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Current and Voltage Imbalances at BPTIK Universitas PGRI Semarang

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Abstract. Energy conservation is an effort to increase energy efficiency. This research conducted an energy audit in the BPTIK (Badan Pengembangan Teknologi Informasi dan Komunikasi) department room at the Universitas PGRI Semarang, observing the value of electrical parameters, especially unbalanced voltage and current that have the potential to cause neutral currents. In this study the calculated unbalanced voltage value is 0.64% and unbalanced current is 20.25%. From the current development, the neutral current produces an average of 1.72 Amperes. From the value of the neutral current can be calculated the energy lost in the conductor neutral wire per day is about 0.01% of energy consumption by the load per day.

Keywords: current, voltage, imbalance

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1. Introduction

Energy conservation is an effort to optimize energy use (increase energy efficiency) in a company with the ultimate goal of increasing economic, social and environmental added value. Basically, energy audit is one of the efforts in energy conservation and the environment that focuses on survey activities to obtain data and information that explains the portrait of energy use, and whether there are opportunities to improve energy quality.

The dominant factors in the consideration of energy efficiency and electrical power quality in the distribution of electricity in buildings are harmonic distortion and imbalance distortion [3]. According to Hossein [2], his research suggests current imbalance and voltage imbalance is a serious problem in the distribution of low-voltage level three-phase systems. In a three-phase system the cause of current imbalance is due to load imbalance, and current imbalance is the main cause of voltage imbalance. The task of balancing currents and loads is the responsibility of both parties, namely electricity providers and consumers. Therefore, it is necessary to calculate special rates based on imbalance.

The importance of the quality of electric power, seen from several studies that have been done before, is the investigation of the quality of electric power in the PGRI University of Semarang. For this research, a study of the electricity network will be carried out at the Main Building of the PGRI University in Semarang, especially on the 3rd floor in The Unit of Technical Information and Communication (BPTIK), due to observations, there are many 1-phase loads such as PC (Personal Computer), servers, lighting and AC (Air Conditioner) installed on network with 3 phase sources. In addition, in the BTIK department, there is a UPS (Uninteruptible Power Supply) which is risky against neutral voltage to ground. To maintain the continuity of the performance of the BPTIK department of the University of PGRI Semarang, it is necessary to conduct an energy audit on the electricity network. In a previous study by Wanimbo [5] located in the same place, the BPTIK room IKE (Energy Consumption Intensity) was 8.11 kWh per month / m2 and calculated daily energy consumption in the measurement time range of 43.29 kWh. This paper compares the amount of energy consumption by the load in the room with the energy lost in the neutral conductor as a result of the imbalance.

2. Methods

This research was conducted in several stages, starting with the observation of the electrical panel in the field, followed by measuring and recording data. After the data recording process is continued with data processing related to current and voltage imbalance parameters. After processing the data, it is continued with drawing conclusions for recommendations for improving the electricity network.

2.1. Measurement and Data Record

Measurements were made on the BPTIK power panel connected to a 3-phase UPS (Uniteruptible Power Supply) that provides energy for the BPTIK room using the Scheneider PM5350. The measured parameters are the current and voltage per phase and recorded for approximately 24 hours with data retrieval every 5 minutes. The results of the current measurement data record per phase are as shown in Figure 1.

As can be seen in Figure1 The highest rated phase current T and the lowest rated phase current R throughout the measurement time range. From this data, the current values in the three phases are obtained as in Table I below. For the results of recording the voltage measurement data per phase as shown in Figure 2. For the results of recording the voltage measurement data per phase as shown in Figure 3. From the voltage per phase data shown in Figure 2, the stress values in the three phases are obtained as in Table 2.

Table 1. Flow rate per phase

Value	**Voltage per phase (A)**		
	R	**S**	**T**
Maximum	4.96	5.55	7.48
Minimum	3.22	4.10	4.40
Average	3.85	4.52	5.58

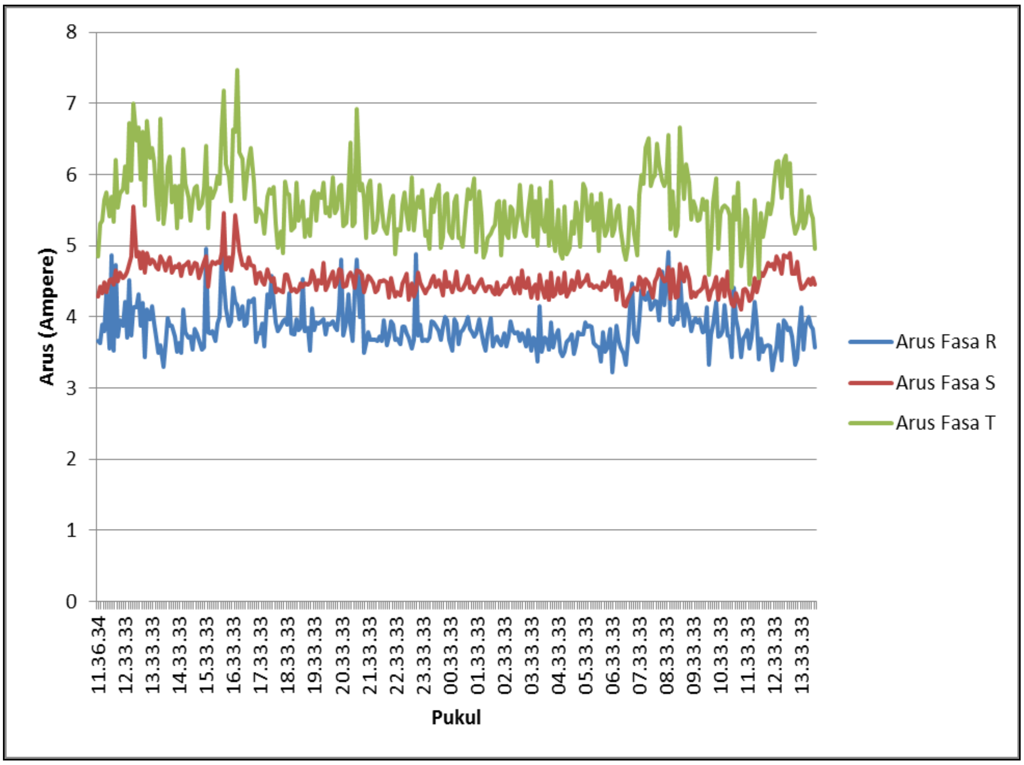

Figure1. Graph of current measurement data per phase

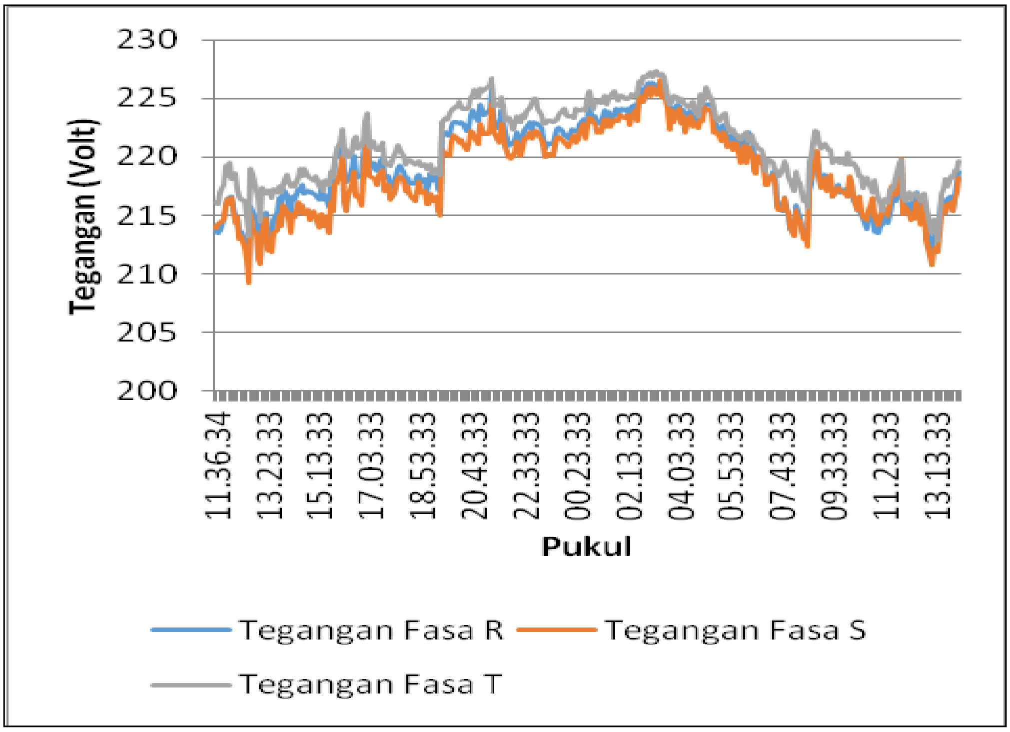

Figure 2. Graph of voltage measurement data per phase

Table 2. Voltage per phase against neutral

Value	**Voltage per phase (V)**		
	R	**S**	**T**
Maximum	226.4	226.59	227.35
Minimum	210.38	209.31	212.94
Average	219.33	218.58	220.97

2.2. Data Processing

2.2.1. Voltage Imbalance

At 11:38:33 WIB the value of the voltage parameter in each phase towards neutral is as shown in Table 3. At the data processing stage, the three parameters are calculated, the value of the voltage imbalance, current imbalance and neutral current. Therefore, the calculated average voltage for each phase to neutral is 214.58 Volts. The largest difference between the value of the voltage per phase and the average voltage per phase at that time is 1.38 volts occurs in phase T. By calculating the imbalance with the IEEE Std 112 standard in equation 2.6, the voltage imbalance is calculated as equation 1.

$$\text{Voltage Imbalance} = \frac{1.38\,Volt}{214.58\,Volt} \times 100\% = 0.64\ \% \tag{1}$$

From all measurement points are calculated, then the result of the stress imbalance calculation is plotted in a graph as shown in the graph in Figure 3 as follows. From the calculation of the voltage imbalance, it is found that the average voltage imbalance is 0.64%.

Table 3. Value of voltage per phase to neutral

Time	Voltage per phase for neutral (V)			
	R	S	T	rata-rata
11:38:33	213.5	214.28	215.96	214.58

2.2.2. Current Imbalance

At 11:38:33 WIB the value of the voltage parameter in each phase to neutral is shown in Table 4. So that the average current for each phase to neutral is calculated at 4.45 Amperes. The largest difference between the current value per phase and the average current per phase at that time is 0.85 Ampere occurs in phase T. By calculating the imbalance with the IEEE Std 112 standard in equation 2.6, the current imbalance is calculated as,

$$\text{Current Imbalance} = \frac{0.85\ ampere}{4.45\ ampere} \times 100\%{=}19.09\% \tag{2}$$

From all measurement points are calculated, then the calculation results of the current imbalance are plotted in a graph as shown in the graph in Figure 4 as follows: From the current imbalance calculation data, the results of the calculation of the average current imbalance are 20.25%.

Tabel 4. Flow value per phase against neutral

Time	Voltage per phase for neutral (V)			
	R	S	T	rata-rata
11:38:33	3.63	4.42	5.3	4.45

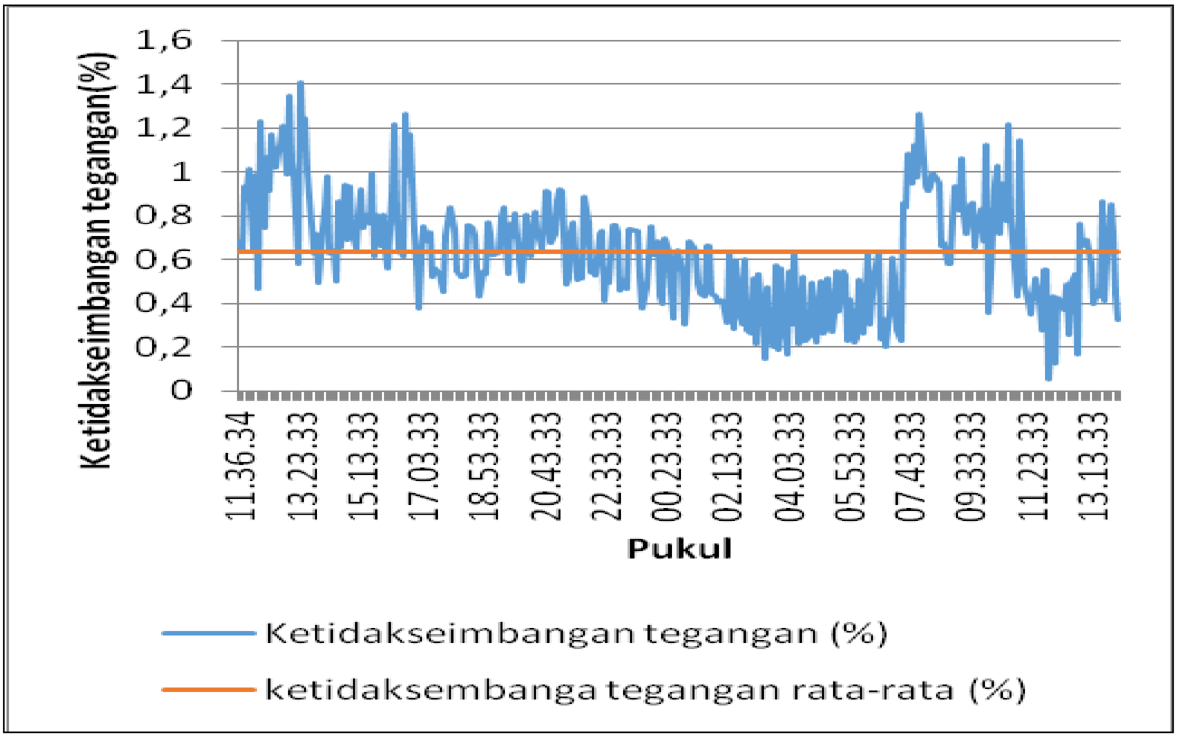

Figure 3. Graph of voltage imbalance between phases

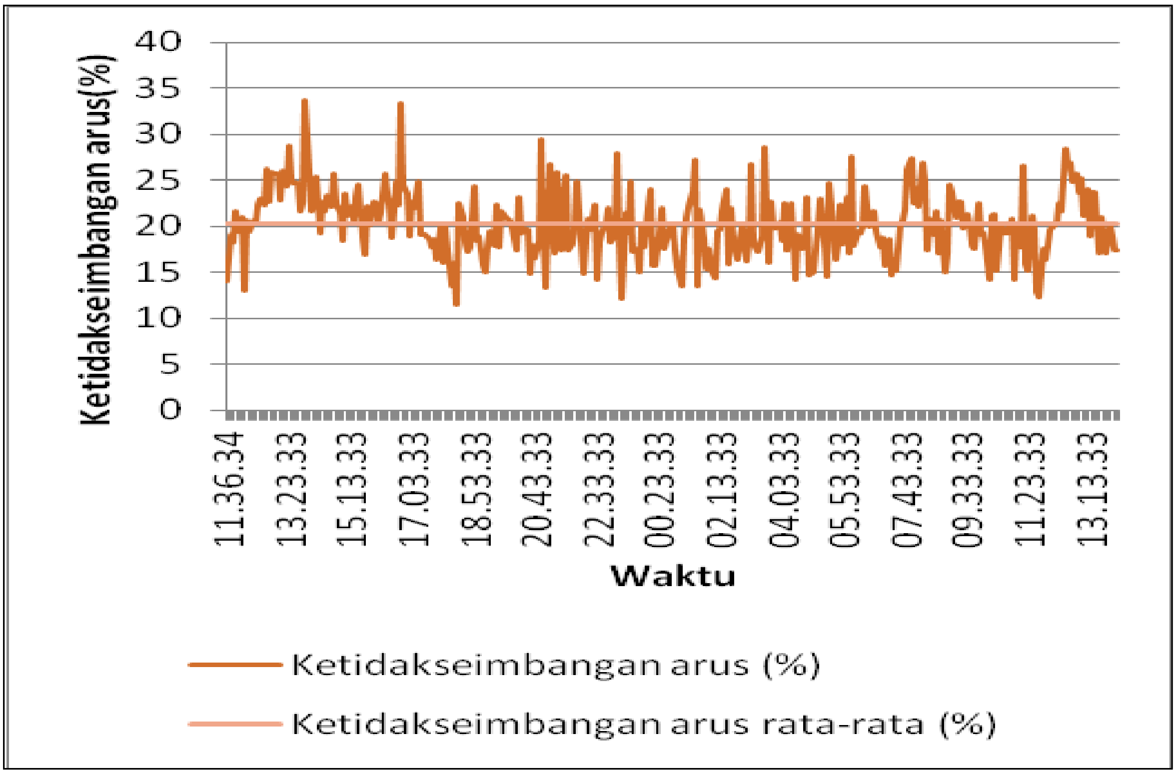

Figure 4. Graph of current imbalance between phases

2.2.3 Neutral Current

From the current imbalance that occurs between the phases, it causes a neutral current which is illustrated in the graph in Figure 5, which is the resultant current vector between the three phases as in formula 2.2 above, each of which has a direction and angle as shown in Figure 6. We get the direction and angle from the calculation of the power factor value. It is known in the 11:38:33 measurement that the values are obtained in Table 5.

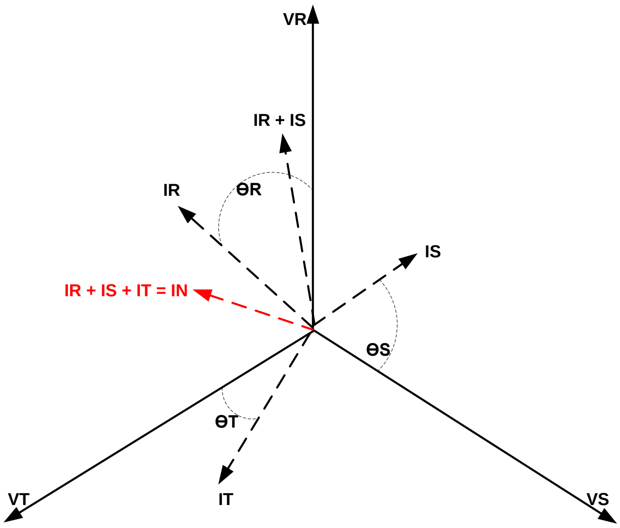

Figure 5. Neutral current vector calculation

Table 5. Flow value and power factors per phase

Time	Voltage per phase (A)			Power factors		
	R	S	T	R	S	T
11:38:33	3.63	4.42	5.30	0.53	0.43	0.64

From this value it can be calculated the value of the angle of the current and the voltage per phase, that is $\theta_R = cos^{-1}\, 0.53$, or the phase angle R $\theta_R = 57.85°$, while the phase angle S is obtained from $\theta_S = cos^{-1}\, 0.43$ or $\theta_S = 64.75°$. In the same way, to find the value of the phase angle T is $\theta_T = cos^{-1}\, 0.64\ or\ \theta_T = 50.33°$. Then it can be calculated the sum of the current vector of phase R and current of phase S as follows

$$|\vec{I_R} + \vec{I_S}| = \sqrt{{I_R}^2 + {I_S}^2 + 2I_R I_s \cos(120 + \theta_R - \theta_S)} \quad (3)$$

$$|\vec{I_R} + \vec{I_S}| = \sqrt{3.63^2 + 4.42^2 + 2 \times 3.63 \times 4.42\ \times \cos(113.09)} \quad |\vec{I_R} + \vec{I_S}| = 4.48\ ampere$$

From this value, the value of the current angle and the voltage per phase can be calculated, that is $\theta_R = cos^{-1}\, 0.53$, or phase angle R $\theta_R = 57.85°$, while the phase angle S is obtained from $\theta_s = cos^{-1}\, 0.43$ or $\theta_S = 64.75°$. In the same way, to find the value of the phase angle T is $\theta_T = cos^{-1} 0.64$ or $\theta_T = 50.33°$. Then it can be calculated the sum of the current vector of phase R and current of phase S as follows

$$|\vec{I_R} + \vec{I_S}| = \sqrt{{I_R}^2 + {I_S}^2 + 2I_R I_s \cos\,(120 + \theta_R - \theta_S)} \quad (4)$$

$$\left|\overrightarrow{I_R}+\overrightarrow{I_S}\right| = \sqrt{3.63^2 + 4.42^2 + 2 \times 3.63 \times 4.42 \times \cos(113.09)} \qquad \left|\overrightarrow{I_R}+\overrightarrow{I_S}\right| = 4.48\ ampere$$

Calculated the amount of current R and S equal to 4.48 ampere and form an angle θ_{RS} namely the intermediate angle $\overrightarrow{I_R} + \overrightarrow{I_S}$ to $\overrightarrow{I_S}$.

$$\frac{\left|\overrightarrow{I_R}+\overrightarrow{I_S}\right|}{\sin(120+\theta_R-\theta_S)} = \frac{\left|\overrightarrow{I_R}\right|}{sin\theta_{RS}} \tag{5}$$

$$sin\theta_{RS} = \frac{\left|\overrightarrow{I_R}\right|\sin(120+\theta_R-\theta_S)}{\left|\overrightarrow{I_R}+\overrightarrow{I_S}\right|}$$

$$sin\theta_{RS} = \frac{3.63\sin(113.09)}{4.48}$$

$$sin\theta_{RS} = 0.905$$

$$\theta_{RS} = 64.93°$$

Then proceed with calculating the value of the neutral current I_N.

$$\left|\overrightarrow{I_N}\right| = \sqrt{\left|\overrightarrow{I_R}+\overrightarrow{I_S}\right|^2 + {I_T}^2 + 2\left|\overrightarrow{I_R}+\overrightarrow{I_S}\right| I_T \cos(120+\theta_{RS}+\theta_S-\theta_T)} \tag{6}$$

$$\left|\overrightarrow{I_N}\right| = \sqrt{4.48^2 + 5.30^2 + 2 \times 4.48 \times 5.30 \times \cos(199.36)}$$

$$\left|\overrightarrow{I_N}\right| = 1.85\ ampere$$

All current and power factor measurement data points during the measurement timeframe are used for the calculation of neutral currents and are plotted in a graph in Figure 6.

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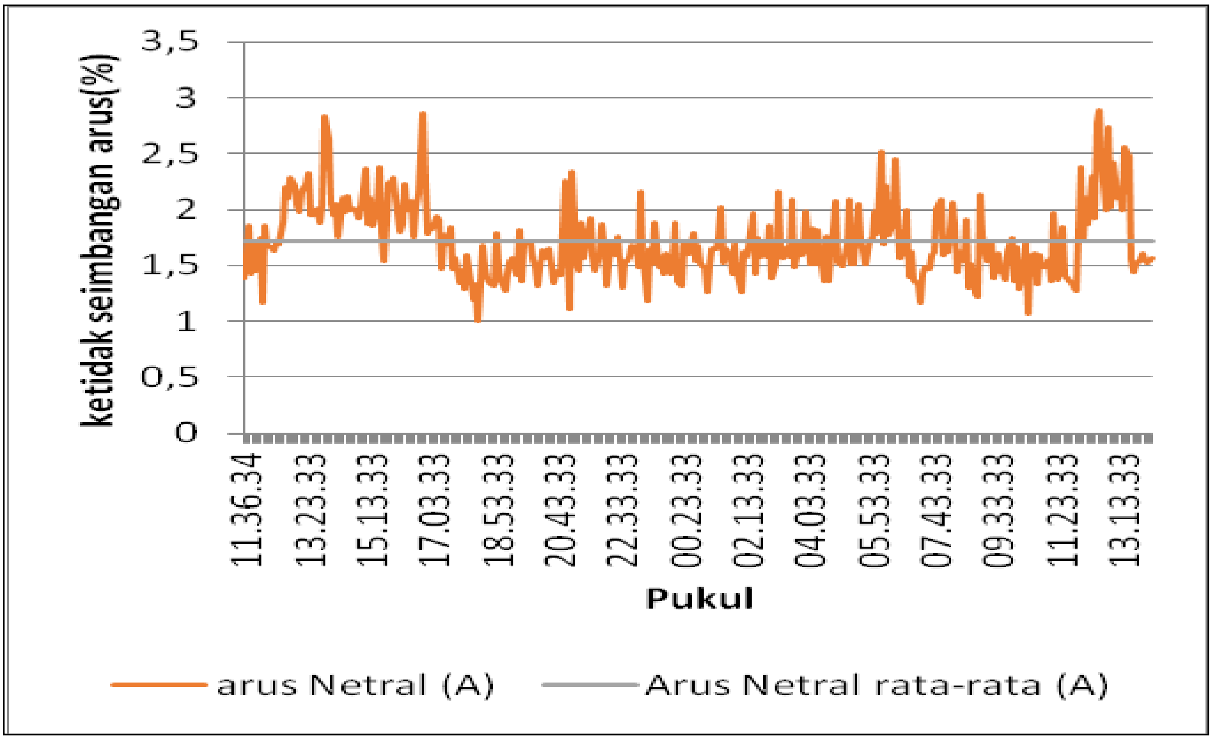

Figure 6. Graph of neutral currents due to current imbalance between phases

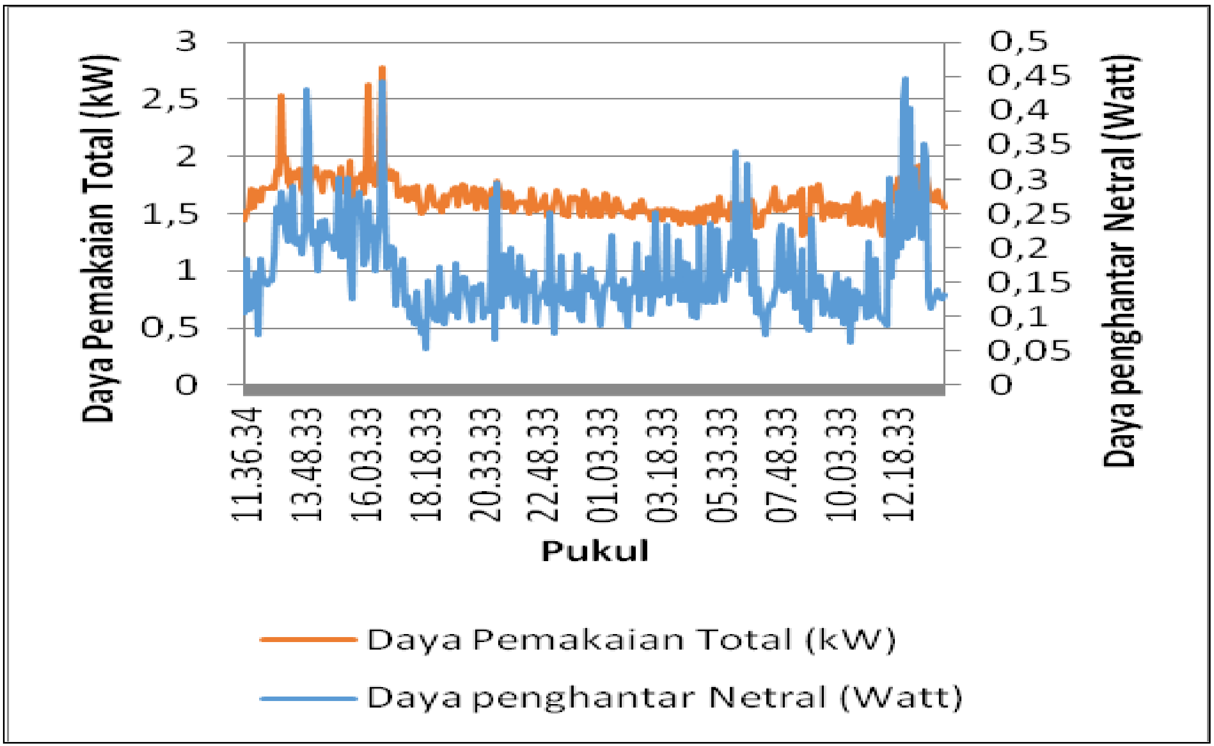

Figure 7. Graph of the total consumption power and neutral power

From the graph in Figure 7 it can be seen that the value of the neutral current is influenced by the current imbalance between the three phases. From the calculation, the neutral current value is obtained as in Table 6.

Table 6. Neutral Current Value

Value	Neutral Current (A)
Max	2.89
Min	1.00

In the electrical panel of this research room, a neutral conducting wire is installed + 50 meters long, with a cross-sectional area of 16 mm2, made of copper, calculated as resistance according to equation 2.4 as follows

$$R = \frac{1{,}72 \times 10^{-8} \times 50}{16 \times 10^{-6}} = 0{,}05375\ \Omega \qquad (7)$$

In the previous study [11], energy consumption by load per day was calculated, which was 43.29 kWh, with the same calculation method in the previous study, namely the numerical integration method, which calculated energy in the neutral conducting wire per day of 4.37 Wh, which is when compared to consumption. energy by load per day is about 0.01%.

3. Conclusion

During the measurement period, the voltage imbalance value is 0.64% and the current imbalance is 20.25%. From this current imbalance, it has the potential to produce an average neutral current of 1.72 Ampere, so that the energy flowing in the neutral wire conductor per day is 4.37 Wh, about 0.01% of the energy consumption by the load per day.

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