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# Power System & Short Circuit Analysis in PLTGU PLN UPDK Keramasan Using ETAP

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**ABSTRACT**

This study aims to analyse the power flow and short circuit faults in the Gas and Steam Power Plant (PLTGU) of PT PLN Keramasan using ETAP software. Power flow analysis is carried out to determine the distribution of voltage, current, and power in the PLTGU electrical system and to ensure the efficiency and stability of system operations. The results of the power flow simulation show that the PT PLN Keramasan PLTGU can generate and distribute power with a stable voltage under various load conditions. In addition, short-circuit fault analysis aims to identify potential impacts. The short-circuit fault analysis finds important areas that are vulnerable to faults and require special protection. ETAP allows simulating various fault scenarios and establishing effective protection systems to reduce damage. This study emphasises the use of ETAP software as a powerful analytical tool in the planning and operation of the PLTGU electrical system. Power flow and short circuit analysis with ETAP is proven to improve the reliability, efficiency and safety of PT PLN Keramasan's PLTGU operations.

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## 1. INTRODUCTION

For run all industrial tools and machines, electricity is now the most important energy source [1]. Generating companies (PLN) usually use a steam power plant system to produce electrical energy which is later distributed to residents' homes [2]. The number of PLN customers in 2017 was 44.26 percent, commercial 2.42 percent, public 1.29 percent, and industrial 52.02 percent. This shows an increase in PLN sales for each sector in 2016, 43.35 per cent, 18.55 pe cent, 6.55 percent, and 31.55 percent respectively. Thus, the demand for electrical energy continues to increase [3]. This condition makes many people, including academics, look for renewable energy sources as an alternative [4]. Potential An increase in the quality of electrical energy supplied must be balanced with the growing demand for electricity. One approach to enhance the quality of electrical energy is to do a power system analysis. This is because the study covers some of the major issues with the power system, such as load flow, short circuit, stability, and safety. The four issues are crucial components in raising the standard of distributed electrical energy [5]. In the transmission system, disturbances that occur in one system due to overload and voltage instability will have an impact on other systems. This disturbance is initially temporary (not long) and occurs in the affected part of the system. If there is no repair, this disturbance will continue and cause cascading discharges, which will eventually result in a total blackout [6].

Power flow analysis is an analysis that shows the performance of a power flow (active and reactive) of a system under certain conditions when the system is operating [1]. Power flow analysis is an important part of the design and operation of power distribution systems. The Newton-Raphson method is one of the most superior methods used to perform power flow analysis [7]. To complete the load flow calculation, the Newton Raphson computational method is superior to choose, this method is very suitable for the system used, including common systems. This method is also chosen for its practicality, accuracy, and speed of completion [8].

In addition to requiring power flow analysis, the power system also requires rechecking for short-circuit faults. If there is a short-circuit fault in the power system, there may be no electricity supply to consumers. Short circuit analysis is the first step in overcoming short circuit faults. This is done to determine the right protection system for the power system. To find out how much short circuit current occurs in each different bus in turn, short circuit faults can be studied using manual calculations and simulation techniques [9]. This paper will explain how to analyse the power flow & short circuit that occurs in the power system using ETAP software.


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### 1.1. Steam Gas Power Plant

PLTGU is the installation of an equipment that can produce electrical energy from heat. PLTGU is basically a system that can combine the working principles of PLTG and PLTU with a double cycle. Steam turbine, generator, gas turbine, HRSG, and other supporting tools are the main components of the equipment [9]. A combination cycle power plant consists of two main cycles, namely the Brayton cycle (gas cycle) and the Rankine cycle (steam cycle). Both gas turbines and steam turbines provide power to the grid [10]. The higher productivity of combined cycle power plants has a greater impact on the environment [11]. There is a need for combined cycle power plants that produce high power and efficiency [12]. This is needed because when gas turbines are used as power plants, they have a low thermal efficiency, ranging between 20 and 30 per cent. The main objective of the combined cycle is to increase the thermal efficiency which is quite high at 50 per cent [12].

### 1.2. Electricity Flow Study

The energy expended to perform an effort is known as power. Power flow studies aim to collect data on power flow under conditions when the system is operating. This information is very important for assessing the performance of energy systems and checking generation and loading conditions [13]. The study or analysis of power system power flow in steady state through solving the power flow equation on the network is needed so that the power system can operate properlythe main objectives of power flow studies is to determine the magnitude, angle, active and reactive power flow on the line, and transmission losses that appear in the power system. The results of this study are also important for many studies, such as contingency and transient stability studies [14].

Power is divided into three namely Active, Reactive, and apparent power. Active power is the real power used in an electrical circuit expressed in units (W), reactive power is power that is not used but isolated between the source and load and expressed in units (VAR), and apparent power is a combination of active and reactive power expressed in units (VA). as for the formula for finding the three powers is as follows:

$$P = V \,.\, I \,.\, \cos(\varnothing) \quad (1)$$

$$Q = V.I.\sin(\varnothing) \quad (2)$$

$$S = \sqrt{(P^2 + Q^2)} \quad (3)$$

Where:
P = active power
V = voltage (volt)
I = current (ampere)

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cos (∅) is a power factor, where ∅ is the phase angle between voltage and current.

$$Q = V.I.\ \sin(\varnothing) \tag{4}$$

Where:
Q is re-active power (VAR)
sin (∅) is the sine of phase angle between voltage and current

$$S = \sqrt{(P^2 + Q^2)} \tag{5}$$

Where:
S is apparent power (VA)

The relationship of re-active power, apparent power and active power can be visualised in a power triangle, Where :

$$S^2 = P^2 + Q^2 \tag{6}$$

In a power triangle:

- S is the hypotenuse which represents the apparent power.
- P is the horizontal component representing active power.
- Q is the vertical component that represents reactive power.

In power flow analysis, there are buses that can form an electric power system. On the i-th bus, the net overall power can be injected into the bus expressed by the following equation [15]:

$$S_i = P_i + jQ = (P_{Gi} - P_{Li}) + j(Q_{Gi} - Q_{Li}) \tag{7}$$

With :
G = Generator ( $S_{Gi} = P_{Gi} + jQ_{Gi}$ )
L = Load ($S_{Li} = P_{Li} + jQ_{Li}$)

In general, for any power system bus with n buses :

$$P_i - jQ_i = V_i.\sum_{k=1}^{n} V_K\ .Y_{ik} \tag{8}$$

or

$$S_i = V_i.\sum_{k=1}^{n} Y_{ik}.V_k \tag{9}$$

To I, k = 1,2,….,n

If a power system has four buses. from the above equation, the transmission line between the 2nd and 3rd bus applies the above equation.

### 1.3. Newton Raphson Method

The Iterative Newton Raphson method approximates non-linear simultaneous equations of one form to linear equations by using Taylor expansions and bounded terms for first-


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order approximations [16]. To solve load flow calculations, computational methods such as Newton Raphson, Fast Decoupled, and Gauss Seidel are often used. The Newton-Raphson method is considered mathematically better compared to the Gauss-Seidel method as it has quadratic convergence properties. The Newton Raphson method is much more efficient and practical for larger systems. The Newton-Raphson method that uses bus admittance is independent of the number of iterations required [17].The Newton Raphson method can solve power flow problems that are often faced by utilising a nonlinear equation to calculate the voltage magnitude and phase angle of the voltage of each bus[18]. The injection power at bus I is as follows:

$$P_i - Q_i = V_i * \sum_{j=0}^{n} Y_{ij} V_j \quad (10)$$

Where :

$P_i$ = The i-th active power

$Q_i$ = The i-th reactive power

$V_i$ = The i-th voltage

$Y_{ij}$ = Admintance

In this problem, the separation between reactive power and real power at bus i is carried out. This separation aims to produce nonlinear simultaneous equations in polar coordinates if known:

$$|Vi| \angle \delta_i = |V_i| \; e^{j\delta i} \quad (11)$$

$$|V_j| \angle \delta_j = |V_j| e^{j\delta j} \quad (12)$$

$$|Y_{ij}| \angle \theta_{ij} = |Y_{ij}| e^{j\delta ij} \quad (13)$$

Because $e^{j(\delta_j - \delta_i + \theta_{ij})} = \cos(\delta_j - \delta_i + \theta_{ij})$ , So the power separation that must be done at bus I into imaginary components and real components is as follows :

$$P_i - jQ_i = |V_i| \angle - \delta_i \sum_{j=1}^{n} Y_{ij} V_j \angle \theta_{ij} + \delta_j = |V_i| e^{-j5} \sum_{j=1}^{n} Y_{ij} V_j \angle \left( e^{j(\delta J - \delta i + \theta_{ij})} \right) \quad (14)$$

$$P_i = \sum_{j=1}^{n} |Vi\ Vj\ Vij| \cos(\delta_j - \delta_i + \theta_{ij}) \quad (15)$$

$$Q_I = \sum_{j=1}^{n} |Vi\ Vj\ Vjj| \cos(\delta_j - \delta_i + \theta_{jj}) \quad (16)$$

The two nonlinear equations above can be decomposed into linear simultaneous equations by expressing the relationship between changes in real power $\Delta P_i$ reactive power $\Delta Q_i$ to the change in voltage magnitude $\Delta V_i$ and voltage phase angle $\Delta \delta_i$.

### 1.4. Short Circuit Study

Ower plants generate electricity, which is then distributed to distribution and users for use in everyday life through transmission networks. Material, conductor type, and distance factors interfere with this distribution process. Short-circuit faults are a problem that often occurs during the distribution process [19]. Disturbances in the load line system and medium voltage distribution lines, as well as three-, inter-, and phase-to-ground faults, are among the many causes of power system disturbances. Overloading, network problems, and others are some of the causes. To prevent damage to electrical equipment, proper equipment must be selected and used to handle faults [20].

## 2. RESEARCH METHOD

This power flow study is carried out by displaying 41 bus electric power system model by completing data from a one-line diagram in the form of Generator data, Load data, Cable data, Generator data, Bus data and Transformer data and several other supporting components. This power flow study is carried out through several stages, namely data collection, making one-line diagrams, simulations and results, the power flow study scheme can be seen from the flowchart image below.

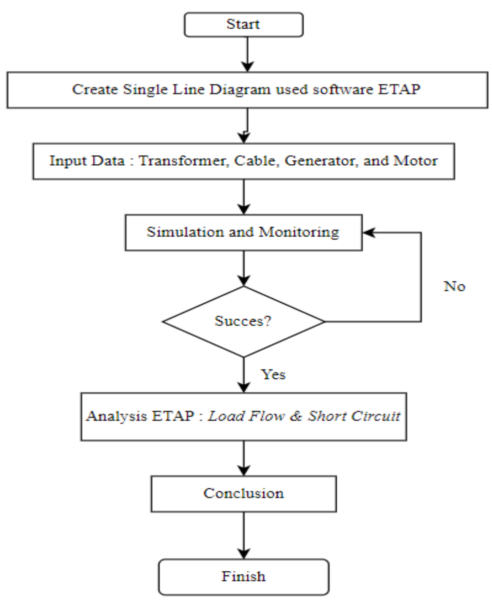


**Figure 1.** Flowchart

In working on this project, several stages are carried out before reaching the finish, namely by following the steps shown in Figure 1Make a one-line diagram according to the electrical power system created.


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1. Input data on components such as transformers, motors, buses, and cables according to the real situation.
2. Simulating the project created and monitoring periodically in order to minimise the occurrence of errors during the simulation run.
3. Make an analysis according to the simulation results.

the main discussion in this paper is the power flow and short circuit that occurs in the power system. the details of the discussion are:

1. Power flow at 2 units of steam gas power plant.
2. Short circuit with three simulation scenarios.
    a) Scenario 1, make some loads in open condition
    b) Scenario 2, connecting between bus 51 and bus 81
    c) Scenario 3, make a unit 2 in open condition, connecting between bus 27 and bus 28

## 2.1. PLTGU System Data

The data collected is data related to the components used in the one-line diagram which can be seen in Figure 1. While for Transformer data, Cable data, and load data can be seen in table 1 to table 3.

**Table 1.** Transformator Data

| Name | CapacityMVA | Input kV | Output kV | Impedance | |
|---|---|---|---|---|---|
| | | | | %Z | X/R |
| T1 | 54 | 150 | 11 | 8.4 | 10 |
| T2 | 54 | 150 | 11 | 8.4 | 10 |
| T3 | 6 | 11 | 6.3 | 8 | 12.85 |
| T4 | 6 | 11 | 6.3 | 8 | 12.85 |
| T5 | 2.5 | 6.3 | 0.4 | 9 | 10.67 |
| T7 | 2.5 | 6.3 | 0.4 | 9 | 10.67 |

**Table 2.** Cable Data

| Name | From Bus | To Bus | Length (Ft) | Size |
|---|---|---|---|---|
| Cable3 | Bus5 | Bus121 | 50.0 | 400 |
| Cable4 | Bus117 | Bus119 | 30.0 | 400 |
| Cable5 | Bus117 | Bus7 | 30.0 | 400 |
| Cable6 | Bus10 | Bus27 | 185.0 | 500 |
| Cable9 | Bus123 | Bus16 | 50.0 | 400 |
| Cable10 | Bus26 | Bus28 | 200.0 | 500 |
| Cable11 | Bus27 | Bus29 | 65.0 | 150 |
| Cable13 | Bus28 | Bus32 | 65.0 | 150 |
| Cable14 | Bus27 | Bus33 | 115.0 | 50 |

| | | | | |
|---|---|---|---|---|
| Cable15 | Bus27 | Bus34 | 115.0 | 50 |
| Cable16 | Bus27 | Bus35 | 200.0 | 50 |
| Cable17 | Bus27 | Bus36 | 135.0 | 50 |
| Cable23 | Bus28 | Bus42 | 175.0 | 50 |
| Cable29 | Bus28 | Bus48 | 115.0 | 50 |
| Cable34 | Bus52 | Bus55 | 160.0 | 150 |
| Cable41 | Bus52 | Bus62 | 140.0 | 150 |
| Cable43 | Bus52 | Bus64 | 145.0 | 150 |
| Cable45 | Bus52 | Bus66 | 145.0 | 150 |
| Cable47 | Bus52 | Bus68 | 175.0 | 150 |
| Cable48 | Bus52 | Bus69 | 200.0 | 400 |
| Cable49 | Bus52 | Bus70 | 200.0 | 150 |
| Cable50 | Bus52 | Bus71 | 175.0 | 150 |
| Cable51 | Bus52 | Bus72 | 175.0 | 150 |
| Cable52 | Bus51 | Bus73 | 20.0 | 400 |
| Cable53 | Bus51 | Bus74 | 50.0 | 400 |
| Cable54 | Bus51 | Bus75 | 30.5 | 120 |
| Cable55 | Bus51 | Bus76 | 30.5 | 120 |
| Cable56 | Bus51 | Bus77 | 20.0 | 400 |
| Cable57 | Bus71 | Bus78 | 40.0 | 70 |
| Cable61 | Bus81 | Bus83 | 155.0 | 400 |
| Cable63 | Bus81 | Bus85 | 155.0 | 150 |
| Cable65 | Bus81 | Bus87 | 240.0 | 150 |
| Cable67 | Bus81 | Bus89 | 185.0 | 150 |
| Cable73 | Bus81 | Bus95 | 44.2 | 150 |
| Cable75 | Bus81 | Bus97 | 145.0 | 150 |
| Cable77 | Bus81 | Bus99 | 140.0 | 150 |
| Cable81 | Bus81 | Bus103 | 130.0 | 150 |
| Cable83 | Bus81 | Bus105 | 145.0 | 150 |
| Cable89 | Bus28 | Bus111 | 215.0 | 50 |
| Cable91 | Bus115 | Bus113 | 50.0 | 400 |
| Cable92 | Bus123 | Bus114 | 30.0 | 630 |

**Table 3.** Load Data

| UNIT 1 | | | UNIT 2 | | |
|---|---|---|---|---|---|
| **Name** | **Active Power (kW)** | **Reactive Power (kVar)** | **Name** | **Active Power (kW)** | **Reactive Power (kVar)** |
| GT1 Crangking | 560 | 225.7 | GT2 Crangking | 560 | 225.7 |
| CWP A | 320 | 131.5 | CWP B | 320 | 131.5 |
| CWP C | 320 | 131.5 | Gas Heater2 | 354 | 615.2 |
| Gas Heater | 354 | 615.2 | BFP A2 | 185 | 77.5 |
| BFP A | 185 | 77.5 | BFP B2 | 185 | 77.5 |
| BFP B | 185 | 77.5 | CT C | 132 | 64.7 |
| CT A | 132 | 64.7 | CT D2 | 132 | 60.9 |
| CT D4 | 132 | 60.9 | 2CEP A | 75 | 82.4 |
| 1CEP A | 75 | 82.4 | 2CEP B | 75 | 82.4 |
| 1CEP B | 75 | 82.4 | ACWP A2 | 55 | 32.4 |


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| | | | | | |
|---|---|---|---|---|---|
| ACWP A | 55 | 32.4 | CCWP A2 | 75 | 32.4 |
| CCWP A | 75 | 32.4 | 2GT EMG LOAD | 800 | 387 |
| 1gt EMG LOAD | 800 | 387 | 2GT MCC LOAD | 113 | 58.3 |
| 1GT MCC LOAD | 113 | 58.3 | 2HRSG | 11 | 56.5 |
| 1HRSG | 11 | 56.5 | 2ST MCC LOAD | 65 | 321.7 |
| 1ST MCC LOAD | 65 | 321.7 | | | |

Making this diagram using the ETAP 22.0.1 application, this creation is also done by entering the data in the table above.

## 2.2. Electricity System Overview

The research conducted took power system data at PT PLN Keramasan, South Sumatra. The single line diagram in ETAP 22.0.1 can be seen in Figure 2.

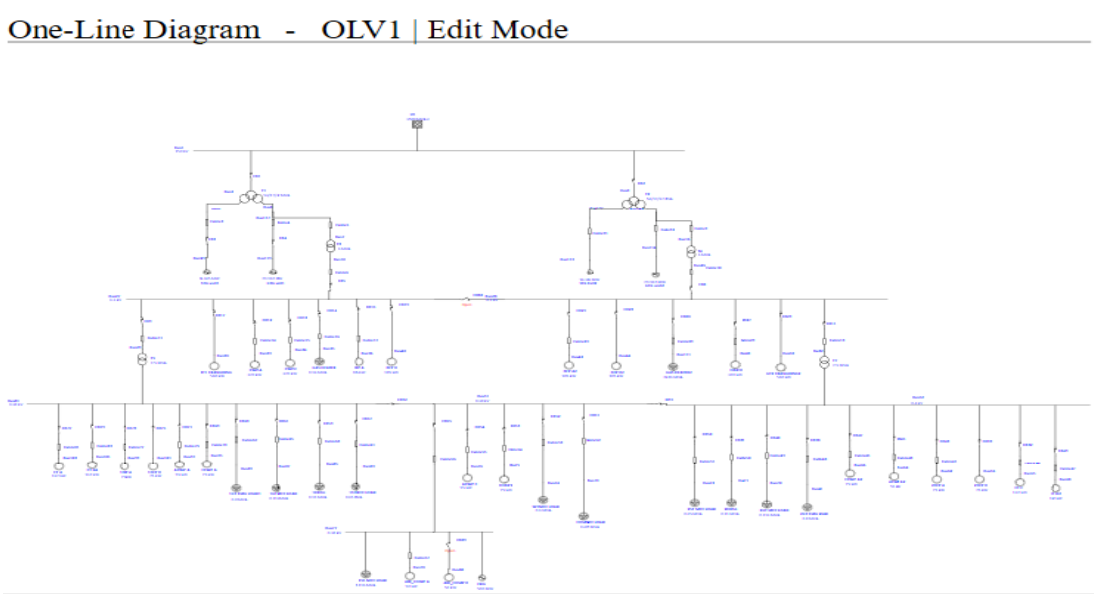


**Figure 2.** One line Diagram

## 3. RESULT AND DISCUSSION

ETAP is a software that is useful for supporting power systems. This tool has the ability to manage real-time data online and for power simulation is done offline. In addition, its features are diverse and can be used to study power transmission, distribution, and generation systems [21]. The software named ETAP 22.0.1 is also used for network design and can be used to calculate maximum short-circuits [22].

### 3.1. LOAD FLOW

Single line diagram of the power generation system in ETAP 22.0.1 format contains components that have been filled with data in the form of :

- Transformator ( rating MVA, kVprim, kVsek, dan impedance )
- Power Grid ( Rated kV )
- Bus ( Nominal kV )
- Generator ( Rated MW, kV, %PF, MVA, %Eff, Poles, and impedance )
- Cable ( Code, type, freq, install, Length, dll )
- Load ( MVA, rated kV, PF, dll )

The display of the single line diagram after simulation focuses on the power flow that occurs and how much power is generated by the two generating units in PLN Keramasan, the results of the simulation can be seen in Figures 3 and 4.

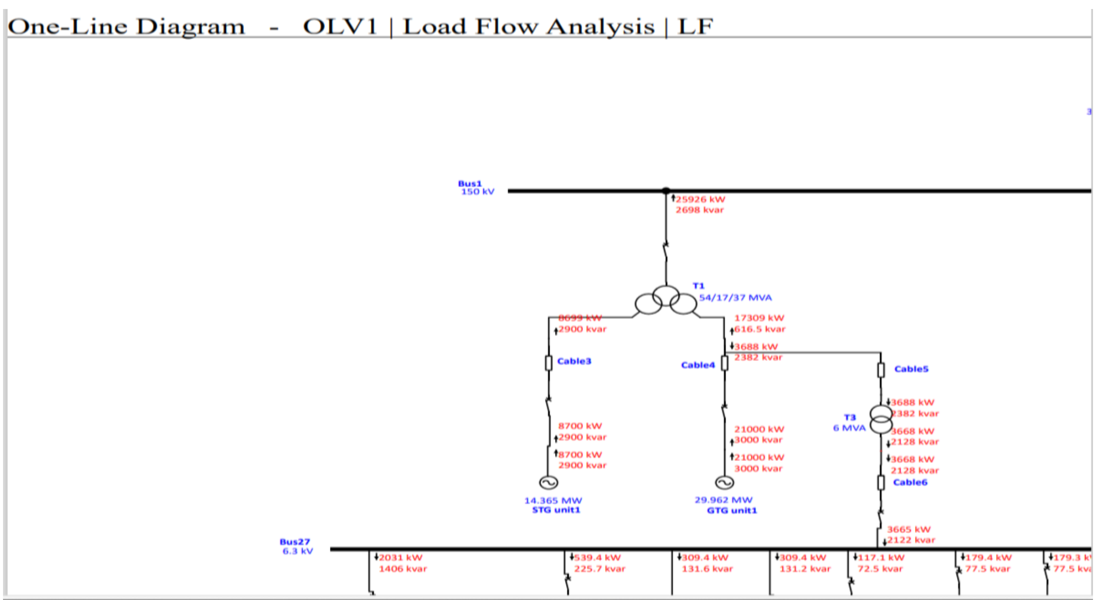


**Figure 3.** Unit 1


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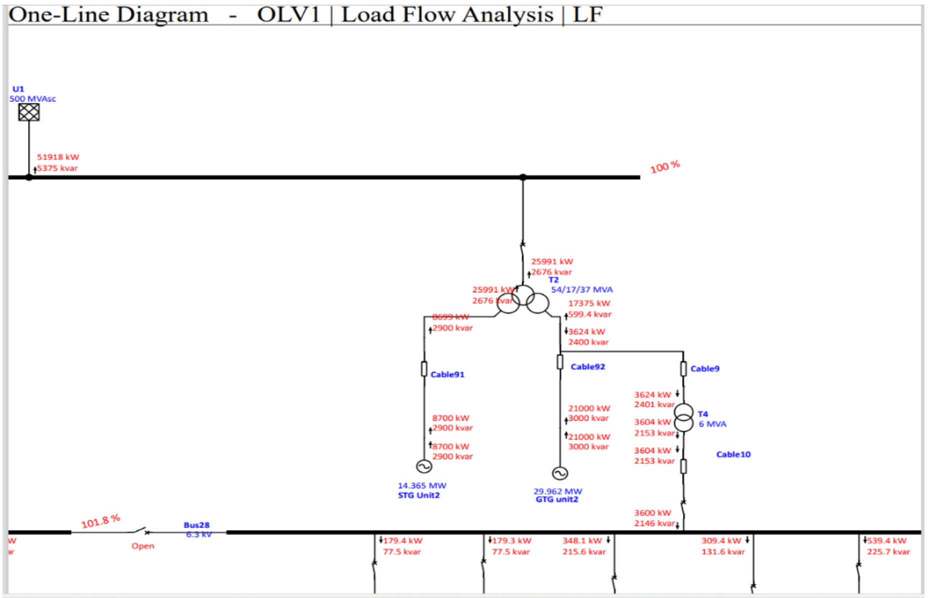


**Figure 4.** Unit 2

From the simulation results, it can be seen that the power flow is correct, this is evident from the data in the field and the data calculated by the concrete software. There are no red coloured components in the power system which means that there are no more critical components that require further evaluation. Both units produce active power of 25.92 MW and 25.99 MW that will be transferred to PLN Transmission, while the reactive power generated is 2698 kVAr and 2676 kVAr. And this system provides information that the system when in operation is able to supply 100% of the load to provide information related to power loss and voltage to see an effective electric power system.

### 3.2. Short Circuit

After the power flow is correct, then the next check on short circuit interference, simulation results based on software can be seen in table 4.1 to 4.3.

a) Scenario 1

**Table 4.** Result Simulation with first scenario

| Fault Bus | Voltage (kV) | Fault Current (kA) |
|---|---|---|
| Bus 1 | 150 | 15.41 |
| Bus 27 | 6.3 | 7.6 |
| Bus 28 | 6.3 | 7.6 |
| Bus 51 | 0.38 | 14.71 |
| Bus 52 | 0.38 | 41.12 |
| Bus 81 | 0.38 | 41.72 |

b) Scenario 2

**Table 5.** Result Simulation with second scenario

| Fault Bus | Voltage (kV) | Fault Current (kA) |
|---|---|---|
| Bus 1 | 150 | 15.41 |
| Bus 27 | 6.3 | 8.09 |
| Bus 28 | 6.3 | 7.6 |
| Bus 51 | 0.38 | 55.79 |
| Bus 52 | 0.38 | 41.72 |
| Bus 81 | 0.38 | 55.79 |

c) Scenario 3

**Table 6** Result Simulation with third scenario

| Fault Bus | Voltage (kV) | Fault Current (kA) |
|---|---|---|
| Bus 1 | 150 | 15.41 |
| Bus 27 | 6.3 | 9.3 |
| Bus 28 | 6.3 | 9.3 |
| Bus 51 | 0.38 | 55.79 |
| Bus 52 | 0.38 | 57.2 |
| Bus 81 | 0.38 | 44.5 |

## 4. CONCLUSION

Based on the results of the study, three important points were obtained, namely as follows:

1. Based on the analysis conducted with ETAP software, the gas and steam power plant (PLTGU) can generate power stably and efficiently. Power flow modelling also confirms the reliability of the PLTGU to maintain the stability of the electricity network.
2. Analysis of short circuit faults with ETAP shows that these faults can lead to instability in the electrical system. Simulation helps in identifying critical points and the need for better protection.
3. Power flow and short circuit simulations using ETAP provide important insights for planning and operational decision making. It enables identification of potential problems before they occur, so that mitigation measures can be taken early.


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