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Performance Analysis of the 2 MW Diesel Engine Generator as an Additional Power Plant at PT. Indolakto Purwosari

Bian Irianti[1*], Aulidina Dwi Nur Andriyanti[2]
Teknik Elektro, Universitas Kahuripan Kediri
Corresponding Author: Bian Irianti bianirianti@gmail.com

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A B S T R A C T

Fluctuations in electricity demand can lead to inefficiencies in diesel generators (DEG) and potentially trigger blackouts, as experienced by PT Indolakto. This study aims to identify the performance parameters of a 2 MW DEG and formulate strategies to prevent blackouts caused by the 2 MW DEG at PT Indolakto. The research used data collection techniques including field observations, interviews, literature studies, and performance test analysis. The results showed that the efficiency of the 2 MW DEG at load reached 44%, indicating there is still reserve power. An overload of 21% from the generator's capacity resulted in a blackout and a system frequency drop of 13.4 Hz from the normal frequency. Although the 2 MW DEG has adequate efficiency, optimization is necessary to prevent blackouts. One strategy is to use the 2 MW DEG as a system reserve for critical loads.

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INTRODUCTION

Electricity is a vital necessity in daily human activities, especially for the operation of machines and electronic devices. Electrical generators, which convert mechanical energy into electrical energy, play a key role in ensuring the availability of electricity. However, the efficiency of the generator can decrease due to load changes, derating, and other disturbances, which affect the stability of the electrical system.

An electric generator converts mechanical energy into electrical energy. However, the operational efficiency of the generator can decrease over time due to various factors, such as derating and trip (Yanuar Astono et al., 2020). The dynamics of large load changes cause variations in power that must be met by the generator, which must remain stable to avoid interruptions to the electrical system.

A blackout is a condition in which the power flow is completely cut off, often due to an excess or undervoltage in the system. When a blackout occurs, all electrical equipment becomes non-functional, resulting in major disruptions to operations.

Transient stability is closely related to large disturbances that occur suddenly (Hatziargyriou et al., 2021). Disturbances such as generator disconnections, short circuits, and sudden disconnections can cause changes in the stability conditions of the system. Blackout occurs when electricity is interrupted due to excess or undervoltage, causing all electrical equipment to malfunction. PT Indolakto experienced a blackout due to a problem with the 2 MW DEG used as an additional power plant, so a performance analysis and how to prevent and handle blackouts in the future is needed.

Based on this background, this study aims to determine the parameters for the performance of the Diesel Engine Generator (DEG) and analyze how to prevent blackouts caused by the 2 MW DEG as an additional power plant in PT Indolakto.

LITERATURE REVIEW

System Stability

The stability of a power system can be broadly defined as the power property of the system that allows it to remain in an operating equilibrium state below normal operating conditions and to regain an acceptable equilibrium state after experiencing a disturbance. Instability in the power system can manifest itself in a variety of ways depending on the configuration of the system and the mode of operation. Traditionally, the stability of the problem has been to maintain synchronous operation.

This aspect of stability is influenced by the angular dynamics of the generator rotor and the angular relationship of the generator (Hatziargyriou et al., 2021). Instability can also occur without losing sync. In the stability evaluation, the concern is the behavior of the electric power system when experiencing temporary disturbances. The disorder may be minor or large. Small disturbances are in the form of continuous load changes, and the system adjusts to the changing conditions. The system must be able to operate satisfactorily under these conditions and successfully supply the maximum amount of load and must also be able to withstand severe disturbances, such as short circuits in transmission lines, loss of generators or large loads, or loss of bonds between two subsystems.

Stability Classification

Based on a paper titled Definition and Classification of Power System Stability in IEEE Transactions on Power Systems, the stability of electric power systems is categorized into three, namely: rotor angle stability, frequency stability, and voltage stability. Energy system stability according to IEEE/CIGRE (2004) can be seen in Figure 1.

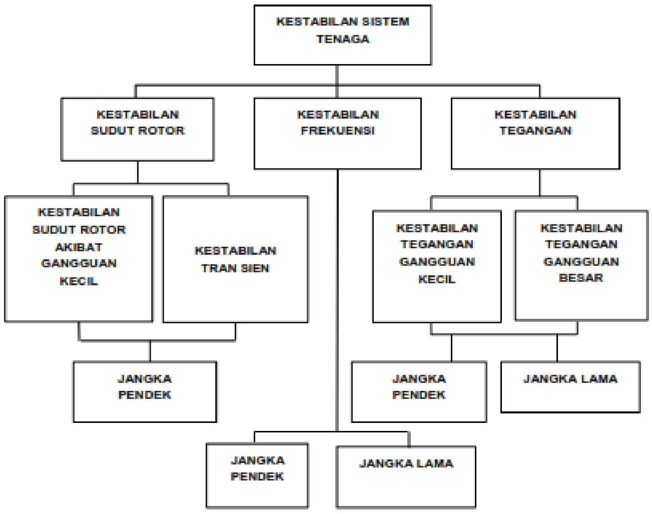

Figure 1. Energy System Stability Classification

Transient Stability

Transient stability is the ability of a power system to maintain synchronization when experiencing large transient disturbances. The resulting system response includes the generator rotor angle and is affected by the nonlinear power angle relationship. Stability depends on both the initials of the operating status of the system and the severity of the fault. Usually, the system is changed so that the post-disruption is different from that before the disruption(Stevenson, W.D. & Genger, 1994).

According to Stevenson, W.D. & Genger (1994), Stability classification is based on the following considerations: the size of the disturbance, proper modeling and specific analysis, the time range during which the disturbance occurs, and the most influential Arameter System.

Frequency Setting

Speed governor is a system setting to obtain a consistent frequency by performing constant rotation (Rizkal & Sudarmanta, 2017). When there is a change in load, there is an instantaneous change in the electrical torque (Te) in the generator. Thus causing a difference between mechanical torque (Tm) and electrical torque (Te) which causes a difference in speed (IEEE/CIGRE, 2004).

Active power is closely related to the nominal frequency in the system. The system's active power supply must be in accordance with the needs so that the frequency remains within safe limits for operation. This active power adjustment is done by arranging a mechanical coupling to rotate the generator, which is related to the setting of providing mechanical power to the turbine. This refueling arrangement is carried out by the governor. The Governor will reduce the fuel capacity when the frequency rises from the nominal, and increase the fuel capacity when the frequency drops from the nominal(Das, 2010). The speed governing chart can be seen in Figure 2.

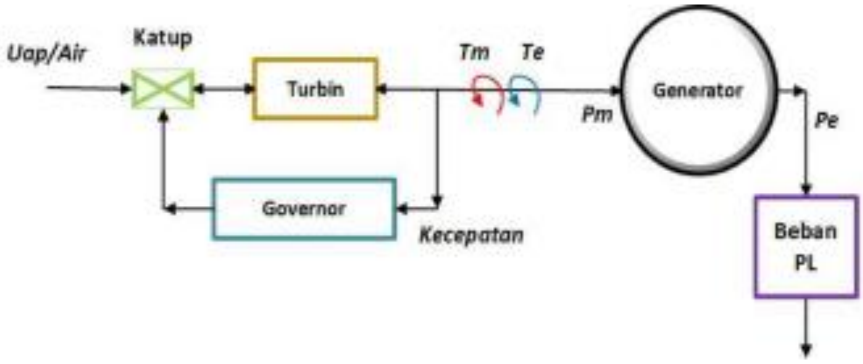

Figure 2. Speed Governing Basic Concept Diagram Block

Load Shadding

If there is a disturbance in the system that causes the amount of power supply produced by the plant to be insufficient for load needs, for example due to a trip plant, then to prevent system instability, it is necessary to carry out load shedding. Critical conditions in the system can be detected through rapidly decreasing system frequencies.

Manual load release can only be used in non-essential circumstances, such as the development of a load that exceeds the power generation capacity or the voltage drop within a certain area caused by a fault (Saiful Anwar, 2017). In an emergency where the voltage drop reaches 80%, the operator will take the initiative to discharge the load. The disadvantage of manual load release is the need for a ready and reliable operator because the operator's delay in overcoming this problem will have a fatal effect on the stability of the system.

Automatic load release using an underfrequency relay is carried out based on how much the frequency drops in the system. The planning and setting of the underfrequency relay for load shedding must be in the condition of overload so that the generator is not able to meet the load requirements. So that with the excess load borne by the generator, the system frequency will decrease. To avoid blackout due to generator overload, load shedding is required(Yanuar Astono et al., 2020).

METHODOLOGY

This study aims to analyze the performance of a 2 MW diesel engine generator (DEG) as an additional power plant at PT Indolakto. The research method used is a combination of quantitative and qualitative methods. DEG performance data was collected through direct observation in the field and interviews with technicians, supervisors, engineers, and field supervisors at PT Indolakto. The data collected includes generator specifications, generator current, power factor, excitation current, and generator output power, which are obtained from name plates, manual books, and performance test results. Researchers also conduct literature studies to gain additional knowledge from various sources. Data analysis was carried out by calculating the efficiency of the generator using a quantitative formula, as well as analyzing the performance results in terms of efficiency, running time, and transient stability of the generator. Conclusions were drawn based on the results of this analysis to provide a comprehensive picture of DEG performance at PT Indolakto. The research flowchart can be seen through Figure 1.

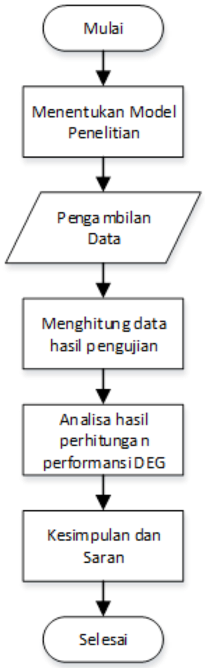

Figure 1. Research flowchart

The calculation of the efficiency value of the generator is by using the following equation.

Generator input power

$$P_{in} = \sqrt{3}\, x\, V_{in} x\, I_{in} x \cos phi \text{..................(1)}$$

Generator output power

$$P_{out} = \sqrt{3}\, x\, V_{out} x\, I_{out} x \cos phi \text{..............(2)}$$

Generator efficiency

$$\eta_{gen} = \frac{P_{out}}{P_{in}}\, x\ 100\% \text{...............................(3)}$$

Information:

Vin : Input Voltage
Iin : Input current
Vout : Output voltage
Iout : Output current
P in : Generator Input Power
P out : Generator Output Power
η : Generator Efficiency

RESEARCH RESULTS

Analysis of the Electrical System of PT. Indolakto Purwosari

PT Indolakto Purwosari uses DEG as an additional supply of 2 MW which is juxtaposed with a supply from PLN of 4 MVA or equivalent to 3.4 MW in the electricity system connected to the Low Voltage Distribution panel unit 4. PT Indolakto's electrical system can be seen in Figure 2.

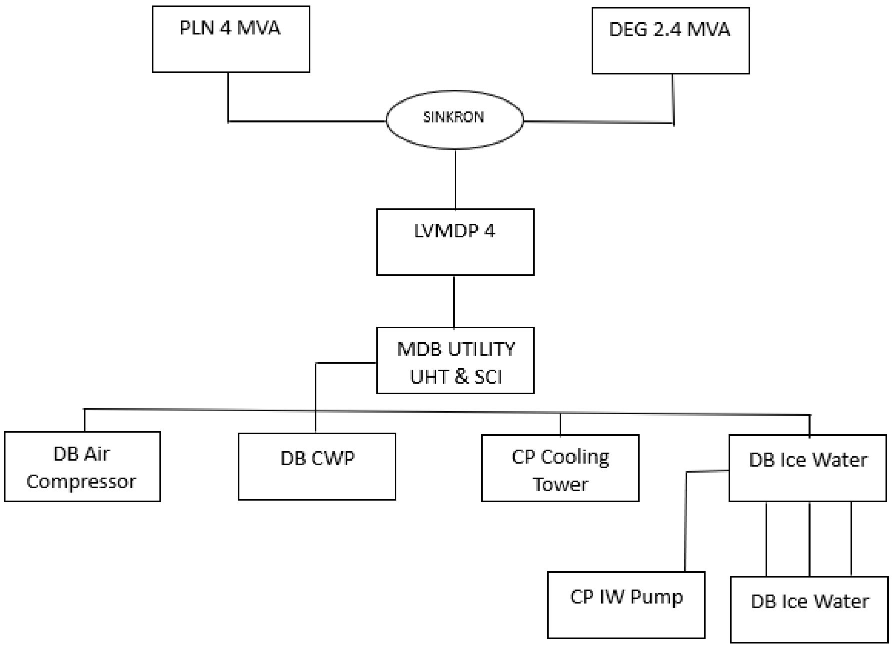

Figure 2. SLD MDB Utility UHT & SCI PT. Indolakto Purwosari

The amount of power installed at each load point in the LVMDB 4 system can be seen in Table 1.

Table 1. Built-in Power on LVMDB System

Load Type	Installed Power (KW)	Line Flow (KA)
MDB Utility UHT & **SCI**	5400	9,664
DB Air Compressor	1315	2,353
DB CWP	120,5	0,216
CP Cooling Tower	130	0,233
DB Ice Water	2540	4,546
CP Ice Water Compressor	1410	2,523
CP Ice Water Condensor	150	0,268

CP IW Pump	372,2	0,666

Based on the data presented by Table 1, the total overall power requirement borne by MDB Utility UHT and SCI at 4 main load points in the system is 4,106 MW with a spare of 1,294 MW.*Analisis Efesiensi Daya Pada DEG 2 MW Terhadap Kebutuhan Beban*

Load requirement measurement data was taken for three months starting from March. The average load data for three months can be seen in Table 2.

Table 2. Average Load for 3 Months

Month	Daily Load (KW)
March	1110,047
April	1111,824
May	1131,088
Average	1117,653
Maximum	1131,088
Minimum	1110,047

Based on the results of these calculations, the average load borne by the generator is 1.12 MW. In accordance with the technical data of the generator and the calculation of the power requirements borne by the engine, the efficiency of the DEG capacity of 2 MW to the load borne is as follows:

Efficiency: (Capable Power – Installed Power / Capable Power) x 100 % ... (4)
Efficiency: (2 MW – 1.12 MW / 2 MW) x 100 %
Efficiency: 44 %

Power to Frequency Analysis

Based on the analysis of load requirements in DEG 2 MW bears a load of 1.12 MW and the load requirement borne by PLN is 2.986 MW. Due to the cessation of DEG operations, the entire load of 4,106 MW was borne by PLN, which in terms of capacity was only 3.4 MW. Then the overload can be calculated through the following calculations:

Overload = (Total Load – PLN Capacity / PLN Capacity) x 100 %
Overload = (4,106 – 3,4/3,4) x 100 %
Overload = 20,764% ~ 21 %

This means that the generator that is being operated from the PLN side is at 121% of its capacity. The extra load will make the generator from PLN's side work harder, resulting in a decrease in frequency. The standard frequency allowed by PLN's electricity system is ± 0.5 to 1 Hz from the normal frequency of the system (50 Hz). The decrease in frequency at the time of blackout at PT. Indolakto can be known through the following analysis:
ΔP = 3,4 MW – 1,12 MW = 2,28 MW.

Where ΔP is the difference in the additional load borne by the plant. In the calculation of the frequency reduction, one of the influential parameters is the governor droop. Governor droop is usually expressed as the percentage change in speed from zero load to full load. For example, if the governor droop is 5%, then when the generator load changes from zero load to full load, the engine speed will drop by 5%. Suppose the Governor drop is 5%, then the decrease in frequency is expressed as follows:

Frequency drop = (ΔP/Rate power) x (1/Governor drop) … (5)
Frequency drop = (2,28/3,4) x (1/0,05)
Frequency drop = 0,67 x 20 = 13,4

This figure represents a load drop of 13.4 Herzt from the system's normal frequency. So the system frequency at the time of blackout at PT. Indolakto is 36.6 Herzt.

Prevention of blackouts to prevent recurrence in the electrical system

The way to prevent this from happening again is to create or make a 2 MW DEG as a backup system that bears vital loads. Changing the auxiliary status to backup is to consider the risk of system failure when electrical aspects both the same and stable voltage and frequency are different. As for if you want to keep it as an addition, more intensive supervision can be carried out in each operation, if there is an overload, the load can be transferred to the backup system. So in this case, a backup system is needed as a minimum backup to bear vital burdens.

DISCUSSION

PT Indolakto Purwosari uses a Diesel Engine Generator (DEG) as an additional power supply of 2 MW which operates with a supply from PLN of 4 MVA or equivalent to 3.4 MW. This electrical system is connected to the Low Voltage Distribution panel unit 4. Based on Table 1, the total overall power requirement borne by MDB Utility UHT and SCI at the four main load points is 4,106 MW, with a power reserve of 1,294 MW.

Load requirement measurement data taken for three months shows an average daily load of 1.12 MW. Based on efficiency calculations, an efficiency value of 44% was obtained. This efficiency indicates that the generator is not operating at full capacity, which may indicate the potential for operational optimization or the need for a review of the load incurred. Good efficiency will have a good influence on the distribution of power from the plant to the user (Matarry & Sanda, 2022).

When DEG was operating, it bore a load of 1.12 MW while PLN bore 2.986 MW of a total load of 4.106 MW. When DEG stopped operating, the entire load was borne by PLN which only had a power capacity of 3.4 MW, resulting in an overload of 21%. This overload causes PLN's generators to run at 121% of their capacity, which has an impact on decreasing the system's frequency (Saputra et al., 2023). Assuming a droop governor of 5%. A frequency reduction of 13.4 Hz from the normal frequency of 50 Hz results in a system frequency of 36.6 Hz when a blackout occurs, far below the standard allowed by PLN (±0.5 to 1 Hz).

To prevent the recurrence of blackouts, it is recommended that the 2 MW DEG be used as a reserve that bears vital burdens. Changing the DEG state from auxiliary to backup takes into account the risk of system failure caused by voltage and frequency differences. If DEGs are still used as an add-on, more intensive supervision is required to shift the load to the backup system in the event of an overload. Thus, a backup system is essential to ensure continuity of power supply, especially for vital loads.

CONCLUSIONS AND RECOMMENDATIONS

The total need for the entire system or installed power is 4.106 MW, the total power capacity of the plant is 5.4 MW, the production efficiency of the 2 MW DEG engine to meet the load needs it bears is 44%, meaning that there are still spares that indicate production safety. The blackout that occurred due to internal/external interference factors in the 2 MW DEG that suddenly stopped operating affected the stability of the entire system. So that the overload on the side of PLN, which only has a capacity of 3.4 MW, is not able to bear the needs of the entire system. The overload that caused the blackout was 21% of the power generation capacity from PLN's side, which was 121% load. At the time of the blackout, it causes a frequency drop of 13.4 Herzt from the normal frequency of the system.

One way that can be done to prevent this from happening again is to make or make a 2 MW DEG as a backup system that bears vital loads. It is also possible to transfer the load to the backup system when the main system is overloaded without having to release the load. Periodic inspections and maintenance can also be carried out to reduce the risk of future generator failure.

ADVANCED RESEARCH

This study explains the performance analysis of DEG as an additional electrical power. Further research can analyze the efficiency of DEG as backup electricity, not as an additional power plant.

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