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Estimation of Power Transformer Loading Based on Population Growth: A Case Study in Kulon Progo Regency

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Abstract – *Along with technological advances, it is estimated that the gross regional domestic product (GRDP) of Kulon Progo Regency increases annually by 7.6%, and the population growth of Kulon Progo regency increases annually by 0.9%. However, after assuming with Muara Bungo Regency as a reference to GRDP growth and Population of Kulon Progo Regency due to the influence of the Establishment of New Yogyakarta International Airport (NYIA) in 2019, the population growth every year is 15.78%. While GRDP in 2018 until 2019 equals to 82.91% and next year equals to 7.6 %. Load forecasting the burden for the next ten years by using multiple linear regression affected by NYIA in 2019, the loading of the 150 kV Wates substation is only up to 2021 for the power transformer I of 24.83 MW and the power transformer II 55.40 MW. So it is estimated that for 2022, power transformer I and power transformer II of 150 kV Wates Substation are no longer able to serve the loading. Then, in 2021 a feeder shift and uprating power transformer I need to be conducted. In 2024 a power transformer III is needed. In that year the feed formation from power transformer I and power transformer II was changed to power transformer III.*

Keywords: *Substation, Power Transformer, Multiple Linear Regression, Loading*

I. Introduction

A power transformer is a static electrical device that is used to move power from one circuit to another by changing the voltage without changing the frequency [1]. In its purest form, the transformer consists of two coils and one mutual inductance. Primary coils are those that receive power, and secondary coils are connected to the load. The two coils are wrapped around a core consisting of laminated magnetic material [2]. The physical foundation of the transformer is mutual inductance between the two circuits connected by a shared magnetic flux that passes through the path of low reluctance. Both coils have high mutual inductance. If the primary coil is connected to a voltage, the current will flow back and forth on the loop. Because the coil has a core, the current causes a magnetic flux that also changes at its core. Due to the changing magnets in the primary coil, emf induction will arise [3]-[4].

Power Transformer is a transformer that is commonly used in substations, both the Power substation and Distribution substation, where the transformer has a large power capacity. In the substation generator, the transformer is used to increase the voltage to the transmission voltage (higher voltage), which is 150 or 500 kV. Whereas in the Distribution substation, the transformer is used to reduce the transmission voltage to the primary or medium voltage, which is 11.6 or 20 kV [5].

In this day and age electricity is one of the most important basic needs in the lives of the general public in various regions of Indonesia so that it is

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often used as a factor in the progress of the community along with technological developments. From BPS Yogyakarta data shows that the population growth of the Kulon Progo Regency continues to increase every year. In 2016, as many as 15,698 people became 16,239 people in 2017, an increase of 3.44%. The rapid population growth accompanied by high economic growth has caused the need for electricity to increase, so that adequate supply and distribution of electricity is needed, both in terms of technical and economic.

Rahman (2015) conducted a study on the forecast and analysis of the electricity needs of West Sumatra Province until 2024. The author conducted a study on the distribution transformer capacity for the Province of West Sumatra. Based on the results of research using multiple linear methods by predicting the next 10 years. For the household sector, the electricity demand is the highest in 2024, which is 2,332,704.91 MWh with an average annual increase of 5.68 percent. However, if viewed from the highest average percentage increase per year, it is in the commercial sector at 7.08 percent. In the public sector the average percentage increase per year is 1.15 percent. The opposite happened in the industrial sector which declined by a percentage of -4.94 percent. This is due to the rapid advancement of industrial technology causing industrial companies to innovate to get energy sources and equipment sources that are more energy efficient [6].

Nugroho (2016) conducted a study of the evaluation of the ability of the 150 KV old Ciligon substation transformer. The author forecasts 2 transformer units in the old Cilegon Substation 150 kV. Based on calculations using the multiple linear regression method, the authors predict in the next 15 years the first transformer with a capacity of 56 (Megavolt-amperes) MVA. With the results that in 2030 the conditions of the first transformer are no longer able to serve a high load of 59.24 MVA (106%). While the availability of installed transformer capacity is 56 MVA. Then the prediction of the second unit transformer with a capacity of 60 MVA in 2030 is still within the limit of the optimal standard of transformer operation that is equal to 47,025 MVA (78%). So that the transformer can work optimally within the next 15 years [7].

Krisno (2017) conducted a study on the evaluation of the ability of power transformers based on population development and peak load at 150 KV substation Cikupa. The author estimates the 2 transformer units in the 150 KV Cikupa substation using the multiple linear regression method, the authors predict in the next 10 years the first transformer with a capacity of 60 MVA. With the results that in 2026 conditions in the first transformer are no longer able to serve a high load of 124 MVA (207%). While in the second transformer with a capacity of 60MVA not able to serve the burden for the next 10 years in 2026 where the burden is predicted to reach 158.5 MVA (264%). So that the transformer at the Cikupa Substation 150 KV is overloaded with a load in the next 10 years [8].

In the 150 KV Wates substation, it is necessary to estimate the load that will be installed in the future. This relates to the construction of NYIA (New Yogyakarta International Airport) in Kulon Progo Regency. Like the case in Muara Bungo District, with the construction of the airport in 2014, the GRDP increased significantly. From this increase the higher the welfare of the community that affects lifestyle as well as in the use of electrical energy. Thus the Kulon Progo Regency must be made an estimated transformer loading and if no estimated loading is made the 150 KV Wates substation will experience an overload on the transformer used in channeling the load along with the development of the Kulon Progo Regency.

II. Methods

The equipment used in this study is a unit of Acer Intel (R) Core i5 notebooks, printers, cameras and reference books. This research was carried out at the 150 KV Wates substation for 2 weeks from 12 to 23 March 2018.

1. Flowchart of Research

Flowchart for the research is presented in Fig. 1.

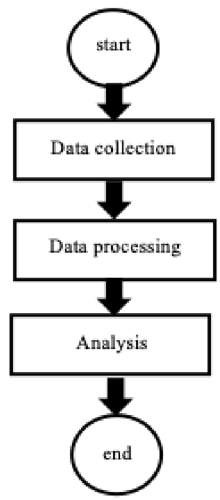

Fig. 1. Research flow chart

Based on the flow chart above, the research carried out includes the following steps:

1. Data Collection

The data for this study were taken directly at the 150 KV Wates substation and the BPS of the Special Region of Yogyakarta. The data were taken from 2013 to 2016, the type of data taken was:

a. Monthly peak load data for 2013-2016 transformer I 30 MVA and transformer II 60 MVA.
b. The rate of population growth and GRDP of Kulon Progo district in 2013-2016.
c. The rate of population growth and GRDP of Muara Bungo Regency 2010-2016.

2. Data Analysis

Electricity load growth in an area is always linear. Annual growth always increases with the influencing factors such as GRDP and population growth. With this background the researchers chose two methods, namely the method of multiple linear regression and the method of 3 assumptions from other districts with the same development.

The method of multiple linear regression can be seen from the following equation 1.

$$Y = a + b1X1 + b2X2 + \cdots + n \tag{1}$$

Where,
Y = dependent variable
X1, X2 = independent variable
a = constant (value of Y if x1 x1... xn =0)
b1, b2 = regression coefficient

To get the values of b1, b2, and a, you can use the following equation:

$$\Sigma X_1^2 = \Sigma X_1^2 \text{-} \frac{(\Sigma X_1)^2}{n}$$

$$\Sigma X_2^2 = \Sigma X_2^2 \text{-} \frac{(\Sigma X_2)^2}{n}$$

$$\Sigma Y^2 = \Sigma Y^2 \text{-} \frac{(\Sigma Y)^2}{n}$$

$$\Sigma X_1 Y = \Sigma X_1 Y \text{-} \frac{\Sigma X_1 \cdot \Sigma Y}{n}$$

$$\Sigma X_2 Y = \Sigma X_2 Y \text{-} \frac{\Sigma X_2 \cdot \Sigma Y}{n}$$

$$\Sigma X_1 X_2 = \Sigma X_1 X_2 \text{-} \frac{\Sigma X_1 \cdot \Sigma X_2}{n}$$

So, from the above equation to find the values of b1 and b2 and a can be found using the following formula:

$$b1 = \frac{[(\Sigma X2^2 \times \Sigma X1Y) - (\Sigma X2Y \times \Sigma X1X2)}{[(\Sigma X1^2 \times \Sigma X2^2) - (\Sigma X1X2)^2]} \tag{2}$$

Then to find the value of b2 you can use the following formula:

$$b2 = \frac{[(\Sigma X1^2 \times \Sigma X2Y) - (\Sigma X1Y \times \Sigma X1X2)}{[(\Sigma X1^2 \times \Sigma X2^2) - (\Sigma X1X2)^2]}$$

$$a = \frac{(\Sigma Y) - (b1 \times \Sigma X1) - (\text{b}2 \times \Sigma X2)}{n} \tag{3}$$

Then population growth and GRDP use the following equation:

GRDP year n = (GRDP year before n × growth rate%) + GRDP year before n

So to find growth (%) use the following equation:

$$P_t = P_0 \left(1 + \frac{X}{100}\right)^t \tag{4}$$

Where,
P_t = value in that year
P_0 = value in the previous year (pt)
X = Value sought
t = time later to find the value of % loading can be done by dividing the results of the equation divided by the capacity of the transformer used.

III. Results and Discussion

III.1. Population and GRDP Data of Kulon Progo Regency

From this study, the estimated results of the 150 KV Wates substation transformer loading are as in Table I.

TABLE I
TOTAL POPULATION AND GRDP OF KULON PROGO

Year	Total Population (in thousandssoul)	GRDP (Million Rupiah)
2013	401	16,165
2014	405	17,345
2015	408	18,736
2016	412	20,145

GRDP year n = (GRDP year before n × 7.6%) + GRDP year before n

1. GRDP 2017 = (20,145 × 7.6%) + 20,145
= 21,676
2. GRDP 2018 = (21,676 × 7.6%) + 21,676
= 23,332

A value of 7.6% is obtained from the GRDP of the Kulon Progo Regency while for population growth using the same equation but with a growth rate of 0.9% obtained from the results the same calculation to look for 7.6%. From the calculation results obtained in the Table II.

After the above results are obtained, then make the following equation to find the transformer I constant value. Whereas to find transformer II equation using the same method as searching for transformer I equation with different peak load values. In order to obtain the transformer I equation as seen in Table III.

TABLE II
CALCULATION OF ESTIMATED NUMBER OF POPULATION AND GRDP OF KULON PROGO REGENCY

Year	Total Population (in thousands soul)	GRDP (Million Rupiah)
2013	401	16,165
2014	405	17,345
2015	408	18,736
2016	412	20,145
2017	415.708	21,676
2018	419.449	23,323
2019	423.224	25,096
2020	427.033	27,003
2021	430.877	29,056
2022	434.755	31,264
2023	438.667	33,640
2024	442.615	36,196
2025	446.599	38,947
2026	450.618	41,907
2027	454.674	45,092

TABLE III
TRANSFORMER I REGRESSION EQUATION

Transformer I	2013	2014	2015	2016	∑
Y (MW)	14.9	15.1	17.7	18.6	66.3
X1	401	405	408	412	1626
X2	16.165	17.345	18.736	20.145	72.391
X21	160801	164025	166464	169744	661034
X22	261,307,225	300,849,025	351,037,696	405,821,025	1319,014971
Y2	222.01	228.01	313.29	345.96	1109.27
X1.X2	6,482,165	7,024,725	7,644,288	8299,74	29,450,918
X1.Y	5974.9	6115.5	7221.6	7663.2	26975.2
X2.Y	2,408,585	2,619,095	3,316,272	374,697	1,209,092

From the calculation of the regression equation above, we can find the values of a, b1, and b2 as follows:

$$\Sigma X_1^2 = \Sigma X_1^2 - \frac{(\Sigma X_1)^2}{n} = 661034 - \frac{1626^2}{4} = 65$$

$$\Sigma X_2^2 = \Sigma X_2^2 - \frac{(\Sigma X_2)^2}{n} = 1319{,}015 - \frac{72{,}391^2}{4} = 8.9$$

$$\Sigma Y^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{n} = 1109.27 - \frac{66.3^2}{4} = 10.35$$

$$\Sigma X_1 Y = \Sigma X_1 Y - \frac{\Sigma X_1 \cdot \Sigma Y}{n} = 26975.2 - \frac{1626 \cdot 66.3}{4} = 24.25$$

$$\Sigma X_2 Y = \Sigma X_2 Y - \frac{\Sigma X_2 \cdot \Sigma Y}{n} = 1209{,}092 - \frac{72{,}391 \cdot 66.3}{4} = 9$$

$$\Sigma X_1 X_2 = \Sigma X_1 X_2 - \frac{\Sigma X_1 \cdot \Sigma X_2}{n} = 29450.92 - \frac{1626 \cdot 72{,}391}{4} = 24.38$$

So to look for the burden of the next 10 years as follows:

$$b1 = \frac{[(\Sigma X2^2 \times \Sigma X1Y) - (\Sigma X2Y \times \Sigma X1X2)]}{[(\Sigma X1^2 \times \Sigma X2^2) - (\Sigma X1X2)^2]}$$

$$= \frac{(8.9 \times 24.25) - (9 \times 24.38)}{(65 \times 8.9) - (24.38)^2}$$

$$= \frac{(215.828) - (219.42)}{(578.5 - 594.384)}$$

$$= \frac{-3.59}{-15.88}$$

$$= 0.22$$

$$b2 = \frac{[(\Sigma X1^2 \times \Sigma X2Y) - (\Sigma X1Y \times \Sigma X1X2)]}{[(\Sigma X1^2 \times \Sigma X2^2) - (\Sigma X1X2)^2]}$$

$$= \frac{(65 \times 9) - (24.25 \times 24.38)}{(65 \times 8.9) - (24.38)^2}$$
$$= \frac{(585 - 591.21)}{(578.5 - 594.384)}$$
$$= \frac{-6.21}{-15.88}$$
$$= 0.39$$

$$a = \frac{(\Sigma Y) - (b1 \times \Sigma X1) - (b2 \times \Sigma X2)]}{n}$$
$$= \frac{(66.3) - (0.22 \times 1626) - (0.39 \times 72.391)}{4}$$
$$= \frac{66.3 - 357.72 - 28.23}{4}$$
$$= \frac{-319.65}{4}$$
$$= -79.91$$

$$Y = a + (b1 \times X1) + (b2 \times X2) + \cdots n$$

As for the loading, the calculation of the equation can be seen below.

2017 = -79.91 + (0.22 x 415.708 + (0.39 x 21.676)
= 20 MW
2018 = -79.91 + (0.22 x 419.449 + (0.39 x 23.323)
= 21 MW
2019 = -79.91 + (0.22 x 423.24 + (0.39 x 25.096)
= 22 MW

The equation is:
%2017 = (20 MW / 30 MW) × 100%
= 66.66%

The results of the overall load calculation for the next 10 years can be seen in Table IV along with the percentage of loading for transformer I and transformer II without the influence of the airport.

From the data in Table IV, it can be seen that without the influence of NYIA transformer I for the next 10 years will only be able to serve up to 2023 with a load of 29.72 MW in the heavy load category. Whereas for the years 2024 to 2027 the transformer I will be in a condition of overload load of 31.58 MW for 2024 and 37.70 MW in 2027 and for transformer II without the influence of NYIA for the next 10 years it is still able to serve loading with the highest load in 2027 of 41.32 MW in the optimal load category with a 68.87% loading. Meanwhile, to see the difference in loading after the operation of NYIA in 2019 can be seen in Table V to find the burden estimated by the existence of the NYIA. Then to find the burden used Muara Bungo Regency as an assumption of the airport in Kulon Progo Regency as seen in Table V. From Table V it can be seen that the growth rate after the airport is shown in Fig. 2.

TABLE IV
COMPARISON TABLE OF LOAD TRANSFORMER I AND TRANSFORMER II WITHOUT THE EFFECT OF NYIA

Year	Transformer I 30 MVA		Transformer II 60 MVA	
	No NYIA (MW)	Percentage (%)	No NYIA (MW)	Percentage (%)
2013	14.92	49.73	7.94	13.23
2014	14.40	48.00	10.45	17.42
2015	17.70	59.00	14.00	23.33
2016	18.60	62.00	13.46	22.43
2017	20.00	66.66	16.52	27.54
2018	21.46	71.55	18.66	31.10
2019	22.99	76.62	20.86	34.76
2020	24.57	81.90	23.12	38.54
2021	26.21	87.38	25.46	42.44
2022	27.93	93.10	27.88	46.47
2023	29.72	99.05	30.38	50.64
2024	31.58	105.27	32.97	54.95
2025	33.53	111.77	35.65	59.42
2026	35.57	118.57	38.43	64.06
2027	37.70	125.68	41.32	68.87

TABLE V
GROWTH RATE OF MUARA BUNGO REGENCY 2010-2016

Year	Total Population (in thousands soul)	GRDP (in Million)
2010	303.135	4,033
2011	310.737	4,755
2012	320.300	5,446
2013	329.934	6,198
2014	336.320	11,808
2015	344.100	12,985
2016	351.878	14,351

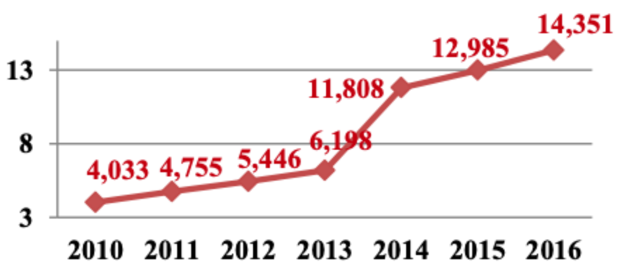

Fig. 2. GRDP growth rate of Muara Bungo Airport 2010-2016

From BPS data on population and GRDP of Muara Bungo Regency in 2011 - 2016, it can be searched the calculation of growth rates after and before the airport operates in Muara Bungo Regency as follows.

GRDP Before operation 2010 – 2013

$$P_t = P_0(1 + \frac{X}{100})^t$$
$$6{,}198 = 4{,}033(1 + \frac{X}{100})^3$$
$$\frac{6{,}198}{4{,}033} = (1 + \frac{X}{100})^3$$
$$1{,}154^{\frac{1}{3}} = (1 + \frac{X}{100})$$
$$X = (1{,}154 - 1) \times 100 = 15{,}4\ \%$$

PDRB after operation 2013 – 2016

$$P_t = P_0(1 + \frac{X}{100})^t$$
$$14{,}351 = 6{,}198(1 + \frac{X}{100})^3$$
$$\frac{14{,}351}{6{,}198} = (1 + \frac{X}{100})^3$$
$$2{,}315^{\frac{1}{3}} = (1 + \frac{X}{100})$$
$$X = (1{,}322 - 1) \times 100 = 32{,}28\%$$

GRDP Growth Rate

2013 – 2014

$$P_t = P_0(1 + \frac{X}{100})^t$$
$$11{,}808 = 6{,}198(1 + \frac{X}{100})^1$$
$$\frac{11{,}808}{6{,}198} = (1 + \frac{X}{100})^1$$
$$1{,}905^{\frac{1}{1}} = (1 + \frac{X}{100})$$
$$X = (1{,}905 - 1) \times 100 = 90{,}51\ \%$$

2014 – 2016

$$P_t = P_0(1 + \frac{X}{100})^t$$
$$14{,}351 = 11{,}808(1 + \frac{X}{100})^2$$
$$\frac{14{,}351}{11{,}808} = (1 + \frac{X}{100})^2$$
$$1{,}215^{\frac{1}{2}} = (1 + \frac{X}{100})$$
$$X = (1{,}102 - 1) \times 100 = 10{,}24\ \%$$

From the results of the calculation of the growth rate in Muara Bungo District above, the average GRDP growth rate before operating was 14.16% and the average GRDP growth rate after operation was 32.28%. While the GRDP growth rate in 2013-2014 was 90.51% and in 2014-2016 it was 10.24%. As for the population growth rate using the same calculation, the population growth rate for 2013-2014 was 1.99% and for 2014-2016 it was 2.2 so that the calculation results above can be assumed into the GRDP growth rate of Kulon Progo Regency. amounted to 82.91% of the value of 90.51% minus the value of the growth rate of Kulon Progo Regency 7.6% for the first year of operation of NYIA in 2019 - 2020 while for the second year 2021 onwards it was 7.6% from the growth rate of the Kulon Regency Progo Whereas the population growth rate for the first year 2019 - 2020 was 1.99% and for the second year 2021 thereafter was 2.2%. The impact of the increase in these two factors influenced the loading of transformer I along with the GRDP growth and population. To more clearly the rate of load growth in transformer I can be seen in Table VI.

From the Table VI, it can be seen that after the operation of NYIA in 2019, the load increased significantly, which previously had not operated by NYIA in 2018 for transformer I of 21.46 MW after operating NYIA in 2019 to 31.50 MW so that transformer I was only able serving the load until 2018 it was due to the influence of the operation of NYIA in 2019 which caused the loading to increase significantly to 31.50 MW in the overload load category. Whereas, for transformer II with the influence of NYIA operation in 2019 which was originally in 2018 amounted to 18.66 MW to 30.53 MW in 2019. Under the influence of NYIA the transformer II was only able to serve loading up to 2024 with load conditions weight of 57.75 MW with heavy loading conditions of 96.26%, it is necessary to have intense supervision because it has exceeded the specified loading limit of 60 - 80% but if the loading is as specified, transformer II is only able to serve loads up to 8 by 2022 with a load of 46.26 MW with a load of 77.10%. So as to anticipate the heavy load on transformer I after NYIA operation, the next step is to shift feeder transformer I to transformer II with data feeder load in May 2018 in Table VII. From the data R, S, and T then the sum and divided by three to get the average value. With this average value, the per-feeder loading can be obtained by dividing the average value by 30 as shown in Table VII.

TABLE VI
EFFECTS OF NYIA ON TRANSFORMER LOADS

Year	Transformer I 30 MVA		Transformer II 60 MVA	
	After Opertae NYIA (MW)	Percentage (%)	After Operate NYIA (MW)	Percentage (%)
2018	21.46	71.55	18.66	31.10
2019	31.50	105.00	30.53	50.89
2020	35.34	117.81	35.59	59.31
2021	39.41	131.37	40.82	68.04
2022	43.73	145.76	46.26	77.10
2023	48.31	161.03	51.90	86.50
2024	53.18	177.28	57.75	96.26
2025	58.38	194.59	63.84	106.40
2026	63.92	213.05	70.17	116.95
2027	69.83	232.77	76.75	127.92

From Table VII in 2018 exchange of feeder 5 to feeder 3, feeder 4 to feeder 1 and feeder 2 shift to feeder 7 are carried out, considering that in 2019 transformer I was in overload load condition. With the change in feeder, the operating period for the loading of transformer I and transformer II can be up to 2021 with a load of 24.83 MW and transformer II of 55.40 MW. For more details the results of the shift feeder can be seen in Table VIII.

From the results of the shift in Table VIII above for transformer I in 2023 experienced overload load and only able to serve loading until 2022 with a heavy load of 29.15 MW while for transformer II after the shift transformer II was only able to serve loading up to the year 2021 with a heavy load category of 55.40 MW. If the shift is carried out, transformers I and transformers II will only be able to serve loads up to 2021 in the category of heavy load transformers while in 2022 to 2027 both transformers 9 will be overloaded. From the results of this shift, the next step in 2021 that must be taken is by Uprating transformer I to 60 MVA and shifting feeder again considering the overload limit of the two transformers occurred in 2022. Data feeder in 2021 can be seen in Table IX from the results of calculations and growth trends in Muara Bungo Regency as an assumption of load growth in the Kulon Progo Regency of 82.91% in 2018 to 2019 while in 2019 to 2027 it was 7.6% transformer load.

From the data in Table IX, the next step is to shift feeder 3 to feeder 4 after uprating transformer I 30 MVA to 60 MVA so the results in Table X are obtained.

TABLE VII
FEEDER LOAD DATA FOR MAY 2018

Data		Load (MW)	Load (MW)	Load (MW)	Average	Transformer I		Transformer II	
		R	S	T		Feeder	Load (MW)	Feeder	Load (MW)
Transformer I	WTS02	135.3	117.4	134	128.96	WTS 2	4.29		
	WTS04	198.6	106.2	135	146.9	WTS 4	4.89		
	WTS05	326.4	272.9	322	307.4	WTS 5	10.24		
Transformer II	WTS01	14	12	24	16.66			WTS 1	0.55
	WTS03	82	65	65	70.66			WTS 3	2.35
	WTS06	171	151	111	144.33			WTS 6	4.81
	WTS07	14	16	16	15.33			WTS 7	0.51
Total	7	941.3	740.5	809	830.24	3	19.42	4	8.22

TABLE VIII
AFTER THE FEEDER SHIFT IN 2018

Year	Transformer I 30 MVA		Transformer II 60 MVA	
	After Operate NYIA (MW)	Percentage (%)	After Operate NYIA (MW)	Percentage (%)
2018	6.88	22.93	33.24	55.40
2019	16.92	56.40	45.11	75.18
2020	20.76	69.20	50.17	83.62
2021	24.83	82.77	55.40	92.33
2022	30.15	100.5	60.84	101.40
2023	33.73	112.43	66.48	110.80
2024	38.60	128.67	72.33	120.55
2025	43.80	146.00	78.42	130.70
2026	49.34	164.47	84.75	141.25
2027	55.25	184.17	91.33	152.22

TABLE IX
FEEDER IN 2021

Data		Load (MW)	Total (MW)
Transformer I	WTS02	9.06	24.18
	WTS04	5.56	
	WTS05	9.56	
Transformer II	WTS01	9.33	54.94
	WTS03	21.62	
	WTS06	11.55	
	WTS07	12.45	

TABLE X
RESULTS OF UPRATING TRANSFORMER I AND FEEDER SHIFT

Year	Transformer I 30 MVA		Transformer II 60 MVA	
	After Operate NYIA (MW)	Percentage (%)	After Operate NYIA (MW)	Percentage (%)
2021	40.99	68.32	39.34	65.57
2022	46.31	77.18	44.78	74.63
2023	49.89	83.15	50.42	84.03
2024	54.76	91.27	56.27	93.78
2025	60.96	101.60	62.36	103.93
2026	65.50	109.17	68.69	114.48
2027	71.41	119.02	75.27	125.45

From Table X transformers I and II are only able to serve loading up to 2024 in the heavy load category. For load of transformer I in 2024 of 54.76 MW and transformer II of 56.27 MW so that the 150 KV Wates substation for the next 10 years requires the addition of transformer III in 2024 before overloading in 2025. From the addition of transformer III In 2024, the transformer feeder I and II shifted to transformer III feeder. With the addition of transformer III and shift in feeders in 2024 it is expected that the 150 KV Wates substation will be able to serve loading up to the next 10 years with factors affecting the increase in transformer loading both by NYIA operating factors in 2019 as well as GRDP and other factors.

IV. Conclusion

Based on the analysis of the calculation of the estimated transformer loading for the next 10 years at the 150 KV Wates substation after assuming the GRDP growth of Muara Bungo district as a reference for load growth in Kulon Progo Regency the following conclusions are obtained:

1. For 2018 a shift in feeders from the transformer will be made. I to transformer II 10.
2. After shifting the feeder in 2018 the 150 KV substation was only able to until 2021. Thus in 2021 the 150 KV substation shifted the feeder again and uprating the 30 MVA transformer I to 60 MVA.

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