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RELIABILITY ANALYSIS OF 3 PHASE GENERATOR SET AS AN EMERGENCY POWER SUPPLY IF THERE ARE ELECTRICITY OUTAGES AT PT. INTRACAWOOD MANUFACTURING

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Abstract

The need for electricity is a problem that occurs every year, especially in environments that really need a very high supply of electricity, such as companies, industries, offices, and lecture buildings. To maintain the continuity of the supply of electrical energy in the event of a disturbance, it is necessary to back up the generating system. As with the operation of a power generation system, it is also necessary to maintain the continuity and reliability of this backup power plant. To determine the level of reliability and availability, equipment data, operational data and damage data are needed. This study calculates the specified operating time (SOT), the total number of damages and the number of generators that are not operated due to routine or scheduled maintenance needs. calculating maintenance hours (S) and total maintenance time for each generator within a predetermined period. From SOT minus the total maintenance time, you will get the actual operating time (AOT) value of each generator. SOT and AOT data are needed to calculate the level of availability of generators individually and the level of availability of generators as a backup power supply. Furthermore, this research calculates the mean time between failure (MTBF) for each generator. The results of the study show that in 2022 the reliability level of PT. Intracawood Manufacturing by 99%. The generator set reliability level is included in the group that rarely experiences disturbances or damage (R≥ 90%) and the average generator set availability rate in 2022 is 98.5%. This study shows that the operating target of the power generation system at PT. Intracawood Manufacturing rarely experiences interruptions.

Keywords:
Generator; reliability; availability; MTBF;

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1. Introduction

At this time, it is known that the development of technology in our country is growing quite rapidly in the field of industry, companies, offices, and other sectors. This technological improvement is in line with the increasing need for electrical equipment. The need for electricity is a problem that occurs every year, especially in environments that really need a very high supply of electricity. In addition to the increasing demand for electricity supply, North Kalimantan province is also one of the areas that still has a deficit of electricity. Statistical data for 2021 shows that the capacity is still lower than the peak load[1]. To need backup generator sets in various industrial sectors and groups with large electricity loads.

The back up of electric power is in the form of a power generation system called a generator, both generators in power plants such as diesel power plants (PLTD), and generator sets. Generator set is equipment used to convert motion energy into electrical energy. The generator set functions to provide electrical energy that is needed by the community and industry. Genset performance is needed so that reliability and availability meet performance standards.

Reliability is defined as the ability of various components of equipment and systems to perform the required work functions under operating conditions. Generator reliability will change over time and the equipment ages. To get the optimal generator set performance value.

Researchers have conducted studies from various aspects related to the performance of generator sets as a back-up supply of electrical energy. Ilmi & Ayong (2019) analyzes the economic side of the generator operating system by arranging PT. Telecommunications (Tbk) Pontianak using the method *Lagrange Multiplier[2]. Tsuuri* *and Deni (2017)*regarding the design of an Automatic Transfer Switch (ATS) generator with a capacity of 1200 VA for the operation of backup electrical energy in emergency conditions. This research is able to integrate the connection between PT. PLN (Persero) and a generator as a backup[3].

Yusniati and Nurcholish (2020) examined the loading system when there was an increase in the demand for electric power which required the generator to carry the overload [4]. Meanwhile, Restu and Ismit (2022) is a research on PLTD loading analysis in the Tana Merah sub-district, Tana Tidung Regency, North Kalimantan province. Qualitative research based on measurement results in the field recommends a parallel loading system with a percentage of 73% of the generating capacity in the area [5]. And to achieve the best performance it is necessary to carry out maintenance, one of which is by using the total productive maintenance method [6]. Generator set reliability analysis has been carried out by researchers (Budi, 2017) by looking at the effect of generator electric torque on generator frequency values [7].

PT. Intracawood Manufacturing, located in Tarakan City, North Kalimantan, is one of the major Indonesian plywood companies. There are 6 generator sets owned by PT. Intracawood Manufacturing, each of the generator sets has a capacity of 3 units of 1000 Kva, 2 units of 1360 KVa and 1 unit of 1400 KVa as a backup power supply for the entire electrical load at PT. Intracawood Manufacturing. Given the importance of the generator as a power generator in the corporate environment, buildings and other mechanical equipment, the researcher wants to know how reliable the performance of the generator is so that it can produce a stable electric power output and have reliable performance and the availability of an optimal supply of electrical energy for the continuity of the company's work. .

2. Methods

This study uses qualitative data based on analytical descriptive methods [5]. Qualitative data is in the form of observation where data is collected on the required object. This research was conducted in approximately 6 months starting from March to August 2022. Data analysis was carried out when 6 generator sets were operating either in parallel or periodically as a back up supply of electrical energy when there was a disruption to PLN operations or scheduled blackouts at PT. Intracawood Manufacturing.

A. Calculation and Data Processing

To determine the level of operational reliability and availability of the generator set, it is necessary to calculate the level of availability and operational data and damage obtained from the generator operational data. Then the specified operating time (SOT) is collected, the total amount of damage and the number of generators not operated for routine or scheduled maintenance, due to maintenance (S) and the total maintenance time for each generator within a predetermined period. From SOT minus the total maintenance time, you will get the actual operating time (AOT) value of each generator. SOT and AOT data are needed to calculate the level of availability of generators individually and the level of availability of generators as a backup power supply. Next AOT=SOT-(S+T), the amount of damage is needed to calculate the mean time between failure (MTBF) of each generator. After obtaining the MTBF value, together with the total failure time (T), the level of reliability and availability can be calculated.

B. Generator Evaluation

To evaluate the performance of the generator set in order to achieve the desired reliability of the generator set, some data is needed, such as generator set maintenance data in the form of a maintenance schedule, generator set failure data, generator set operational data in a year and also analytical calculation data in the form of generator set operational data. which has been set or Specified Operating Time (SOT), real generator set operational data or Actual operating time (AOT), the average time between failures or Mean time between failure (MTBF), reliability or reliability and availability or availability. To be able to find out that the maintenance program has met the standards of the objectives to be achieved, each technician has the responsibility to evaluate the maintenance program that has been implemented. So that the performance of the equipment can meet the standards set. What is meant by maintenance technique is scheduled prevention including weekly and monthly maintenance. What is meant by the performance of the generator is the result of work which is the operation of the generator.
Generator set analysis to achieve the desired generator set reliability is divided into:

1. *Specified operating time (SOT)*

*Specified operating time (SOT)*or the amount of operating time that has been set is written in the following equation [6]:

$$SOT = A \times B \quad (1)$$

With:

A = Total standby Genset Operation time
B = Number of days in a year
2. *Actual operating time (AOT)*
*Actual operating time*or the amount of actual operating time and remaining on standby for the generator set for 24 hours a day is written in the following equation [8]:

$$AOT = SOT - (S + T) \quad (2)$$

With:
AOT = Actual Operating Time
SOT = specified operating time
S = Total scheduled maintenance time in 1 year
T = Total unscheduled maintenance time in 1 year
3. *Mean Time Between Failures (MTBF)*
Mean Time Between Failures(MTBF) or the average time between failures is written in the following equation [6]:

$$MTBF = \frac{AOT}{Number\ of\ failures\ in\ a\ year} \quad (3)$$

With:
MTBF= *Mean Time Between Failures*
AOT = *Actual Operating Time*

4. Reliability
The equation for finding the reliability value is written in the following equation:

$$R = 100.e{-}t/m \quad (4)$$

With:
R = Reliability
e = 2.718
t = SOT
m = MTBF
5. Availability
The equation for finding the availability value is written in the following equation[8]:

$$A = \frac{(AOT)}{(SOT)}\ x\ 100\% \quad (5)$$

With:
A = Availability (Availability).
AOT = Actual Operating Time (actual operating time).
SOT = Specified Operating Time (specified operating time.

3. Results and Discussion

To obtain generator set performance results, several calculations are carried out, namely by determining the specified operating time (SOT), the actual operating time (AOT), the average time between failures or the mean time between failures. (MTBF), reliability and availability for each generator set unit.

Calculation of Generator Set Performance
The SOT calculation uses the equation for one of the generator sets in 2022.

A. Calculation of SOT in January 2022 is as follows.
- For generator set 02

  SOT = 24 × 31

  SOT = 744 Hours

Calculation of the specified operating time (SOT) generator set 02 in January. The calculation above is the same as the calculation for generator sets 06, 07, 09, 11, 12 and according to the number of days in the following month. Calculation of SOT Generator Set is presented in table 1.

Table 1. SOT Generator Set in 2022

No	Generator	SOT 2022			SOT (HOURS)
		Month	Hours/day	Total Days	
1	G2, G6, G7, G9, G11, G12	January	24	31	744
2	G2, G6, G7, G9, G11, G12	February	24	28	672
3	G2, G6, G7, G9, G11, G12	March	24	31	744
4	G2, G6, G7, G9, G11, G12	April	24	30	720
5	G2, G6, G7, G9, G11, G12	May	24	31	744
6	G2, G6, G7, G9, G11, G12	June	24	30	720
7	G2, G6, G7, G9, G11, G12	July	24	31	744
8	G2, G6, G7, G9, G11, G12	August	24	31	744
9	G2, G6, G7, G9, G11, G12	September	24	30	720
10	G2, G6, G7, G9, G11, G12	October	24	31	744
11	G2, G6, G7, G9, G11, G12	November	24	30	720
12	G2, G6, G7, G9, G11, G12	December	24	31	744
Total					**8760**

B. Scheduled Maintenance Time (S)

Generator set (Genset) PT. Intracawood Manufacturing is not operated because routine scheduled maintenance is carried out by technicians to prevent errors or failures. On average per month, scheduled routine maintenance and inspections are carried out within 10 hours (10*12 months) = 120 hours (S). SOP set by PT. Intacawood Manufacturing as a generator set is carried out routine maintenance and inspection every month.

C. Total Breakdown Time (T)

The total breakdown time is the number of times the generator set is not operating (hours) for 12 months in 2022 caused by damage shown in table 2 below.

Table 2. SOT Generator Set in 2022

Year		Month												T Broken
2022		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	dec	(O'clock)
Generator Sets	G2													0
	G6													0
	G7													0
	G9								3					3
	G11							2			2	4		8
	G12									4			2	6

D. *Actual Operating Time (AOT)*

The AOT calculation uses equation 2.5 for 6 generator set units in 2022

The calculation of AOT in January 2022 is as follows

- For Generator Sets 02
  Scheduled maintenance (S) = 10 Hours

Unscheduled maintenance (T)= 0 Hours
Total equipment not operating = 10 hours
Then,AOT G02 = 744 - (10+0)
AOT G02 = 744 - 10
AOT G02 = 734 Hours

- For Generator Set 06
  Scheduled maintenance (S) = 10 Hours
  Unscheduled maintenance (T)= 0 Hours
  Total equipment not operating = 10 hours
  Then,AOT G02 = 744 - (10+0)
  AOT G02 = 744 - 10
  AOT G02 = 734 Hours
- For Generator Sets 07
  Scheduled maintenance (S) = 10 Hours
  Unscheduled maintenance (T)= 0 Hours
  Total equipment not operating = 10 hours
  Then,AOT G02 = 744 - (10+0)
  AOT G02 = 744 - 10
  AOT G02 = 734 Hours
- For Generator Set 09
  Scheduled maintenance (S) = 10 Hours
  Unscheduled maintenance (T)= 0 Hours
  Total equipment not operating = 10 hours
  Then,AOT G02 = 744 - (10+0)
  AOT G02 = 744 - 10
  AOT G02 = 734 Hours
- For Generator Sets 11
  Scheduled maintenance (S) = 10 Hours
  Unscheduled maintenance (T)= 0 Hours
  Total equipment not operating = 10 hours
  Then,AOT G02 = 744 - (10+0)
  AOT G02 = 744 - 10
  AOT G02 = 734 Hours
- For Generator Sets 12
  Scheduled maintenance (S) = 10 Hours
  Unscheduled maintenance (T)= 0 Hours
  Total equipment not operating = 10 hours
  Then,AOT G02 = 744 - (10+0)
  AOT G02 = 744 - 10
  AOT G02 = 734 Hours

To find the AOT Generator Set value in February-December in 2022, the same calculation is carried out as the calculation above, the results are presented in table 3.

Table 3. Calculation results of AOT Generator Set in 2022

Genset 2022	**Month**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**dec**
G2(Hour)	734	662	734	710	734	710	734	734	710	734	710	734
G6(Hour)	734	662	734	710	734	710	734	734	710	734	710	734
G7(Hour)	734	662	734	710	734	710	734	734	710	734	710	734
G9(Hour)	734	662	734	710	734	710	734	731	710	734	710	734
G11(Hour)	734	662	734	710	734	710	732	734	710	732	706	734

G12(Hour)	734	662	734	710	734	710	734	734	706	734	710	732

E. Mean Time Between Failure (MTBF)

The MTBF calculation uses actual operational data and the number of failures in a year as in equation 3 for 6 generator sets in 2022.

The calculation of MTBF Generator Set in January 2022 is as follows.

- $MTBF\ G02 = \frac{734}{0} = \infty$ hour
- $MTBF\ G06 = \frac{734}{0} = \infty$ hour
- $MTBF\ G07 = \frac{734}{0} = \infty$ hour
- $MTBF\ G09 = \frac{734}{0} = \infty$ hour
- $MTBF\ G11 = \frac{734}{0} = \infty$ hour
- $MTBF\ G12 = \frac{734}{0} = \infty$ hour

To find the SOT Generator Set value in February-December in 2022, the same calculation is carried out as the calculation above, the results are shown in table 4.

Table 4. 2022 Generator Set MTBF Calculation Results

Genset 2022	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**dec**	**Average**
G2 (Hour)	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
G6 (Hour)	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
G7 (Hour)	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	
G9 (Hour)	∞	∞	∞	∞	∞	∞	∞	244	∞	∞	∞	∞	20.30556
G11 (Hour)	∞	∞	∞	∞	∞	∞	366	∞	∞	366	177	∞	75.70833
G12 (Hour)	∞	∞	∞	∞	∞	∞	∞	∞	177	∞	∞	366	45.20833

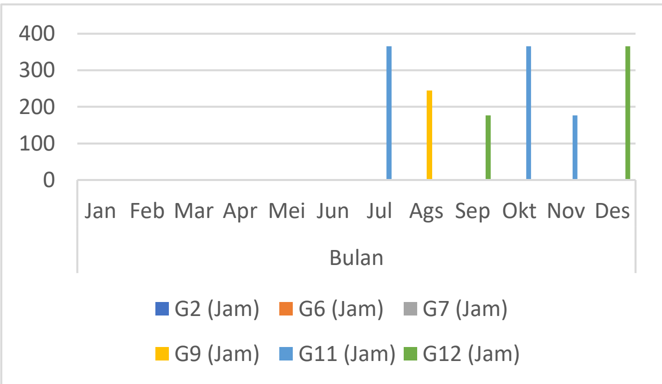

Figure 1. Graph of 2022 Generator Set MTBF

F. Level of Reliability (Reliability)

To calculate the reliability level of the generator set, it takes data on the actual operating time of the generator set and the number of damage to the generator set in 2022 based on (4). Calculation of the reliability level of the generator set in January 2022

- $R\ G02 = 100\ \times 2{,}718^{-\frac{0}{734}}$
  $R\ G02 = 100\%$
- $R\ G06 = 100\ \times 2{,}718^{-\frac{0}{734}}$
  $R\ G06 = 100\%$
- $R\ G07 = 100\ \times 2{,}718^{-\frac{0}{734}}$
  $R\ G07 = 100\%$
- $R\ G09 = 100\ \times 2{,}718^{-\frac{0}{734}}$
  $R\ G09 = 100\%$
- $R\ G11 = 100\ \times 2{,}718^{-\frac{0}{734}}$
  $R\ G11 = 100\%$
- $R\ G12 = 100\ \times 2{,}718^{-\frac{0}{734}}$
  $R\ G12 = 100\%$

Table 5. Generator Set Reliability Calculation Results for 2022

Genset 2022	**Month**												
	Jan	**Feb**	**Mar**	**Apr**	**Ma y**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**dec**	**Average**
G2 (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
G6 (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
G7 (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
G9 (%)	100	100	100	100	100	100	100	99.6	100	100	100	100	99.96
G11 (%)	100	100	100	100	100	100	99.7	100	100	99.7	99.4	100	99.90
G12 (%)	100	100	100	100	100	100	100	100	99.4	100	100	99.7	99.93

Information:
< 70% (Very frequent interruptions)
70%-95% (Frequent crashes)
≥ 90% (Rarely experience interference)

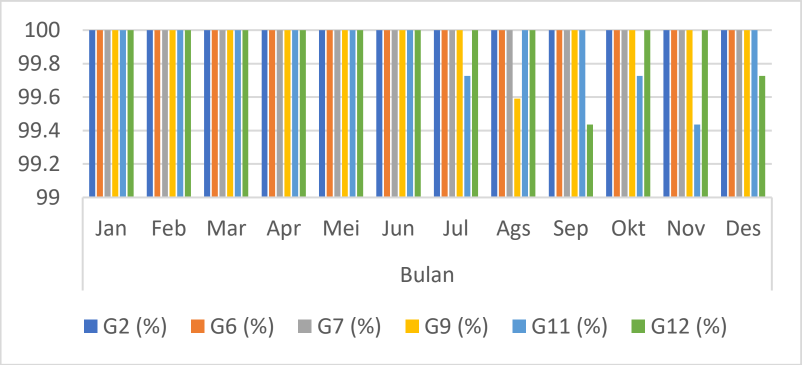

Figure 2. Generator set Reliability Graph for 2022

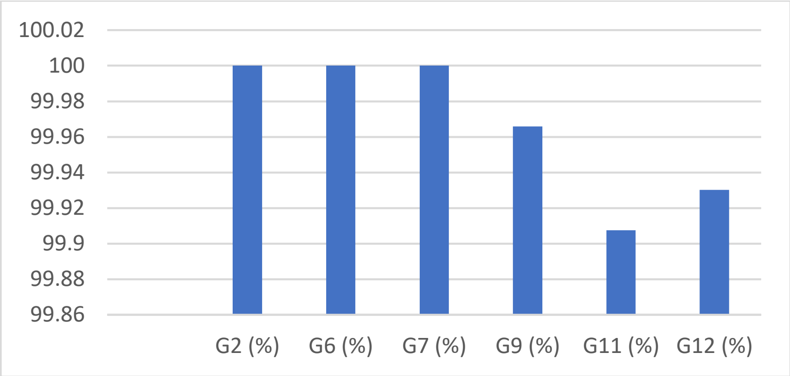

Figure 3. Graph of average Reliability of Generator sets in 2022

G. Availability

To calculate the level of availability of the generator set, data on the actual operating time of the generator set and the operating time of the generator set are required in 2022 based on (5).
Calculation of the level of availability of generator sets in January 2022

- $A\ G02 = \frac{734}{744} \times 100\% = 98.6\%$
- $A\ G06 = \frac{734}{744} \times 100\% = 98.6\%$
- $A\ G07 = \frac{734}{744} \times 100\% = 98.6\%$
- $A\ G09 = \frac{734}{744} \times 100\% = 98.6\%$
- $A\ G11 = \frac{734}{744} \times 100\% = 98.6\%$
- $A\ G12 = \frac{734}{744} \times 100\% = 98.6\%$

To find Generator Set Availability in February-December in 2022, the same calculation is carried out as the calculation above, the results are shown in table 6.

Table 6. Generator Set Availability Calculation Results for 2022

Genset 2022	**Month**											
	Jan	**Feb**	**Mar**	**Apr**	**Ma y**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**dec**
G2 (%)	98.7	98.5	98.7	98.6	98.7	98.6	98.7	98.7	98.6	98.7	98.6	98.7
G6 (%)	98.7	98.5	98.7	98.6	98.7	98.6	98.7	98.7	98.6	98.7	98.6	98.7
G7 (%)	98.7	98.5	98.7	98.6	98.7	98.6	98.7	98.7	98.6	98.7	98.6	98.7
G9 (%)	98.7	98.5	98.7	98.6	98.7	98.6	98.7	98.3	98.6	98.7	98.6	98.7
G11 (%)	98.7	98.5	98.7	98.6	98.7	98.6	98.4	98.7	98.6	98.4	98.1	98.7
G12 (%)	98.7	98.5	98.7	98.6	98.7	98.6	98.7	98.7	98.1	98.7	98.6	98.4

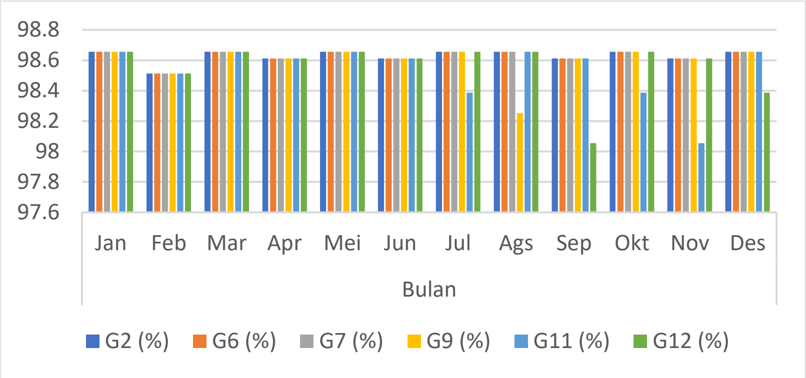

Figure 4. Graph of the level of availability of generator sets in 2022

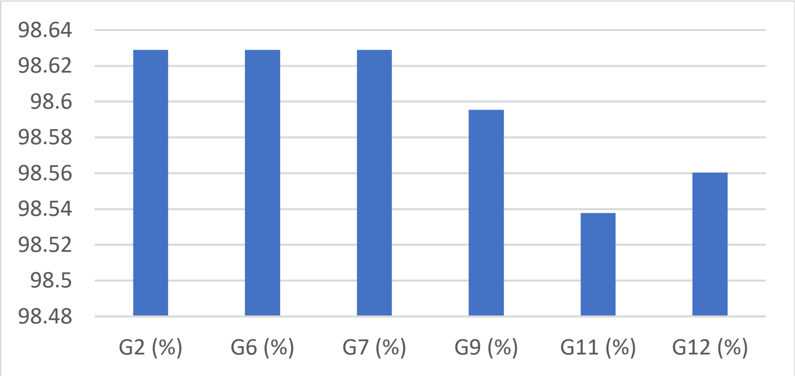

Figure 5. Graph of the average availability of generator sets in 2022

4. Conclusion

Generator set performance at PT. Intracawood Manufacturing is very reliable as a replacement or emergency supply when the power goes out. The average generator set reliability rate in 2022 has an average of 99%. The reliability level of the generator set is included in the group that rarely experiences disturbance or damage ($R \geq 90\%$) and the average level of availability (*Reliability) of generator sets in 2022 is 98.5% and is included in the group that rarely experiences disturbances.*

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