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Load Forecasting of Feeder Palur 4 PLN Unit Induk Distribusi Jawa Tengah & DIY Based on Linear Regression

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Abstract— *Along with economic development, then the need for electrical energy will increase. Electrical energy is now one of the primary energies needed in all sectors from household, social, business to industrial sectors. Therefore, the provision of electrical energy must be done well and with quality. In this research, an analysis will be carried out on the 20 kV Palur 4 feeder in Karanganyar Regency regarding the increase in load it experiences. In January 2021, the Palur 4 feeder recorded the highest day load at 10.00 WIB of 340 A, and during the night load at 19.00 WIB the highest load was 286 A. Then in June 2023, the highest day load at 10.00 WIB was recorded at 314 A and during the night load at 19.00 WIB the highest load was 340 A. PLR4 load forecasting is divided into 2 parts, namely daytime load forecasting at 10.00 WIB and night load forecasting at 19.00 WIB. Later, the load forecast will be taken that reaches 400 A and 480 A the fastest as a result of the analysis which can be used as a reference for future follow-up. At 10.00 WIB, the linear regression equation was Y = 289.92 + 1.7X. It is predicted that it will reach a value of 400 A (status requires attention) in May 2026. And it is predicted that it will reach a value of 480 A (overcurrent status) in 2030 in April. At 19.00 WIB, the linear regression equation was Y = 280.18 + 3X. It is predicted that it will reach a value of 400 A (status requires attention) in April 2024. And it is predicted that it will reach a value of 480 A (overcurrent status) in 2026 in July. Based on these results, the linear regression equation that can be used as a reference for recommendations for additional feeders or other follow-up actions is the equation that produces faster time, namely the linear regression equation Y = 280.18 + 3X. This is intended to prevent trips due to overcurrent. From the calculation results, an average error of 4.9% was obtained.*

Keywords— *Load, forcasting, error.*

I. INTRODUCTION

Along with the development of infrastructure and the economy in the Karanganyar Regency area, energy needs will also increase, including electrical energy. In this case, the Palur 4 feeder is one of the feeders from the Palur Main Substation which is tasked with distributing electrical energy to parts of the Karanganyar area, where this feeder is through 2 Customer Service Units (ULP), namely ULP Palur and ULP Karanganyar.

Based on asset data in June 2024, the Palur 4 feeder has a 3-phase Medium Voltage Network (JTM) with a length of 16.12 circuit kilometers (kms), a 1-phase JTM with a length of 7.75 kms, 38 3-phase distribution transformers with a total power 4030 kVA, and 82 single phase distribution transformers with a total power of 4055 kVA[1][2].

During its development, the Palur 4 feeder experienced load fluctuations (increases and decreases in load) which were continuously monitored by the Jogjakarta Distribution Management Implementation Unit (UP2D). In January 2021, the Palur 4 feeder recorded the highest day load at 10.00 WIB of 340 A, and during the night load at 19.00 WIB the highest load was 286 A[3]. Then in June 2023, the highest day load at 10.00 WIB was recorded at 314 A and during the night load at 19.00 WIB the highest load was 340 A[4].

II. LITERATURE REVIEW AND THEORY

A. Literature Review

Calculation analysis in regression tests is related to several statistical calculations, for example significance tests (t-test, F-test), anova and hypothesis determination. The results of the regression analysis/test are in the form of a regression equation. This regression equation is a prediction function for variables that can influence other variables [5].

Forecasting the population using the least squares method has an annual increase of 0.84% to 0.86%. (ii) forecasting the Wayame 2 feeder load from 2022 to 2027 using a simple linear regression method with population data as a variable factor. The results of forecasting Wayame 2 feeder load from 2022 to 2027 using the Least Square method have increased every year by 7.89% to 12.06% [6].

The parameters used withinside the genetic set of rules are a populace of 1000, 500 iterations and a mutation rate of 0.15. The level of accuracy of forecasting is calculated using MAPE. MAPE in the 3rd week of May 2020 in genetic algorithm-based linear regression modeling was 6.653% and in ordinary linear regression was 6.669%. These results show that the MAPE of genetic algorithm-based linear regression modeling is better than the MAPE of ordinary linear regression [7].

B. Electrical Power System

The Electric Power System is divided into 3 stages, namely the electrical energy generation system, the electrical energy transmission system, and the electrical energy distribution system [8].

An electrical energy generation system is a system that functions to produce or generate electrical energy from various energy sources. The voltage released in the electric power generation system is 6,000 volts to 24,000 volts.

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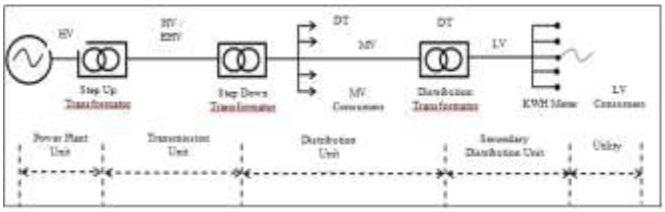

Fig. 1. Electric power system

The electrical energy transmission system is a system that functions to transmit electrical energy from power plants to distribution channels. The voltage transmitted in the electric power transmission system is 500 kV (Extra High Voltage) and 150 kV (High Voltage).

The electrical energy distribution system is a system that functions to distribute electrical energy from the transmission system to customers. The voltage distributed in the electric power distribution system is 220 volts, 380 volts (Low Voltage) and 20,000 volts (Medium Voltage).

C. Linear Regression

Regression analysis is used to examine the relationship between two or more variables, with at least one variable as the dependent (response) variable Y and the other variable as the independent variable (predictor variable) X. The relationship between these variables is modeled in the form of a function (equation), for example function linear y=a+bx. Regression models can be used for explanation and prediction [9].

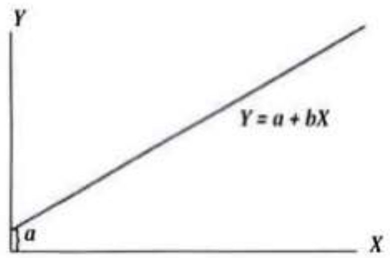

Fig. 2. Regression Linear Line

The simple linear regression equation is mathematically expressed by (1).

$$Y = a + b\,X \quad (1)$$

with : Y = regression line / response variable, a = constant (intercept), intersection with the vertical axis, b = regression constant (slope), X = independent variable/predictor.

The magnitude of the constants a and b can be determined using the equation (2) and (3).

$$a = \frac{(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)}{n\Sigma X^2 - (\Sigma X)^2} \quad (2)$$

$$b = \frac{n\Sigma XY - (\Sigma X)(\Sigma Y)}{n\Sigma X^2 - (\Sigma X)^2} \quad (3)$$

with n = amount of data

D. Error Calculation

To test the accuracy of the linear regression equation obtained, the error percentage was calculated. The percentage error formula is the absolute value of the difference between the predicted value and the actual value divided by the actual value and multiplied by 100% [10], as shown in (4).

$$\text{Percentage Error} = \frac{|\,\text{predicted value} - \text{actual value}\,|}{\text{actual value}} \times 100\% \quad (4)$$

III. RESEARCH MODEL

The PLR4 feeder is one of the feeders sourced from the 60 MVA Transformer IV at the Palur Main Substation. Based on asset data in June 2024, the Palur 4 feeder has a 3-phase Medium Voltage Network (JTM) of 16.12 kms, a 1-phase JTM of 7.75 kms, 38 3-phase distribution transformers with a total power of 4030 kVA, and 82 single phase distribution transformers with a total power of 4055 kVA.

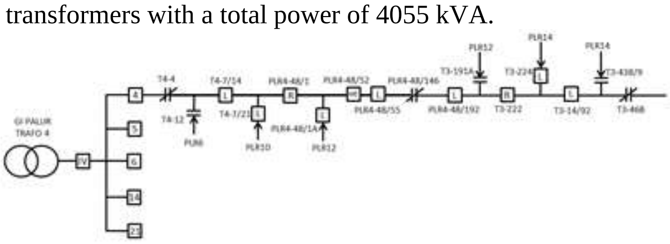

Fig. 3. Object of Research

If the load on the PLR4 feeder reaches 400 A, an attention or warning sign will appear on the SCADA (Supervisory Control And Data Acquisition) system, which means that this condition cannot be left for long, the load must be immediately reduced or transferred to another feeder.

If the load on the PLR4 feeder reaches 480 A, it will be read by the OCR (Over Current Relay) relay as overcurrent so that it triggers the PLR4 PMT (Power Breaker) to trip. This is of course to be avoided for the sake of continuity in the distribution of electrical energy to consumers.

Using load data from January 2021 to June 2024, we can predict when the PLR4 feeder load will reach 400 A (needs attention) and when the PLR4 feeder load will reach 480 A (overcurrent relay limit) using the linear regression equation.

IV. RESEARCH PARAMETERS

The data needed is the highest monthly load data for Palur 4 feeders from January 2021 to June 2024.

On the PLR4 feeder, the OCR relay is set at 480 A. This means that if the feeder load reaches 480 A, the OCR relay will order/trigger the PMT to trip/open.

With the linear regression equation that has been found, calculate the value of X when Y = 400 A at 10.00 WIT, the value of = 480 A at 19.00 WIB. After all the results are found, the regression equation with the lowest X value is selected between 10.00 WIB or 19.00 WIB. The linear regression equation chosen is considered to be representative and can be used as a recommendation for follow-up planning for the construction of a new feeder because of course it is not desirable for the worst thing to happen, namely a power outage due to overcurrent.

To test the linear regression equation found, a load forecasting calculation was tested for July 2023 to June 2024. A comparison and error calculation was carried out between the prediction results using the linear regression equation and the actual load data for July 2023 to June 2024 based on table

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1. The smaller the error, the linear regression equation is considered representative and can be used. The target error is below 5%.

TABLE 1. Highest Load Data for PLR4 Feeders January 2021 to June 2024.

NO	YEAR	MONTH	MAX LOAD 10.00 WIB (A)	MAX LOAD 19.00 WIB (A)
1	2021	JANUARY	340	286
2		FEBRUARY	282	370
3		MARCH	289	313
4		APRIL	257	221
5		MAY	280	226
6		JUNE	278	226
7		JULY	287	217
8		AUGUST	275	225
9		SEPTEMBER	362	350
10		OCTOBER	313	360
11		NOVEMBER	309	348
12		DECEMBER	308	357
13	2022	JANUARY	308	362
14		FEBRUARY	313	351
15		MARCH	349	355
16		APRIL	319	343
17		MAY	336	366
18		JUNE	343	350
19		JULY	333	348
20		AUGUST	313	351
21		SEPTEMBER	323	351
22		OCTOBER	292	336
23		NOVEMBER	301	341
24		DECEMBER	356	383
25	2023	JANUARY	387	347
26		FEBRUARY	300	341
27		MARCH	356	357
28		APRIL	339	340
29		MAY	326	340
30		JUNE	314	340
31		JULY	302	356
32		AUGUST	352	367
33		SEPTEMBER	340	374
34		OCTOBER	347	390
35		NOVEMBER	318	372
36		DECEMBER	355	380
37	2024	JANUARY	311	370
38		FEBRUARY	323	376
39		MARCH	321	366
40		APRIL	325	374
41		MAY	360	374
42		JUNE	342	376

V. Research Flow

The flow of the research carried out can be seen in Fig. 4 flowchart.

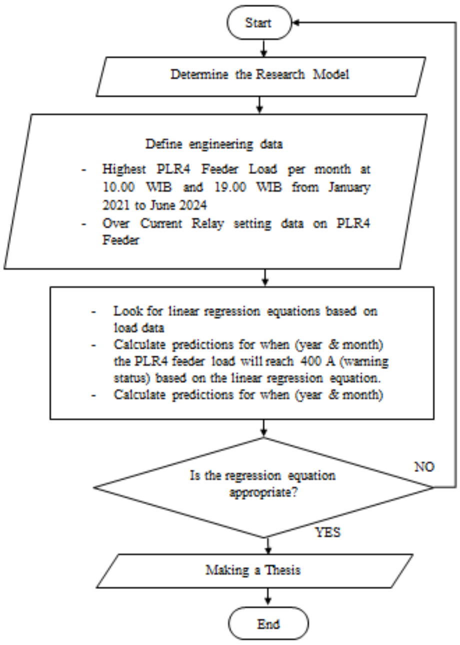

Fig. 4. Flowchart of Research

VI. Results and Discussion

Calculation of the values of ΣX, ΣY, ΣXY, ΣX^2, ΣY^2, a and b as well as the linear regression equation at 10.00 WIB.

TABLE 2. Calculation of ΣX, ΣY, ΣXY, ΣX^2, ΣY^2 at 10.00 WIB

NO	YEAR	MONTH	MAX LOAD AT 10.00 WIB				
			X	Y	XY	X^2	Y^2
1	2021	JANUARY	1	340	340	1	115600
2		FEBRUARY	2	282	564	4	79524
3		MARCH	3	289	867	9	83521
4		APRIL	4	257	1028	16	66049
5		MAY	5	280	1400	25	78400
6		JUNE	6	278	1668	36	77284
7		JULY	7	287	2009	49	82369
8		AUGUST	8	275	2200	64	75625
9		SEPTEMBER	9	362	3258	81	131044
10		OCTOBER	10	313	3130	100	97969
11		NOVEMBER	11	309	3399	121	95481
12		DECEMBER	12	308	3696	144	94864
13	2022	JANUARY	13	308	4004	169	94864
14		FEBRUARY	14	313	4382	196	97969
15		MARCH	15	349	5235	225	121801
16		APRIL	16	319	5104	256	101761
17		MAY	17	336	5712	289	112896
18		JUNE	18	343	6174	324	117649
19		JULY	19	333	6327	361	110889
20		AUGUST	20	313	6260	400	97969
21		SEPTEMBER	21	323	6783	441	104329
22		OCTOBER	22	292	6424	484	85264
23		NOVEMBER	23	301	6923	529	90601
24		DECEMBER	24	356	8544	576	126736
25	2023	JANUARY	25	387	9675	625	149769
26		FEBRUARY	26	300	7800	676	90000
27		MARCH	27	356	9612	729	126736
28		APRIL	28	339	9492	784	114921
29		MAY	29	326	9454	841	106276
30		JUNE	30	314	9420	900	98596
		Σ	465	9488	150884	9455	3026756

From table 2, the results obtained for the values of ΣX, ΣY, ΣXY, ΣX^2, and ΣY^2 are:

$\Sigma X = 465$

$\Sigma Y = 9488$

$\Sigma XY = 150884$

$\Sigma X^2 = 9455$

$\Sigma Y^2 = 3026756$

$n = 30$

Then look for the value of a using equation (2), to become :

$$a = \frac{(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)}{n\Sigma X^2 - (\Sigma X)^2}$$

$$a = \frac{9488 \;.\; 9455 - 465 \;.\; 150884}{30 \;.\; 9455 - 465^2}$$

$$a = \frac{89709040 - 70161060}{283650 - 216225}$$

$$a = \frac{19547980}{67425}$$

$$a = 289{,}92$$

Then look for the value of b using equation (3), to become :

$$b = \frac{n\Sigma XY - (\Sigma X)(\Sigma Y)}{n\Sigma X^2 - (\Sigma X)^2}$$

$$b = \frac{30 \;.\; 150884 - 465 \;.\; 9488}{30 \;.\; 9455 - 465^2}$$

$$b = \frac{4526520 - 4411920}{283650 - 216225}$$

$$b = \frac{114600}{67425}$$

$$b = 1{,}7$$

Then the values a and b are substituted into equation (1) to become :

Y = a + bX
Y = 289,92 + 1,7X

This equation is the linear regression equation for the load of Palur 4 at 10.00 WIB.

The following is a graphic image of the PLR 4 feeder load at 10.00 WIB from January 2021 to June 2023 along with the linear regression line.

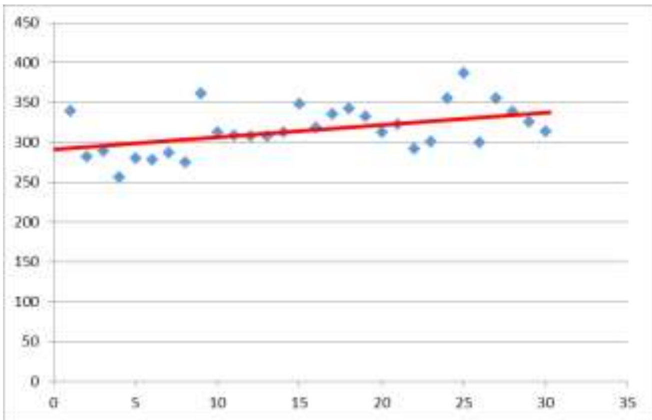

Fig. 5. Graph of PLR4 feeder load at 10.00 WIB and the regression line

The value of X (month) is calculated when Y (load) reaches 400 A. Substitute the value of Y in equation Y = 289,92 + 1,7X.
Y = 289,92 + 1,7X
400 = 289,92 + 1,7 X
110,08 = 1,7X
X = 64,75 months
X = 64,75 / 12 months
X = 5,4 years
X = 5 years + (0,4 x 12) months
X = 5 years + 4,8 months
Because expenses are recorded from the 1st to the end of January, the monthly calculations are rounded up.
X = 5 years + 5 months

If calculated from the initial data used, namely January 2021, then Y (load) at 10.00 WIB reached 400 A at:

year (2021 + 5) month 5 = year 2026 month May

The value of X (month) is calculated when Y (load) reaches 480 A. Substitute the value of Y in equation Y = 289,92 + 1,7X.
Y = 289,92 + 1,7X
480 = 289,92 + 1,7 X
190,08 = 1,7X
X = 111,81 months
X = 111,81 / 12 years
X = 9,3 years
X = 9 years + (0,3 x 12) months
X = 9 years + 3,6 months
Because expenses are recorded from the 1st to the end of January, the monthly calculations are rounded up.
X = 9 years + 4 months

If calculated from the initial data used, namely January 2021, then Y (load) at 10.00 WIB reached 480 A at:
year (2021 + 9) month 4 = year 2030 month April

Calculation of the values of ΣX, ΣY, ΣXY, $ΣX^2$, $ΣY^2$, a and b as well as the linear regression equation at 19.00 WIB.

TABLE 3. Calculation of ΣX, ΣY, ΣXY, $ΣX^2$, $ΣY^2$ at 19.00 WIB

NO	YEAR	MONTH	MAX LOAD AT 19.00 WIB				
			X	Y	XY	X^2	Y^2
1	2021	JANUARY	1	286	286	1	81796
2		FEBRUARY	2	370	740	4	136900
3		MARCH	3	313	939	9	97969
4		APRIL	4	221	884	16	48841
5		MAY	5	226	1130	25	51076
6		JUNE	6	226	1356	36	51076
7		JULY	7	217	1519	49	47089
8		AUGUST	8	225	1800	64	50625
9		SEPTEMBER	9	350	3150	81	122500
10		OCTOBER	10	360	3600	100	129600
11		NOVEMBER	11	348	3828	121	121104
12		DECEMBER	12	357	4284	144	127449
13	2022	JANUARY	13	362	4706	169	131044
14		FEBRUARY	14	351	4914	196	123201
15		MARCH	15	355	5325	225	126025
16		APRIL	16	343	5488	256	117649
17		MAY	17	366	6222	289	133956
18		JUNE	18	350	6300	324	122500
19		JULY	19	348	6612	361	121104
20		AUGUST	20	351	7020	400	123201
21		SEPTEMBER	21	351	7371	441	123201
22		OCTOBER	22	336	7392	484	112896
23		NOVEMBER	23	341	7843	529	116281
24		DECEMBER	24	383	9192	576	146689
25	2023	JANUARY	25	347	8675	625	120409
26		FEBRUARY	26	341	8866	676	116281
27		MARCH	27	357	9639	729	127449
28		APRIL	28	340	9520	784	115600
29		MAY	29	340	9860	841	115600
30		JUNE	30	340	10200	900	115600
		Σ	465	9801	158661	9455	3274711

From table 3, the results obtained for the values of ΣX, ΣY, ΣXY, $ΣX^2$, and $ΣY^2$ are :
ΣX = 465
ΣY = 9801
ΣXY = 158661
ΣX^2 = 9455
ΣY^2 = 3274711
n = 30

Then look for the value of a using equation (2), to become:

$$a = \frac{(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)}{n\Sigma X^2 - (\Sigma X)^2}$$

$$a = \frac{9801 \cdot 9455 - 465 \cdot 158661}{30 \cdot 9455 - 465^2}$$

$$a = \frac{92668455 - 73777365}{283650 - 216225}$$

$$a = \frac{18891090}{67425}$$

$$a = 280{,}18$$

Then look for the value of b using equation (3), to become :

$$b = \frac{n\Sigma XY - (\Sigma X)(\Sigma Y)}{n\Sigma X^2 - (\Sigma X)^2}$$

$$b = \frac{30 \cdot 158661 - 465 \cdot 9801}{30 \cdot 9455 - 465^2}$$

$$b = \frac{4759830 - 4557465}{283650 - 216225}$$

$$b = \frac{202365}{67425}$$

$$b = 3$$

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Then the values a and b are substituted into equation (1) to become :
Y = a + bX
Y = 280,18 + 3X
This equation is the linear regression equation for the load of Palur 4 at 19.00 WIB.

The following is a graphic image of the PLR 4 feeder load at 10.00 WIB from January 2021 to June 2023 along with the linear regression line.

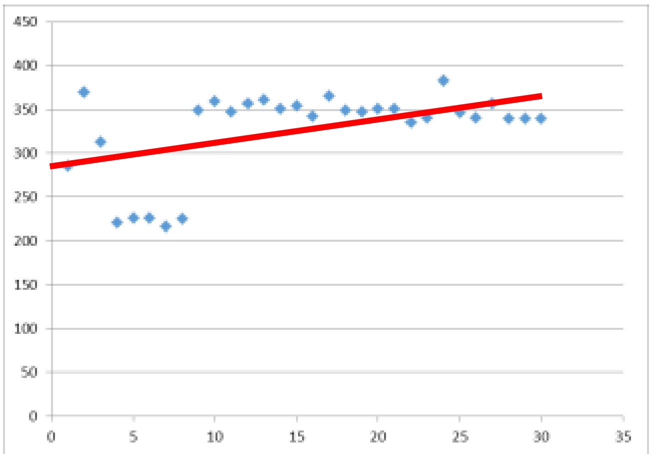

Fig. 6. Graph of PLR4 feeder load at 19.00 WIB and the regression line

The value of X (month) is calculated when Y (load) reaches 400 A. Substitute the value of Y in equation Y = 280,18 + 3X.
Y = 280,18 + 3X
400 = 280,18 + 3X
119,82 = 3X
X = 39,94 months
X = 39,34/12 years
X = 3,33 years
X = 3 years + (0,33 x 12) months
X = 3 years + 3,9 months
Because expenses are recorded from the 1st to the end of January, the monthly calculations are rounded up.
X = 5 years + 4 months
If calculated from the initial data used, namely January 2021, then Y (load) at 19.00 WIB reached 400 A at :
year (2021 + 3) month 4 = year 2024 month April

The value of X (month) is calculated when Y (load) reaches 480 A. Substitute the value of Y in equation Y = 280,18 + 3X.
Y = 280,18 + 3X
480 = 280,18 + 3X
199,82 = 3X
X = 66,6 months
X = 66,6 / 12 years
X = 5,55 years
X = 5 years + (0,55 x 12) months
X = 5 years + 6,6 months
Because expenses are recorded from the 1st to the end of January, the monthly calculations are rounded up.
X = 5 years + 7 months

If calculated from the initial data used, namely January 2021, then Y (load) at 19.00 WIB reached 480 A at:
years (2021 + 5) month 7 = years 2026 month July

From the results of the calculations above, it is obtained:

At 10.00 WIB, the linear regression equation is Y = 289.92 + 1.7X. It is predicted that it will reach a value of 400 A (status requires attention) in May 2026. And it is predicted that it will reach a value of 480 A (overcurrent status) in 2030 in April.

At 19.00 WIB, the linear regression equation is Y = 280.18 + 3X. It is predicted that it will reach a value of 400 A (status requires attention) in April 2024. And it is predicted that it will reach a value of 480 A (overcurrent status) in 2026 in July.

Based on these results, the linear regression equation that can be used as a reference for recommendations for additional feeders or other follow-up actions is the equation that produces faster time, namely the linear regression equation Y = 280.18 + 3X.

To test the suitability of the results of the linear regression equation Y = 280.18 + 3X with the real value, the error percentage was calculated. The error percentage calculation was carried out on the 31st data (July 2023) to the 42nd data (June 2024). The formula for calculating the error percentage uses equation (2.5). To simplify calculations and analysis, a table for calculating the percentage error has been created as follows.

TABLE 4. Calculation of Percentage Error for Linear Regression Equation Y = 280.18 + 3X

NO	YEAR	MONTH	MAX LOAD AT 19.00 WIB		
			REAL	PREDICT	ERROR
31	2023	JULY	356	373.22	4.8
32		AUGUST	367	376.22	2.5
33		SEPTEMBER	374	379.22	1.4
34		OCTOBER	390	382.22	2.0
35		NOVEMBER	372	385.23	3.6
36		DECEMBER	380	388.23	2.2
37	2024	JANUARY	370	391.23	5.7
38		FEBRUARY	376	394.23	4.8
39		MARCH	366	397.23	8.5
40		APRIL	374	400.23	7.0
41		MAY	374	403.23	7.8
42		JUNE	376	406.24	8.0
AVERAGE					4.9

From the calculation results, an average error of 4.9% was obtained. This figure is in accordance with the target of this research, namely below 5% and it is considered that this linear regression equation can represent and can be used as a reference for predicting the load or predicting when the PLR4 feeder will reach a certain load.

VII. CONCLUSION

From the research conducted, several conclusions can be drawn as follows:
1. The linear regression equation for the load on Palur 4 at 10.00 WIB is Y = 289.92 + 1.7X.

2. The load on Palur 4 at 10.00 WIB will reach warning status in 2026 in May and will reach overcurrent status in 2030 April.
3. The linear regression equation for the load on Palur 4 at 19.00 WIB is Y = 280.18 + 3X.
4. The load on Palur 4 at 19.00 WIB will reach warning status in 2024 in April and will reach overcurrent status in 2026 July.
5. The linear regression equation that can be used as a reference for recommendations for additional feeders or other follow-up actions is the equation that produces the fastest time, namely the linear regression equation Y = 280.18 + 3X. This is intended to prevent trips due to overcurrent. The average error value in this equation is 4.9%.
6. The linear regression equation Y = 280.18 + 3X can represent and can be used as a reference for predicting the load or predicting when the Palur 4 feeder will reach a certain load.

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