The 2nd International Conference on
Multidisciplinary Engineering
(2nd ICOMDEN 2024)

Proceedings of International Conference on Multidisciplinary Engineering (ICOMDEN): 00002 (2024)
https://doi.org/10.29103/icomden.v2.xxxx
Volume 2, 2024
eISSN: xxxx-xxxx

Research Original Article

Putri Mandasari[1] Badriana[2] Fakhruddin Ahmad Nasution[3]
[1]Department of Electrical Engineering, Malikussaleh University, Muara Satu, Lhokseumawe, Indonesia, putri.200150070@mhs.unimal.ac.id
[2]Department of Electrical Engineering, Malikussaleh University, Muara Satu, Lhokseumawe, Indonesia, badriana@unimal.ac.id
[3]Department of Electrical Engineering, Malikussaleh University, Muara Satu, Lhokseumawe, Indonesia, fakhruddinahmadnst@unimal.ac.id
✉Corresponding Author : **badriana@unimal.ac.id | Phone: +62852-7744-4558**

Abstract

Load maneuvering on the power distribution network can have a significant impact on voltage drops along the *feeder,* especially in distribution substations such as PT. PLN (Persero) Idi Substation. The analysis was carried out to examine the effect of load maneuver on voltage drops in several *feeders* at the substation. The data used included a single line diagram, daily load patterns, feeder cable lengths and the number of *feeders* analyzed. Using ETAP simulation software, this study evaluates the percentage drop in voltage during load manoeuvre operations to determine its conformity to operational standards. This analysis identifies critical feeders where voltage drops exceed the allowable threshold, and provides solutions to mitigate these problems, thus ensuring stable power supply and minimizing the risk of low voltage during the load transfer process. This study analyzes the voltage *drop* in the electricity distribution network at PT. PLN (Persero) Idi Substation using two methods, namely manual calculation and ETAP simulation. The results of the analysis show that the value of the voltage drop percentage from the manual calculation is 1.85%, while the results of the ETAP simulation show a value of 0.013%. This significant difference shows that the method that the simulation method is more accurate in modeling the conditions of the distribution network. As an effort to mitigate voltage drops in the electricity distribution network at PT. PLN (Persero) Idi Substation, an increase in transformer capacity was carried out. The capacity of power transformer 1 is increased from 20 MVA to 25 MVA and power transformer 2 from 30 MVA to 40 MVA. In addition, the size of the cable cross-section was also increased from 240 mm to 300 mm. These results can be used as a reference in network performance evaluation and decision-making for load maneuvering to ensure a more efficient and reliable distribution of electricity.

Keywords: Load maneuver, voltage drop, ETAP simulation, mitigation efforts.

Introduction

Electrical energy is one of the most important things in human life. Electrical energy is needed in several sectors, namely the household, industry, business, social, government office buildings, and public street lighting. Electrical energy, which has become a consumer need and is one of the axes of economic drivers, has also become a necessity for the industry, so there is a need for reliable services in the process of distributing electrical energy to improve the standard of living of Indonesian consumers. Electric power systems around the world have evolved as isolated systems. They are built to distribute electrical power from centralized power stations to a wide area distributed load. The provision of stable electrical energy is an absolute requirement that must be met in meeting the needs of electrical energy [2].

To minimize power outages, it is necessary to carry out regular maintenance to ensure that the equipment is working properly. When routine maintenance is carried out, electricity must also be distributed to consumers. Maintenance with mains voltage can be dangerous if it is carried out not in accordance with the standard of work operations. One of the routine maintenance of the power transformer bay can be done and the consumer remains connected by manipulating the load of the power transformer [3].

The Idi Aceh Timur substation is a substation with a voltage of 150 kV located in East Aceh Regency, Aceh Province. This substation serves the needs of electric power in the East Aceh region and its surroundings. The reliability of the East Aceh Idi Substation is very important to maintain a smooth electricity supply in the region. Therefore, it is important to perform a voltage drop analysis when manoeuvring the load of the power transformer in this substation to determine its impact on the reliability of the substation and take the necessary steps to minimize such impact. The reliability of the electrical system at the idi substation is very important to ensure a stable and quality electricity supply for customers. One of the factors that can affect the reliability of the electrical system is the occurrence of voltage drops when manoeuvring the load of the power transformer. Load maneuvering can include adding, subtracting, or moving loads from one part of the network to another, affecting the flow of power in the system. These changes cause different current distributions through the conductors, resulting in voltage changes at specific points in the grid [4].

Voltage drop *(voltage drop*) refers to the decrease in electrical voltage that occurs when electricity flows through certain components or segments in an electrical power distribution system, such as cables, transformers, or loads. In the context of load maneuvering, voltage drops occur due to changes in load distribution or switching operations carried out in the power distribution network. Voltage drop due to load maneuvering is a voltage drop that occurs in the power grid when there is a sudden change or shift in load. Load maneuvering can include adding, subtracting, or moving loads from one part of the network to another, affecting the flow of power in the system[5].

Materials & Methods

In an electrical system, the phase angle between current and voltage determines the power factor, which affects the efficiency of power delivery. A large phase angle indicates that there is a lot of reactive power that is not doing any real work, so the system becomes less efficient.

Table 1. Phase Angle

No	Parameter	Symbol	Value
1	Phase Angle	θ	30^{o}
2	Cosine Sudut	Cos (30^{o})	0,866
3	Angular sinus	Without (30^{o})	0,5
4	Angular Tangent	Tan (30^{o})	0,577

Feeder or *Feeder* is a vital component in the electric power distribution system. It acts as a connecting bridge between substations, which serve as the center for the transformation and distribution of high-voltage electrical energy, with various load points such as factories, housing, office buildings, and other commercial centers. Simply put, the feeder functions to distribute electrical energy from the main source to the places where it is needed. Through the feeder network, electrical energy that was previously of high voltage is transmitted and lowered to a level suitable for use by various types of electrical equipment[26]. At the idi substation there are 7 trays in operation, the following are the trays found in the idi substation:

Tabel 2. *The feeder* guard was induke

It	Name of Tray	
	Trafo Daya 1	Trafo Daya 2
1	Idi 1 (Polres)	Idi 9 (Ranto Peureulak)
2	Idi 2 (GH Kota Binje)	Idi 10 (GH Kota Idi)
3	Idi 6 (Alue Bu)	Idi 11 (Ranto Peureulak)
4	-	Idi 12 (Company)

A. Research Location

This research was conducted at PT. PLN (Persero) Iduk Idi Substation located in Paya Bili 1 village, Peudawa District, East Aceh Regency postal code 24454.

B. *Research Stages*

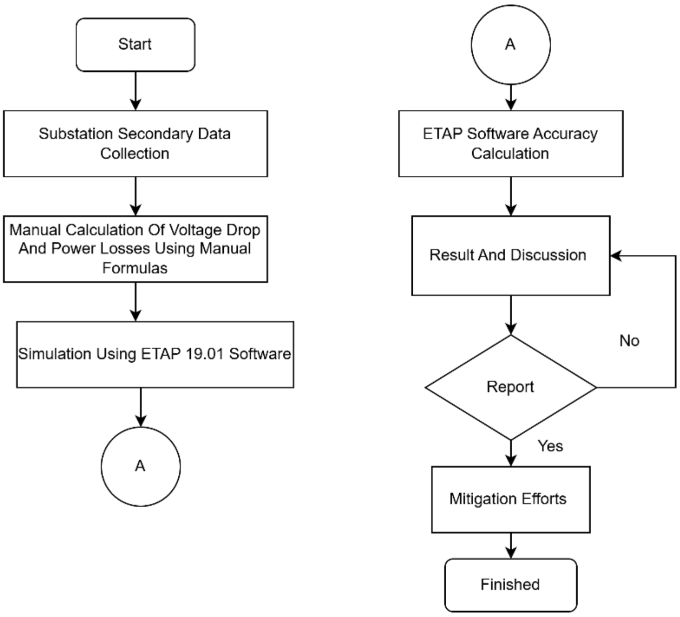

Figure 1. Research Flow Diagram

Results And Discussion

A. *Results of manual calculations before and after the maneuver*

In this calculation, the author focuses on calculating one of the feeders, namely the Idi 1 feeder (Polres) with a feeder length of 12.26 km and calculates each phase of R, S, T. The purpose of the manual calculation before using ETAP is to initially identify the feasibility of a feeder to receive maneuvers from other feeders. Feasibility is determined by looking at whether the voltage drop percentage on the tray exceeds the specified tolerance, in this case the tolerance limit in accordance with SPLN 72 of 1987 is a maximum of 5% - 10%.

Table 3. Manual Voltage Drop Percentage

No	Feeder Name	Percentage of Voltage Before Maneuver (%)			Voltage Percentage After the Maneuver (%)		
		R	S	T	R	S	T
1.	Idi 1 (Polres)	1,8	1,7	1,6	3,6	3,4	3,2
2.	Idi 2 (GH Binje City)	1,6	1,8	1,7	3,1	3,6	3,4
3.	Idi 6 (Alue Bu)	0,8	0,8	0,8	1,7	1,7	1,7
4.	Idi 9 (GH Perlak)	1,6	1,6	1,6	3,2	3,2	3,2
5.	Idi 10 (GH Kota Idi)	1,9	1,9	1,9	3,7	3,9	3,9
6.	Idi 11 (Ranto Perlak)	1,4	1,4	1,4	2,6	2,7	2,7
7.	Idi 12 (Company)	0,1	0,2	0,1	0,3	0,4	0,4

Voltage drops and power losses on the feeder during power transformer load maneuvers can be calculated using several formulas, depending on the model used and the data available. Here are some commonly used formulas:

$$\Delta V1 = \sqrt{3} \text{ x } I1 \text{ x } (R_{total} \cos\theta \text{ x } + X_{total} \text{ without } \theta)$$
$$\Delta V2 = \sqrt{3} \text{ X } I2 \text{ } (R_{total} \cos\theta + X \text{ total without } \theta)$$

Where:
$I1$ = Load current before maneuver

I2 = Load current after maneuver
Rt = Total reactance
X t= Total reactance
Phase Angle = $30\theta°$

In the substation or transformer, there is a tap changer that can automatically adjust the voltage. If the current increases, the tap changer automatically raises the voltage to keep the voltage stable. That is, even if the current increases (which usualy causes a *voltage drop*) the tap changer adjusts the voltage at the source to compensate for the effect of the increased current. The feeder is connected to a source with a higher capacity so that the voltage in the feeder rises even as the current increases.

Table 4. Power Loss Before and After Manual Maneuver

No	Feeder Name	Loss of Power Before Maneuver (Watts)			Power Loss After Maneuver (Watts)		
		R	S	T	R	S	T
1.	Idi 1 (Polres)	60.552	52.488	48.672	233.928	206.082	190.962
2.	Idi 2 (GH Binje City)	45.904	58.482	52.448	118.804	227.812	204.160
3.	Idi 6 (Alue Bu)	12.168	12.168	12.168	54.450	55.444	55.444
4.	Idi 9 (GH Perlak)	47.740	48.672	48.672	187.272	187.272	187.272
5.	Idi 10 (GH Kota Idi)	63.724	68.080	69.192	252.760	267.912	267.912
6.	Idi 11 (Ranto Perlak)	34.848	36.450	37.264	124.002	134.680	130.050
7.	Idi 12 (Company)	648	882	648	2.592	3.280	2.812

$$Ploss1 = 3\ x\ I1\ 2\ x\ Rtotal$$
$$Ploss2 = 3\ x\ I2\ 2\ x\ Rtotal$$

C. *ETAP Simulation Results*

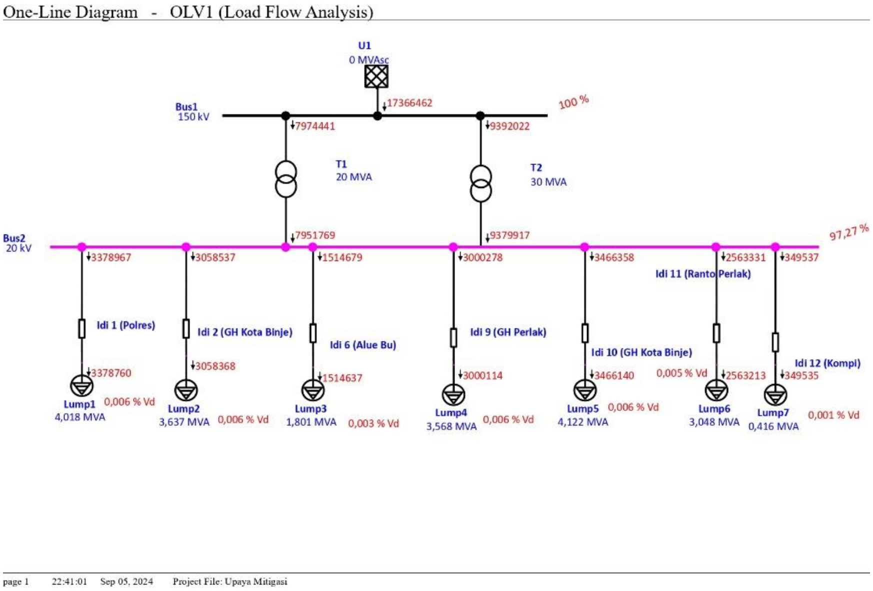

Figure 2. ETAP Simulation Before Maneuvering

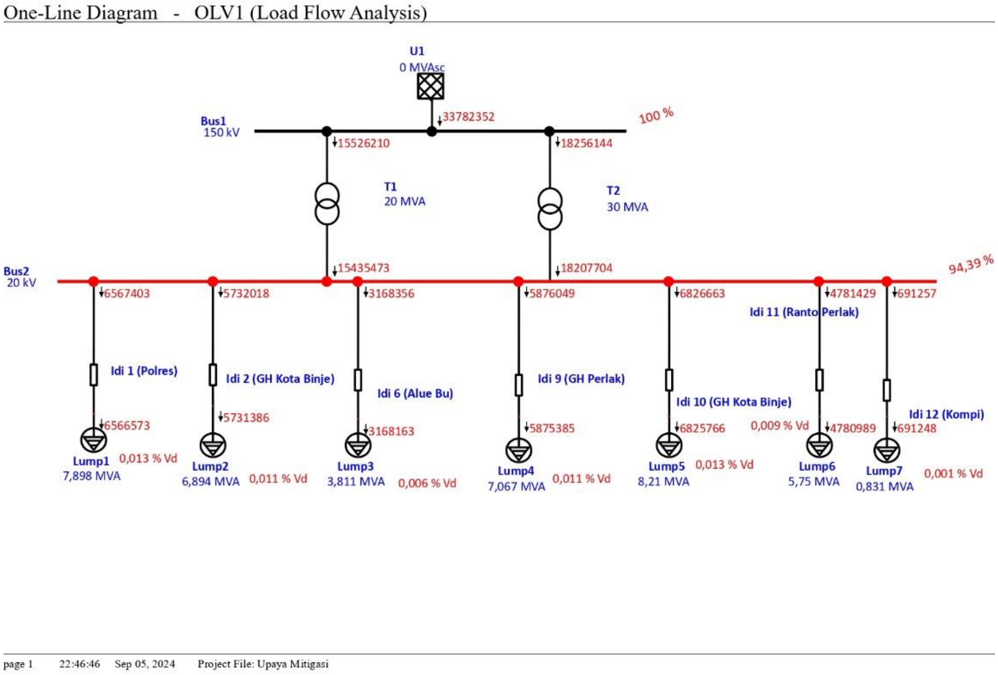

Figure 3. ETAP Results After Maneuver

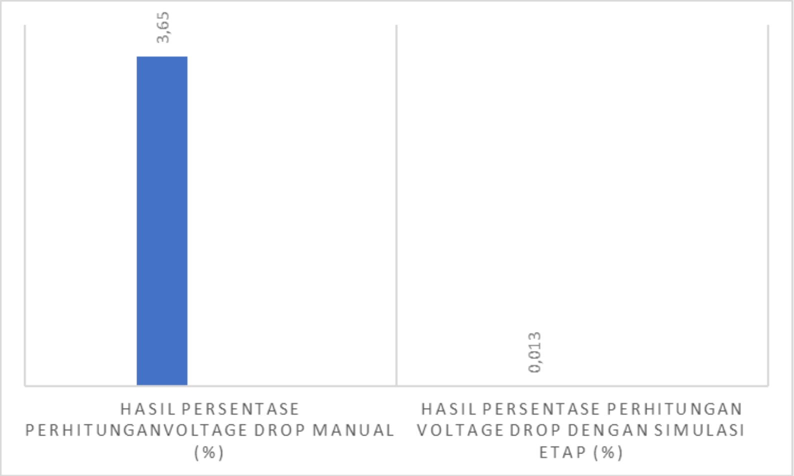

Figure 4. Comparison of Manual and ETAP Voltage Drop

Based on the table and graph above, it shows a significant difference between the results of the percentage of voltage drop calculation using the manual method and the ETAP simulation for the feeder "Idi 1 (Polres)." The results of the manual calculation showed a voltage drop of 3.65%, while the ETAP simulation showed a much smaller voltage drop, which was 0.013%. This striking difference emphasizes the advantages of using ETAP in the analysis of electricity distribution systems. This huge percentage difference can be explained by several factors. Manual methods often rely on assumptions that may be less accurate, and do not consider all variables and operational conditions in detail.

In contrast, ETAP is a simulation tool designed to better handle the complexities of electrical distribution systems, taking into account various factors such as cable impedance, dynamic loads, and system configurations in more detail. ETAP is also able to run simulations under various operational conditions and provide more in-depth and accurate analysis. Therefore, the results of the ETAP simulations tend to be more precise, reflecting the real conditions of the electricity distribution system better than manual calculations.

D. Mitigation Efforts

From the results of the calculation and analysis, it can be seen that *the drop voltage* on the *feeder* studied is still below the tolerance limit after load maneuvers in manual calculations and ETAP simulations, this indicates that the current electricity distribution system is still in a stable condition and operates in a safe and acceptable range. However, it is important to remember that system conditions can change over time, especially in the event of additional loads, changes in network configurations, or other external factors that affect system operations. Therefore, even though the current drop voltage is still within the permissible limits, long-term actions and strategies are needed to ensure the ETAP system operates safely and efficiently in the future.

Although the results in this study are still below the tolerance limit, it is necessary to anticipate if in the future there will be a more significant drop voltage due to increased load, system configuration changes, or unexpected operating conditions.

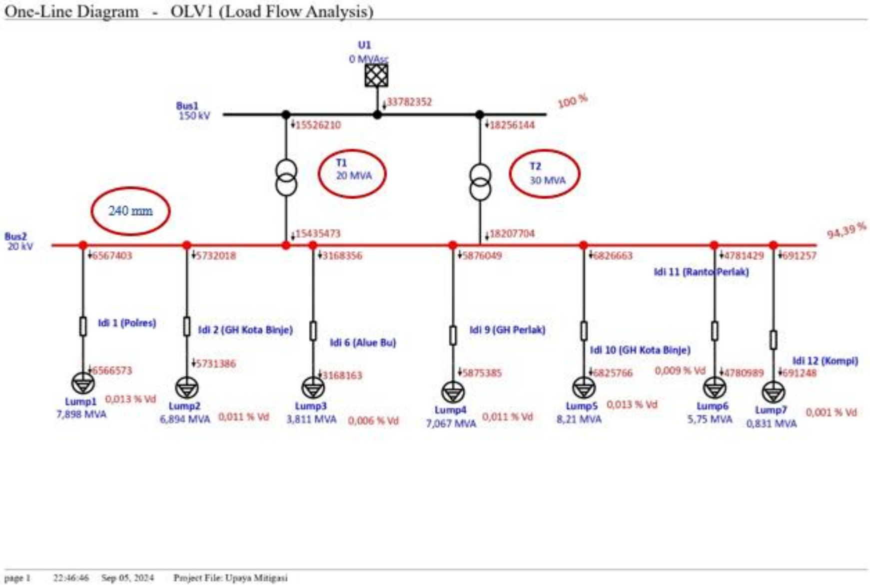

Figure 5. *Voltage Drop* Before Mitigation Efforts

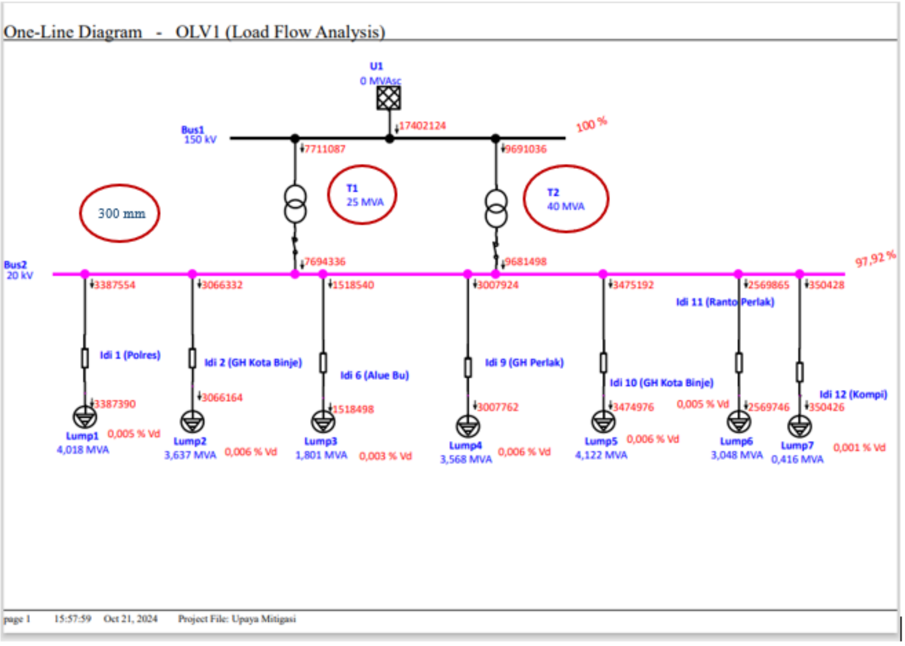

Figure 6. *Voltage Drop* After Mitigation Efforts

Conclusion

1. The conclusion from the results of the analysis and discussion, *the voltage drop* percentage value with manual calculation produced a value of 1.85%, while the ETAP simulation produced a value of 0.013%.
2. Mitigation efforts are carried out by increasing the capacity of power transformer 1 from 20 MVA to 25 MVA, power transformer 2 which was originally worth 30 MVA to 40 MVA. In addition, mitigation efforts are also carried out by increasing the size of the cable cross-section which was initially 240 mm to 300 mm.
3. The results of the manual calculations show a higher voltage drop compared to the ETAP simulation. These differences indicate that manual calculation methods often simplify or ignore some important variables that affect system performance, such as cable impedance, uneven load distribution, or dynamic changes in the power grid. In contrast, ETAP simulations are able to consider a variety of factors in more detail and realistically, including component characteristics, network configurations, and actual operating conditions. Therefore, the results of manual calculations tend to be less accurate when applied to distribution systems.
4. The results of manual and simulation calculations show significant differences, where the results of ETAP simulations show a much smaller voltage drop value compared to manual calculations. This difference shows that ETAP simulations are able to provide more accurate results by taking into account various variables that may not be taken into account in manual calculations. Thus, the use of ETAP in the analysis of electrical distribution systems is highly recommended to obtain more precise and accurate results, especially in complex operating conditions such as load maneuvering.
5. The more accurate the data in the field input into ETAP, the smaller the error rate or the more accurate the ETAP simulation value is.
6. The results of the calculation of the manual percentage or ETAP simulation did not exceed the tolerance limit, which is 5% - 10%.

Bibliography

[1] S. Purwanto, S. Rahayu, and A. Z. Burhan, "Energy and Electricity: Scientific Journal of Design and Construction of Load Supply Regulation System in Hybrid Power Plants for Household Electricity Group R-1 / Tr 2200 Va Energy and Electricity: Scientific Journal," *Energy and Electricity J. Ilm.*, vol. 14, no. 2, pp. 169–178, 2023, [Online]. Available: https://jurnal.itpln.ac.id/energi/article/view/1006

[2] Y. Hakimah, "Analysis of electricity needs and addition of power plants," *J. Chem. Inf. Model.*, Vol. 53, No. 9, pp. 1689–1699, 2019.

[3] Imdadullah, S. M. Amrr, M. S. Jamil Asghar, I. Ashraf, and M. Meraj, "A comprehensive review of power flow controllers in interconnected power system networks," *IEEE Access*, vol. 8, pp. 18036–18063, 2020, doi: 10.1109/ACCESS.2020.2968461.

[4] A. Jamaah, "Section Load Analysis to Determine Alternative Maneuvers for the 20 kV Distribution Network of BRG-3 Feeder PT PLN (Persero) Salatiga Service Unit," *Jtet*, vol. 2, no. 3, p. 160, 2013.

[5] M. A. Sobikin, "Voltage Drop Analysis and Network Maneuver on SGN11 Repeater and SGN14 Repeater Using ETAP 16.0.0 Software," *Cyclotron*, vol. 5, no. 1, 2022, doi: 10.30651/cl.v5i1.10638.

[6] Musthopa, B. Harsanto, and A. Yunani, “Electric power distribution maintenance model for industrial customers: Total productive maintenance (TPM), reliability-centered maintenance (RCM), and four-discipline execution (4DX) approach,” *Energy Reports*, Vol. 10, no. September, pp. 3186–3196, 2023, Yogurt: 10.1016/J.Egir.2023.09.129.

[7] A. Ramadhan and B. Yulianti, "Power Meter on Scada Telemetering at 150 Kv Substation to Improve Data Accuracy," *J....*, 2022.

[8] R. H. Annuru and I. Abdi Bangsa, "Optimization of Network Maneuvers Using Supervisory Control and Data Aquisition (SCADA) in Improving the Reliability of the 20 Kv Distribution System at Pt Pln (Persero) Up3 Bekasi," *Aisyah J. Informatics Electr. Eng.*, vol. 6, no. 1, pp. 56–66, 2024, doi: 10.30604/jti.v6i1.167.

[9] C. A. Santjiatodjaja, L. S. Patras, G. Mangindaan, and J. T. Elektro-ft, "Analysis of Running Waves on the 70 kV Transmission Line of the Teling Substation," *Anal. Waves travel on the transm channel. 70 kV Teling Substation*, vol. 8, no. 1, pp. 1–8, 2019.

[10] S. R. Pertiwi, U. Latifa, R. Hidayat, and I. Ibrahim, “Analisis Kelayakan CVT (Capacitive Voltage Transformer) Phasa S Bay Busbar 2 150 kV di GI PT. XYZ Indonesia,” *Techné J. Ilm. Elektrotek.*, vol. 20, no. 1, pp. 35–42, 2021, doi: 10.31358/techne.v20i1.259.

[11] E. S. Wardoyo, A. S. Sinaga, E. Ohee, and I. Article, "Analysis of power losses due to load imbalance in distribution transformers," pp. 1–6, 2023.

[12] R. Ondrialdi, U. Situmeang, and Zulfahri, "Analysis of Insulation Quality Testing of Power Transformers at PT. Indah Kiat Pulp and Paper Perawang," *SainETI*, vol. 4, no. 2, pp. 72–81, 2020, doi: 10.31849/sainetin.v4i2.6288.

[13] Ari Susanto, "Based on the Results of Isolation Prisoner Tests, Prisoners," *Fac. Tech. Tanjungpura University*, 2021.

[14] A. G. Firdaus and R. Hidayat, "Analysis of the Feasibility Testing of PMT 150 kV Bay Mandirancan I Based on Breaker Analyzer Parameters at Sunyaragi Substation," *Elektron J. Ilm.*, Vol. 13, pp. 17–24, 2021, yogurt: 10.30630/AG.0.0.217.

[15] D. S. Lambey, N. Amin, Y. S. Pirade, and R. Santoso, "Energy Efficiency in the Office of the Regional People's Representative Council of Tojo Una-Una Regency," pp. 108–114, 2021.

[16] I. Roza, L. A. Siregar, and A. A. Nasution, "Reducing the Percentage of Voltage Drop in the 20 Kv Substation Feeder of Pt. Pln (Persero)," *Semin. Us. Running. …*, vol. 16, no. 1, p. 6, 2020.

[17] R. Ardiansyah, M. L. I., S. D. S., M. Facta, . S., and A. A. Z., "Design of Comparative Equipment for Measurement of Passive Resistance and Reactance Parameters of 150 Kv Transmission Tower Material," *Transient J. Ilm. Tek. Elektro*, vol. 13, no. 1, pp. 1–10, 2024, doi: 10.14710/transient.v13i1.1-10.

[18] P. Mangera, M. Rusdi, and A. P. Fridana, "Analysis of Voltage Loss of 20 Kv Distribution Network in Company C Feeder Pt. Pln (Persero) Up3 Merauke Introduction Electricity is one of the necessities of life, which is used to support daily life activities. Electrical energy is a joint," vol. 12, no. 01, 2023.

[19] A. T W and S. P. Astuti, "Testing the Relationship of Inductive Reactance in Inductors to Changes in Current Source Frequency with LEDs as Indicators," *Navig. Phys. J. Phys. Educ.*, vol. 3, no. 2, pp. 59–65, 2022, doi: 10.30998/npjpe.v3i2.803.

[20] A. Nizar, "Analysis of the Use of ETAP in Life," *J. Tek. Elektro*, vol. 10, pp. 195–202, 2021.