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Power Losses Caused by Load Imbalance in the Center Building of PGRI Semarang University

Muhammad Zaenal Arifin[1], Muhammad Amirudin[2], Margono[3]

[1,2,3]Department of Electrical Engineering, Faculty of Engineering and Informatics, PGRI Semarang University, Jl. Sidodadi-Timur No.24 Semarang, Central Java 50232, Indonesia

zaenal.ariiff@gmail.com

Abstract. The use of energy is basically very much needed in everyday life. Energy that is widely used is electrical energy, because electricity is one of the important factors in human life. Some electrical energy producers, in the country use fossil fuel sources such as coal and petroleum, and fossil energy is not renewable. Therefore, the government through the Regulation of the Minister of Energy and Mineral Resources number 14 of 2012 regulates energy management to control energy consumption in order to achieve effective and efficient energy utilization. PGRI Semarang University as an academic institution uses a lot of non-linear loads for administrative, teaching, laboratory and other supporting activities. Based on the analysis of data obtained at the Center Building of PGRI Semarang University experiencing an imbalance, the condition is not in accordance with the standards and risks increasing power losses. Seeing these conditions, recommendations were obtained that can be implemented at the Center Building of PGRI Semarang University, namely, balancing the load of phases R, S, T to reduce current imbalances. From the load imbalance, there were power losses on the neutral wire of 889,363 kW and power usage for one day in the R, S, T phases of 15,497,991 kW.

Keywords: Efficiency, Load Imbalance, Neutral Wire Losses

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1. Introduction

The use of energies is basically very much needed in everyday human life. Energy cannot be separated in many aspects as a support for household, commercial, government agencies, industry and so on. Energy that is widely used is electrical energy, because electricity is one of the important factors in industrial operations and other agencies. Some electrical energy producers in the country use fossil fuel sources such as coal and petroleum. Fossil energy sources are non-renewable, causing energy reserves to decrease. Therefore, the government through the Regulation of the Minister of Energy and Mineral

Resources number 14 of 2012 regulates energy management to control energy consumption in order to achieve effective and efficient energy utilization.

PGRI Semarang University as an academic institution uses a lot of non-linear loads for administrative, teaching, laboratory and other supporting activities. As a result of the use of such loads there is a possibility of an impact on the quality of electrical power. This research is expected to provide information on the effect of these burdens on the amount of losses generated and can achieve effective and efficient energy utilization.

2. Research Methodology

This study was conducted to reduce losses caused by inefficient use of loads. The method used in this study is to use quantitative methods. The research procedure in this study used a Power Quality Analyzer (PQA) tool to obtain research data. The data taken are data on electrical load, voltage, frequency, current, power factor, and Total Harmonic Distortion. The design of this study was carried out based on the analysis to determine the quality of electrical power shown in Figure 1 and figure 2 showing the flowchart implementation carried out to obtain the results of the study, along with the stages. The collection of data carried out by researchers is data collection at the Center Building of PGRI Semarang University which is taken in the Main Distribution Panel panel and the floor panel. The data taken include data on electrical load, voltage, frequency, current, power factor, and voltage THD. Load measurement on the Center Building of PGRI Semarang University MDP is carried out by recording data for 24 hours. In the data process, the data taken is calculated using formulas and then graphed using Microsoft Excel software to facilitate the analysis process and compare with existing standards. The economic value in this study is to be able to find out the losses caused by poor quality of electrical power, then recommendations are made to reduce losses.

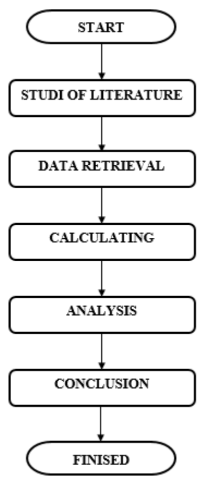

Figure 1. Research Design

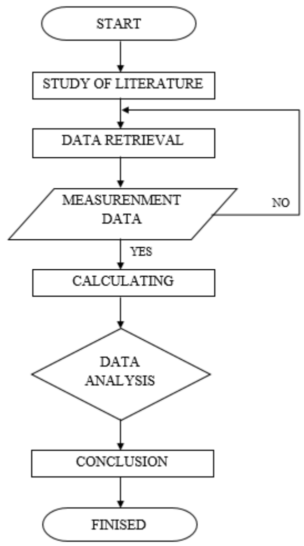

Figure 2. Research Flowchart

3. Results and Discussion

In lecture and office activities as well as laboratory activities at the Center Building of PGRI Semarang University, it is not spared from the use of electrical energy. The electric power system of the Center Building of PGRI Semarang University comes from Perusahaan Listrik Negara (PLN) sources in the 20 KV distribution network system which is lowered in voltage by the power transformer to 380/220 V and a 400 KVA capacity generator that works and is regulated by the Automatic Transfer Switch panel (Kusmantoro, Adhi 2015).

3.1. Current Imbalance

The current imbalance will be analyis using the existing formula. Dan current imbalance is taken when the Center Buildingis in high load condition. The following is a picture of the current chart on the MDP of the Center Building of PGRI Semarang University:

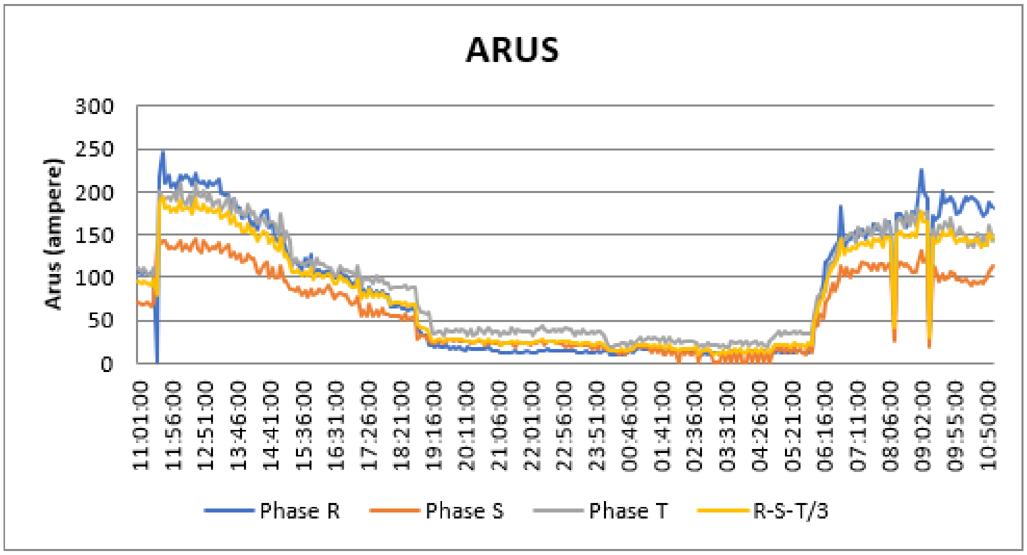

Figure 3. Graph Flows between phases

We can see in Figure 3 that there is a considerable difference in current in each phase. To find out the imbalance value, you can take an example of current data in MDP under certain conditions with the highest average value, an example of calculating the current imbalance value will be made as follows:

Table 1. Example of current data

Time	R	S	T	Current AVG
11:31:00	0	136,5	100,4	78,98
16:21:00	107	91,45	111,7	103,37

The formula for calculating the current imbalance is shown in the following equation:

$$I_{Rata-rata} = \frac{R+S+T}{3} \quad (1)$$

Where the magnitude of the phase current in the balanced state I is equal to the magnitude of the average current, then the coefficients a,b and c are obtained by :

$$a = \frac{\mathrm{IR}}{\mathrm{Irata-rata}} \quad (2)$$

$$b = \frac{\mathrm{IS}}{\mathrm{Irata-rata}} \quad (3)$$

$$c = \frac{\mathrm{IT}}{\mathrm{Irata-rata}} \quad (4)$$

In the equilibrium state the coefficients a,b,c are equal to 1 then the mean load imbalance in (%) is :

$$\%ketidakseimbangan\ beban = \left(\frac{|a-1|+|b-1|+|c-1|}{3}\right)100\% \qquad (5)$$

1. Highest imbalance
Coefficients a, b, c:

$$a = \frac{\mathrm{IR}}{\mathrm{Irata-rata}} = \frac{0}{78{,}98} = 0$$

$$b = \frac{\mathrm{IS}}{\mathrm{Irata-rata}} = \frac{136{,}5}{78{,}98} = 1{,}73$$

$$c = \frac{\mathrm{IT}}{\mathrm{Irata-rata}} = \frac{100{,}4}{78{,}98} = 1{,}27$$

$$\%ketidakseimbangan = \frac{|a-1|+|b-1|+|c-1|}{3} \times 100\%$$

$$= \frac{|0-1|+|1{,}73-1|+|1{,}27-1|}{3} \times 100\%$$

$$= \frac{1+0{,}73+0{,}27}{3} \times 100\%$$

= 66,67 %

2. Lowest imbalance
Coefficients a, b, c:

$$a = \frac{\mathrm{IR}}{\mathrm{Irata-rata}} = \frac{107}{103{,}37} = 1{,}03$$

$$b = \frac{\mathrm{IS}}{\mathrm{Irata-rata}} = \frac{91{,}45}{103{,}37} = 0{,}88$$

$$c = \frac{\mathrm{IT}}{\mathrm{Irata-rata}} = \frac{111{,}7}{103{,}37} = 1{,}08$$

$$\%ketidakseimbangan = \frac{|a-1|+|b-1|+|c-1|}{3} \times 100\%$$

$$= \frac{|1{,}03-1|+|0{,}88-1|+|1{,}08-1|}{3} \times 100\%$$

$$= \frac{0{,}3+0{,}12+0{,}8}{3} \times 100\%$$

= 7,69 %

Based on the calculation of the lowest current imbalance value of 7.69% while the highest of 66.67%, the value is far from the IEC (International Electrotechnical Commission) standard of 5%. The value is in a bad condition, so it is necessary to equalize the load on each phase.

Table 2. IEC imbalance standards

Characteristic	Index			
	Good	Not Good Enough	Bad	Very Bad
Inter-Phase Current Imbalance	< 5	< 10	< 15	> 20

We can see from the calculation using the formula, the current imbalance value contained in the MDP of the Center Building as measured by the time span of data retrieval looks quite high. To make analysis easier, the calculated data can be changed graphically as shown in figure 4 below:

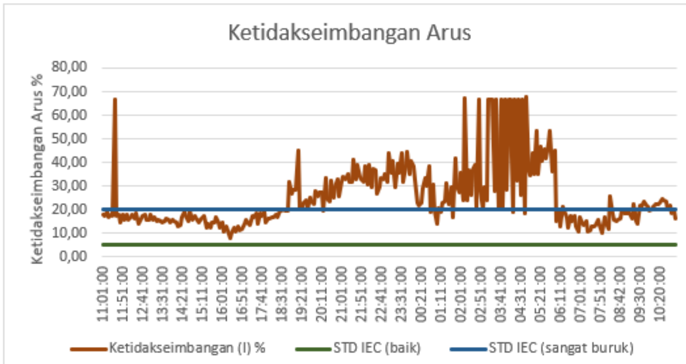

Figure 4. Current imbalance graph

When used during working hours, there are differences between phases. Therefore, there is an imbalance in current, a significant imbalance occurs at night. The use of electrical power at night is building lighting, garden lighting, radio transmitters. It is most likely that the current imbalance occurs in the phase used for motors and radio transmitters.

3.2. Neutral Wire Losses

The load imbalance in all three channel currents results in an outflow in the neutral wire. neutral wire that should be zero, due to the unbalanced current between phases, causing power losses. Resistance (R) on neutral conducting wire is assumed to be 0.00114 Ω. In order to make it easier to analyze, we can take an example of calculations with existing data, as follows:

Table 3. Examples of current and neutral current data

Time	Current (I)			
	R	S	T	N
11:31:00	0	136,51	100,44	127,69
01:01:00	17,29	20,165	25,331	9,23

1. At 11: 31 WIB

In the morning, it was seen that there was a current that multiplied on the neutral wire, which was 127.69 A.

$$P_N = I_N^2 \times R_N$$
$$= 127.69^2 \times 0.00114$$
$$= 18.59 \text{ kW}$$

2. At 01:01 WIB

In the morning, it was seen that there was a multiplied current on the neutral wire, which was 9.23 A.

$$P_N = I_N^2 \times R_N$$
$$= 9.23^2 \times 0.00114$$
$$= 0.10 \text{ kW}$$

From the example taken from the measurement data from the calculation of the equation above, we can see that the outgoing current flowing on the neutral wire causes power losses of 18.59 kW as the highest value and 0.10 kW as the lowest value. The loss for consumers is the loss on electricity bills due to losses of power flowing on the neutral wire.

(a) Sample data

To support the data, a full load of data samples was taken on the 3rd, 4th, 5th, 6th floors of the Central Building, in table 4, the current in each phase was calculated. When compared with the IEC standard, the current imbalance value in the Center Building floor data sample is not up to standard. Here is Table 4 which shows the results of calculating the current imbalance:

Table 4. Data samples taken in the central compose

Panel	Current			Unb. Current %	Information
	R	S	T		
LT 3	32,5	22,4	21,8	18,08	Not Up to Standard
LT 4	33,9	33,9	16,3	39,04	Not Up to Standard
LT 5	33,9	17,02	32,1	25,66	Not Up to Standard
LT 6	25	15,81	37,2	28,71	Not Up to Standard

By looking at table 4, it can be seen that the difference in current between phases is very high. As an example of calculations can be taken data on the 6th floor of the Central Building, here are the results of the calculations:

Coefficients a, b, c:

$$a = \frac{\text{IR}}{\text{Irata} - \text{rata}} = \frac{25}{26{,}003} = 0{,}961$$

$$b = \frac{\text{IS}}{\text{Irata} - \text{rata}} = \frac{15{,}81}{26{,}003} = 0{,}608$$

$$c = \frac{\text{IT}}{\text{Irata} - \text{rata}} = \frac{37{,}2}{26{,}003} = 1{,}43$$

$$\%ketidakseimbangan = \frac{|a-1| + |b-1| + |c-1|}{3} \times 100\%$$

$$= \frac{|0{,}961-1|+|0{,}608-1|+|1{,}43-1|}{3} \times 100\%$$

$$= \frac{0{,}039+0{,}392+0{,}43}{3} \times 100\%$$

= 28,7 %

Based on data on the 6th floor, the load used is air conditioning, projector and lights. The highest current of 37.2 A is located in the T phase which is indicated as an AC load, therefore it is necessary to transfer the load at the smallest current, namely in the S phase of 15.81 A. For equalization, it can be done by moving the AC load from the T phase to the S phase so that the current imbalance of 28.7% can be reduced.

(b) Equalization of Load

By looking at the calculation results in table 4, it is required to equalize the load so that the current imbalance value can be suppressed. For this reason, some recommendations so that the load imbalance value can be suppressed, namely by moving the phase from the highest to the lowest. The following table 5 is the result of the calculation after equalization of the load:

Table 5. Data after load transfer

Panel	Current			Unb. Current	Information
	R	S	T		
LT 3	25,3	26	25,4	1,13	As Standard Compliant
LT 4	21,3	21,7	21,14	1	As Standard Compliant
LT 5	28,5	27,82	26,7	2,34	As Standard Compliant
LT 6	25	26,61	26,4	2,57	As Standard Compliant

As an example of calculations can be taken data on the 6th floor of the Central Building, here are the results of the calculations:

Coefficients a, b, c:

$$a = \frac{\mathrm{IR}}{\mathrm{Irata} - \mathrm{rata}} = \frac{25}{26{,}003} = 0{,}961$$

$$b = \frac{\mathrm{IS}}{\mathrm{Irata}-\mathrm{rata}} = \frac{26{,}61}{26{,}003} = 0{,}023$$

$$c = \frac{\mathrm{IT}}{\mathrm{Irata}-\mathrm{rata}} = \frac{26{,}4}{26{,}003} = 0{,}015$$

$$\%ketidakseimbangan = \frac{|a-1| + |b-1| + |c-1|}{3} \times 100\%$$

$$= \frac{|0{,}961-1|+|1{,}023-1|+|1{,}015-1|}{3} \times 100\%$$

$$= \frac{0{,}039+0{,}023+0{,}015}{3} \times 100\%$$

= 2,56 %

Based on the data of table 5 equalization with the transfer of part of the load to the lowest phase, it is proven that it can reduce the current imbalance figure according to the standard. Therefore, this recommendation can be implemented in the Center Building of PGRI Semarang University in order to minimize load imbalances.

4. Conclusions

Based on the process that has been carried out, that the electricity in the Center Building of PGRI Semarang University is in accordance with data and calculations, it can be concluded that there is a large enough current difference in each phase, the lowest current imbalance is 7.69% while the highest is 66.67%, the value is far from the IEC (International Electrotechnical Commission) standard of 5%. These conditions are in a bad condition, so it is necessary to equalize the load on each phase.

Due to the occurrence of a current imbalance, resulting in the occurrence of current flowing in the neutral phase which results in power losses of 889,363 kW borne by the customer, the condition becomes ineffective because the customer has to pay more to replace the lost power.

To overcome the problem of current imbalance, there must be an even distribution in each phase, for example, on the 6th floor, load transfer is carried out from phase T to Phase S. Therefore, the same can be done on each floor in the Center Building of PGRI Semarang University in order to minimize losses due to load imbalance.

5. Acknowledgments

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