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Analysis Of Load Balance In 20 Kv Distribution Systems On Power Losses

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Abstract

Load balancing is one of the things that must be considered by reducing the value of voltage drops or power losses that occur in distribution channels. It is necessary to know the characteristics of the load in an area or area with a balanced supply so that each phase is burdened evenly. Calculating the voltage drop on the distribution network conductors, the voltage drop on the KBN09 Slawi feeder was calculated. What will be calculated here is from the line to the transformer furthest from the GI, namely from the three-phase 20 kV main line, single-phase branching. The results of power calculations from GI Kebasen Tegal show differences between R, S and T phases with three 20 kV phases in pre-balance and post-balance conditions. As written, the value for R wire is 82661.52 W, for S 52613 W, while for the T phase the value is 60127.06 W. Meanwhile, the calculation of power losses from GI Kebasen Tegal shows differences between the R, S and T phases with 1 phase voltage in the conditions before balance and after balanced. On the 3-phase line for the R wire, the power loss decreases from 34,198 W to 17,0425 W, for S it increases from 11,540 W to 19,077 W, while for the T phase the value remains 15,274 W.

Abstrak

Keseimbangan beban merupakan salah satu hal yang harus diperhatikan dengan mengurangi nilai jatuh tegangan atau rugi daya yang terjadi di saluran distribusi. Perlu mengetahui karakteristik beban yang terdapat dalam suatu kawasan atau daerah dengan diimbangi suplay agar masing-masing phasa terbebani secara merata. Perhitungan jatuh tegangan pada penghantar jaringan distribusi, diambil perhitungan jatuh tegangan pada feeder KBN09 Slawi. Adapun yang akan dihitung disini adalah dari saluran sampai ke trafo terjauh dari GI, yaitu dari saluran utama tiga phasa 20 kV, percabangan satu phasa. Hasil perhitungan daya dari GI Kebasen Tegal terjadi perbedaan antar fasa R, S dan T dengan tiga phasa 20 kV pada kondisi sebelum seimbang dan setelah seimbang. Seperti yang dituliskan yaitu untuk kawat R 82661.52 W, untuk S 52613 W sedangkan untuk fasa T nilainya 60127.06 W. Sedangkan perhitungan rugi-rugi daya dari GI Kebasen Tegal terjadi perbedaan antar fasa R, S dan T dengan tegangan 1phasa pada kondisi sebelum seimbang dan setelah seimbang. Pada saluran 3fasa untuk kawat R rugi dayanya turun dari 34.198 W menjadi 17.0425 W, untuk S naik dari 11.540 W menjadi 19.077 W sedangkan untuk fasa T nilainya tetap 15.274 W.

Kata kunci : keseimbangan beban, jatuh tegangan ,rugi daya

INTRODUCTION

The distribution system is one of the systems in electric power that has an important role because it is directly related to users of electrical energy, especially users of medium voltage and low voltage electrical energy. Usually there is often an unbalanced load on the phases (the distribution system is a 3 phase system) or an overload occurs due to the use of electrical equipment from consumers of electrical energy.

Load balance between phases is needed to evenly distribute the load so as to minimize changes caused by full load. This is also important because it is useful in optimization techniques to produce a reliable and efficient system.

A 1 phase configuration with 3 wires can be said to be unbalanced if the neutral current is not zero. This happens because the load connected to the phase and neutral is not the same. One of the methods used to analyze load balance is by calculating the voltage drop and power losses on the KBN09 Slawi feeder.

METHOD

1. Voltage Drop Calculation Method

In this discussion, we will explain the calculation of the voltage drop on distribution network conductors, taking the calculation of the voltage drop on the KBN09 Slawi feeder. What will be calculated here is from the line to the transformer furthest from the GI, namely from the three-phase 20 kV main line, single-phase branch. The formula for voltage drop is:

$$VD = r\int_0^K ixdx\cos\phi + \int_0^L ixdx\sin\phi$$

$$= ri\frac{L}{2}\cos\phi + xi\frac{L}{2}\sin\phi$$

$$= \frac{L.r}{2}I\cos\phi + \frac{L.x}{2}I\sin\phi$$

Cos ϕ dan sin ϕ is the power factor.

We will calculate the power factor on the conductor based on existing data, namely loose load data from the GI to the network distribution (Data I). In a simple series circuit Z = R + jx considering I . Z is the same as V, so for a 3 phase load:

$P = \sqrt{3}\ I_L^2 . Z_L . \cos Ø = \sqrt{3}\ V_L^2 . I_L . \cos Ø$

$Q = \sqrt{3}\ I_L^2 . Z_L . \cos Ø = \sqrt{3}\ V_L^2 . I_L . \cos Ø$

Then by remembering that R = Z cos Ø, and X = Z sin Ø, we get:

$P = \sqrt{3\ I_L^2 . R_L}$ dan $Q = \sqrt{3\ I_L^2 . X_L}$

Next, the power factor formula is obtained:

$$\text{Cos } Ø = \cos \tan^{-1}$$

$$\text{Cos } Ø = \frac{P}{\sqrt{P^2 + Q^2}}$$

Next, calculate the branch current 3, the voltage drop and the voltage calculated from pole number T9-1 to pole number T9-44, where the data is known from PLN UPJ Slawi.

With the data above, the current at branch 3 is:

$$I = \frac{\text{Total KVA}}{\text{Voltage pol}}$$

2. Basic Calculation of Voltage Drop on Fedeer KBN09

This voltage drop calculation is only specifically for calculating channels from the Kebasen Tegal KBN09 GI, for example to channels (Feeders) entering the Slawi network unit.

$$VD = r\int_0^K ixdx\cos\phi + \int_0^L ixdx\sin\phi$$

$$= ri\frac{L}{2}\cos\phi + xi\frac{L}{2}\sin\phi$$

$$= \frac{L.r}{2}I\cos\phi + \frac{L.x}{2}I\sin\phi$$

Information :

L = channel length (m)
r = conductor resistance (Ohm)
x = conductor inductive reactance (Ohm)

The following is the calculation of cos Ø recorded on February 1 2022 from the KBN09 transformer (data taken from the UPJ Slawi 20 kV single line diagram) at night peak load and at daytime peak load,

Table 1 Power Factor primary data on February 1 2022

Hour load 05.00			Peak load during the day			Evening peak load		
kW	kvar	Cos Ø	kW	kvar	Cos Ø	kW	kvar	Cos Ø
345	153	0,9	185	84	0,9	590	262	0,9
370	165	0,9	210	105	0,8	645	290	0,9

From the table above, the average cos Ø = 0.9 so sin Ø = 0.4. Current calculation, voltage drop and voltage are calculated in several areas which can be mentioned below.

1. **Basics for Calculating Power Losses in KBN09 Feeder Channels**

Losses can be stated as follows:

- Real power loss = I^2 . R Watt
- Reactive power loss = I^2 . X Watt
- Apparent power loss = $\sqrt{(I^2.R)^2 + (I^2.X)^2}$

RESULTS AND DISCUSSION

In this discussion, a 3 phase system is used, to be able to determine the magnitude of the load for each phase, a mathematical equation is needed to make the calculations easier.

1. Power Calculation Results

The calculated power can be made into a table as below:

Table 2. Power Calculation Results

Feeder	Current	Power
Main	80	1439339.838
Feeder	36.25588431	652308.6945

1. Phase Feeders R, S, T

The calculated power at the feeder R S T can be made in a table as below:

Tabel 3 Power Calculation Results

Fasa	3 fasa	
	Current	Power
R	7.950025209	82661.52
S	5.059106951	52613
T	5.781836516	60127.06

By making a table, it can be compared graphically, namely:

2. Branch Feeders

The calculated power at the branch feeder can be made in a table as below:

Tabel 4 Power Calculation Results

Feeder	Current	Power
Ketanggungan I	2.163057314	584976.9
Ketanggungan II	4.326114627	44999.4
Pengarasan	8.652229254	89995.05
Gumalar I	4.326114627	44999.52
Gumalar II	4.326114627	44999.4
Pecangakan	8.652229254	89996.14
Kupu I	12.97834388	134991.9
Kupu II	10.81528657	112495.7

So the total installed power or fixed power,

$$P = \sum Si$$

= 404564.157 Watt.

So it can be seen that the unstable power or reserve power is:

Pnot fixed = Pavailable – Pfixed
= 652313.7005 – 404564.157
= 247749.543
= 247 kW

2. Calculation of Voltage Drop
3 Phase Voltage Drop
Calculating the voltage drop in the R, S, and T phases, the magnitude can be determined:

Table 5. VD (Drop Voltage) in the R Phase

L (m)	VD (Volt)	∑L (m)	VD (Volt)
175	0.86089501	175	0.860895013
80	0.39355201	255	1.254447019
80	0.39355201	335	1.647999025
50	0.24597	385	1.893969029
40	0.196776	425	2.090745032
25	0.122985	450	2.213730033

Table 6. VD (Drop Voltage) in the S Phase

L (m)	VD (Volt)	∑ L (m)	VD (Volt)
75	0.23478955	75	0.234784585
200	0.62610546	275	0.860890049
50	0.15652637	325	1.017416415
50	0.15652637	375	1.173942781

Table 7. VD (Drop Voltage) in the T Phase

L (m)	VD (Volt)	∑ L (m)	VD (Volt)
100	0.35777455	100	0.357774551
100	0.35777455	200	0.715549102
100	0.35777455	300	1.073323653
80	0.28621964	380	1.359543293

5. Branching Fedeer Voltage Drop

From the calculation of the branching feeder, a table of results from the calculation of current and voltage drop is produced.

Table 8. Current and Voltage Drop Calculation Results

Feeder	Calculation Results	
	Current (A)	VD (V)
Ketanggungan I	2.163057314	0.100517
Ketanggungan II	4.326114627	0.268046
Pengarasan	8.652229254	1.09899
Gumalar I	4.326114627	0.214437
Gumalar II	4.326114627	0.268046
Pecangakan	8.652229254	0.857748
Kupu I	12.97834388	1.206208
Kupu II	10.81528657	0.770633

6. Power Loss Calculation Analysis

Power loss in Phase

The calculated power losses in the transformer can be made into a table as below:

Table 9. Power Loss Calculation Results

Fasa	Power loss	
	3fasa	1fasa
R	102.351523	34.19810999
S	34.5401146	11.5406845
T	45.7151341	15.27452773

Transformer power loss at Branch Feeder

Calculation of transformer power losses at each pole or branch feeder can be tabled as below:

Table 10. Transformer Power Loss Calculation Table

Feeder	Feeder Symbol	Power Loss
Ketanggungan I	A	0.422570861
Ketanggungan II	B	2.25371126
Pengarasan	C	18.48043233

Gumalar I	D	1.802969008
Gumalar II	E	2.25371126
Pecangakan	F	14.42375206
Kupu I	G	30.42510201
Kupu II	H	16.19854968

7. Load Balancing Calculation

Balance Value

To find the balance value, you can use the mean value (calculated mean) as in mathematics. The mean value can be found using a formula:

$$\Sigma X = \frac{X_1 + X_2 + X_3 + X_n}{n}$$

Known $X_1 = 275$

$X_2 = 175$

$X_3 = 200$

With the formula above it can be calculated as follows:

$X = X_1 + X_2 + X_3 / 3$

$= 275 + 175 + 200 / 3$

$= 650 / 3$

$= 216.67$

Changes in power that occur in wires R and S, because wire R is reduced, the load is transferred to wire S so that load balance occurs. On a single line, it can be seen that the R wire at T9-64/50 kVA can have its load transferred to the S wire so that each phase has almost the same value.

8. Power Calculation for Balanced Phase

The calculated power in the balanced phase can be made in a table as below:

Table 11. Power Calculation Results

Fasa	Power	
	Before	After
R	82593.36	67609.12
S	52590	67603.03
T	60096.62	60096.62

9. Phase Voltage Drop after Balance

The calculated voltage drop in the R S T phase can be made in a table as below:

Table 12. VD (Drop Voltage) in the R Phase

L (m)	VD (Volt)	∑L (m)	VD (Volt)

175	0.70436865	175	0.704368647
80	0.3219971	255	1.026365743
80	0.3219971	335	1.348362839
	0	335	1.348362839
40	0.16099855	375	1.509361386
25	0.10062409	400	1.609985479

Table 13. VD (Drop Voltage) in the S Phase

L (m)	VD (Volt)	∑ L (m)	VD (Volt)
75	0.30187228	75	0.234784585
200	0.80499274	275	1.039777324
50	0.20124818	325	1.241025509
50	0.20124818	375	1.442273694
50	0.20124818	425	1.643521879

Table 14. VD (Drop Voltage) in the T Phase

L (m)	VD (Volt)	∑ L (m)	VD (Volt)
100	0.35777455	100	0.357774551
100	0.35777455	200	0.715549102
100	0.35777455	300	1.073323653
80	0.28621964	380	1.359543293

The three tables above can be grouped as follows:

Table 15. Table of Changes in Voltage Drop

fasa	**VD (V)**	
	Before	After
Fasa R	2.21373	1.609985
Fasa S	1.173943	1.643522

Fasa T	1.359543	1.359543

From the table above, it can be seen that the VD value before equilibrium is not evenly distributed in each phase. After calculating and analyzing the balance value, the VD value in the table after balance produces a value that is almost the same or equal.

After calculating the VD of each phase according to the balance data, the value of the transformer power loss after balance can also be calculated.

The calculated power loss at the R S T feeder can be made into a table as below:

Table 16. Power Loss Calculation Results

Fasa	Power loss	
	Before	After
R	34.19810999	17.04252919
S	11.5406845	19.07745805
T	15.27452773	15.27452773

In cases where this occurs, system balance can usually occur if the technical and non-technical sides can support each other and work well. Based on the calculated data, it can be analyzed that a balanced system is influenced by:

- Length and cross-sectional area of the channel
- The amount of power installed
- Number of consumers / loads.

In general, a balanced system is very difficult to achieve because geographically our area is not evenly distributed so the distance between the lines from generation to consumers is very long, this affects the amount of power flowing through the lines which can decrease, this is caused by power losses in the lines.

CONCLUSION

In calculating the voltage drop from the Kebasen Tegal GI as in the table, there are differences in the R, S and T phases before balancing and after balancing. In the R phase the value drops from 2.213 V to 1.6098 V. In the S phase the value increases from 1.1739 V to 1.4128 V while the T phase remains at 1.3587 V.

In the power calculations from the Kebasen Tegal GI as in the table there is a difference between the R, S and T phases with three 20 kV phases in the pre-balance and post-balance conditions. As written, the value for the R wire is 82661.52 W, for S 52613 W, while for the T phase the value is 60127.06 W.

In the calculation of power losses from the Kebasen Tegal GI, as in the table, there is a difference between the R, S and T phases with single-phase voltage in pre-balance and post-balance conditions. As written, for 3 phases, for the R wire, the power loss decreases from 34,198 W to 17,0425 W, for S it increases from 11,540 W to 19,077 W, while for the T phase the value remains 15,274 W.

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