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LOAD DISTRIBUTION TO REDUCE POWER LOSS IN DISTRIBUTION TRANSFORMERS AT PT PLN (PERSERO) ULP LEMBAYUNG

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ABSTRACT

Load balancing on distribution transformers is an important step to improve the efficiency of electricity distribution and reduce power losses. Load imbalance between phases can cause an increase in neutral current, contributing to conductor power loss and financial loss. This research was conducted on the BR 114 distribution transformer at PT PLN (Persero) ULP Lembayung, with the aim of analyzing the impact of load balancing on neutral current, conductor power loss, and financial loss. The calculation results show that load balancing can reduce the neutral current from 150 A to 97 A, thereby decreasing the neutral conductor power loss from 2.00797 kW to 0.37129 kW. Financially, the savings obtained from load balancing amount to Rp 80,460,399. Thus, load balancing has proven to be an effective solution in reducing power losses and improving the efficiency of electricity distribution.

Keyword : Load balancing, power loss, neutral current, electrical efficiency, distribution transformer;

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1. INTRODUCTION

Background

Electrical energy is one of the energies that everyone needs at this time. Electrical energy is widely used by the community for all activities and purposes such as in households and industries. The supply and distribution of electricity in Indonesia is managed directly by PT. PLN (Persero) consists of three processes of electricity delivery, namely generation, transmission, and distribution. Generation is the process of producing electrical power that is carried out at the power plant using generators. Transmission is the massive distribution of electricity from the generating site to the substation. Meanwhile, distribution is the delivery of electricity from the substation to the distribution substation and directly to consumers. In distributing electricity so that it can be enjoyed by consumers who are all Indonesian people, PT. PLN (Persero) as an electric power company, forms distribution branch units throughout Indonesia, both in urban areas and in remote villages, which are distribution services in each unit according to their respective regions. The safety and satisfaction of electricity consumers is one of the missions of PT PLN (Persero). For this reason, the electrical energy that reaches the consumer must be in accordance with the voltage required by each electrical equipment and without interruption to its use. Before reaching the consumer, the voltage coming from the plant will be regulated and distributed using a distribution processor using a low-voltage distribution system. However, the increase in the number of people in an area increases the number of new customers which results in the optimization of the working distribution transformer will decrease. One of the things that causes the work of the distribution transformer to decrease is the presence of current in the neutral conductor which causes conductor losses caused by load imbalance in the low-voltage distribution network. For this reason, it is necessary to distribute the burden equally, namely by moving the heavy load phase to the light load phase.

1.2 Problem Formulation

The problem formulation in this report is as follows:

1. How is the load balancing process carried out on the distribution substation transformer?
2. How does the load imbalance of the transformer affect the neutral current and power loss?
3. What is the effect of load balancing on the power loss due to neutral current caused by load imbalance?
4. What is the total energy saved and financial losses due to power losses in Load Equalization Process in Distribution Transformers?

1.3 Problem Limitations

The following are the problem limits formulated based on that information:

1. This research focuses on the LA 0409 distribution transformer
2. The analysis includes load imbalance, neutral current, and power loss.
3. Load balancing is carried out to reduce power losses and financial impacts.

1.4 Final Project Objectives

The objectives of this final project report are as follows:

1. Find out how PT PLN ULP lembayung handles Transformer load imbalance at Substation LA 0409
2. Determine how much power is lost on the neutral conductor due to load imbalance before and after load equalization
3. Calculate the total energy saved and financial losses caused by power losses on neutral conductors caused by load imbalances at distribution substations LA 0409 before and after load equalization

1.5 Benefits of Final Project

1. Calculate revenue losses caused by power losses.
2. Compare theoretical calculations with field data to get more accurate results.
3. It is a reference in overcoming power losses in low-voltage distribution networks caused by load imbalances in transformers through load equalization efforts.

II. THEORETICAL OVERVIEW

2.1 Previous Research

Based on the background of this final project, the researcher first conducted a literature review of previous studies. Below are some literature searches used by Ir. Marconi, S.H., and M.T. (2017) in their book Fundamental Theory of Power Engineering, 2nd Edition, explaining that although on the low voltage side, most customers use single-phase power, in distribution transformers there can be kWh energy loss due to asynchronous load start-up times, which leads to energy wastage and reduces efficiency due to the need for periodic load balancing at the load peaks at balanced or unbalanced load conditions.

2.2 Load Balance

A balanced phase load is a load whose current flows through a load is symmetrical and the load is connected to a symmetrical voltage. Therefore, the analysis can only be done step by step. So in this case, we always assume a balanced load on each phase, which in reality is not the case. A transformer is balanced when the three current and voltage vectors are equal and the three vectors form an angle of 120° to each other.

2.3 Load Imbalance

Load imbalance occurs when one or both conditions of equilibrium are not met. Here are some conditions that can occur if the transformer is unbalanced: The current vectors in the R, S, and T phases have the same large value, but the angles between phases do not form 120°, the angles between the phase vectors already form 120°, but the vector values in the R, S, and T phases are different and the vector values in the R, S, and T phases are different and the angles between the phase vectors do not form 120°.

III. RESEARCH METHODS

3.1 Data Collection Methods

The data collection methods in writing this final project include:

a. Literature Studies
   Collect theories, data, and information needed for problem discussion.
b. Field Observation
   Observing and following the load distribution process at the LA 0409 distribution substation in the work area of PT. PLN (Persero) Lembayung Customer Service Unit, as well as measuring the load before and after the equal distribution of the load.

IV. RESULTS AND DISCUSSION

4.1 Calculation of Full Load Current and Load of LA 0409 Transformer

Transformer power **=** 200 kVA
Transformer line voltage = 380 Volts
The full load current of the distribution transformer can be calculated as follows:

$$I_{FL} = \frac{S}{\sqrt{3} \times V}$$

$$I_{FL} = \frac{200000\,VA}{\sqrt{3} \times 380\,V}$$

$$I_{FL} = 303{,}868\,A$$

Table 1. LA 0409 Transformer Data

Station Code/Transformer No.	LA 0409
Primary Voltage L-L (kV)	24
Secondary Voltage L-L(V)	380
Power (kVA)	200 kVA
Tap Position	5
Phase	3
Vector Group	Dyn11
Impedance	4,5%
Brand	Starlite
Temperature	400-900 C
Secondary Security In	Fuse Cut Out and Lightning Arrester
Opstig Cable Incoming	NYY 95 mm2
Opstig Cable Outgoing	NFA2X-T 185 mm2
Construction	Portal Storage

4.2 Calculation of Measurements Before Load Equalization

Table 2. Measurement Results Before Load Equalization

Peak Load Time (WBP)				
Thursday, December 12, 2024 / 7:00 p.m.				
PLT	Incoming	A Major	Major: B	Majors C
Current (Amp)				
R	309	175	189	41
S	363	91	205	64
T	175	40	105	29
N	150	73	124	33

To find out the percentage of load imbalance in the transformer, the average current at the incoming is first calculated.

Average current at the incoming $= \dfrac{I_R + I_S + I_R}{3}$

Average current at incoming = $\dfrac{309 + 363 + 175}{3} = 282{,}333$ A

Next, calculate the percentage of the current imbalance between phases

$$= \frac{\text{Arus maks incoming fasa R, S atau T - arus min incoming fasa R, S atau T}}{\text{Arus rata - rata pada incoming}} \times 100\%$$

% Current imbalance between phases = $= \dfrac{363 - 175}{282{,}333} \times 100\% = 66{,}588\%$

According to the circular of the board of directors of PT PLN (Persero) number 0017.E/DIR/2014 concerning Maintenance Methods of Transformers Based on Asset Management Principles, it is stated that if the percentage of flow imbalance between **phases ≥** 25%, then the Health Index of the transformer falls into the category of "Bad" and needs to be evenly distributed.

From the calculation above, it is known that the percentage of inter-phase current imbalance in LB 0409 is 66.588%. The percentage of imbalance has exceeded 25%, so it can be said that the load on the transformer is unbalanced so it is necessary to distribute the load equally.

4.3 Calculation of Measurements After Equalization of Substations

Table 3. Measurement Results After Load Equalization

Peak Load Time (WBP)				
Thursday, 16 January 2025 / 19.00				
PLT	Incoming	A Major	Major: B	Majors C
Current (Amp)				
R	258	117	129	35

S	287	92	145	45
T	239	91	113	40
N	97	37	54	11

To find out the percentage of load imbalance in the transformer, the average current at the incoming is first calculated.

Average current at the incoming $= \dfrac{I_R + I_S + I_R}{3}$

Average current at incoming = A$\frac{250+280+240}{3} = 261{,}333$

Next, calculate the percentage of the current imbalance between phases

$$= \frac{\text{Arus maks incoming fasa R, S atau T - arus min incoming fasa R, S atau T}}{\text{Arus rata - rata pada incoming}} \times 100\%$$

% Current imbalance between phases = $= \frac{287-239}{261{,}333} \times 100\% = 18{,}367\%$

From the calculation above, it is known that the percentage of current imbalance between phases is 18.367% and the Health Index of the Transformer is included in the "Sufficient" category.

4.4 Power Losses in Neutral Before and After Load Equalization

4.4.1 Power Loss on Incoming

The length of the cable from the secondary transformer to the incoming is 8 m. The cable used is a 95 mm2 NYFGbY cable with multiple cores, so that the phase and neutral conductive resistance is 0.913 ohms/km in accordance with SPLN 87:1991

The value of phase and neutral conductor resistance at the incoming is:

R = 0.193 Ω/km × 8 m

= 0.193 Ω/km × 0.008 km = 0.001544 Ω

Power loss in phase and neutral conveyors before load equalization

P = I2 × R

PR = 1.47 kW, PS = 0.203 kW, PT = 0.0472 kW, PN = 0.0347 kW

Power loss in phase and neutral conductors after load equalization

PR = 0.103 kW, PS = 0.00212 kW, PT = 0.0881 kW, PN = 0.0145 kW

4.4.2 Power Losses in Department A, Department B, Department C

The cable length from outgoing to the low-voltage network and the home connection is 6 m. The cable used is a 70 mm2 NYFGbY cable with multiple cores, so the phase and neutral conductor resistance is 0.268 ohms/km.

The value of phase and neutral conductive resistance in each department is:

$R = 0.268\ \Omega/km \times 6\ m$

$= 0.268\ \Omega/km \times 0.006\ km = 0.001608\ \Omega$

Power loss on phase and neutral conductors in A Majors before load equalization

P = I2 × R

PR = 0.0492 kW, PS = 0.0133 kW, PT = 0.00257 kW, PN = 0.0085 kW

Power loss on phase and neutral conductors in A Department after load equalization

PR = 0.022 kW, PS = 0.0136 kW, PT = 0.0133 kW, PN = 0.0022 watts

Power loss on phase and neutral conductors in Grade B before load equalization

PR = 0.0574 kW kW, PS = 0.0675 kW, PT = 0.0177 kW, PN = 0.0247 kW

Power loss in phase and neutral conductors in Department B after load equalization

PR = 0.0267 kW kW, PS = 0.0338 kW, PT = 0.0205 kW, PN = 0.0046 kW

Power loss on phase and neutral conductors in Department C before load equalization

PR = 0.0027 kW kW, PS = 0.0065 kW, PT = 0.0013 kW, PN = 0.0017 kW

Power loss in phase and neutral conductors in Department C after load equalization

PR = 0.0019 kW kW, PS = 0.0032 kW, PT = 0.0025, PN = 0.00019 kW

4.5 Financial Losses Due to Power Losses

The calculation of financial losses is carried out by assuming that each house has a power of 1300 VA with 5 hours of power (18.00-23.00) in one month (30 days). The tariff charged per kWh is Rp.1444.70 in accordance with the adjustment tariff of PT PLN (Persero) in January-March 2025.

4.5.1 Before Load Equalization

Energy Loss in a month = 2.00797 kW × 5 h × 30 = 301.1955 kWh
Financial Loss = 301.1955 kwh × IDR 1444.70 = IDR 435,137,139

4.5.2 After Load Equalization

Energy Loss in a month = 0.37129 kW × 5 h × 30 = 55.6935 kWh
Financial Loss = 55.6935 kwh × IDR 1444.70 = IDR 80,460,399

V. CONCLUSION

Due to the load imbalance in the LA 0409 distribution transformer, the neutral current increases, resulting in loss of conductivity and financial loss. Before load equalization, the neutral current dropped from 150 A to 97 A, reducing the loss of conductive power from 2.00797 kW to 0.37129 kW. The financial loss before the equalization was IDR 435,137,139, after the equal distribution of the load decreased to IDR 80,460,399. Load equalization has been shown to be an effective method to reduce the amount of power lost and improve the efficiency of power distribution in low-voltage networks.

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