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RELIABILITY ANALYSIS OF PLTMG SYSTEM OPERATION PT PERTAMINA EP. BUNYU BASED ON LOAD LOSS PROBABILITY INDEX

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Abstract
Power plants are equipment used to generate electricity by converting an energy into electrical energy. In power plants, it is necessary to pay attention to the reliability of the generating system in meeting the needs of a load. The reliability of the generating system can be described by the plant reliability index. To pay attention to the reliability of the generating system, an analysis is needed that is used to evaluate the reliability index of the plant, one of which is Loss of Load Probability (LOLP). This study presents the calculation of the LOLP value at the PT Pertamina EP Bunyu PLTMG in 2022. In calculating the LOLP value, namely by using Microsoft Exel and Matrix laboratory simulation. PT Pertamina EP Bunyu PLTMG has 4 generating units with each capacity having a power of 1000 KW. The duration of disruption of the generating unit affects the Forced Outage Rate (FOR) value which will be used to find the probability of each combination of generating units. From this probability value, the LOLP value is obtained. At the PT Pertamina EP Bunyu PLTMG, the LOLP value is 0.00005579646% with an outage probability of 0.0203657079 days/year. While the standard set by PT PLN (Persero) in the 2018-2027 PLN RUPTL of LOLP is smaller than 0.274% or equivalent to a probability of outage of 1 day / year, it can be said that the reliability index of the power plant at PT Pertamina EP Bunyu PLTMG in 2022 is in the reliable category.

Keywords:
PLTMG; reliability; probability; LOLP

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1. Introduction

As time goes by, electricity is an energy needed for households and industries. There are industries that have their own power plants, for example PT Pertamina EP BUNYU. Where the generation system is independent of PT PLN (Persero), PT Pertamina EP Bunyu has 4 generating units, namely the Gas Engine Power Plant (PTMG). In the generation system, one of the important things to maintain is its reliability. In generation units, disturbances often occur. To minimize the disturbance, periodic maintenance is carried out or maintenance. The power in the system will decrease when several generating units occur simultaneously. This results in system outages and load loss.

The changing nature of the generating system load is accompanied by the characteristics of the electricity load which is increasing along with the development of technology, so the reliability of the generating system is increasingly needed to remain reliable in operation [1].

In the power generation system, the reliability of a power generation unit must be considered. Therefore, the calculation of the power plant reliability index is very important to ensure the availability of power. Loss of Load Probability (LOLP) is one of the methods used to calculate the reliability index [2].

LOLP LOLP describes the chances of load loss due to lack of available power in the system. Based on this, the author feels the need to conduct a study of this matter. Calculation and analysis of LOLP will be done manually and use the help of matrix laboratory software (MATLAB) to simulate the addition of generators to the PT Pertamina EP Bunyu PLTMG. Plant planning is simulated up to 1 year ahead with utilizing the Graphic User Interface (GUI) tool, making it easier to calculate and analyze system reliability.

2. Theory Foundation

A. Loss Of Load Probability (LOLP) Theory

LOLP is a reliability index that considers the chance of a plant when the system load exceeds the available generating capacity [3]. With the LOLP index, the company can make a target to determine the ability of the plant in the coming year, whether the plant can meet the load or not. High LOLP indicates a low plant reliability index, while a low LOLP indicates a high plant reliability index [4]. The LOLP reliability index is expressed in days per year. This figure shows the number of days that may occur per year, where the disturbance capacity of a system will be equal to or greater than the system's reserve capacity. Therefore, the value of the possible loss of load is the annual risk faced by the generating system in serving load demand [5]. The LOLP reliability index standard set by PT PLN (Persero) in the PLN 2018-2027 Electricity Supply Business Plan (RUPTL) is less than 0.274% or equivalent to 1 day/year [3].

$$LOLP = \sum_{t=1}^{t=365} \mathrm{P} \times t \tag{1}$$

Description:

P = Cumulative probability

t = Duration of Load Loss

A measure that states the value of a generating unit experiencing frequent interruptions is expressed by the Forced Outage Rate (FOR), namely: [3].

$$\text{FOR}=\frac{\text{Number of unit hours disrupted}}{\text{Number of unit hours operating+Number of unit hours disrupted}} \tag{2}$$

The value of Forced Outage Rated (FOR) gives an understanding that the smaller the FOR, the higher the reliability assurance obtained, conversely the greater the FOR, the smaller the reliability assurance obtained.

B. LOLP (Lost of Load Probability)

The LOLP index is calculated by summing the length of time of disturbance against all possible loss of load in the period of a certain time. The LOLP index can be calculated using (1) [3].

$$LOLP = \sum_{n=1}^{i} P^i \times t^i \tag{3}$$

Description:
P : Cumulative probability of combination
t : Duration of load loss
n : Number of combinations
i : Combination index

C. Determining Plant Reliability

The reliability of units in electricity generation can be seen from the value influenced by various factors. These factors are often used as parameters in determining the reliability of the power generation system. The parameters include the following: [6].

Load Factor, which is the ratio between the magnitude of the average value in a certain time interval and the value of the load

1. Load Factor, which is the ratio between the average value in a given time interval and the peak load value in the same time period.
   $$\text{Load Factor} = \frac{\text{average load rate(MW)}}{\text{peak load(MW)}} x100\% \tag{4}$$
   The load factor shows the characteristics of the load, where the greater the load factor (100%), the flatter the system load, the better the reliability of the plant.

2. Availability Factor, which is the ratio of the amount of power available at a certain time period to the power installed in the system at the same time period.
   $$\text{Availability Factor} = \frac{installed\ power}{power\ available} x100\% \tag{5}$$

The availability factor shows the operating readiness of the generating unit in the system. The higher the availability factor (100%), the better the reliability of the generating unit.

3. Usage Factor, which is the ratio of the peak load value to the power installed in the system.

$$\text{Usage Factor} = \frac{\text{Peak Load}}{\textit{installed power}}\, x100\% \tag{6}$$

The usage factor shows a large picture of the installed capability (installed power) in the installation that is utilized in terms of usage. When the usage factor has reached the value installed in the system, the usage factor shows the magnitude of the installed capability (installed power) in the installation that is utilized in terms of usage. When the usage factor has reached the value installed in the system.

4. Capacity Factor Capacity Factor (CF) shows how much a generating unit is utilized. The annual capacity factor (8760 hours) is defined as:

$$CF = \frac{Energy\ Production\ (MWh)\ In\ one\ day}{Capable\ Power\ (MW) x\ 24\ hours}\, x100\% \tag{7}$$

Capacity factor shows the utilization of energy utilization of the generating unit in one year from the production capability. The higher the capacity factor (100%), the better the reliability of the generating unit.

3. Methods

A. Data Collection

The process of collecting data that supports the completion of research is obtained from PT Pertamina EP Bunyu. The data obtained includes the duration of interference for each plant, operating hours for each plant, daily load for each plant and peak load data.

B. Research Stages

The author performs several stages that must be carried out as follows:

1. Conduct a literature study.
   Collecting some reference data as a reference for completing this research such as journals, books and other reference sources.
2. Data collection
   The data required in this study at PT Pertamina EP Bunyu for the past year. The data obtained includes the duration of interference each plant, operating hours of each plant, daily load of each plant and peak load data
3. Analyzing the reliability index based on the possibility of loss of load.
4. Calculating the reliability index value using Loss of Load Probability (LOLP). Of Load Probability (LOLP).
5. Take load data consisting of daily data, average daily load data and peak load data. Data and peak load data used as the basis for calculating the load factor. load factor whether it is in accordance with the PLN 2018-2027 RUPTL standard.
6. Making conclusions.

C. Stages of data processing

After the required data has been fulfilled, the calculation and analysis of the reliability index based on the probability of loss of load will be carried out as follows:

1. Data processing, After obtaining the required data, analyze the data and analyze the capacity of the generating system.
2. Performing FOR calculations to get the percentage of load loss and then adjusting to the PLN RUPTL standard value to measure the reliability index of each PLTMG unit.
3. Taking load data consisting of daily data, daily average load data and peak load data is used as a basis for calculating the PLTMG load factor whether it is in accordance with PLN RUPTL standards.
4. Calculate the availability factor, daily usage factor, daily capacity factor and outage factor.
5. From the results of load factor analysis, load availability factor, usage factor, capacity factor and outage factor. Furthermore, the reliability of the plant is calculated using LOLP.

4. Results and Discussion

A. Power Plant

Gas Engine Power Plant (PLTMG) is a power generation system managed by PT Pertamina EP. Bunyu which is used for Pertamina's distribution system, where PT Pertamina EP. Bunyu has 4 generating units. Where each generating unit has a maximum power capacity of 1000 KW so that the total installed power capacity of PT Pertamina EP. Bunyu amounted to 4000 KW.

B. System Data

The data used in this study uses power plant operation data for 2022, including

1. Power Capacity Data

PT Pertamina EP. Bunyu has 4 power plant units, each with a capacity of 1000 KW, where the details of the data are shown in table 1.

Table 1. Generating Unit Data of PT Pertamina EP. Bunyu

No	Generator	Capacity (KW)
1.	Unit D	1000
2.	Unit E	1000
3.	Unit F	1000
4.	Unit G	1000

2. Forced Outage Rate (FOR) Data

The Forced Outage Rate (FOR) value at PT Pertamina EP. Bunyu is obtained from daily operating data, dividing the number of hours of disturbed generating units removed from the system by the number of hours of disturbed generating units from the system added to the number of hours the generating unit operates during the year. Obtained the FOR index of each unit of PT Pertamina EP. Bunyu during the year 2022 operates as in table 2.

Table 2. FOR Index of PT Pertamina EP. Bunyu Year 2022

Generator	FOR (%)	Innage Rate (%)
Unit D	0,032697	99,967
Unit E	0,031916	99,968
Unit F	0,028311	99,971
Unit G	0,027974	99,972

3. Load Data

The load data used as experimental data is using the plant operation data recorded in 2022, to calculate the factors that determine the reliability of the plant using parameters such as Load Factor, Availability Factor, Usage Factor, Capacity Factor and Loss of Load Probability (LOLP). November data will be used as experimental data in the calculation because it has the highest average load during 2022. November data has the highest load reaching 635 KW which can be seen in table 3.

Table 3. Load Data November 30, 2022

Hours	Load #D	Load #E	Load #F	Load #G	ROH #D	ROH #E	ROH #F	ROH #G	Total Load	Total ROH
01.00	389	472	390	393	750	750	750	750	1644	3000
02.00	343	409	416	418	750	750	750	750	1586	3000
03.00	400	422	396	390	750	750	750	750	1608	3000

Hours	Load #D	Load #E	Load #F	Load #G	ROH #D	ROH #E	ROH #F	ROH #G	Total Load	Total ROH
04.00	426	453	442	473	750	750	750	750	1794	3000
05.00	399	444	471	445	750	750	750	750	1759	3000
06.00	450	463	405	410	750	750	750	750	1728	3000
07.00	361	487	476	424	750	750	750	750	1748	3000
08.00	372	480	465	430	750	750	750	750	1747	3000
09.00	407	421	531	523	750	750	750	750	1882	3000
10.00	386	447	534	538	750	750	750	750	1905	3000
11.00	395	459	518	524	750	750	750	750	1896	3000
12.00	349	438	555	537	750	750	750	750	1879	3000
13.00	384	444	584	589	750	750	750	750	2001	3000
14.00	359	450	591	572	750	750	750	750	1972	3000
15.00	456	466	635	622	750	750	750	750	2179	3000
16.00	592	476	622	609	750	750	750	750	2299	3000
17.00	406	446	577	560	750	750	750	750	1989	3000
18.00	431	453	540	574	750	750	750	750	1998	3000
19.00	355	452	619	622	750	750	750	750	2048	3000
20.00	370	425	608	613	750	750	750	750	2016	3000
21.00	365	455	533	533	750	750	750	750	1886	3000
22.00	439	471	493	483	750	750	750	750	1886	3000
23.00	366	444	564	562	750	750	750	750	1936	3000
24.00	344	455	514	495	750	750	750	750	1808	3000

Table 4. Average Daily Load Data

No	**Hours**	**Load #D(KW)**	**Load #E(KW)**	**Load #F(KW)**	**Load #G(KW)**	**Total Load (KW)**
1	01.00	389	472	390	393	1644
2	02.00	343	409	416	418	1586
3	03.00	400	422	396	390	1608
4	04.00	426	453	442	473	1794
5	05.00	399	444	471	445	1759
6	06.00	450	463	405	410	1728
7	07.00	361	487	476	424	1748
8	08.00	372	480	465	430	1747
9	09.00	407	421	531	523	1882
10	10.00	386	447	534	538	1905
11	11.00	395	459	518	524	1896
12	12.00	349	438	555	537	1879
13	13.00	384	444	584	589	2001
14	14.00	359	450	591	572	1972
15	15.00	456	466	635	622	2179
16	16.00	592	476	622	609	2299
17	17.00	406	446	577	560	1989
18	18.00	431	453	540	574	1998

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No	Hours	Load #D(KW)	Load #E(KW)	Load #F(KW)	Load #G(KW)	Total Load (KW)
19	19.00	355	452	619	622	2048
20	20.00	370	425	608	613	2016
21	21.00	365	455	533	533	1886
22	22.00	439	471	493	483	1886
23	23.00	366	444	564	562	1936
24	24.00	344	455	514	495	1808
Total						45194
Average Load						1883
Peak Load						2299

Table 5. Monthly Average and Peak Load Data

November 2022		
Date	Date Average Load (KW) Peak	Date Average Load (KW) Peak Load
1	1534	1794
2	1625	1782
3	1550	1768
4	1633	1848
5	1825	2077
6	1850	2069
7	1635	1903
8	1808	2005
9	1738	1558
10	1738	1897
11	1773	2062
12	1866	2036
13	1860	1976
14	1708	1910
15	1818	1994
16	1849	1971
17	1787	1930
18	1674	1779
19	1802	2067
20	1823	2023
21	1723	1922
22	1569	1855
23	1731	1929
24	1778	2002
25	1846	2040
26	1781	1998
27	1658	1826

November 2022		
Date	Date Average Load (KW) Peak	Date Average Load (KW) Peak Load
28	1810	2038
29	1886	2052
30	1883	2299

C. Calculation of Plant Loading

The load data table provides data that can be used in determining the reliability of the Power Plant through the following parameters.
Daily Load Factor.

1. Daily Load Factor

   Load Factor = $\frac{\text{Average Load(KW)}}{\text{Peak Load(KW)}} x100\%$

   Load Factor = $\frac{\text{1883 KW}}{\text{2299 KW}} x100\%$

   Load Factor = 81.9%

The load factor describes the load distribution on the system, the greater the load factor (100%) the better the reliability of the plant, the PLN standard annual load factor ranges from 70% - 90%, [6]. but from the results of the above calculations obtained a value of 81.90%, meaning that from the load factor parameter the reliability level of PT Pertamina EP. Bunyu can be said to be still in the reliable category.

2. Daily Availability Factor

   Availability Factor = $\frac{\text{Available Power(KW)}}{\text{Installed Power(KW)}} x100\%$

   Availability Factor = $\frac{\text{3000 KW}}{\text{4000 KW}} x100\%$

   Availability Factor = 75 %

The Availability Factor shows the operating readiness of the generating units in the system from the results of the above calculations obtained the value of the daily availability factor at PT Pertamina EP. Bunyu is 75%, where the more (80%), [6]. the value of the availability factor, the reliability of the generating unit can be categorized as good / reliable.

3. Daily Usage Factor

   Utilization Factor = $\frac{Peak\ Load}{Installed\ Power} x100\%$

   Usage Factor= $\frac{2299}{4000} x100\%$

   Usage Factor= 57,4 %

The usage factor shows the ability of the installed power to be used. If the value of the usage factor is high, it means that the plant needs to be developed so as not to experience overload, meaning that the value of the usage factor of the PT Pertamina EP generating units. Bunyu which reaches a value of 57.4% can still be categorized as using a reliable unit.

4. Daily Capacity Factor

   CF = $\frac{\text{Energy Production (MWh) } In\ one\ day}{\text{Capable Power (MW)x 24 hours}} x100\%$

   CF = $\frac{\text{12.490 (KWh) in one day}}{\text{4000 (KW)x 24 hours}} x100\%$

   CF = 74,9 %

The annual capacity factor above is 74.9%, where the capacity factor shows the energy utilization of the generating unit in a day from the production capability, the PLN standard for the generating capacity factor ranges from 70%-90%, [6]. from the calculation of the capacity factor of PT Pertamina EP. Bunyu shows that the plant is still in the reliable category.

D. LOLP Calculation Using Microsoft Exel Application

Table 6. PT Pertamina EP MHP Unit Data. Bunyu in 2022

No. Unit	Power (KW)	FOR	1-FOR
1	1000	0,032697	0,99967
2	1000	0,031916	0,99968
3	1000	0,028311	0,99971
4	1000	0,027974	0,99972

Table 7 Probability Calculation Results

No.	Operation/Disturbance Unit				Power Outage	Probability
	P1	P2	P3	P4		
1	0	0	0	0	0	0,998780557
2	0	0	0	1	1000	0,027947713
3	0	0	1	0	1000	0,028284679
4	0	1	0	0	1000	0,031887284
5	1	0	0	0	1000	0,032667908
6	1	0	1	0	2000	0,000925129
7	0	1	0	1	2000	0,000892265
8	0	1	1	0	2000	0,000903023
9	1	1	0	0	2000	0,001042963
10	1	0	0	1	2000	0,000914108
11	0	0	1	1	2000	0,000791457
12	1	1	1	0	3000	2,95359E-05
13	1	1	0	1	3000	2,9184E-05
14	1	0	1	1	3000	2,58868E-05
15	0	1	1	1	3000	2,52682E-05
16	1	1	1	1	4000	8,26468E-07
Total						1

Description:
0 states the unit is operating
1 denotes unit fault
Probability Formula with Microsoft Excel
No.1
=(IF(B4=1;L2;M2)*(IF(C4=1;L3;M3))*(IF(D4=1;L4;M4)*(IF(E4=1;L5;M5))))
No.2

=(IF(B5=1;L2;M2)*(IF(C5=1;L3;M3))*(IF(D5=1;L4;M4)*(IF(E5=1;L5;M5))))
No.3
=(IF(B6=1;L2;M2)*(IF(C6=1;L3;M3))*(IF(D6=1;L4;M4)*(IF(E6=1;L5;M5))))
No.4
=(IF(B7=1;L2;M2)*(IF(C7=1;L3;M3))*(IF(D7=1;L4;M4)*(IF(E7=1;L5;M5))))
No.5
=(IF(B8=1;L2;M2)*(IF(C8=1;L3;M3))*(IF(D8=1;L4;M4)*(IF(E8=1;L5;M5))))
No.6
=(IF(B9=1;L2;M2)*(IF(C9=1;L3;M3))*(IF(D9=1;L4;M4)*(IF(E9=1;L5;M5))))
No.7
=(IF(B10=1;L2;M2)*(IF(C10=1;L3;M3))*(IF(D10=1;L4;M4)*(IF(E10=1;L5;M5))))
No.8
=(IF(B11=1;L2;M2)*(IF(C11=1;L3;M3))*(IF(D11=1;L4;M4)*(IF(E11=1;L5;M5))))
No.9
=(IF(B12=1;L2;M2)*(IF(C12=1;L3;M3))*(IF(D12=1;L4;M4)*(IF(E12=1;L5;M5))))
No.10
=(IF(B13=1;L2;M2)*(IF(C13=1;L3;M3))*(IF(D13=1;L4;M4)*(IF(E13=1;L5;M5))))
No.11
=(IF(B14=1;L2;M2)*(IF(C14=1;L3;M3))*(IF(D14=1;L4;M4)*(IF(E14=1;L5;M5))))
No.12
=(IF(B15=1;L2;M2)*(IF(C15=1;L3;M3))*(IF(D15=1;L4;M4)*(IF(E15=1;L5;M5))))
No.13
=(IF(B16=1;L2;M2)*(IF(C16=1;L3;M3))*(IF(D16=1;L4;M4)*(IF(E16=1;L5;M5))))
No.14
=(IF(B17=1;L2;M2)*(IF(C17=1;L3;M3))*(IF(D17=1;L4;M4)*(IF(E17=1;L5;M5))))
No.15
=(IF(B18=1;L2;M2)*(IF(C18=1;L3;M3))*(IF(D18=1;L4;M4)*(IF(E18=1;L5;M5))))
No.16
=(IF(B19=1;L2;M2)*(IF(C19=1;L3;M3))*(IF(D19=1;L4;M4)*(IF(E19=1;L5;M5))))

The definition of the Formula above is as follows.

=(IF(P1=1,FOR_P1,1-FOR_P1)*(IF(P2=1,FOR_P2,1-FOR_P2))*(IF(P3=1, FOR_P3,1-FOR_P3))*(IF(P4=1,FOR_P4,1-FOR_P4))

This means that if the Unit 1 generator is binary 1 will enter the FOR value for the unit 1 generator otherwise the 1-FOR (innage rate) value of the unit 1 generator will be entered multiplied if the unit 2 generator is binary 1 will enter the FOR value for the unit 2 generator otherwise the 1-FOR value of the unit 2 generator will be entered multiplied if the unit 3 generator is binary 1 will enter the FOR value for the unit 3 generator otherwise the 1-FOR value of the unit 3 generator will be entered multiplied if the unit 4 generator is binary 1 will enter the FOR value for the unit 4 generator otherwise the 1-FOR value of the unit 4 generator will be entered.

Table 8. LOLP Calculation Results

No.	Power Available	Power Available	Probability	LOLP
1	4000	0	0,998780557	0
2	3000	1000	0,027947713	0
3	3000	1000	0,028284679	0
4	3000	1000	0,031887284	0
5	3000	1000	0,032667908	0
6	2000	2000	0,000925129	0,000925129

7	2000	2000	0,000892265	0,000892265
8	2000	2000	0,000903023	0,000903023
9	2000	2000	0,001042963	0,001042963
10	2000	2000	0,000914108	0,000914108
11	2000	2000	0,000791457	0,000791457
12	1000	3000	2,95E-05	2,95359E-05
13	1000	3000	2,92E-05	0,000029184
14	1000	3000	2,59E-05	2,58868E-05
15	1000	3000	2,53E-05	2,52682E-05
16	0	4000	8,26E-07	8,26468E-07
Total LOLP				0,005579646

LOLP Calculation Formula with Microsoft Excel
No.1
=IF(B3<=C3;D3;0)
No.2
=IF(B4<=C4;D4;0)
No.3
=IF(B5<=C5;D5;0)
No.4
=IF(B6<=C6;D6;0)
No.5
=IF(B7<=C7;D7;0)
No.6
=IF(B8<=C8;D8;0)
No.7
=IF(B9<=C9;D9;0)
No.8
=IF(B10<=C10;D10;0)
No.9
=IF(B11<=C11;D11;0)
No.10
=IF(B12<=C12;D12;0)
No.11
=IF(B13<=C13;D13;0)
No.12
=IF(B14<=C14;D14;0)
No.13
=IF(B15<=C15;D15;0)
No.14
=IF(B16<=C16;D16;0)
No.15
=IF(B17<=C17;D17;0)
No.16
=IF(B18<=C18;D18;0)
The meaning of the formula above is as follows.

=IF(Power Reserve<= Outage Power, Probability Value,0)

This means that if the power reserve value is smaller or equal to the outage power value, it will be equal to the probability value, but otherwise it will be zero (0).

E. Calculation of Annual LOLE Reliability Index Using Microsoft Exel

$$LOLP = \sum probabilitas\ capacity\ in\ < Load$$

$LOLP$ = 0+0+0+0+0+0,000925129+0,000892265+0,000903023
+0,001042963+0,000914108+0,000791457+0,000025359+0,000029184+0,0000258868
+0,0000252682+0,000000826468
$LOLP$ = 0,005579646 / 100
$LOLP$ = 0,00005579646 %
$LOLE = LOLP \times 365\ days/year$
$LOLE$ = 0,00005579646 × 365 $days/year$
$LOLE$ = 0,0203657079 $days/year$

F. LOLP Calculation using Matlab Application

1. Program Design

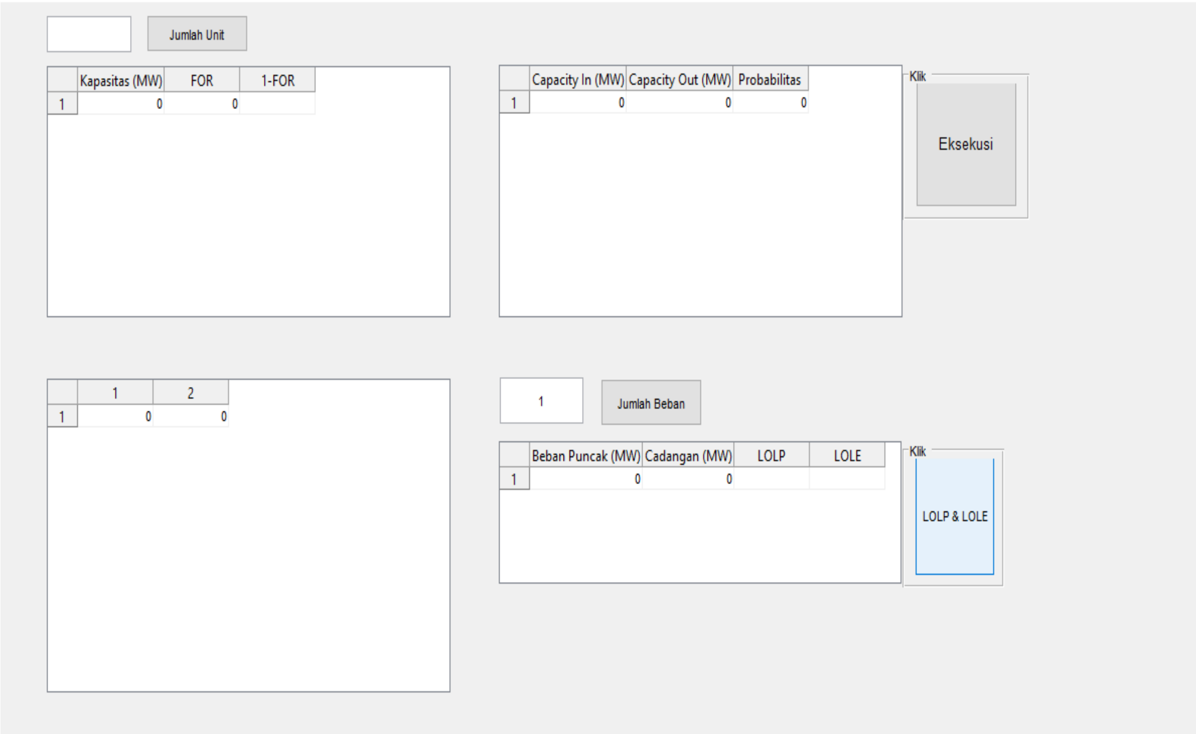

Figure 1. Initial View of the LOLP GUI

```
data = get(handles.uitable1, 'data')
data= [0 0];
set(handles.uitable1, 'data',data);
 data = get(handles.uitable2, 'data')
data= [0 0];
set(handles.uitable2, 'data',data);
data = get(handles.uitable3, 'data')
data= [0 0];
set(handles.uitable3, 'data',data);
data = get(handles.uitable5, 'data')
data= [0 0 0];
set(handles.uitable5, 'data',data);
```

The coding program above is a program that is used to display the initial numbers when the program is run.

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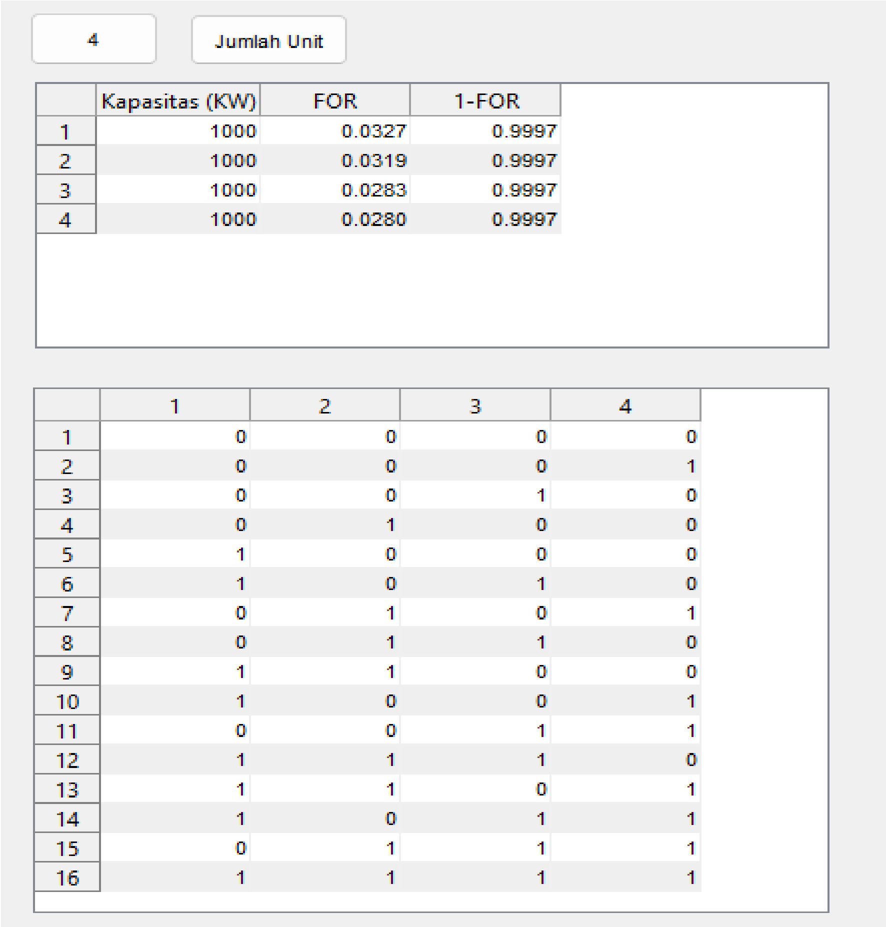

	Kapasitas (KW)	FOR	1-FOR
1	1000	0.0327	0.9997
2	1000	0.0319	0.9997
3	1000	0.0283	0.9997
4	1000	0.0280	0.9997

	1	2	3	4
1	0	0	0	0
2	0	0	0	1
3	0	0	1	0
4	0	1	0	0
5	1	0	0	0
6	1	0	1	0
7	0	1	0	1
8	0	1	1	0
9	1	1	0	0
10	1	0	0	1
11	0	0	1	1
12	1	1	1	0
13	1	1	0	1
14	1	0	1	1
15	0	1	1	1
16	1	1	1	1

Figure 2. Many Generators and Binary Disturbance Probability

```
baris =str2num(get(findobj(gcf,'Tag','edit1'),'string'));
data = get(handles.uitable1, 'data');
data(baris,:)=0;
data_1(2^baris,:)=0
set(handles.uitable1,'data',data);
set(handles.uitable5,'data',data_1);

derett=(0:((2^baris)-1))
probb=de2bi(derett)
set(handles.uitable2,'data',probb);
```

The program function above displays the number of plants and displays the number of possible plants experiencing interference in binary form.

	Capacity In (KW)	Capacity Out (KW)	Probabilitas
1	4000	0	0.9988
2	3000	1000	0.0279
3	3000	1000	0.0283
4	3000	1000	0.0319
5	3000	1000	0.0327
6	2000	2000	9.2513e-04
7	2000	2000	8.9227e-04
8	2000	2000	9.0302e-04
9	2000	2000	0.0010
10	2000	2000	9.1411e-04
11	2000	2000	7.9146e-04
12	1000	3000	2.9500e-05
13	1000	3000	2.9200e-05
14	1000	3000	2.5900e-05
15	1000	3000	2.5300e-05
16	0	4000	8.2600e-07

Klik
Eksekusi

Figure 3. Probability of Plant Disruption

```
baris =str2num(get(findobj(gcf,'Tag','edit1'),'string'));
data = get(handles.uitable1, 'data');
daya = get(handles.uitable5, 'data');
biner_pembangkit = get(handles.uitable2, 'data');
data(:,4)=1-data(:,2);
set(handles.uitable1,'data',data);
for c=1 : 1 : (2^baris) % baris
     for d=1 : 1 : baris % kolom
      if biner_pembangkit(c,d)==0
     hd=data(d,2);
     else
 hd=data(d,4);
    end
matriks(c,d)=hd;
    end
     end
     daya(:,4)= sum(data(:,1))-daya(:,1);
     daya(:,3)=prod(matriks,2);
     daya(:,1)=mtimes(biner_pembangkit,data(:,1));
     daya(:,2)= sum(data(:,1))-daya(:,1);
set(handles.uitable5,'data',daya);
```

The function of the above coding program is to generate a probability of on each possibility of the plant experiencing interference

2. Calculation of the annual LOLE reliability index using Matlab

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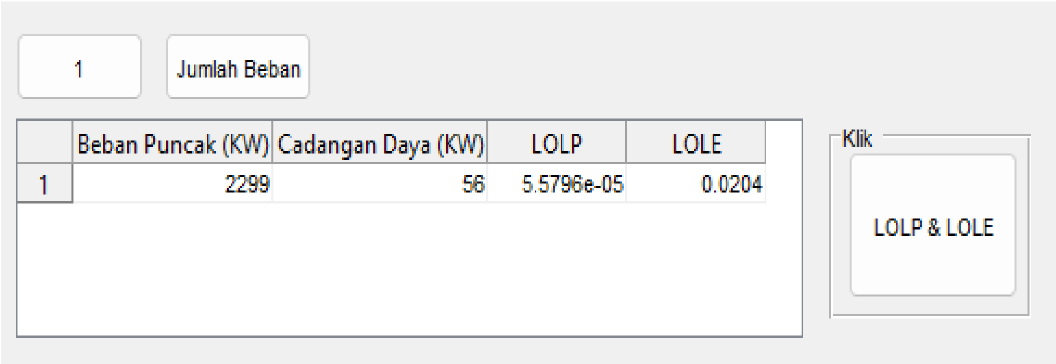

Figure 4. Display of LOLP and LOLE results

```
baris1 =str2num(get(findobj(gcf,'Tag','edit2'),'string'));
daya = get(handles.uitable1, 'data');
daya_beban(baris1,:)=0;
set(handles.uitable3,'data',daya_beban);
```

Program code to display the load data to be entered

```
line =str2num(get(findobj(gcf,'Tag','edit1'),'string'));
data = get(handles.uitable1,'data');
power = get(handles.uitable5,'data');
load = get(handles.uitable3, 'data');
binary-generator = get(handles.uitable2, 'data');
row1 =str2num(get(findobj(gcf,'Tag','edit2'),'string'))
peak_load=sum(data)
load(:,2)=peak_load(1,1)-load(:,1)
set(handles.uitable3,'data',load)
for u=1 : 1 : row1 % load row
for t=1 : 1 : (2^row) % probability row
     if power(t,1)<=load(u,1)
        demand=power(t,3)
     else
        demand=0
end
       power_matrix(u,t)=demand
    end
end
load(:,3)=sum(matrix_power,2)
load(:,4)=load(:,3)*365
set(handles.uitable3,'data',load)
```

Program coding to generate LOLE values and LOLP values from the load data entered. Program coding is a language command used to direct the computer to work according to our wishes. In this case the command that is addressed is to calculate the value of LOLP in Matlab from the operating data of the PT Pertamina EP PLTMG plant. Bunyu in 2022.

1. set(handles.uitable1, 'data',data);
This program states that the data to be displayed, namely the data named "data", will be placed in uitable 1.
2. line =str2num(get(findobj(gcf,'Tag','edit1'),'string'));
This program declares that string format (word format) is converted to
into the number format and the variable to be
is taken from the tag number in edit1.
probb=de2bi(derett)
This program code tells the definition of probb as a variable
that comes from a decimal sequence number to be converted into a binary number.
binary number.
4. data(:,3)=1-data(:,2);

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This program tells the contents of the data matrix all rows of column 3
equal to one minus all rows in column 2 (1FOR calculation).
5. power(:,1)=mtimes(binary-generator,data(:,1));
This program expresses that power in all rows of column 1 is multiplication of the data from the binary generator with the data value in the data "(:,1)".

3. Program Simulation
Simulation of 4 Generating Units

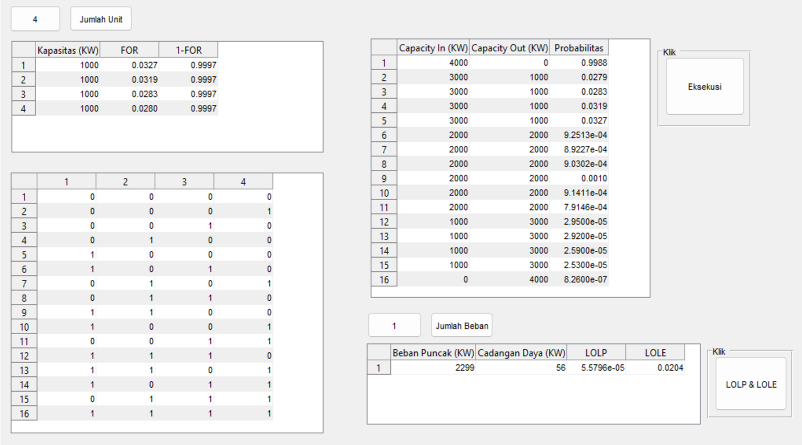

Figure 5. LOLP Results of 4 Generating Units

From the results of the calculation using the Matlab application program above, the LOLP result is 0.00005579646 and LOLE is 0.0203657079 days / year where these results have the same value as doing manual calculations using Microsoft Excel, namely LOLP 0.00005579646 and LOLE 0.0203657079, in this case it means that calculating LOLP can use Microsoft Excel and Matlab applications because they have the same results but the results of the matlab program have a higher level of accuracy. in Microsoft Excel there will also be weaknesses when you want to calculate LOLP with more generating capacity, in Microsoft Excel you have to use a different formula and the addition of binary probabilities will double and the occurrence of human error is higher in making the formula, Microsoft Excel will also find weaknesses when you want to calculate LOLP with more generating capacity, in Microsoft Excel you have to use a different formula and the addition of binary probabilities will multiply and the occurrence of human error is higher in making the formula. The LOLP and LOLE values obtained are smaller than the standards set by the 2018-2025 PLN RUPTL, namely LOLP < 0.274% and LOLE < 0.274%. Reserve margin = 40%, where the simulation of 4 plants against a peak load of 2299 KW is worth LOLP = 0.00005579646 and LOLE = 0.0203657079 days / year, respectively, meaning that the PT Pertamina EP Bunyu plant is good and can be categorized as reliable.

5. Conclusion

A. From the results of the calculation of the reliability of the plant using the LOLP index, the reliability value of the PT Pertamina EP plant is obtained. Bunyu with a Loss of Load Probability (LOLP) value of 0.00005579646% with an outage probability of 0.0203657079 days a year due to the availability of PT Pertamina EP Bunyu's power plant of 75% which can be categorized as good and reliable.
B. The results of the analysis of the calculation value of the reliability of the PT Pertamina EP plant. Bunyu in 2022 shows that the reliability of the plant can be categorized as reliable because it is in accordance with the reliability criteria used, namely LOLP is smaller than 0.274% or equivalent to a probability of outage of 1 day / year based on PT PLN's RUPTL in the Decree of the Minister and Energy and Mineral Resources of the Republic of Indonesia Number 1567 K/21 / MEM / 2018 RUPTL 2018-2027.

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