine working value with the equation,

$\dot{w}turbin$ = (ṁa + ṁf) × (h3 - h4) (5)
$\dot{w}turbin$ = (28,646 Kg/s + 1,505 Kg/s) × (2226,950 kJ/kg - 1059,007 kJ/kg)
$\dot{w}turbin$ = 35215,516 kJ/s

Calculating the heat leaving the turbine (*Qout*)

Qout = (ṁa + ṁf) × (h4 - h1) (6)
Qout = (28,646 Kg/s + 1,505 Kg/s) × (1059,007 kJ/kg - 299,467 kJ/kg)
Qout = 22901,41 kJ/s

To find Wnetto (*Wnett*)

From the calculation above, the work value of the compressor and turbine work has been obtained, so the difference in work used in calculating efficiency can be found.

$\dot{w}nett = \dot{w}turbin - \dot{w}kompresor$ *(7)*
$\dot{w}nett$ = 35215,516 kJ/s - 12726,654 kJ/s
$\dot{w}nett$ = 22488,862 kJ/s

To find *Back Ratio Work Value*

From the work value of the compressor and turbine work that has been obtained, it can be found the specific work value of the turbine used to drive the compressor, namely the Back Work Ratio (Bwr) as:

$Bwr = \frac{\dot{w}compressor}{\dot{w}turbin}$ (8)

$Bwr = \frac{12726{,}654 \text{ kJ/s}}{35214{,}516 \text{ kJ/s}}$

Bwr = 0,361

To find *Heat Rate Gas Turbine* (HR_{GT})

$HR_{GT} = \frac{Qin}{\dot{w}turbin - \dot{w}kompresor \text{ atau } \dot{w}nett}$ (9)

$HR_{GT} = \frac{66511{,}744 \text{ kJ/s}}{22488{,}861 \text{ kJ/s}}$

HR_{GT} = 2,958 kJ/kWh

From the calculations that have been obtained above, to find the efficiency value for each component with the following equation:

Determine Compressor Efficiency Value (ηca)

$\eta ca = \frac{h2' - h1}{h2 - h1} \times 100\ \%$ (10)

$\eta ca = \frac{667{,}860 \text{ kJ/kg} - 299{,}467 \text{ kJ/kg}}{743{,}730 \text{ kJ/kg} - 299{,}467 \text{ kJ/kg}} \times 100\ \%$

ηca = 82,92 %

Determining Combustion Room Efficiency Value

$\eta ruang\ bakar = \frac{T2 - T3}{T2' - T3} \times 100\ \%$ (11)

$\eta ruang\ bakar = \frac{728{,}25 \text{ K} - 1979{,}850 \text{ K}}{667{,}851 \text{ K} - 1979{,}850 \text{ K}} \times 100\ \%$

ηruang bakar = 95,40 %

Determining Turbine Efficiency Value

$\eta Turbin = \frac{h3 - h4}{h3 - h4'} \times 100\ \%$ (12)

$\eta Turbin = \frac{2226{,}953 \text{ kJ/kg} - 1059{,}007 \text{ kJ/kg}}{2226{,}953 \text{ kJ/kg} - 918{,}632 \text{ kJ/kg}} \times 100\ \%$

ηTurbin = 89,27 %

Determining Thermal Efficiency Value

In the calculation above, the calorific value entering the turbine (Qin) and thes value of the difference between the work of the compressor and the work of the turbine (Ẇnett) have been obtained, so the thermal efficiency at a load of 22.21 MW is obtained by the following equation:

$$\eta Thermal = \frac{\dot{W}nett}{Qin} \times 100\ \% \quad (13)$$

$$\eta Thermal = \frac{22488{,}292\ kJ/s}{66511{,}744\ kJ/s} \times 100\ \%$$

$$\eta Thermal = 33{,}81\ \%$$

The results of property calculations at each point and performance calculations for different load variations can be simplified in tabular form to make it easier to read the calculation results and compare. Calculation of gas turbine properties and performance with different load variations can be seen in the following table.

Table 2.a. Operational Data and Calculation of Properties for each Point on Load Variations

Load (MW)	Temperature (K)						Pressure (bar)			
	Process						Process			
	1	2	2s	3	4	4s	1	2	3	4
22,21	299,28	728,25	667,852	1979,850	1011,35	887,217	1	16,6	16,6	1
23,77	299,39	736,95	669,341	2027,261	1028,65	899,294	1	17,2	17,2	1
24,7	299,87	739,05	673,659	2045,522	1035,65	904,402	1	17,4	17,4	1
25,02	299,26	738,55	675,488	2047,759	1035,35	903,910	1	17,5	17,5	1
25,35	299,99	742,25	682,920	2069,057	1042,95	908,886	1	17,8	17,8	1
25,35	299,56	743,35	680,616	2075,397	1044,95	910,213	1	17,9	17,9	1
26,01	299,54	743,95	682,121	2079,473	1047,15	912,001	1	17,9	17,9	1
26,6	299,42	748,95	687,796	2106,485	1056,05	918,033	1	18,3	18,3	1
27,55	299,67	752,65	693,189	2128,795	1064,05	923,455	1	18,6	18,6	1
27,75	299,98	754,75	693,645	2142,842	1068,65	926,712	1	18,8	18,8	1

Tabel 2.b. Operational Data and Calculation of Properties for each Point on Load Variations

Beban (MW)	***Enthalpy* (kJ/kg)**					
	1	**2**	**2s**	**3**	**4**	**4s**
22,21	299,467	743,73	667,861	2226,953	1059,007	918,633
23,77	299,578	753,140	674,826	2286,176	1078,82	932,140
24,7	300,059	755,412	678,096	2309,003	1086,856	937,871
25,35	299,748	760,075	682,866	2346,498	1097,545	944,394
26,6	299,608	766,151	686,793	2385,559	1110,316	953,172
27,75	300,170	772,463	693,312	2431,295	1124,82	962,945

From table 2. is the operating data for each point at various loads showing the actual and ideal temperature, pressure for each process, and actual and ideal enthalpy which is affected by temperature in each gas turbine process.

Table 3 (a). Performance Calculation at Load Variation

Load (MW)	**Wnett (MW)**	**AFR**	**ṁf (Kg/s)**	**ṁa (Kg/s)**	**ṁa + ṁf (Kg/s)**	**$\dot{w}$*kompres* (kJ/s)**	**$\dot{w}$*turbin* (kJ/s)**
22,21	22,49	19,034	1,505	28,647	30,152	12726,654	35215,516
22,84	23,13	18,835	1,547	29,138	30,685	12993,671	36120,443
23,17	23,46	18,878	1,555	29,355	30,910	13113,615	36574,530
23,77	24,07	18,243	1,609	29,353	30,962	13313,242	37381,690
24,1	24,40	18,300	1,615	29,554	31,169	13413,111	37815,704
24,7	25,01	18,331	1,637	30,007	31,644	13663,940	38674,066
25,02	25,33	18,376	1,648	30,284	31,932	13792,255	39126,398
25,35	25,67	17,664	1,691	29,870	31,561	13749,970	39418,256

26,01	26,34	17,865	1,713	30,603	32,316	14107,704	40444,278
26,6	26,93	17,466	1,749	30,547	32,296	14251,618	41185,600
27,55	27,90	17,464	1,779	31,068	32,847	14612,039	42507,948
27,75	28,11	16,999	1,815	30,853	32,668	14571,814	42680,360

Table 3 (b). Performance Calculation at Load Variation

Load (MW)	Efisiensi (%)				Bwr	*Heat rate* (kJ/kWh)	*Qout* (kJ/s)	*Qin* (kJ/s)
	Thermal	Compress	Combustion Chamber	Turbin				
22,21	33,81	82,92	95,40	89,27	0,361	2,958	22901,41	66511,744
22,84	33,83	82,86	94,88	89,24	0,360	2,956	23486,95	68367,886
23,17	34,14	82,99	94,98	89,24	0,359	2,929	23737,96	68721,437
23,77	33,85	82,73	95,02	89,17	0,356	2,954	24126,61	71107,905
24,1	34,19	82,94	95,15	89,16	0,355	2,925	24365,9	71373,068
24,7	34,57	83,02	95,23	89,13	0,353	2,893	24897,7	72345,332
25,02	34,78	83,09	95,40	89,15	0,353	2,875	25132,88	72831,465
25,35	34,35	83,23	95,50	89,08	0,349	2,911	25179,29	74731,800
26,01	34,79	83,10	95,58	89,06	0,349	2,874	25863,69	75704,065
26,6	34,85	82,99	95,69	89,03	0,346	2,870	26182,84	77295,044
27,55	35,48	83,07	95,86	88,98	0,344	2,818	26923,92	78620,859
27,75	35,04	83,24	95,78	88,98	0,341	2,854	26939,97	80211,838

From table 3. is the result of calculating the performance of the gas turbine at various loads, showing net work, air fuel ratio, mass flow rate of fuel, air flow rate, compressor work, and gas turbine work needed in calculating thermal efficiency, compressor, combustion chamber , turbine, back work ratio, heat rate, work out and work into the gas turbine at each load variation.

Table 4. Calculation of Average Performance for each Load Variation

Load	Efisiensi (%)					*Heat rate(kJ/kWh)*	*Qin* (kJ/s)
	Load (MW)	Thermal	Comp	Combution Chamber	Turbin		
22 MW	22,21 22,84	33,82	82,89	95,14	89,26	2,957	67,439,815
23MW	23,17 23,77	33,95	82,98	95,13	89,20	2,946	69,994,220
24 MW	24,1 24,7	34,25	83,08	95,31	89,15	2,919	72,356,381
25 MW	25,02 25,35	34,57	83,24	95,54	89,10	2,893	73,936,311
26 MW	26,01 26,6	35,06	83,16	95,65	89,06	2,853	75,760,886
27 MW	27,55 27,75	35,18	83,08	95,88	88,98	2,842	79,931,943

Table 4 shows the results of calculating the average gas turbine performance for each load variation classified into 22 MW, 23 MW, 24 MW, 25 MW, 26 MW and 27 MW loads, with the aim of facilitating the analysis and discussion of thermal efficiency, compressors, space fuel, turbine, heat rate, and work entering the gas turbine.

Analysis and Discussion of Gas Turbine Performance Calculation of PLTGU Panaran 1 Unit 1 with different Load Variations

The calculation of the average gas turbine performance in Panaran 1 Unit 1 can be seen in table 5. in the previous sub-chapter. In this sub-chapter, you can see the difference in efficiency, heat rate, and heat input for each variation of the generator load. If we present these differences in graphical form the results will be as :

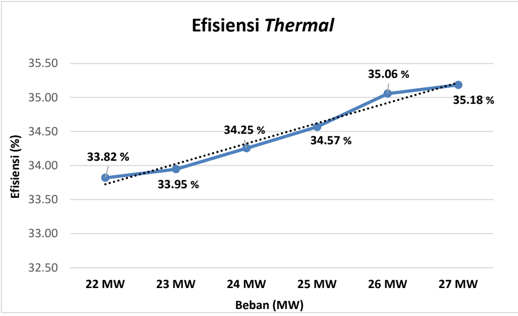

Figure 2. Thermal Efficiency Comparison Chart at Each Load Variation

The results of the gas turbine thermal efficiency show an increase in efficiency as the load increases, the highest average thermal efficiency is at 27 MW load of 35.18% and the lowest is at 22 MW load of 33.82%. From the calculation results, the thermal efficiency is obtained from the compressor work ($\dot{W}c$), turbine work ($\dot{W}t$) and incoming heat (Qin). Net work is the result of the reduction between turbine work and compressor work, because the turbine produces work while the compressor is given work by the turbine. The turbine work ($\dot{W}t$) is influenced by the size of the flue gas mass flow rate. The flue gas mass flow rate is the sum of the mass flow rates of air and fuel. Another thing that can affect it is that the turbine inlet temperature must be high and the exhaust gas temperature must be low. With a decrease in exhaust gas temperature, the enthalpy will decrease so that the turbine work will increase. Meanwhile, heat input (Qin) is influenced by the size of the low heating value (LHV) and the mass flow rate of the fuel. Low heating value (LHV) is the heating value of fuel. The higher the low heating value and the mass flow rate of the fuel, the heat input will increase. Meanwhile, based on the book "Gas Turbine Engineering Handbook 2nd" by Meherwan P. Boyce, ideally the system efficiency value on a GTG with an aeroderivative type ranges from 35% -45% with a resulting load capacity of 2.5 MW to 50 MW. From the calculation results that have been obtained, it can be seen that the efficiency value of the Panaran 1 Unit 1 unit can be categorized as normal at a load of 26 MW and 27 MW because it does not exceed the minimum limit for the ideal range of efficiency values [15].

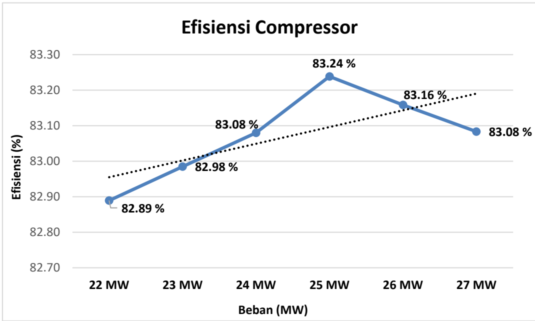

Figure 3. Compressor Efficiency Comparison Chart for each Load

On the compressor side, the load variation shows the highest average efficiency increase at 25 MW load with an increase from 83.08% to 83.24% with an increase of 0.16%. Based on the graph above it can be seen that the compressor efficiency at each load, changes in compressor efficiency are affected by ideal and actual compressor work. The ideal compressor work can be determined from the ideal enthalpy temperature in and out of the compressor. Meanwhile, for the compressor output pressure ratio, each value also increases with each increase in operating load.

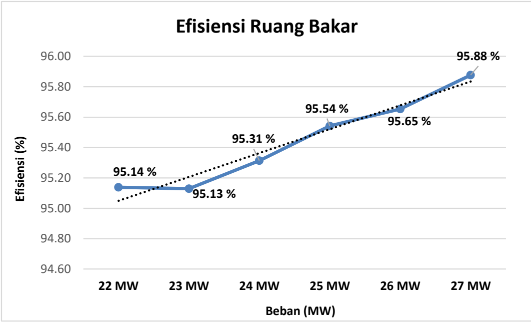

Figure 4. Graph Comparison of Combustion Room Efficiency for each Load

According to the description of the chart above, the results of the average efficiency of the gas turbine combustion chamber show a tendency to increase with changes in each load. Combustion chamber efficiency can be affected by the compressor outlet temperature and turbine inlet temperature. Under load conditions of 22.21 MW, the temperature at the exit of the compressor is 728.25 K, while the temperature entering the turbine is 1979.850 K and there is an increase in temperature leaving the compressor and entering the turbine at 754.75 K and 2142.842 K at a load of 27.75 MW. . Compressor outlet temperature affects the combustion process in the combustion chamber. Then the combustion process in the combustion chamber affects the size of the temperature that will enter the turbine.

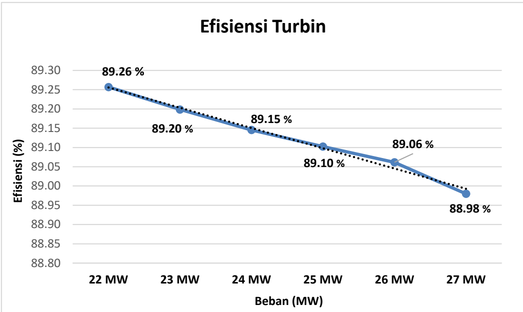

Figure 5. Graph of Comparison of Turbine Efficiency for each Load

Based on the chart in Figure 19, it can be seen that the average turbine efficiency decreases with each increase in load. the decrease in isentropic efficiency of the turbine is affected by the actual and ideal turbine work. The ideal turbine work can be determined from the enthalpy temperature entering the turbine and the ideal temperature leaving the turbine. The higher the actual turbine work compared to the ideal work, the isentropic efficiency of the turbine will also increase. Conversely, if the ideal turbine work is higher than the actual turbine work, the isentropic efficiency of the turbine will decrease. The parameters that affect the turbine inlet temperature (T3) have increased due to the combustion process that occurs in the combustion chamber where the turbine inlet temperature must be higher because the expansion process in the turbine will increase the power produced. While the turbine exit temperature parameter (T4) has decreased in temperature which is appropriate in the gas turbine cycle that the turbine exit temperature or exhaust gas temperature must be as low as possible because so that the wasted gas will not be wasted during the exhaust process into the atmosphere.

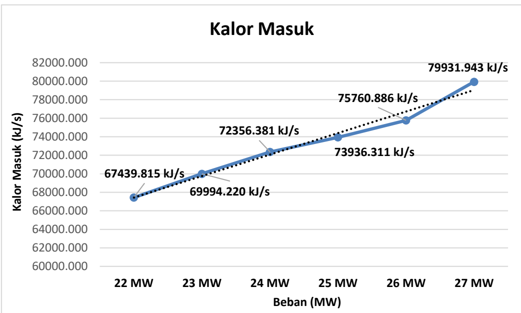

Figure 6. Graph of Comparison of Calories Entered for each Load

In the chart above, heat input has increased which is influenced by the LHV (Low Heating Value) value and Fuel Gas Mass Flow or the mass flow rate of fuel. In the input data, the LHV value is the same for each load variation of 44193.85 kJ/kg and there is a change in the increase in Fuel Gas Mass Flow at each load of 1.505 kJ/s, 1.561, 1.659 kJ/s, 1.680, 1.684 and 1.815 kJ/ s and so on. Thus the value of Fuel Gas Mass Flow affects the incoming calorific value, as shown in graphic 20. that the increase in average heat input has increased at a load of 27 MW up to 79931.943 kJ/s.

Perbandingan Heat rate pada tiap Variasi Beban

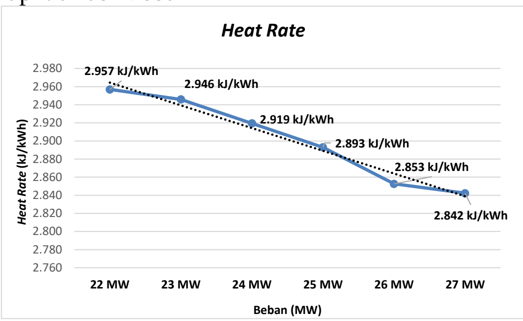

Figure 7. Graph of Comparison of Heat Rate for each Load

The results of the gas turbine heat rate show an average decrease in heat rate for each increase in load. The decrease in heat rate at 27 MW load condition is 2.842 kJ/kWh. The heat rate value is the ratio between the incoming heating value (Qin) and the net work (Ẇn). The smaller the heat rate value obtained, the higher the thermal efficiency of the gas turbine and conversely the greater the heat rate value obtained, the value of the gas turbine thermal efficiency will decrease. So with a small heat rate, the energy needed to produce 1 kWh is smaller

Conclusion

Based on the research process and calculated data, it can be concluded that the highest average thermal efficiency at 27 MW load is 35.18% and the lowest efficiency at 22 MW load is 33.82%. While the average efficiency of the compressor experienced the highest increase of 83.24% at 25 MW load. So that the average efficiency of the gas turbine combustion chamber shows a tendency to increase with changes in each load. The average efficiency of the turbine decreases with every increase in load.

The average heat rate measurement experienced the smallest decrease at a 27 MW load of 2.842 kJ/kWh, where the smaller the heat rate value obtained, the higher the thermal efficiency of the gas turbine and vice versa the greater the heat rate value obtained, the value of efficiency gas turbine thermal will decrease.

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