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CALCULATION OF GENERATOR REABILITY INDEX WITH LOAD FORECASTING AT PLTU (ELECTRIC STEAM POWER PLANT) ANGGREK IN GORONTALO

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Abstract (10-pt bold, alignment left flush)

The calculation of the reliability at the PLTU Anggrek 2×25 MW Gorontalo obtained a LOLP value of 61.5 days/year. This value was still above the standard reliability value of PLN, this was due to the occurrence of PO (Planned Outage) and MO (Maintenance Outage) in unit 2 in June-July 2021, namely in the form of the first-year inspection in July. The FOR (Force Outage Rate) value was calculated based on the disturbance data from the generator in 2021. The daily load value was obtained from the load forecast value in January-July using FIS (Fuzzy Inference System) Mamdani type using the Matlab Toolbox. The error value in the proposed load forecast was 8%. The rules that had been compiled were used to predict expenses in August-December 2021. From the results of forecasting From the results of forecasting expenses, it was found that the trend of expenses was increasing every month.

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Key Words - LOLP , Planned outage, Maintance outage, Force outage rate (FOR)

1. Introduction

The growth in the use of electricity consumption nationally is increasing. This is evident from the increase in the electrification ratio every year. This also applies outside Java, especially in Gorontalo. The electrification ratio in Gorontalo reaches almost 99.9%, while the electrified village in Gorontalo reaches 100%. This is offset by the construction of power plants in Gorontalo, especially the construction of the PLTU (Electric Steam Power Plant) Anggrek, therefore a reliability analysis is needed to determine in one year of generation the duration of the power plant cannot meet the peak load of consumers.

PLTU Anggrek is located in Anggrek Sub District, North Gorontalo Regency, Gorontalo Province. PLTU Anggrek or what is known as PLTU Gorontalo is classified as a new power plant because it only started operating in 2019 although it has been under construction since 2007. The power plant using coal and Lamtoro (Leucaena glauca) woodchip has 2 power plants with a capacity of 25 MW each. Apart from PLTU Anggrek, Gorontalo also developed several power plants, including the Sumalata Solar Power Plant (PLTS), as well as the Mongango and Taludaa Microhydro Power Plants (PLTM) that are under construction.

Based on Gorontalo BPS data [1], the number of electricity customers has increased every year, this means that it is proportional to the increase in electricity consumption. With the increasing rate of growth, it is necessary to research the reliability value of the power plant so that planning can be done that should be done for future services. The level of reliability of the electric power system can be seen from the value of Loss of Load Probability (LOLP) which is expressed in days per year. Planning can be done by increasing the number of generators or reducing the FOR value so that continuity is maintained. In evaluating the reliability, it is necessary to represent the load in the future using the daily peak load data in the previous year [2]. This daily peak load is sorted from the highest to the lowest value for 1 year to get the LDC (Load Duration Curve) or the load duration curve.

In this study, the calculation of FOR and LOLP values at PLTU Anggrek was carried out to determine the reliability value of the generator so that improvement plans could be made for the next time.

2. Research Method

Reliability was the ability of the power system to provide services to consumers while maintaining the quality and price of electricity at an acceptable level [3]. There were four factors related to reliability, namely probability, working according to its function, period, and operating conditions. In this study, the calculated reliability was the LOLP value. The Loss of Load Probability (LOLP) was the result of multiplying the probability of the load occurring and the time of the load loss being expressed in days per year [4]. Expressed by the following formula:

$$LOLP = P \times t \qquad (1)$$

where,
P = cumulative probability of the combination

t = duration of loss of load

LOLP gave the probability of the available generating capacity to meet the daily peak load. The unreliability of a system could be known if the system was not able to supply the peak load. Loss of load occurred if the system demand exceeded the available capacity [5].

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$$\% \, eror = \frac{(actual - foreca \quad)}{actual} x \; 100\% \qquad .. (2)$$

The fuzzy system modeling process used the Fuzzy Logic Toolbox in Matlab. Using the toolbox, a Fuzzy Inference System (FIS) was built. In Matlab, there were 2 types of FIS, namely Mamdani FIS type and Sugeno FIS type. In this study, the Mamdani type FIS was used. The designed FIS used 2 input variables, namely the number of electricity customers and temperature, and 1 output variable, namely the forecast load. The fuzzy Logic Process was shown in Figure 1.

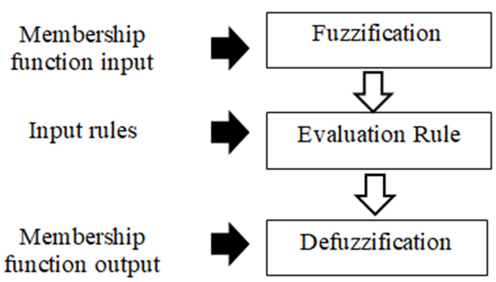

Figure 1. Fuzzy Logic Process

Input and output variables were needed to create rules in the fuzzy Toolbox. The rules are shown in Table 1. The membership function of the input variable number of electricity customers consisted of 7 member functions in the form of Minimum (Min), Very Small (VS), Small (S), Medium (M), Big (B), Very Big (VB), Maximum(Max). While the temperature input variable consisted of 3 members in the form of low, average, and high. The predictive load output variable had the same membership function as the input variable for the number of electricity customers.

Table 1. Input and output variables

Function	Variable name	Fuzzy set	Domain
Input	Number of electricity customers	A1	133011 - 133511
		A2	133512 - 134023
		A3	134025 - 134553
		A4	135067 - 135789
		A5	135801 - 135921
		A6	135512 - 135911
		A7	135967 - 136401
	Temperature	B1	22 – 25
		B2	26 – 29
		B3	30 – 33
Output	Electrical power forecast	C1	880 – 929
		C2	830 – 979
		C3	980 – 1029
		C4	1030 – 1079
		C5	1080 – 1129
		C6	1130 – 1179
		C7	1180 - 1230

Data on the number of electricity customers of PT PLN (Persero) was obtained from the website of the Central Statistics Agency (BPS) of the city of Gorontalo [1]. Data on the number of electricity customers of PT PLN (Persero) was obtained from the website of the Central Statistics Agency (BPS) of the city of Gorontalo [1]. From this data, it could be seen that every month the number of PLN (Persero) electricity customers had increased. The complete research flowchart can be seen in Figure 2.

Each generator had a FOR value, which indicated the unavailability of generating units by taking data on the duration of disturbance in each generating unit [7]. Based on the disturbance data at the PLTU Anggrek [8] the FOR (Force outage Rate) value was obtained as shown in Table 2.

Table 2. FOR generator values

Unit	FOR
Unit #1	0,05
Unit #2	0,08

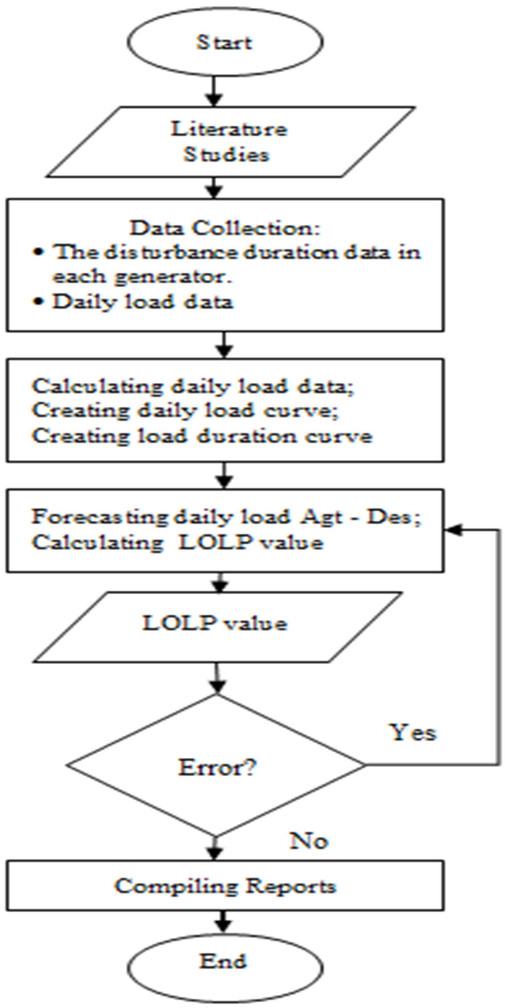

Figure 2. Research flowchart

3. Result dan Discussion

The generator load data was taken from the daily load data of PT PJB UBJOM PLTU Anggrek 2x 25 MW in 2021 Gorontalo. The data was obtained from January 2021 to July 2021. Fuzzy logic was compiled to determine the load forecasting rules, then the performance of the proposed fuzzy was compared with the actual data to see the error percentage of the compiled rules. Results Comparison of actual data with forecasting data with fuzzy logic can be seen in Table 3. The largest error value in May was 14%, but fuzzy logic forecasting was able to follow an upward pattern from the previous month's load. In June and July, the value of the forecast load was higher than the actual load. This was because the actual load had decreased due to several things, including PO and MO in one of the generating units. The average error value with the designed fuzzy obtained a value of 8%.

Table 3. Error-values of actual and forecasted loads

Month	Actual Data (MW)	Forecast Data (MW)	Error (%)
January '21	937,88	905	4%
February '21	953,87	955	0%
March '21	1245,8	1220	2%
April '21	1207,4	1060	12%
Mei '21	1291,4	1080	14%
June '21	869,12	968	11%
July '21	885,5	1020	13%
Average			**8%**

In June and July 2021 the load data decreased due to one of the generators experiencing an outage, Unit #2 for 18-30 June 2021 experienced PO (Planned Outage), namely the output of voltage due to periodic maintenance work of the plant such as inspection, overhaul or other work that had previously scheduled in the annual plant maintenance plan. In July unit #2 also experienced PO due to the first year's inspection. Unit #1 on 5-7 June 2021 experienced MO (Maintenance Outage) due to stability testing on CT Neutral GT unit 1.

For the calculation of generator reliability, daily load data was needed from January to December 2021. Therefore, load forecasting was carried out from August to December 2021 using Fuzzy Mamdani logic with the help of Matlab 2014 software. The load forecasting data was shown in Table 4. The value of this load was in the form of a forecasted load, it was not certain according to the actual situation later. To get the actual value, it was necessary to collect data again at the end of 2021.

Table 4. Error-values of actual and forecasted loads

Bulan	Forecast Data (MW)
August '21	1020
Sepetember '21	1110
October '21	1150
November '21	1210
December '21	1110

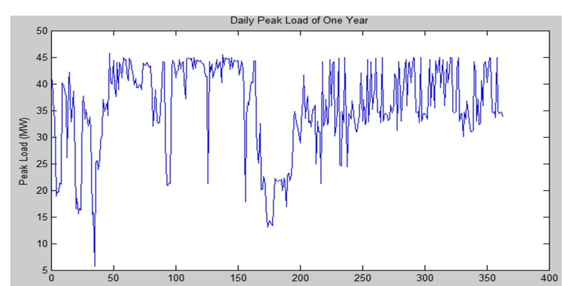

Figure 3. Daily load curve

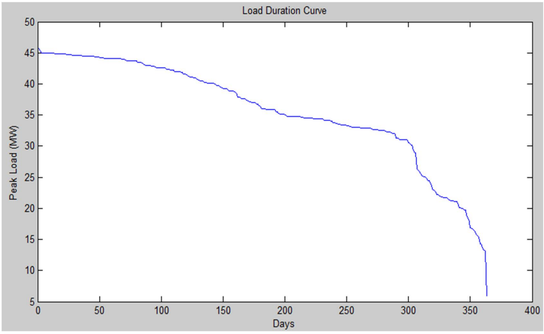

Figure 4. Load duration curve

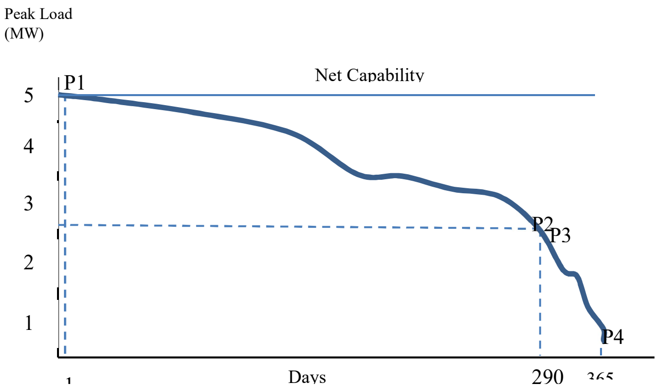

Figure 5. Merging LDC with Probability

The duration of load loss was obtained by combining generating capacity, cumulative probability, and Load Duration Curve (LDC) [9]. Figure 5 shows the combined generating capacity and LDC. When the generating capacity was 50 MW, the LDC curve was truncated on day 1 and the cumulative probability was 1. At the capacity of 25 MW, the LDC curve was truncated on day 290 with a cumulative probability of P2.

The daily load curve for 1 year is shown in Figure 3 and the load duration curve is shown in Figure 4. Based on the 2021 daily load data [8], the reliability of the PLTU Anggrek power plant was calculated and the LOLP reliability value was 61.5 days per year. This value was still above the PLN standard, which was 5 days/year for outside Java. This was because the unit 2 generator PO (Planned Outage) was carried out in June and July. And there was MO (Maintenance outage) generator 1 in June.

The PLTU Anggrek power plant had 2 generating units, then the number of probability combinations was determined by the following formula, and is presented in Table 5.

$$\text{Combinations}=2^n = 2^2 = 4\ combination \quad (3)$$

Table 5. Calculation of LOLP value

Generation Combination		Power	Pind	Pkum	t (days)	LOLP = P×t
1	1	50	0,877278977	1	1	1
0	1	25	0,041724067	0,122721023	290	35,5891
1	0	25	0,077319577	0,080996956	291	23,57011
0	0	0	0,003677379	0,003677379	365	1,342243
				Total		**61,50145**

4. Conclussion

Load forecasting using fuzzy logic still had a large error. So it was necessary to add input and rules from Fuzzy so that the forecasting was more accurate. The reliability analysis of the PLTU Anggrek generating unit yielded 61.5 days per year, this value was still above the PLN standard, this was because one of the generators was undergoing maintenance. This study did not compare the value of reliability with the value of the previous year. So that further research is expected to improve from this research.

5. Acknowledgement

The author would like to thanks the electric steam power plant Anggrek in Gorontalo for providing the data needed to carry out the research. Author are also thanking to Universitas PGRI Madiun for their support..

6. Reference

[1] "Badan Pusat Statistik," [Online]. Available: https://gorontalokota.bps.go.id/indicator/7/197/1/jumlah-pelanggan-listrik-pt-pln-persero-menurut-bulan-.html. [Diakses Agustus 2021].

[2] A. N. Widiastuti, Sarjiya, K. A. Pinandhito dan E. T. Prastyo, "Evaluasi Keandalan Perencanaan Pembangkit Wilayah Jawa Bali dengan Mempertimbangkan Ketidakpastian Peramalan Beban," *JNTETI,* vol. VOl 6; No 2, pp. 230-234, Mei 2017.

[3] K. Khan, Evaluation of Loss of Load Probability and Expected Energy Generation in Multi-Area Interconnected System with Wind Generating Units, New York: State University of New York, 2013.

[4] D. Marsudi, Operasi Sistem Tenaga Listrik, Yogyakarta: Graha Ilmu, 2006.

[5] R. R. Dharmawan dan U. T. Kartini, "Analisis Indeks Keandalan PLTGU Blok 1 PT PJB UP Gresik Menggunakan Perhitungan Teorema Bayes dan Decomposisi LU," *Jurnal Teknik Elektro,* vol. 09 Nomer 03, pp. 658-665, 2020.

[6] H. D. Laksono, "Aplikasi Logika Fuzzy pada Perkiraan Kebutuhan Energi Lisrik Jangka Panjang di Provinsi Sumatra Barat sampai tahun 2018," *Jurnal Teknologi Informasi & Pendidikan,* vol. Vol 3; No 1, pp. 42-53, Maret 2011.

[7] I. Qamber, "Loss of Load Probability Effect in Four-Power Stations," dalam *International Conference on Fourth Industrial Revolution*, University of Bahrain, 2019.

[8] A, " PT PJB Service Unit PLTU Anggrek," Gorontalo, 2021.

[9] R. F. S. Budi, M. D. Birmano dan I. Bastori, "Pemodelan Perhitungan Indeks Lost of Load Probability untuk N Unit Pembangkit pada Sistem Kelistrikan Opsi Nuklir," *Jurnal Pengembangan Energi Nuklir,* vol. Vol 19; No 2, pp. 61-68, 2017.

reference. All references are collected in a Reference section at the end of the main text, and they are cited using *The Chicago Manual of Style* [1].

7. Figures and Tables

7.1 Figures

All figures should be centred and clearly distinguishable. The image quality and resolution must be sufficient so that reduction to publication size does not render the image illegible. Please submit an electronic copy of the figures. Figures will be printed in black and white and published online in colour.

Figure captions appear below the figure, are flush left, and are in lower case letters. When referring to a figure in the body of the text, the abbreviation "Fig." is used. For example, Fig. 1 is an image of a building at the pier.

7.2 Tables

Table captions appear centered above the table in upper and lower case letters. When referring to a table in the text, NO abbreviation is used.

The first line in the title is the table numbering without a period at the end of the number, for example "Table 1" and this is followed by the title in the next line. The caption is set in upper and lower case, centered, 12-pt spacing, and without a period at the end of the title.

Table 1
Correlation Coefficient r of Greenberg, Underwood, and CSUF Models

	Greenberg (Nonlinear)	Underwood (Nonlinear)	CSUF Model (Linear)
r	0.998	0.978	0.95

Table 2
Caption (centered, 12-pt spacing)

Element	Fe	Ni
% Weight	19.5	80.5

8. Conclusion

A conclusion section must be included and should clearly indicate the advantages, limitations and possible applications of the paper. The conclusion is the final numbered section of the paper.

Acknowledgement

Place all acknowledgements (including those concerning research grants and funding) in this section of the paper in between the Conclusion and References. The acknowledgement section is optional.

References

Bibliographical references should be listed in the order that they appear in the article. The title of the section, "References", should be a level 1 heading. References need to be numbered as they appear in your text ([1], [2], [3], etc) and should appear in your reference section in numerical order (not alphabetically); set in Times New Roman 8- pt with line spacing of 12-pt.; left indentation 0.1".

[1] *The Chicago Manual of Style,* 15th ed. (Chicago: University of Chicago Press, 2003).

[2] A.T. Osaka, G. Thomas, & K. Izuki, "This is a journal article", *Journal Name*, *128*, 2008, 123-156.

[3] A.T. Osaka & G. Thomas, "This is a journal article", *Journal Name*, *148*, 2010, 15-36.

[4] A.T. Osaka, *This is a book* (Bombay, India: McGraw Hill, 2006).

[5] A.T. Osaka, G. Thomas, *et. al.*," This is a proceeding paper", *Proc. 25th Annual Conf. of the IEEE*, IECON'98, *2*, 1998, 144-149.