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Analysis of The Effect of Fuel Switching on The Thermal Efficiency of PLTG Unit 1.3 PT. PLN Indonesia Power Priok PGU

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KEYWORDS
gas turbine; LNG; HSD; load; efficiency

ABSTRACT
This study discusses the topic of thermal efficiency analysis in gas turbines. This study aims to determine the effect of using LNG and HSD fuel on the value of thermal efficiency. Therefore, the actual brayton cycle calculation method is used. This research is doing data processing using software, namely Microsoft Excel, Engineering Equation Solver (EES) and Cycle Tempo. Based on the results of the calculations that have been carried out, the thermal efficiency at a load of 75 MW with LNG fuel is 37.96% to 44.62% at a load of 100 MW and with HSD fuel at a load of 75 MW it is 40.61% and 45.60% at a load of 100 MW. Then in the EES simulation results with LNG fuel at a load of 75 MW it is obtained 37.51%, and 41.96% at a load of 100 MW. whereas with HSD fuel at a load of 75 MW it was obtained 41.76% and 46.15% at a load of 100 MW, and also the results of the cycle tempo simulation with LNG fuel at a load of 75 MW were 32.56% to 37.43% at a load 100MW. Then with HSD fuel at a load of 75 MW it is 34.47% to 38.14% at a load of 100 MW

Introduction

As time goes by, the development and development in Indonesia is getting higher. These developments and developments will have an impact on the increasing needs of the community, one of which is the community's needs, namely electrical energy (Ali & Nugroho, 2017).

To meet the needs of the community for electricity comes from PT. PLN and from the private sector. PT. PLN will continue to improve and optimize electricity production. Therefore PT. PLN directs its subsidiaries to generate electrical energy. One of these subsidiaries is PT. PLN Indonesia Power Priok (Dewi, 2013).

In operation, PLTG unit 1.3 PT. PLN Indonesia Power Priok uses two fuels, namely Liquified Natural Gas (LNG) and High-Speed Diesel (HSD) or diesel oil. LNG fuel is the main fuel used by PLTG to operate its units, while HSD is a reserve fuel when the supply of LNG fuel decreases in supply. The use of fuel from LNG on July 08, 2023 at 18:08

WIB, while on HSD fuel on July 08, 2023 00:02 WIB. The change of fuel from LNG to HSD fuel is due to reduced LNG fuel supply (Kunthi & Gantina, 2012).

Differences in fuel use and loading variations in operating the PLTG can affect the efficiency of the plant. Therefore, a performance analysis of the efficiency of the PLTG is carried out with variations in loading and fuel variations so that it can find out from the engineering side, which shows quantitative measures of fuel and performance of the PLTG which include engine power, specific fuel consumption, and thermal efficiency. In analyzing the research using the calculation application Ms. Excel, EES software and Cycle Tempo, this is done to validate the results of the calculations that the author has done so that accurate calculations are obtained (BillingsleyUniversity, 2009).

In connection with the background above, the analysis of the effect of the use of LNG and HSD fuel on the efficiency of PLTG is very important, because it can determine the effect of the use of these fuels on the efficiency of PLTG and become a recommendation for PT. PLN Indonesia Power Priok to choose fuel that has good efficiency (Mulyono et al., 2020).

The novelty of analyzing the effect of fuel switching on the thermal efficiency of PLTG Unit 1.3 PT. PLN Indonesia Power Priok PGU lies in its potential to provide valuable insights into optimizing energy production and resource utilization in power generation facilities. By investigating how switching fuel sources impacts the thermal efficiency of the gas turbine unit, this study contributes to the ongoing efforts in the energy sector to enhance operational efficiency and environmental sustainability. Understanding the dynamics of fuel switching and its effects on thermal efficiency can inform decision-making processes regarding fuel selection, operational strategies, and investment in infrastructure upgrades. Additionally, this research may offer practical recommendations for maximizing energy output while minimizing environmental impact, aligning with broader goals of achieving energy security and reducing greenhouse gas emissions. Through rigorous analysis and data-driven insights, this study holds promise for advancing the efficiency and sustainability of power generation operations, benefiting both the energy industry and society as a whole. This study aims to determine the effect of using LNG and HSD fuel on the value of thermal efficiency.

Research Methods

This research was conducted by qualitative methods. Then it is based on field case studies on the Priok Unit 1.3 PLTG system and reinforced by several theories and scientific journals. The data used in this study was obtained from several related parties, namely CCR (Central Control Room) PLTG, Rendal MCR (Maintenance Control Room) and Engineering Team. In addition, data and information are obtained from literature studies obtained from manual books, scientific journals, and books.

Where the qualitative method uses calculations from existing data and parameters at the Priok PLTG then uses formulas related to the thermal efficiency of gas turbines. In data processing using Ms.Excel, EES and Cycle Tempo applications.

Brayton cycle (gas turbine)

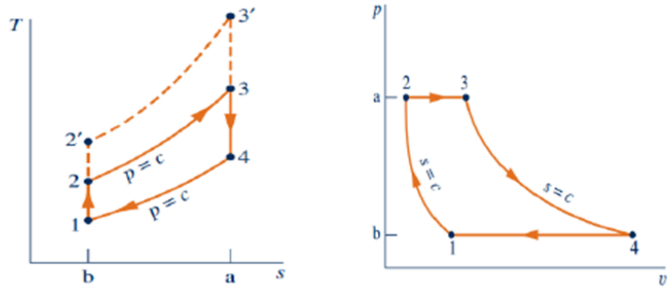

Figure 1 Brayton Cycle Diagram

The processes that occur from the diagram above are as follows:

1. Process 1 – 2: The isentropic compression process on the compressor.
2. Process 2 – 3: The combustion process at constant pressure (isobar) in the combustion chamber, there is heat intake.
3. Process 3 – 4: The process of isentropic expansion in the turbine.
4. Process 4 – 1: The process of calor release at constant pressure.

PLTG (Gas Power Plant)

PLTG is a power plant that uses gas fuel as a working fluid, but there are some PLTG that use fuels other than gas, namely diesel oil which functions as a backup fuel. PLTG has a function to convert kinetic energy into mechanical energy. PLTG has main equipment, namely compressors, combuster chambers, and turbines.

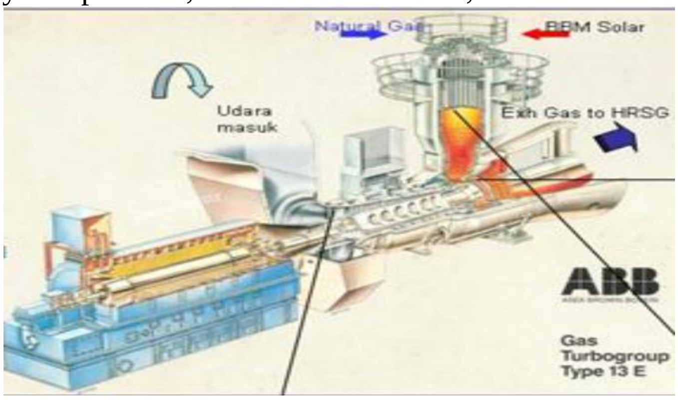

Figure 2 Priok PLTG System

a. Compressor

The Main Compressor functions to increase the pressure and temperature of the air before entering the combustion chamber. Air is also used for: combustion air, fuel fogging air, cooling air of blades and combustion chambers and sealing bearing lubricants.

b. Combustion Chamber (Combuster)

Combuster chamber or combustion chamber is a component where mixing occurs between the working fluid, namely compressed air with fuel. The result of combustion is in the form of high-pressure hot air.

c. Turbine

The turbine is the place where the conversion of kinetic energy into mechanical energy occurs. The hot gas serves to rotate the turbine blades so that they can rotate (Wibisono et al., 2022).

PLTG Efficiency Calculation

With the brayton cycle the air moves through various components ignoring the irreverence, there is no decrease in pressure because the air flows with constant pressure through the heat exchanger. If heat transfer to the environment is also negligible, then it occurs through turbines and comparsors is isentropic adjustable on the Brayton cycle. If the air table is used in calculations with the brayton cycle, it can be used in processes 1-2 (isentropic compression) and processes 3-4 (isentropic expansion).(Kurniawan & Sutardi, 2022)

$$\mathbf{r_p} = \frac{\mathbf{p_2}}{\mathbf{p_1}} = \frac{\mathbf{p_3}}{\mathbf{p_4}}$$

- In Steps 1 – 2 the calculation of the compression process takes place from atmospheric air entering the ker in the gas turbine system through the inlet side of the compressor.
  $W_{compressor} = m_{udara}(h_2 - h_{\mathbf{1}})$
- In stages 2 – 3, namely the stages of the combustion process in the combustion chamber
  $Q_{in} = m_{bahan\ bakar} \times \text{LHV}$
- In stages 3 – 4, namely in the expansion process, there is friction between the combustion gas and the turbine blades
  $W_T = (m_{udara} + m_{bb}) \times (h_3 - h_4)$
- Process 4 – 1 The next stage is the discharge of air back into the atmosphere.
  $Q_{out} = (h_4 - h_1)$
- Calculating Compressor efficiency
  $\eta_c = \frac{h_2' - h_1}{h_2 - h_1} \times 100\%$
- Calculating Combuster efficiency
  $\eta_{comb} = \frac{h_2 - h_3}{h_2' - h_3}$
- Calculating turbine efficiency
  $\eta_t = \frac{h_3 - h_4}{h_3 - h_4{'}}$
- Calculate actual net work
  $W_{netto} = w_t - w_c$
- Calculating thermal efficiency
  $\eta_{ttg} = \frac{w_t - w_c}{Q_{in}} \times 100\%$
- Calculating the back work ratio
  $Bwt_a = \frac{w_c}{w_t} \times 100\%$
- Calculating heat rate
  $\text{heat rate}_a = \frac{Q_{in}}{w_{nettoa}}$

Results and Discussions

The calculation of thermal efficiency of PLTG Unit 1.3 is carried out with different fuels, namely LNG and HSD fuel at operating loads of 75 MW and 100 MW (Rafif, 2020). The calculation is carried out using the Ms.Excel application and the EES and Cycle Tempo applications as a validation tool for the actual calculation results. Below are the results of the efficiency calculation at PLTG Priok Unit 1.3 as follows:

Table 1. Actual Calculation Results

Parameter	Symbol	Unit	75 MW		100 MW	
			fuel			
			LNG	HSD	LNG	HSD
Incoming Heat	Qin	kJ/s	282517,905	283404,077	309193,416	311829,336
Actual airflow rate	mudara	kg/s	351,919	323,445118	339,598	321,024
Working Compressor	Wkomp	kJ/s	126184,256	116132,972	120733,998	112933,192
Turbine Work	Wturbin	kJ/s	233441,917	231236,139	258724,314	255130,531
Turbine Plug-Out	Qout	kJ/s	248883540	259198545	276149996,5	288996453
Wnetto	Wnett	kJ/s	107257,661	115103,169	137990,315	142197,339
Back Work Ratio	Bwr	%	54,053	50,222	46,665	44,264
Heat Rate Gas Turbin	THR Gas	kJ/kWh	2,634	2,462	2,240	2,192
Spesific fuel Consumption	Sfc	kg/kWh	0,234	0,208	0,199	0,186
Efisiensi Kompresor	Eff Compressor	%	75,903	79,835	88,709	90,781
Combustion Chamber Efficiency	Eff Combustor	%	89,960	92,108	95,617	96,647
Turbine Efficiency	Eff Turbin	%	91,420	91,199	91,352	91,162
Thermal Efficiency	Eff Thermal	%	37,964	40,614	44,629	45,601

Table 2 Comparison Results of Actual Calculations and EES Simulations

Information	Current				Simulation			
	75 MW		100 MW		75 MW		100 MW	
	LNG	HSD	LNG	HSD	LNG	HSD	LNG	HSD
Compressor efficiency (%)	75,9	79,83	88,7	90,78	75,9	79,78	88,71	90,78
Combustor efficiency (%)	89,96	92,10	95,61	96,64	89,96	92,08	95,62	96,65
Turbine efficiency (%)	91,42	91,19	91,35	91,16	91,46	91,24	91,43	91,2
Thermal efficiency (%)	37,96	40,61	44,62	45,6	37,51	38,43	40	40,26

Table 3 Comparison Results of Actual Calculations and Tempo Cycle Simulation

Information	Current				Simulation			
	75 MW		100 MW		75 MW		100 MW	
	LNG	HSD	LNG	HSD	LNG	HSD	LNG	HSD
In Compressor	126184	116132	120733	1129333	126261	116238	120052	112344
In turbines	233441	231236	258724	255130	288993	287144	321706	318287

Information	Current				Simulation			
	75 MW		100 MW		75 MW		100 MW	
	LNG	HSD	LNG	HSD	LNG	HSD	LNG	HSD
Thermal efficiency (%)	37,96	40,61	44,62	45,60	32,56	34,47	37,43	38,14

Compressor Efficiency Analysis

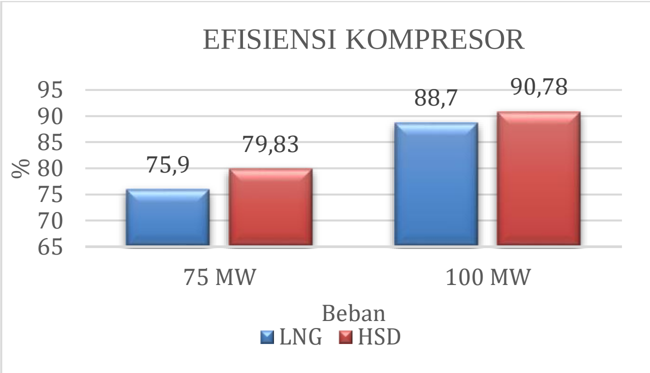

Figure 3. Compressor Efficiency Graph

The efficiency results of compressors with LNG fuel at a load of 75 MW were obtained at 75.9% and 88.7% at a load of 100 MW. Meanwhile, HSD fuel at a load of 75 MW was obtained at 79.83% and 90.78% at a load of 100 MW (Putra et al., 2018). Compressor efficiency is affected by compressor work, the greater the compressor work, it will cause efficiency to decrease. Based on the calculation data, the greater the work of the LNG compressor, the better compressor efficiency, namely HSD fuel (Zulkarnain et al., 2023).

Combustor Efficiency Analysis

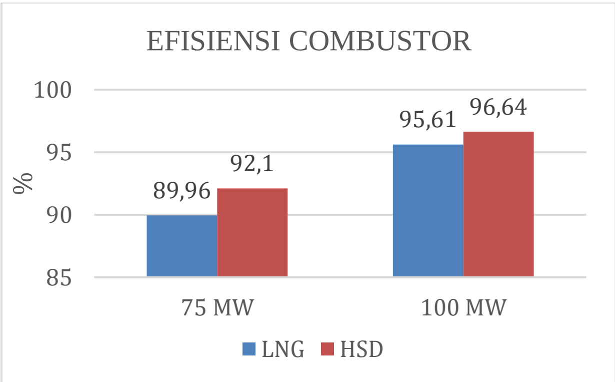

Figure 4Combustor Efficiency Graph

The calculation results with LNG fuel at a load of 75 MW were obtained at 89.96% and 95.61% at a load of 100 MW. Meanwhile, HSD fuel at a load of 75 MW was obtained by 92.1% and 96.64% at a load of 100 MW (Leilan et al., 2021). The efficiency of the combustor is affected by the compressor outlet temperature and turbine inlet temperature. Low temperatures will have an impact on efficiency for the better. Based on the data, the temperature out of the compressor and in the turbine is lower on HSD fuel so that the efficiency of the combustor is better than LNG fuel (Fatimah et al., 2019).

Turbine Efficiency Analysis

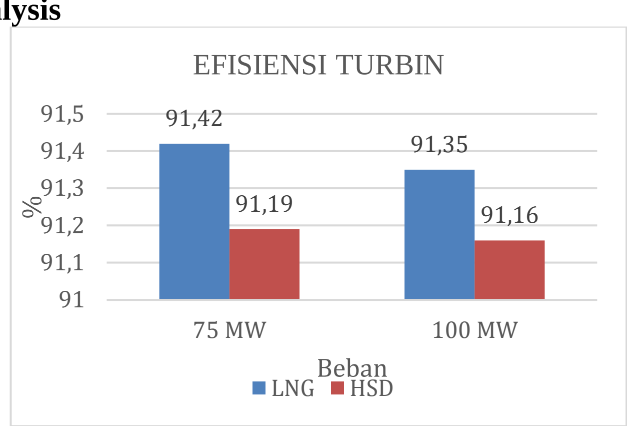

Figure 5. Turbine Efficiency Graph

The calculation results with LNG fuel at a load of 75 MW were obtained at 91.42% and 91.35% at a load of 100 MW. while HSD fuel at a load of 75 MW was obtained by 91.19% and 91.16% at a load of 100 MW, Turbine efficiency is influenced by the enthalpi of combustion gases in and out of the turbine, eating lower will have an impact on increased turbine efficiency. Based on data on the calculation of enthalpi gas from combustion in and out of the turbine on LNG fuel is lower so that the efficiency of the turbine on LNG fuel is better than HSD fuel (Wahid, 2014).

Thermal Efficiency Analysis

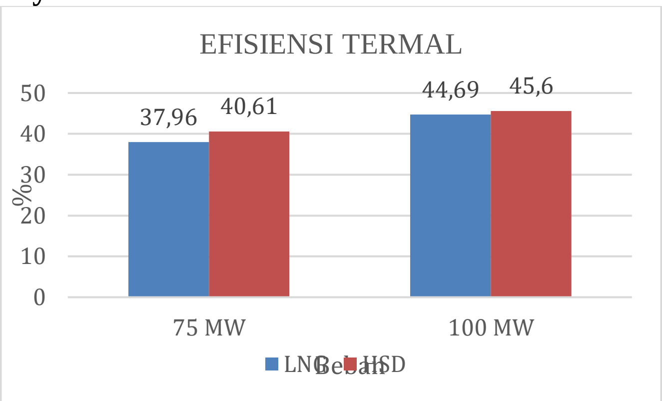

Figure 6. Thermal Efficiency Graph

The calculation results with LNG fuel at a load of 75 MW were obtained at 37.96% and 44.62% at a load of 100 MW. while HSD fuel at a load of 75 MW was obtained at 40.61% and 45.60% at a load of 100 MW (Winanti et al., 2017). The thermal efficiency value is still relatively good, this is because PLTG with a capacity of 3-480 MW is said to be good if it has a thermal efficiency of between 30-46%. Thermal efficiency is influenced by the incoming and outgoing calorific values and also the ambient temperature. Thermal efficiency is also affected by compressor work, the lower the compressor work, it can increase thermal efficiency. So that thermal efficiency is better, namely on HSD fuel (Wibowo, 2021).

Conclusion

Based on the results of the analysis that has been done, it can be concluded that fuel switching or fuel switching can affect the thermal efficiency of PLTG. Based on the calculation of thermal efficiency with LNG fuel at a load of 75 MW, 37.96% and 37.96% at a load of 100 MW were obtained. while HSD fuel at a load of 75 MW obtained 40.61% and 45.60% at a load of 100 MW. Based on these data, there are differences in the use of different fuels in PLTG Unit 1.3. This is due to the work of compressors and turbines on HSD fuel is lower than on LNG fuel. So that the smaller the work of the compressor and turbine, the thermal efficiency will be high.

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