Journal of Social Research

P-ISSN: 2827-9832
E-ISSN: 2828-335x
Vol.5, No.5, April 2026
http://ijsr.internationaljournallabs.com/index.php/ijsr

Optimalization Strategy for kWh Savings at the JE016 Substation in Labu Lalar at PT PLN (Persero) ULP Taliwang

Luh Rismayoni*, I Wayan Sukadana, I Nyoman Gede Adrama, I Wayan Sutama
Universitas Pendidikan Nasional, Indonesia
Email: rismayoni2014@gmail.com*, sukadana@undiknas.ac.id, nyomanadrama@undiknas.ac.id, wayansutama@undiknas.ac.id

Keywords:
Load Balancing, power losses, energy losses, saved energy (kWH)

ABSTRACT

Electricity is a primary necessity that must be supplied continuously with reliable quality to meet increasing societal demand. However, technical losses in distribution systems, particularly those caused by transformer load imbalance, can reduce system efficiency and lead to energy losses. This study aims to analyze the effectiveness of load-balancing methods in optimizing kWh energy savings at the JE016 substation in *Labu Lalar*, operated by PT PLN (*Persero*) *ULP Taliwang*. This research employs a quantitative experimental approach using load measurement data obtained from field observations and the AMG application. The analysis focuses on load-imbalance percentage, neutral current, power losses, and energy losses before and after load-balancing implementation. The results show that the load-balancing method successfully reduced the load-imbalance percentage to 20.29% and decreased the neutral current to 40.67%. Consequently, energy losses were reduced to 241.52 kWh, while the transformer achieved energy savings of up to 25.53 kWh. These findings indicate that load balancing significantly improves transformer efficiency by minimizing losses and optimizing energy usage. In conclusion, the implementation of load balancing is an effective strategy for reducing technical losses and enhancing energy efficiency in distribution substations. This method can be applied as a practical solution to optimize transformer performance and improve the quality of electrical power distribution.

INTRODUCTION

Electricity has become a primary necessity that is expected to always be available to meet demand. PT PLN (Persero), as a company that provides electrical energy services in Indonesia, is committed to maintaining the quality of the electrical energy distributed in accordance with established standards. One of the efforts is reducing technical losses that occur due to load imbalance between phases, which causes current to flow through the neutral conductor of the transformer (Eduful et al. 2016; Pratama et al. 2020; Solnørdal et al. 2018). Based on the Circular Letter of the Board of Directors of PT PLN (Persero) No. 0017.E/DIR/2014 concerning Distribution Transformer Maintenance Methods Based on Management Principles, the acceptable tolerance limit for transformer load imbalance is not recommended to exceed 19% (sufficient category). Meanwhile, the neutral current relative to the transformer load is not recommended to exceed 14% (sufficient category) (Chen et al. 2018, 2020; Pan et al. 2016).

The load balance of a transformer is influenced by the service connection (SR) load distribution point on each phase. Field personnel performing new installations or service upgrades often do not adequately consider the phase load to which they are connecting (Ali et al. 2017; Eduful et al. 2016). As a result, load imbalance occurs between phases on the transformer side, potentially causing voltage drops at the end of the low-voltage network (JTR) (Basyiruddin et al. 2025; Prastia et al. 2024; Zulfiyan 2026). Measurement results show that the voltage at the end user is 171.2 V, which is below the standard set by PLN, referring to the SPLN 1:1995 standard on standard voltages, where the allowable service voltage ranges from +5% (231 V) to -10% (198 V) of the nominal voltage.

In the February 2025 load measurement, the load imbalance percentage at the JE016 substation reached 30%, with a loading level of 59% or 95 kVA. Meanwhile, in the June 2025 measurements, the load imbalance decreased to 27%, with a loading level of 63.09% or 100.95 kVA. Despite this improvement, the imbalance level still does not meet the applicable standards, and the resulting neutral current remains relatively high at 81 A, or 40.9% of the transformer load (Chen et al. 2018, 2020; Pan et al. 2016). To reduce load imbalance and power losses, transformer optimization is carried out through a load balancing method aimed at equalizing phase loads, reducing neutral current, and consequently minimizing power losses and transformer energy losses (Shao et al. 2024; Sinurat et al. 2026).

Several previous studies have shown that load balancing is an effective method for reducing neutral currents and minimizing power losses in distribution transformers (Ayuningtyas et al. 2023; Chew et al. 2018; Ibrahim et al. 2021). However, most studies focus on general cases and have not specifically analyzed optimization strategies in the context of the JE016 substation in Labu Lalar, particularly in relation to measurable kWh savings. Therefore, this study introduces novelty by focusing on an empirical analysis of load balancing implementation and its direct impact on energy efficiency and kWh savings in a specific operational area (Prity et al. 2024; Solnørdal et al. 2018).

This study aims to analyze the effectiveness of load balancing methods in reducing transformer load imbalance, minimizing neutral current, and optimizing kWh energy savings at the JE016 substation in Labu Lalar. The expected benefits of this research include both theoretical and practical contributions. Theoretically, this study enriches the literature on electrical distribution efficiency, particularly in transformer load management. Practically, the findings can serve as a reference for engineers and practitioners at PT PLN (Persero) in implementing load balancing strategies to reduce energy losses, improve service quality, and enhance the operational efficiency and lifespan of distribution transformers.

METHOD

The research related to the optimization of kWh savings at the JE016 Labu Lalar feeder substation was conducted at PT PLN (Persero) ULP Taliwang, located on Jalan Sutan Syahrir, Taliwang, West Sumbawa, from April to November 2025.

This study employed a quantitative research approach using an experimental method, which involved processing numerical data and applying scientific principles to test the research hypothesis (Waruwu, 2023).

The neutral current of the transformer was treated as the independent variable, while kWh savings served as the dependent variable, in order to evaluate energy losses before and after transformer load balancing.

The results of the JE016 substation load measurements were obtained from the Substation Management Application (AMG), an internal company system used to monitor load development (Tim Inovasi, 2013).

The object of this study focused on the energy losses caused by transformer neutral current resulting from load imbalance (Sari, 2018). To address this issue, load balancing was implemented to reduce the transformer's neutral current and, consequently, minimize energy losses.

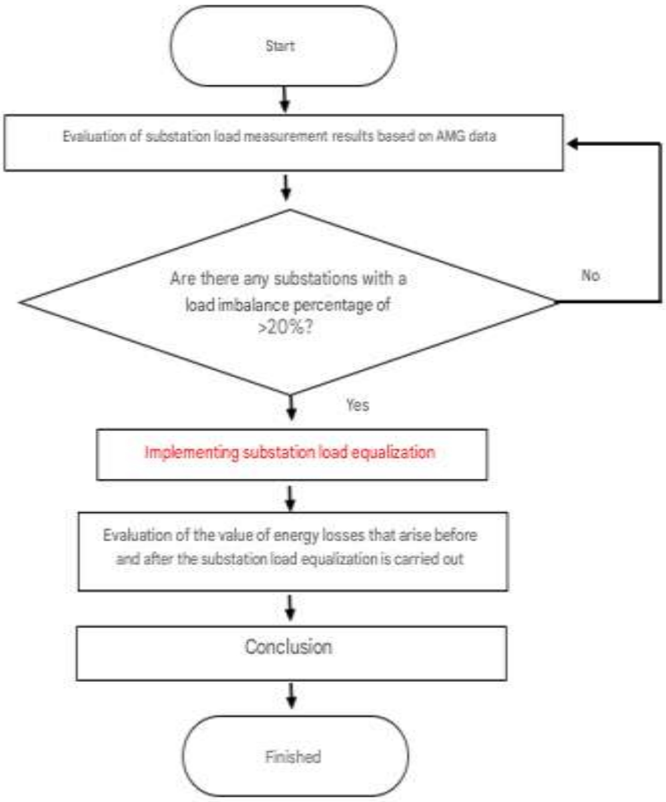

Figure 1. Research Flow Diagram

Source: Developed by the author, 2025

RESULTS AND DISCUSSION

A. *Load Measurement Data*

The AMG application as a storage and monitoring of substation load JE016 measurement results that are carried out every 4 months according to the substation load measurement period describes the measurement data in Table 1 below.

Table 1. Substation Load Measurement Results JE016

Measurement Time		**After Equity**		**Before Equity**	
	Date	**4 Oct 2025**	**25 Jun 2025**	**11 Jun 2025**	**24 Feb 2025**
	Time	**19:19**	**19:07**	**20:32**	**19:15**
Load Measurement of A Majors	R	53.7	66	58	55
	S	74.3	69	64	52
	T	61.1	62	54	54
	N	34	62	32	32
Load Measurement of Majors C	R	139.6	89	131	137
	S	57	63	61	56
	T	61.5	81	57	63
	N	65.8	59	64	77

Total Load (A)	R	196.7	159	202	192
	S	131.1	138	121	101
	T	124.6	140	109	114
	N	80	85	81	92
Tegangan (V)	R-S	389	397	390	398
	R-T	384	397	391	393
	S-T	392.9	398	391	399
	R-N	221	229	225	226
	S-N	226.1	230	226	230
	NL	223.6	230	225	227
Neutral Current to Ground (A)		51,3	42,5	46,7	44,8

Source: Field measurement data and AMG Application of PT PLN (Persero), 2025

B. *Load Balancing*

The load balancing of the JE016 substation will be carried out on June 11, 2025. The average load flow is as follows.

Irata-rata = $\frac{IR+IS+IT}{3}$

Irata-rata = $\frac{202+121+109}{3}$

Irata-rata = 144A

With the Average value, the difference value of each phase is calculated, for example in phase R as follows.

I'R = IR – Irata-rata
= 202 - 144
= 58A

In the same way, the other phases are grouped in the following Table 2.

Table 2. Difference in Value of Each Phase for Load Balancing

Irata-rata (A)	**I'(A)**		**Remarks**
	Fasa	**Value Difference**	
144	R	58	The load R is separated into the S and T phases by 58A
	S	-23	Receives an additional load of 23A from the R phase
	T	-35	Accepts a load of 35A from the R phase

Source: Author's calculation based on measurement data, 2025

C. *Load Calculation and Analysis Results*

Based on the results of the measurements in Table 3 that have been carried out, the value of the percentage of imbalance, the percentage of neutral current value to the load, power loss and energy loss, and the value of kWH that can be saved are as follows.

1. Load Imbalance Percentage (%UBL)

   Based on the results of the load measurement in Table 3, the calculation of the percentage of imbalance can be exemplified as follows.

   Irata-rata = $\frac{IR+IS+IT}{3}$

   Irata-rata = = 135.67A$\frac{192+101+114}{3}$

   With the value of the equilibrium coefficient as follows.

   a = (192) / (135.67) = 1.41
   b = (101) / (135.67) = 0.74
   c = (114) / (135,67) = 0,84

   Thus, the value of the percentage of load imbalance can be obtained as follows.

$\%UBL = \text{ x100\%}\frac{|a-1|+|b-1|+|c-1|}{3}$

$\%UBL = \text{ x100\%}\frac{|1{,}41-1|+|0{,}74-1|+|0{,}84-1|}{3}$

$\%UBL = \text{ x100\%} = 27{,}6\%\frac{0{,}83}{3}$

In the same way, the percentage of load imbalance is compiled in the following Table 3.

Table 3. Load Imbalance Percentage

Before Balancing	**After Balancing**		
24 Feb 2025	11 June 2025	25 June 2025	4 Oct 2025
27,68%	26,85%	6,10%	20,29%

Source: Author's analysis based on JE016 measurement data, 2025

It can be analyzed that the percentage of load imbalance tends to decrease to reach a value of 20% in accordance with the applicable standards which can be illustrated in Figure 1 below.

Figure 2. Load Imbalance Percentage Graph

Source: Author's data processing results, 2025

2. Neutral Current to Load Percentage

Based on the results of load measurement in Table 1, the calculation of the percentage of neutral current to load can be done as follows.

$\%IN = \text{x 100\%}\frac{IN}{Arus\ beban\ tertinggi}$

$\%IN = \text{x 100\%} = 47.92\%\frac{92}{192}$

In the same way, the percentage of neutral current to load can be gathered in the following Table 4.

Table 4. Percentage of Neutral Current Value to Load

Before Balancing	**After Balancing**		
Feb 24, 2025	11 June 2025	June 25, 2025	Oct 4, 2025
47,92%	40,10%	53,46%	40,67%

Source: Author's calculation based on measurement data, 2025

It can be analyzed that the value of the neutral current percentage to the load can be reduced which can be seen in Figure 3. This proves that the value of the neutral current can be reduced by balancing the load so that it can be used as a solution to reduce transformer losses.

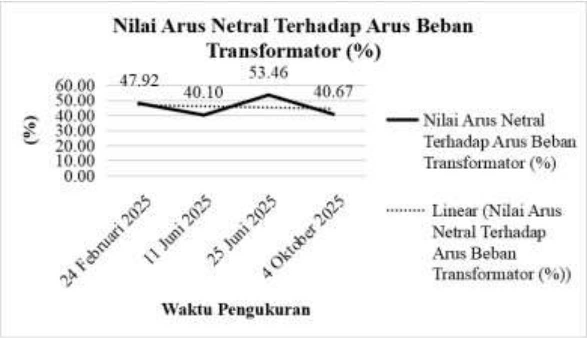

Figure 3. Graph of the Percentage of Neutral Current Value to Load
Source: Author's data processing results, 2025

3. Power Losses and Energy Losses

Power losses occur due to load imbalances that arise in the transformer. Power losses are obtained from the amount of neutral current value and neutral grounding value. It is known that the JTR NFA2X-T conductor has an impedance value of 0.568+h0.00845Ω/km. Based on the results of the measurements in Table 3 above, the calculation of the power losses of the neutral side of the transformer can be exemplified as follows.

$PN = IN^2 . R_N$

$PN = 922. 0,586$

$PN = 4807.55W = 4.81kW$

It is known that the grounding value of the JE016 substation is 2.2Ω, so the loss of transformer grounding power can be calculated as follows.

$PG = IG^2 . R_G$

$PG = 51,3^2 . 2,2$

$PG = 5789W = 5.79kW$

Energy losses can be calculated from power losses in table xx above assuming the duration of WBP is 6 hours/day.

$WN = P_N . t$

$WN = 10.6 . 6 = 63.58$ kWh/day

If the value is calculated in a 1-month (30-day) time period, it can be estimated to reach 317.92kWh/mo. The following is a set of transformer neutral side power losses, transformer grounding power losses, and energy losses according to the load measurement results in Table 5.

Table 5. Power and Energy Losses of Substation JE016

	Before Balancing		**After Balancing**	
Measurement Time	**24 Feb 2025**	**11 Jun 2025**	**25 Jun 2025**	**4 Oct 2025**
Neutral Current Loss (kW)	4,81	3,73	4,10	3,64
Neutral Landing Loss (kW)	5,79	3,97	4,80	4,42
Daily Energy Losses (kWh/day)	63,58	46,20	53,41	48,30
Daily Energy Losses (kWh/mo)	317,92	231,01	267,05	241,52

Source: Author's analysis based on measurement data and loss calculations, 2025

It can be illustrated in the graph the value of the transformer's neutral current power loss, transformer's neutral grounding power loss, and energy loss respectively at the time of measurement are shown in Figure 4, Figure 5, and Figure 6 respectively as follows.

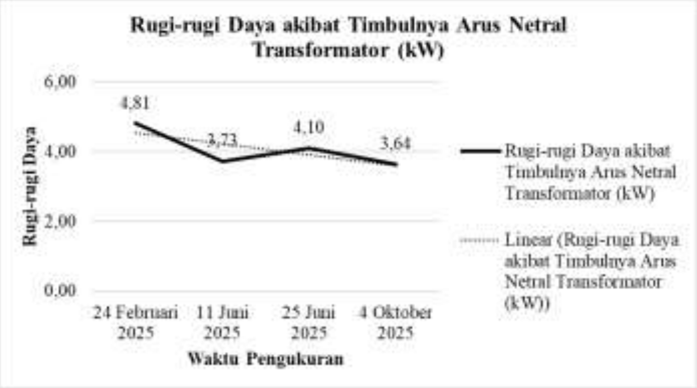

Figure 4. Transformer Neutral Current Power Loss Graph
Source: Author’s analysis, 2025

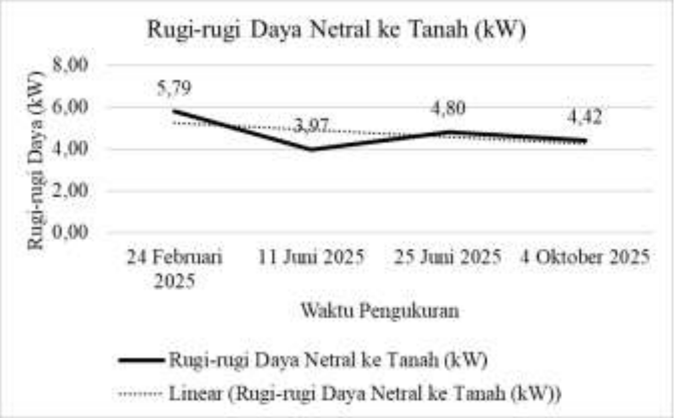

Figure 5. Transformer Neutral Grounding Power Loss Graph
Source: Author’s analysis, 2025

Figure 6. Graph of Daily and Monthly Energy Losses Incurred on Transformers
Source: Author’s data processing results, 2025

Based on the results of the calculation of power losses above, the neutral current losses of the transformer can be reduced to 1.17kW and the loss of transformer grounding power can be reduced to 1.37kW. The value of power losses can decrease significantly so that the value of energy losses that arise can be reduced to an average value of 25.47kWh/month or 5.09kWh/day. So, it can be said that this load balancing method can be used as a method of saving kWh transformers by reducing the losses that arise.

4. Salvageable kWh Value
   The value of kWh that can be saved as an illustration of the effectiveness of the transformer's energy loss suppression using the load balancing method. This value can be obtained from the results of the following calculation.
   kWh saved = energy loss before – energy loss after.
   kWh saved = 317.92 – 231.01
   kWh saved = 86.91kWh
   Respectively, the kWh values saved were 86.91kWh, -36.04kWh, and 25.35kWh. It is known that the value of kWh saved on June 25, 2025 has decreased or rather no kWh has been saved. When compared to the value of kWh that can be saved on October 4, 2025, the value of kWh that can be saved is 25.23kWh. This shows that the time of load measurement greatly affects the accuracy of the load measurement results so it is highly recommended to carry out load measurements according to the characteristics of the load to be measured.

CONCLUSION

Based on the calculation and analysis of the JE016 substation load before and after load balancing, load balancing proved to be an effective strategy for optimizing kWh savings. The measurements conducted on October 4, 2025, showed that the load imbalance percentage decreased to 20.29%, while the ratio of neutral current to load dropped to 40.67%. This reduction in imbalance directly contributed to lower transformer losses, as indicated by an increase in energy savings of up to 25.53 kWh. These results demonstrate that the magnitude of load imbalance significantly influences the amount of kWh that can be saved, confirming that load balancing is an appropriate and effective method for improving energy efficiency, reducing transformer losses, and optimizing transformer utilization, which may also extend the operational lifespan of distribution transformers. For future research, it is recommended to explore the integration of real-time monitoring systems and automated phase balancing technologies to further enhance efficiency and achieve more consistent and scalable kWh savings across different substations.

REFERENCES

Ali, B., & Siddique, I. (2017). Distribution system loss reduction by automatic transformer load balancing. In *2017 International Multi-Topic Conference (INMIC)* (pp. 1–5). IEEE.

Ayuningtyas, D., Afandi, A. N., & Sujito, S. (2023). Analysis of loads effect on neutral current of distribution transformers. In *2023 International Seminar on Application for Technology of Information and Communication (ISemantic)* (pp. 97–100). IEEE.

Basyiruddin, A., & Anisah, S. (2025). Analysis of distribution network losses of Nr. 04 feeders at Namorambe substation (PLN ULP Johor case study). *International Conference of Digital Sciences and Engineering Technology*, 116–130.

Chen, J., Yang, T., O'Loughlin, C., & O'Donnell, T. (2018). Neutral current minimization control for solid state transformers under unbalanced loads in distribution systems. *IEEE Transactions on Industrial Electronics, 66*(10), 8253–8262.

Chen, J., et al. (2020). Neutral current optimization control for smart transformer-fed distribution system under unbalanced loads. *IEEE Journal of Emerging and Selected*

Topics in Power Electronics, 9(2), 1696–1707.

Chew, B. S. H., Xu, Y., & Wu, Q. (2018). Voltage balancing for bipolar DC distribution grids: A power flow based binary integer multi-objective optimization approach. *IEEE Transactions on Power Systems, 34*(1), 28–39.

Eduful, G., & Atanga, K. J. A. (2016). Analysis of high neutral currents and harmonic impacts on losses and capacities of distribution transformers. In *Proceedings of the World Congress on Engineering*.

Ibrahim, I. A., & Hossain, M. J. (2021). Low voltage distribution networks modeling and unbalanced (optimal) power flow: A comprehensive review. *IEEE Access, 9*, 143026–143084.

Pan, Z., et al. (2016). A transformer neutral current balancing device to restrain half-cycle saturation induced by HVDC monopolar operations. *Electric Power Systems Research, 132*, 104–114.

Prastia, R., et al. (2024). Analysis of voltage drop improvement using transformer insertion method in LG-02 receiver Lhokseumawe city. *Applied Engineering, Innovation, and Technology, 1*(1), 47–58.

Pratama, N. A., & Rahmawati, Y. (2020). Evaluation of unbalanced load impacts on distribution transformer performances. *Frontiers in Energy Systems and Power Engineering, 2*(1), 28–35.

Prity, F. S., & Hossain, M. M. (2024). A comprehensive examination of load balancing algorithms in cloud environments: A systematic literature review, comparative analysis, taxonomy, open challenges, and future trends. *Iran Journal of Computer Science, 7*(3), 663–698.

PT PLN (Persero). (2010a). *Buku 1: Kriteria desain enjiniring konstruksi jaringan distribusi tenaga listrik*. PT PLN (Persero).

PT PLN (Persero). (2010b). *Buku 4: Standar konstruksi gardu distribusi dan gardu hubung tenaga listrik*. PT PLN (Persero).

PT PLN (Persero). (2014). *Surat edaran direksi nomor 0017.E/DIR/2014 tentang metode pemeliharaan transformator distribusi berbasis kaidah manajemen aset*. PT PLN (Persero).

Sari, G. A. K. (2018). *Analisa pengaruh ketidakseimbangan beban terhadap arus netral dan losses pada trafo distribusi studi kasus pada PT PLN (Persero) Rayon Blora* (Skripsi). Universitas Muhammadiyah Surakarta.

Shao, C., et al. (2024). Multiple-zone synchronous voltage regulation and loss reduction optimization of distribution networks based on a dual rotary phase-shifting transformer. *Sustainability, 16*(3), 1029.

Sinurat, A. F., & Mungkin, M. (2026). Optimization of three-phase load balancing to improve the efficiency and reliability of power transformers at the Tanjung Morawa substation. *Journal of Computer Science, Information Technology and Telecommunication Engineering, 7*(1), 1119–1127.

Solnørdal, M. T., & Foss, L. (2018). Closing the energy efficiency gap—A systematic review of empirical articles on drivers to energy efficiency in manufacturing firms. *Energies, 11*(3), 518.

Tim Inovasi. (2013). *Panduan aplikasi manajemen gardu*. PT PLN (Persero) Area Mataram Wilayah Nusa Tenggara Barat.

Waruwu, M. (2023). Pendekatan penelitian pendidikan: Metode penelitian kualitatif, metode penelitian kuantitatif dan metode penelitian kombinasi (mixed method). *Jurnal Pendidikan Tambusai, 7*(1), 2896–2910. https://doi.org/10.31004/jptam.v7i1.6187

Zulfiyan, L. (2026). Analysis of voltage drop causes at SMK Ponpes Manbaul Ulum Cirebon. *Journal of Emerging Innovations in Engineering, 2*(1), 31–42.