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Analysis of Parameters That Affect the Efficiency of Gas Power Plants

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Abstract: This study aims to analyze the parameters that actively affect the efficiency of gas power plants in order to optimize their performance. The method used in this study was an analytical approach based on the results of performance tests conducted in 2018, 2020, and 2022 on gas power plants in the sumatera selatan area, based on thermodynamic equations. Based on the results of the study, it is explained that there is a very significant relationship between the inlet air temperature of the compressor, the inlet fuel temperature, and the turbine exhaust temperature and active power to the efficiency of gas-fired power plants, where an increase in the inlet air temperature to the compressor will reduce the compressor efficiency, which is predicted using linear regression with an R^2=0.82. An increase in the exhaust temperature and active power will significantly reduce the thermal cycle efficiency, which is predicted using linear regression with an average R2 =0.96. In addition, an increase in the fuel mass flow rate and inlet fuel temperature will increase the turbine efficiency, which is predicted using linear regression with an average R2 =0.97. Therefore, the relationships obtained in this study can be used as a reference for energy companies and governments in developing more efficient gas-fired power plants in the future and this research is intended to maintain the parameters of the gas power plant so that the efficiency of the gas power plant is maintained and optimal.

Keywords: Gas, Power Plant, Efficiency

1. Introduction

The request for electricity is increasing along with the population growth and economic development of a country. Gas-fired power plants have become one of the alternatives to meet the increasing demand for electricity [1]. Gas-fired power plants have several advantages, including high efficiency and lower greenhouse gas emissions compared to other fossil fuel power plants [2]. Furthermore, in order to support the new and renewable energy (EBT) program, the use of gas-fired power plants is one of the strategies that can be implemented by the Indonesian government. Therefore, research on the efficiency of gas-fired power plants is very important to support the success of the EBT program in Indonesia[3].

Although gas-fired power plants have been a technology that has been used for a long time, their efficiency can be improved to make them more efficient and environmentally friendly. Regarding the efficiency of gas-fired power plants, it is very important to improve it because it can affect the cost of energy production and environmental impact. Parameters that can affect the efficiency of gas-fired power plants include gas outlet temperature, air temperature entering the compressor, gas outlet pressure, fuel mass flow rate, and so on [4]–[6]. Previous studies have shown very good results. However, there are still many other parameters that greatly affect the efficiency of gas-fired power plants. Therefore, an analysis of these parameters is needed to improve the efficiency of gas-fired power plants. Although parameters that affect the efficiency of gas-fired power plants are already known, there are still differences in the results of previous studies. Some studies show that gas outlet temperature has the greatest influence on efficiency, while others show that gas outlet pressure and air velocity also have a significant effect on efficiency. Therefore, further research is needed to gain a better understanding of the influence of these parameters on the efficiency of gas-fired power plants.

In this study The purpose of this study is intended to determine the parameter parameters that affect the efficiency of the gas powerplant such as, an analysis of the influence of fuel mass flow rate, inlet and outlet fuel temperatures, and active power on the efficiency of gas-fired power plants will be conducted. The results of this study are expected to provide useful information for energy companies and the government in developing more efficient gas-fired power plants in the future. It is hoped that the results of this study can help in gaining a better understanding of the factors that affect the efficiency of gas-fired power plants and provide useful recommendations for energy companies and the government in improving the efficiency of gas-fired power plants. Additionally, this study can also serve as a reference.

2. Research Methods

2.1. Alsthom Atlantique frame 5 specification

In this study, the data obtained are from the years 2018, 2020, and 2022 from gas power plants in the Sumatra Selatan area. The machine used is the Alsthom Atlantique Frame 5 with specifications that can be seen in Table 1.

Table 1. *Alsthom Atlantique frame 5 specification*

Serial Number	**MS-5001**
Installed Power	Base 20100 KW, Peak 21650 KW
Capable Power	14000 KW
Under Voltage	10.2 Kv
Over Voltage	10.85 KV
Frequency	50 Hz
Production year	1982
Cos phi	0.8

2.2. Data Processing

Furthermore, in this study, data collection was carried out through field monitoring results during performance tests conducted every 2 years for a 1-hour operation. In this case, the research collected data on compressor, combustion chamber, and gas turbine temperatures in the power plant engine. The data used to support this study includes temperature, pressure, and fuel consumption mass at each measurement point**.** The data used are unit operation data during operation with active power differences of 18 MW, 15, MW and 14 MW. The complete raw data can be seen in Table 2.

Table 2. *Raw data Monitoring*

Parameter	Years		
	2018	2020	2022
Active Power	18 MW	15 MW	14 MW
IT. Kompresor	27 °C	29 °C	31 °C
OT. Kompresor	327 °C	315 °C	308 °C
IT. Turbin	628 °C	581 °C	556 °C
Ex. Gas Temp	345 °C	336 °C	323.3 °C
IP. Air	14.7 Psia	14.7 Psia	14.7 Psia
OP. Kompresor	121 Psia	110 Psia	101 Psia
Specific Gravity	0.6421	0.6349	0.6332
Gross Fitting Value	1037 Btu/Scf	1031 Btu/Scf	1030 Btu/Scf
Fuel Flow Gas	5408 Scfm	3123 Scfm	2835 Scfm

IT : Inlet Temperature
OT : Outlet Temperature
IP : Internal Pressure
OP : Outlet Pressure

Data management is carried out based on calculation equations to obtain good thermodynamic performance calculations for gas power plants using compressor efficiency, turbine efficiency, and cycle thermal efficiency calculations.

2.3. Efficiency calculation

Figure 1 and 2, [7] [8]Based on previous research Ahmadi and Ibrahim at all, states that the schematic diagram for a simple gas power plant, in which the compressor draws outside air and compresses the outside air into compressed air to be supplied to the combustion chamber, in the combustion chamber combustion occurs, because the compressed air is mixed with fuel and sparks from the spark plug so that it becomes a pressurized hot fluid to move the turbine blades, where the rotation of the turbine produces kinetic energy to rotate the electric generator.

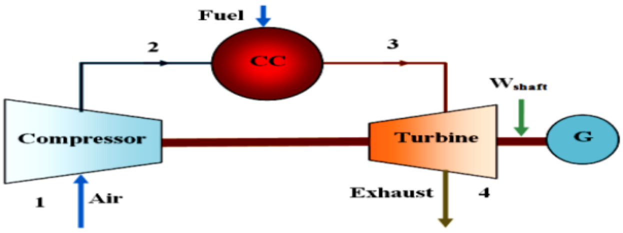

Figure 1. Schematic diagram for simple GT cycle

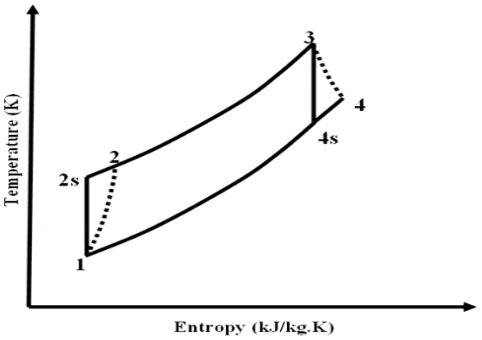

Figure 2. Temperature-entropy diagram for simple GT cycle

Equation (3) demonstrates specific heat of flue gas[9]

Based on the raw data obtained from the monitoring results, the efficiency value can be calculated using the following equation 1,2, 3 and 4 [10].

$$\eta_{kompresor} = h_{2'} - h_1 / h_2 - h_1 \qquad (1)$$

$$= \mathrm{Cp}\ (T_{2'} - T_1)/Cp(T_2 - T_1)$$

$$= T_{atm}\ [\left(\frac{P_2}{P_1}\right)^{K-1/K} - 1]/\ T_2 - T_1$$

Where h_2' is an ideal enthalpy for the outlet compressor, h1is an enthalpy for the inlet compressor, h_2 is an enthalpy for the outlet compressor T_1 is an inlet temperature compressor, T_2 is an outlet temperature compressor, T_{atm} is a temperatur atmosfir, P_2 is a pressure outlet compressor, P_1 is a pressure 1 atm, Cp is a heat capacity.

$$\eta_{Turbin} = h_3 - h_4 / h_3 - h_{4'} \qquad (2)$$

$$= \mathrm{Cp}\ (T_3 - T_4)/Cp(T_3 - T_4)$$

$$= (T_3 - T_4)/T_3\ [1 - T_{4'}/T_3)$$

$$= (T_3 - T_4)/\ T_3\ [1 - (P_4 - P_3)\ \frac{K-1}{K}\ ]$$

Where h3 is an enthalpy gas for the turbine inlet, h4 is an enthalpy gas for the turbine outlet, h4' is an enthalpy for the outlet ideal gas turbine, T3 is an inlet temperature turbine, T4 is a temperature exhaust, P4 is a pressure exhaust, P3 is an inlet pressure turbine, Cp is an heat capacity

$$\eta_{thermal\ eficiency} = W_{ta} - \frac{W_{ca}}{M_f}\ x\ LHV \qquad (4)$$

Where W_{ta} is a work turbine, W_{ca} is a work compressor, M_f is a mass flowrate, LHV is a low heating value.

3. Results and Discussion

In this study, the relationship between air inlet temperature and compressor efficiency was predicted using linear regression with an R^2=0.82, as shown in Figure 1. This indicates that as the air inlet temperature increases, the efficiency will decrease significantly [11]. This is due to the thermal characteristics of gas. When air enters the compressor at a higher temperature, the gas molecules in the air have higher kinetic energy, causing the gas to have a larger volume. When the gas has a larger volume, the compressor has to do more work to compress the gas into the same space, resulting in lower compressor efficiency. Therefore, in gas power plants, the air inlet temperature should be kept as low as possible to improve compressor efficiency [12]. One way to lower the air inlet temperature is by using a heat exchanger system, which can reduce the air inlet temperature before it enters the compressor. By lowering the air inlet temperature, compressor efficiency can be improved, which can ultimately increase the overall efficiency of gas power plants.

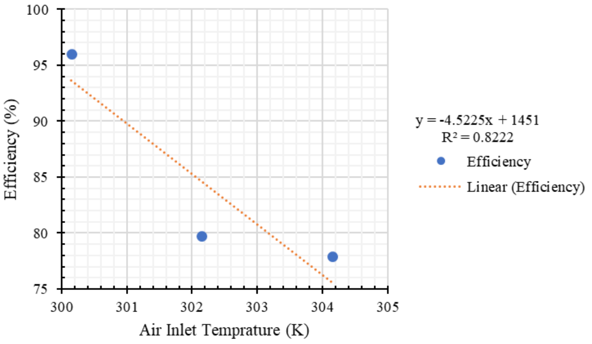

Figure 3. Relationship Between air inlet temperature and compressor efficiency

In this study, the relationship between the mass flow rate of fuel and turbine efficiency, which can be seen in figure 2, was predicted using linear regression with an R^2=0.96. This explains that with an increase in the mass flow rate of fuel, the efficiency will increase. However, this does not mean that increasing the amount of fuel added to the gas turbine will increase turbine efficiency [13][14]. This is because an excessive amount of fuel can result in incomplete combustion, which will ultimately reduce turbine efficiency. Incomplete combustion in gas turbines occurs when the fuel introduced into the gas turbine is not completely burned. This can be caused by various factors, such as insufficient or excess air, inappropriate temperature, and poor fuel quality. When incomplete combustion occurs, some of the energy produced cannot be maximized and is wasted, resulting in reduced turbine efficiency. Therefore, to maintain turbine efficiency, appropriate mass flow rate of fuel adjustment is necessary. Appropriate mass flow rate of fuel adjustment ensures that the fuel introduced into the gas turbine is burned completely, so that the energy produced can be utilized to the maximum and the turbine efficiency can be maintained. In addition, regular monitoring and maintenance of gas turbines, including the fuel mass control system, are necessary to ensure that the gas turbine works optimally and efficiently. Thus, proper fuel mass flow rate adjustment and good maintenance of gas turbines can help improve turbine efficiency, resulting in more cost-efficient and environmentally friendly electricity generation.

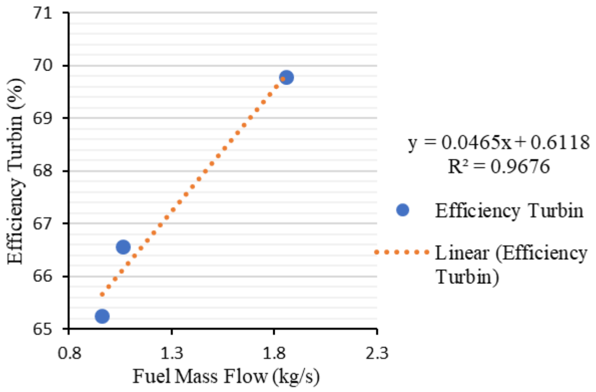

Figure 4. Relationship Between fuel mass flow and turbine efficiency

The relationship between the inlet temperature of turbine fuel and efficiency is predicted using linear regression with an R^2=0.98, as shown in Figure 3. This explains that as the inlet temperature of the fuel increases, the turbine efficiency will also increase. This is because the higher the temperature of the fuel, the greater the potential energy stored in the fuel [15]. therefore, when the fuel is burned in the gas turbine combustion chamber, the higher the inlet temperature of the fuel, the higher the temperature of the combustion gas entering the gas turbine. The higher gas temperature will allow the turbine to generate more power [16]because the higher the gas temperature entering the turbine, the greater the temperature difference between the gas and the surrounding air. This temperature difference will result in greater pressure on the turbine, which will then generate faster turbine rotation and greater kinetic energy.

Based on previous research Apriansyah at all [17]. Stated that the higher the mass flow of fuel, the shorter the combustion time, so this can increase the combustion efficiency in the combustion chamber, combustion efficiency can increase the efficiency of the turbine. However, there are limits to the fuel inlet temperature into the gas turbine, because if the inlet temperature is too high, it can cause damage to the gas turbine components. Therefore, the fuel inlet temperature must be carefully controlled to maximize turbine efficiency without damaging the gas turbine components itself.

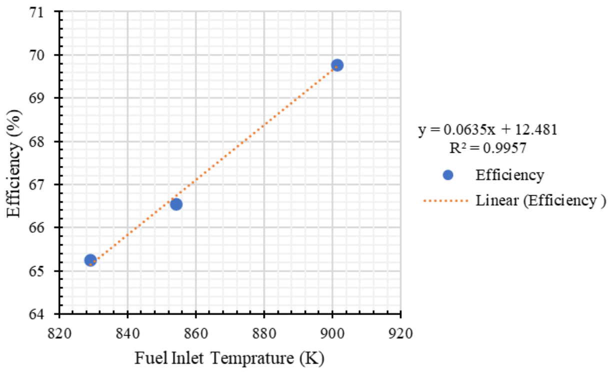

***Figure 5.** Relationship Fuel Temperature Inlet and turbin efficiency*

In this study, the relationship between exhaust gas temperature and thermal cycle efficiency is predicted using linear regression with an R2 value of 0.99, which can be seen in Figure 4. This explains that an increase in exhaust gas temperature in the turbine will decrease the thermal cycle efficiency, as a high exhaust gas temperature indicates that not all the energy produced by fuel combustion is utilized by the engine, and most of the energy is lost in the form of heat. This is consistent with previous studies conducted by Thamir et al [18]. Furthermore, when the exhaust gas temperature increases, the amount of wasted heat energy also increases, so the engine will require more fuel to produce the same amount of work, resulting in a decrease in thermal cycle efficiency because the ratio of useful work produced to the energy consumed by the system becomes smaller. Therefore, to increase the thermal efficiency of internal combustion engines, it is important to reduce exhaust gas temperature by using better cooling technology on engine components affected by high exhaust gas temperature.

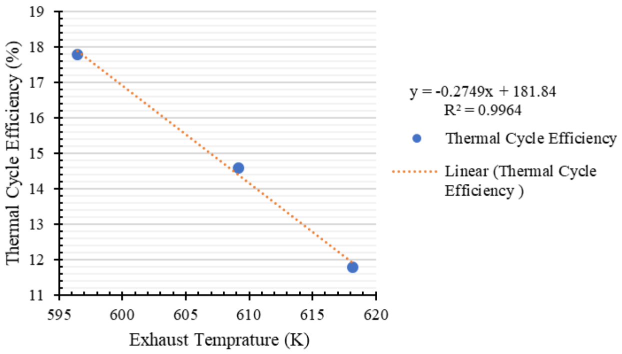

***Figure 6.** Relationship between exhaust temperature and thermal efficiency*

In this study, the relationship between active power and thermal cycle efficiency is predicted using linear regression with an R2 value of 0.93, as seen in Figure 4. This explains that as the active power increases, the value of thermal cycle efficiency will decrease. This relationship is related to Figure 3 because the larger the electrical power generated by the power plant, the greater the heat produced from the combustion of fuel [19]. This will cause thermal efficiency to decrease because more heat is wasted without being used to generate electricity [20]. Therefore, proper active power control in gas power plants is essential to minimize the amount of wasted heat and maximize thermal efficiency. When adjusting the active power, it should be noted that increasing the active power can increase electricity production but will add to the amount of wasted heat, while decreasing the active power can reduce electricity production but will also reduce the amount of wasted heat. Thus, to achieve optimal thermal efficiency in gas power plants, proper active power control is necessary to balance electricity production and wasted heat.

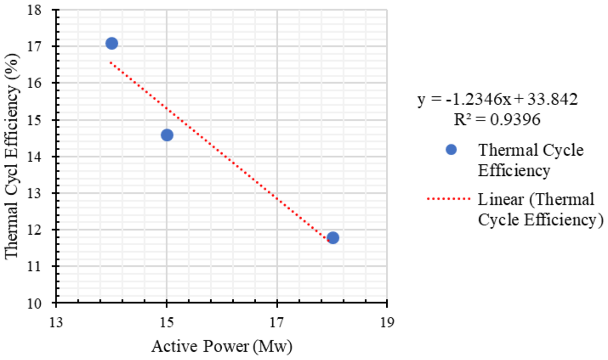

***Figure** 7. Relationship Between active power and thermal cycle efficiency*

4. Conclusion

Based on the results of the study, it is explained that there is a very significant relationship between the inlet air temperature of the compressor, the inlet fuel temperature, and the turbine exhaust temperature and active power to the efficiency of gas-fired power plants, where an increase in the inlet air temperature to the compressor will reduce the compressor efficiency, which is predicted using linear regression with an R^2=0.82, This has been explained in the discussion of Figure 3 where the temperature in the compressor affects the efficiency of the compressor. An increase in the exhaust temperature and active power will significantly reduce the thermal cycle efficiency, which is predicted using linear regression with an average R^2 =0.96**,** this has been explained in the discussion of figures 6 and 7 that exhaust temperature and active power affect thermal efficiency**.** In addition, an increase in the fuel mass flow rate and inlet fuel temperature will increase the turbine efficiency, which is predicted using linear regression with an average R^2 =0.97. This has been explained in the discussion of Figure 4, that the mass flow of fuel can affect the efficiency of turbines. Therefore, the relationships obtained in this study can be used as a reference for energy companies and governments in developing more efficient gas-fired power plants in the future and this research is intended to maintain the parameters of the gas power plant so that the efficiency of the gas power plant is maintained and optimal.

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