

Optimizing Technical Losses of the PLN Distribution Network with Changes in Operational Patterns in 2023 at PLN ULP Lhokseumawe

Arnawan Hasibuan^{1*}, Ari Afrizal¹, Misbahul Jannah¹, Sapto Nisworo², Fajar Syahbakti Lukman³, and I Made Ari Nrartha⁴

¹Department of Electrical Engineering, Malikussaleh University
Jl. Batam No.16 Kampus Bukit Indah Muara Satu, Lhokseumawe 24351

²Department of Electrical Engineering, Tidar University
Jl. Kapten Suparman 39 Potrobangsari, North Magelang 56116

³PT. PLN (Persero) UP3 Lhokseumawe

Jl. Merdeka, No. 2, Cunda, Lhokseumawe 24351

⁴Department of Electrical Engineering, Mataram University
Jl. Majapahit No.62 Selaparang, Mataram 83125.

*e-mail: arnawan@unimal.ac.id

Abstract—Technical shrinkage is shrinkage caused by impedance in generation equipment or transmission equipment to the distribution network so that there is energy loss. There are several technical shrinkage problems at PT. Perusahaan Listrik Negara (PLN) especially in Customer Service Unit (ULP) Lhokseumawe City and for now the cause is still unsolved, because this technical shrinkage problem will harm and have an impact on consumers and PLN itself. The purpose of the study was to optimize technical shrinkage in the distribution network to reduce energy losses that occurred during the electrical power distribution process in the distribution network of PT. PLN (Persero) ULP Lhokseumawe City. This study uses the help of Electrical Transient Analyzer Program (ETAP) software to simulate the power flow so that the depreciation value that occurs is obtained, then re-load adjustment is carried out to simulate again to determine the change in the depreciation value obtained after load adjustment. The results of the ETAP simulation show the depreciation value that occurred before the load adjustment was made by 76.7 kW after the depreciation load adjustment was adjusted to 59.6 kW. This means that this technical shrinkage can be suppressed by changing the feeder operation pattern and voltage drop value in accordance with the limitation provisions set in SPLN 72:1987.

Keywords: *etap, losses, load adjustment, power distribution network, technical shrinkage optimization*

I. INTRODUCTION

PT. Perusahaan Listrik Negara (PLN) is an Indonesian state-owned company that has the task of regulating all electrical parts throughout Indonesia. The existence of quality and sufficient electricity supply has a significant impact on sooner or later economic growth and development in various sectors. As well as supporting productivity for the community [1]. Broadly speaking, the distribution system starts from the feeder of the substation (GI) then divided and flowed to the Customer Service Unit (ULP). This line conducts electricity that reaches so far that it causes current and voltage to disappear or known as voltage drop [2].

Voltage drop in general can be interpreted by the voltage applied to the load [3]. The voltage drop is caused due to the current running past the resistance of the wire. The voltage drop on the conductor increases when the current in the conductor is greater and if also the resistance of the

conductor is greater [4]–[7]. Power loss in power system networks can be affected by several factors, including load imbalances of three-phase systems, high temperatures generated by line conductors and transformers, as well as heat generation in poor conductor connections (loss contact) [8].

There are several kinds of disturbances that usually exist in distribution channels such as technical shrinkage, this technical shrinkage disorder is a problem found by PT. PLN (Persero), especially in ULP Lhokseumawe City and for now the cause is still unsolved, because this technical shrinkage problem will harm and have an impact on consumers and PLN itself [3]. From these problems, it is necessary to conduct a technical shrinkage study to see the amount of shrinkage along the distribution channel, this is done to determine whether the technical shrinkage that occurs has a large enough value or has a low value in accordance with the provisions of PT. PLN, which later after the cause and effect of technical shrinkage is known,

can be carried out the maintenance and repair needed for this technical shrinkage [9]. In conducting this study, Electrical Transient Analyzer Program (ETAP) software is used, this program is a consideration in solving electrical problems so that technical shrinkage problems based simulation [4], [10].

This technical shrinkage cannot be 100% avoided because the equipment may not have a high efficiency value, but it needs to be underlined that the technical shrinkage that occurs is still within the limits of fairness in accordance with the regulations of PT. PLN (Persero). Considering the crucial information about the amount of shrinkage in a distribution network for the purposes of planning the development of the network. So, there is a need to learn about energy shrinkage in distribution network systems [11]. To increase voltage and to control reactive power, the distribution system is equipped with many voltage control devices such as network restructuring, tap change transformer, voltage regulator, shunt/series capacitor etc. [12]. Based on the explanation, this work was conducted to optimize the technical shrinkage of electric power distribution network with changes in operating patterns in 2023 at PT PLN (Persero) ULP Lhokseumawe City using ETAP simulation software.

II. LITERATURE STUDY

A. Electric Power Distribution Network

Electrical energy distribution is the last process of distributing electrical energy from the transmission system to customers [13], this distribution network usually includes medium voltage networks and low voltage networks (below 50 kV). Distribution voltage can be categorized into two types, namely primary distribution and secondary distribution. The primary distribution network is called medium voltage (20 kV) while the secondary distribution network is called low voltage (220/380 V).

When distributing electricity over long distances, the issue that must be avoided is the occurrence of voltage drops if the feeder is too far away from the distribution substation. Hence, the location of one substation to another must consider the size of the load and distance so that there is no voltage drop on the 20 kV side.

B. Electric Power

Power can be said by the use of energy to run a job. In electrical systems, power can be interpreted as electrical energy used to do work [14]. Or power can also be interpreted by the product between voltage and electric current. When applying power is divided into several types, namely active power denoted by P with its unit Watt, reactive power denoted by Q with its unit VAR, then apparent power denoted by S with its unit VA.

C. Distribution Network Losses

Generally, losses can be distinguished into two types, namely technical losses and non-technical losses [15], while the explanation between the two is as follows.

1. Technical shrinkage is shrinkage caused by impedance in generating equipment or transmission equipment to the distribution network, as a result of which there is energy loss.
2. Non-technical shrinkage is losses caused by errors during the reading of measuring instruments, or when calibrating measuring instruments, errors in inputting data, or theft of power and voltage, and other things whose causes are not from electrical equipment.

D. Voltage Drop

Voltage drop is the amount of voltage that decreases in an electrical conductor caused by a current traveling in a plane that has impedance. Impedance in the network is influenced by the magnitude of the resistance and also the reactance of the entire network itself. To find the magnitude of the impedance value can be calculated as follows [16].

$$Z = R + jX \quad (1)$$

where Z denotes impedance in Ω , R is conducting resistance in Ω/km , and X is conductor reactance in Ω/km . For primary networks, most of the voltage drops and power losses are found in the network and transformers. During the day the voltage drop is usually smaller because the load power is not large, another case at night, the load power increases so that the voltage drop usually becomes larger. Therefore, the magnitude of the voltage drop at the time of electricity distribution can be calculated as follows [17].

$$\Delta V = \sqrt{3} (I_s \times Z_L) \quad (2)$$

where ΔV is voltage drop in V, I_s is line current in A, and Z_L is impedance (Ω).

When distributing to electricity consumers, PT. PLN often experiences losses which result in losses for PT. PLN or consumers, the definition of shrinkage itself is the difference between the power distributed and the energy used that can be expressed as [18].

$$\% \text{Losses} = \frac{\text{Losses}}{\text{Channeled Energy}} \times 100\%. \quad (3)$$

E. ETAP Software

ETAP software or power station is one of the programs widely used in efforts to solve problems related to the electricity system. There are many advantages to this ETAP software, but what is usually used is for power flow analysis, short circuit current simulation, and system capabilities.

III. IMPLEMENTATION METHOD

A. Types of Research and Data Sources

The type of research used in this study is a combination of quantitative and qualitative methods. Quantitative research was obtained from interviews with technical coordinators and employees of PT. PLN ULP Lhokseumawe and data collection at locations experiencing technical shrinkage [18]. Qualitative research is used to simulate data and conduct analysis using ETAP software [17]. The research methods used are interviews, observations, and documentation. The method used in optimizing technical shrinkage is carried out by changing the loading operation pattern by adjusting based on the feeder on a single line diagram and focusing on one of the feeders at the connecting substation that experiences alerts, namely the HG-08 GH Hagu feeder [18].

B. Research Flowchart

The research flowchart is illustrated in Figure 1 divided into several stages of implementation which are arranged sequentially in order to obtain data and results that are in line with the needs of research made on electrical technical shrinkage at PT. PLN ULP Lhokseumawe City.

The research flow diagram is depicted in Figure 1 which is divided into several implementation stages which are arranged sequentially so that data and results are obtained that are in accordance with the needs of research carried out on technical electrical depreciation at PT. PLN ULP Lhokseumawe City.

After reading and determining the problem formulation, the author then determines what data is needed for this study Starting from identifying the problem, then collecting data from the distribution system to be studied, then drawing a one-line diagram in stages, then entering the required system distribution data, then running the program, reviewing the running results and analyzing them, then making a final conclusion.

IV. RESULTS AND DISCUSSION

A. System Simulation Results before Repair

The simulation was carried out using ETAP 16.0.0 software which aims to see the power flow capacity in Lhokseumawe City consisting of three connecting substations and two substations as seen in Figure 2. It can be seen that the current flowing in each unit is different. After simulating the power flow of the Lhokseumawe City power system, a report was obtained. Where is the indication of the report that is still thresholded on the power flow that has been done. In the simulation results of the Alert marginal report of the power system of Lhokseumawe City, there are 130 buses that are under voltage and are still at the threshold. The bus that experienced voltage drop was located at the Arun Substation at the refinery. So, it can be

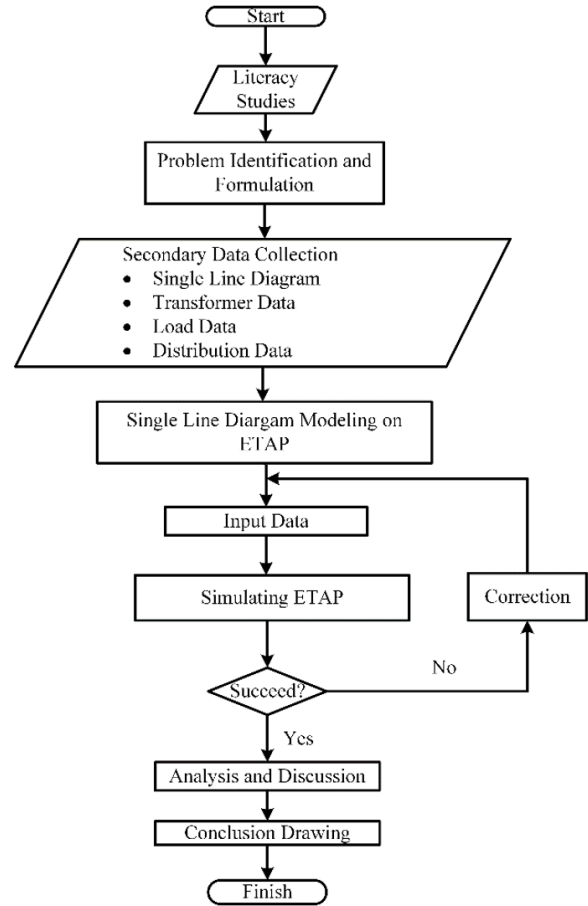


Figure 1. Research flowchart

seen that the lack of power supply contained in GI Arun.

After obtaining a marginal alert on the electricity system of Lhokseumawe City, there is an alert critical report or crisis report generated. From this simulation, there are 20 units that get crisis reports, all of which are transformers. The units that experienced this amounted to 20 transformers spread across several substations. The occurrence of more load conditions on the transformer is due to the inability of the transformer to supply the required power, where the percentage carried out by the transformer exceeds its normal threshold as in BAS25 and MDA40 which reaches 200%.

B. Manual Calculation of Voltage Drop before Repair

After a simulation was carried out in Lhokseumawe City, it was found that there was a voltage drop. Before changing the loading operation pattern, a manual calculation of the voltage drop is carried out. The calculation is carried out by calculate the line current, line parameters, voltage loss on the line, and the percentage of voltage drop. Manual calculations are carried out on feeders that experience overvoltage drops, namely at HG-08 Hagu Connecting Substation as shown in Figure 3.

In Figure 3, it is found that there are buses and transformers that have colors other than black. This indicates the occurrence of voltage drops so that manual

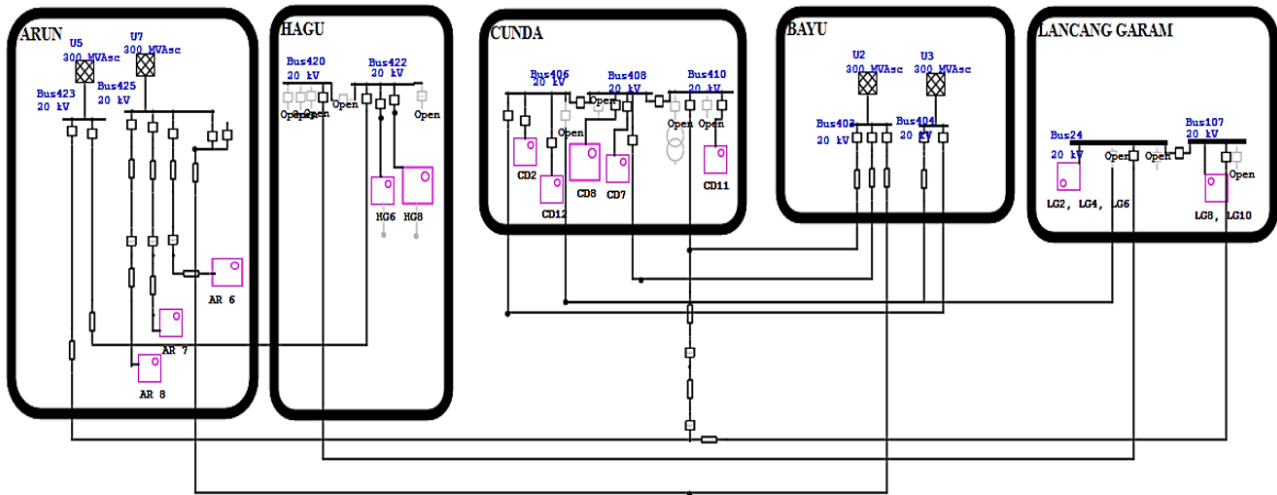


Figure 2. Display when ETAP simulation is run

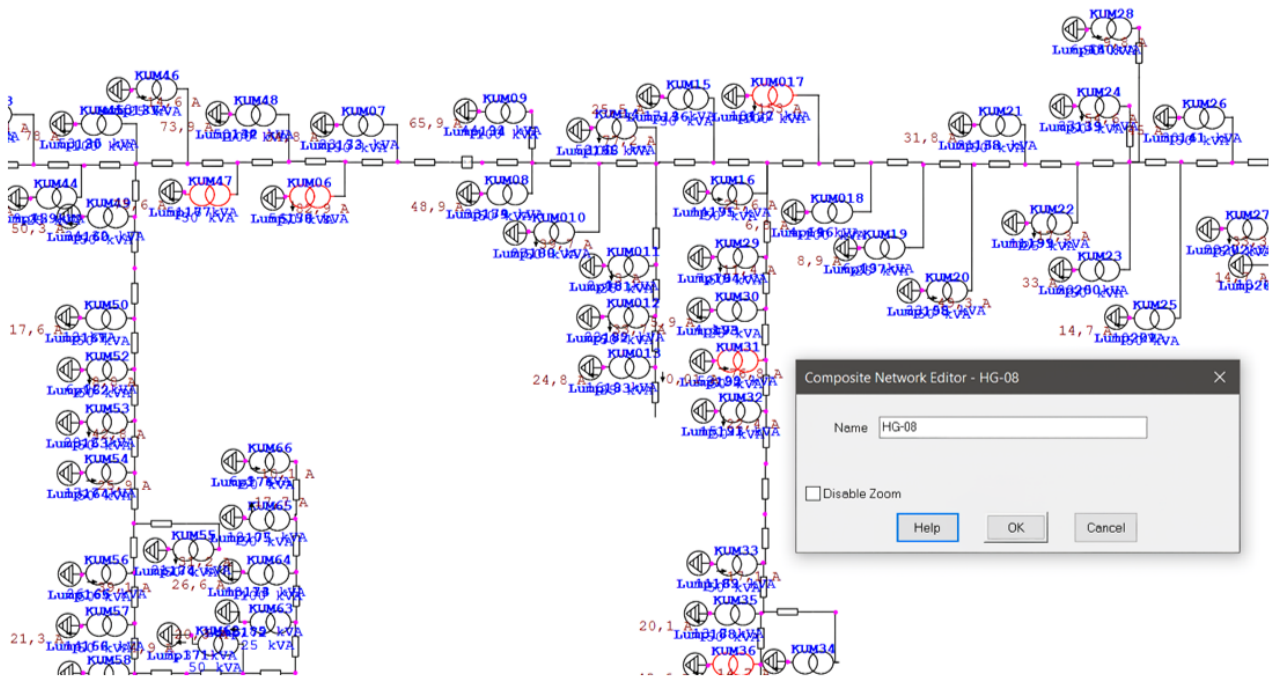


Figure 3. HG-08 voltage drop display in ETAP simulation

calculation efforts are made to see the comparison of the results obtained. Conducting data or channel data on HG-08 can be seen in Table 1.

An example of calculating the voltage drop at point 1-2 can explained as below:

$$Z = 0,486 + j0.3473131 \Omega$$

$$R = 0.468 \Omega/\text{km}$$

$$X = 0.3473 \Omega/\text{km}$$

$$L = 200 \text{ m} = 0.2 \text{ km}$$

$$I_s = 0.625 \text{ A.}$$

Then, the channel parameters can be specified as

$$R = 0.468 \Omega/\text{km} \times 0.2 \text{ km} = 0.0936 \text{ km}$$

$$X = 0.347314 \Omega/\text{km} \times 0.2 \text{ km} = 0.069 \Omega$$

$$Z_L = 0,936 + j0.069 = 0.11 \angle 36.58^\circ$$

so, the voltage drops on the line at points 1-2 of the HG-08

Table 1. Channel data on HG-08 Hagu feeder

No.	Length (km)	R (pu)	X (pu)	Y (pu)
1	76.0	0.468000	0.347314	0.0000034
2	9.6	0.231000	0.320336	0.0000037
3	1.8	0.140000	0.303441	0.0000039

GH Hagu feeder can be obtained by using (2) as follows

$$V = \sqrt{3} \times 0.625 \times 0.11 = 0.1190 \text{ V}$$

$$\%V \text{ losses} = \frac{0.1190}{20000} \times 100\% = 0.0006\%.$$

C. Comparison of Voltage Drop before Repair

From the calculations that have been done, both the

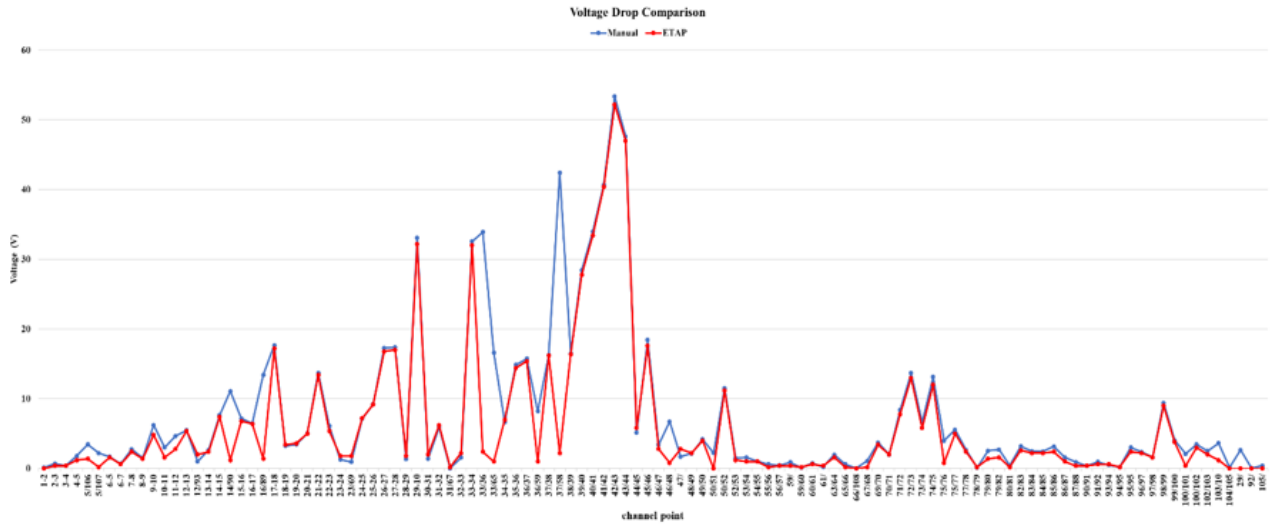


Figure 4. ETAP and manual drop voltage comparison graph

voltage calculations obtained in ETAP 16.0.0 and manual calculations can be compared as in Figure 4. From Figure 4 can be observed that the difference of the voltage drops between ETAP and the manual calculation in the HG-08 feeder is not too significant. From the graph and the previous table shows that the largest difference between these two methods is found at the point 35-58 with a difference of 40.24 V.

Based on manual and ETAP calculations, the total voltage drop is 4.1% and 3.2%, respectively. So that the voltage drop value obtained is close to the limit set in SPLN 72:1987, which is 5% of the nominal voltage.

To overcome the drop voltage that occurs in this GH Hagu feeder, PT. PLN can take several steps, such as raising the transformer tap, changing the type of conductor, and maneuvering the network or changing operating patterns. The GH Hagu feeder because the refiner is too long and also for the efficiency of time and funds from PT. PLN (Persero), the author suggests doing the third option. Judging from the location/point of the area, the point that experiences the highest voltage drop is points 23-24. Hence, this point should be maneuvered to the nearest feeder.

D. Optimization of Technical Shrinkage of Lhokseumawe City

One step to minimize the value of voltage drop on a feeder is to carry out load shifting or load maneuvering [19]. Under these conditions, the load at points 17-18 is planned to move to the nearest feeder, the CD-2 GH Cunda feeder. After the distribution of loading transfer on HG-08, there are two circuit results found in the refiner. It can be observed in Figure 5 and Figure 6. Based on these figures, it is clear that the HG-08 feeder at the Hagu Connecting Substation has been divided into two parts precisely at points 17-18. The placement of the disconnection in PTS Pulo is carried out according to the point of the largest voltage drop in this feeder and becomes the closest PTS to other feeders.

E. System Simulation Results after Repair

The simulation was performed using ETAP 16.0.0 software. This simulation was carried out again after changes in loading operations in Lhokseumawe City which consisted of three connecting substations and two substations as can be seen in Figure 7. After the ETAP simulation was carried out again in the power system of Lhokseumawe City, it was found that there was no voltage drop in the simulation. This is reinforced in the alert view on ETAP as can be seen in Figure 8.

From Figure 8, it can be seen that there is no indication of the report after changes in the operating pattern of the Lhokseumawe City power system. This is because the load balancing through the line has been balanced so that the indication of voltage drop on feeder HG-08 at Hagu Substation no longer exists. Analysis of Feeder Condition After Repair

After repairs were made to the HG-08 feeder of the Lhokseumawe City connecting substation, the calculations were carried out again to obtain a comparison of the voltage drops on this feeder. As example, the manual calculation from point 1-2 can be done as follows

$$Z = 0.468 + j0.3473131$$

$$R = 0.468 \text{ /km}$$

$$X = 0.3473 \text{ /km}$$

$$L = 200 \text{ m} = 0.2 \text{ km}$$

$$I = 21.365 \text{ A}$$

Then, the channel parameters can be calculated as follows

$$R = 0.468 \text{ /km} \times 0.2 \text{ km} = 0.0936$$

$$X = 0.3473 \text{ /km} \times 0.2 \text{ km} = 0.0694$$

$$Z_L = 0.0936 + j0.0694 = 0.11 \angle 36.58^\circ$$

So, the voltage drops on the line at points 1-2 of the HG-08 GH Hagu feeder is obtained by using (2)-(3) as follows

$$V = \sqrt{3} \times 0.625 \times 0.11 = 0.1190 \text{ V}$$

$$\%V \text{ losses} = \frac{0.1190}{20000} \times 100\% = 0.0006\%.$$

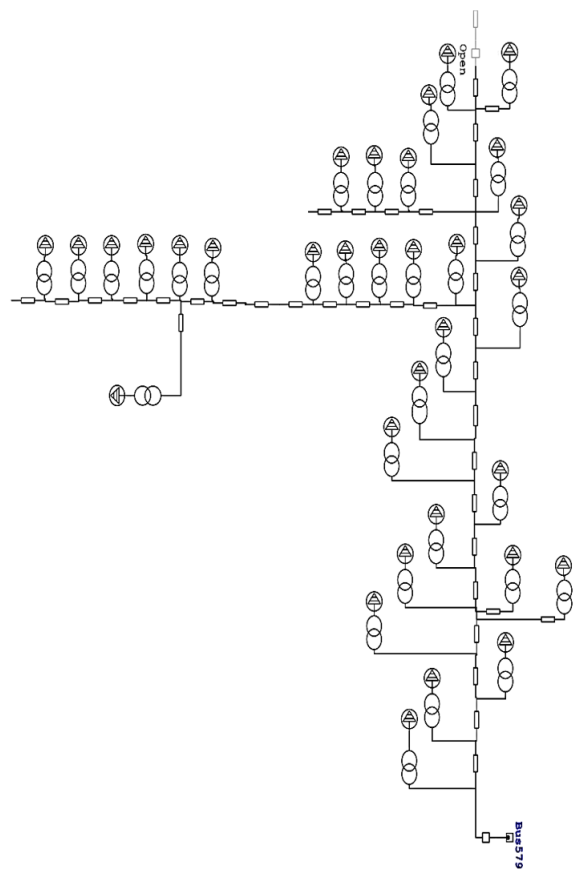


Figure 5. HG-08 view of GH Hagu

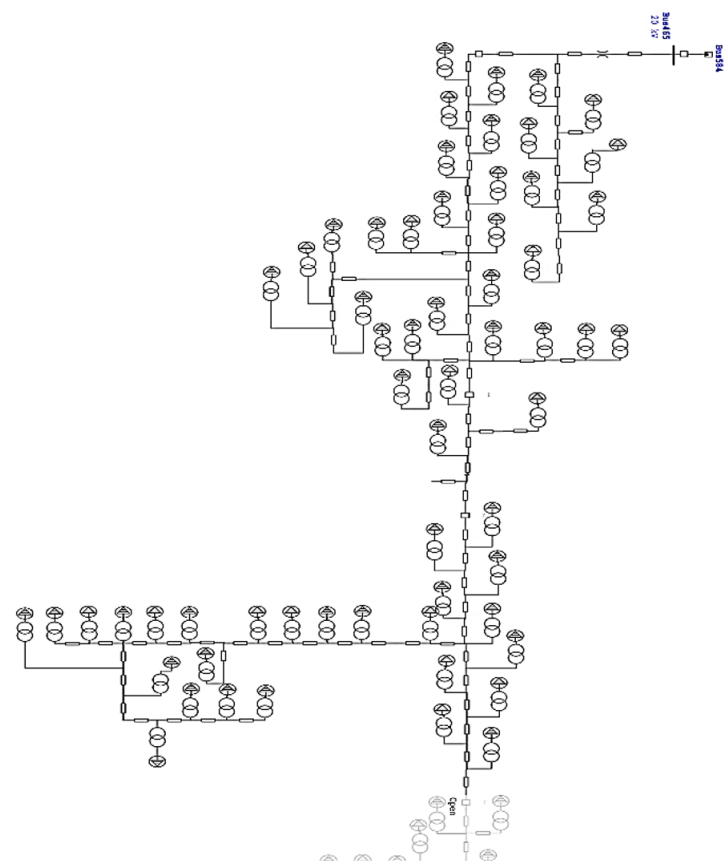
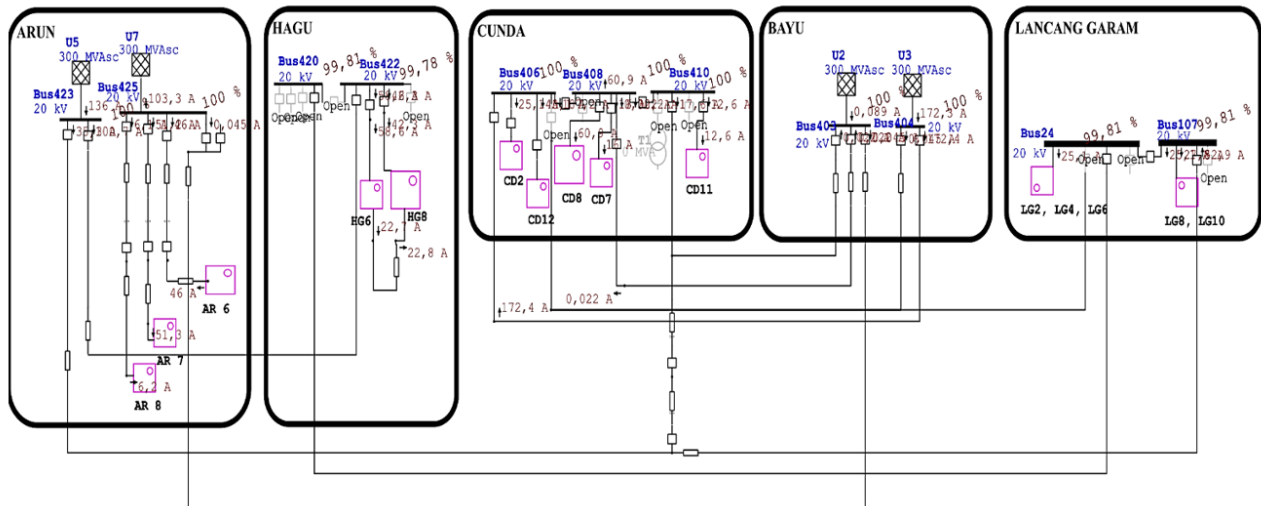


Figure 6. HG-08 view of the CD-2 feeder



ETAP 16.0.0 - [OLV1 (Load Flow Analysis)]

File Edit View Project Library Warehouse Rules Defaults Tools RevControl Real-Time Window Help

ETAP (Default) Phase

Base OLVI OLVI Normal Impedance Diagram 1100 kV

Alert Complete

ARUN US 300 MVAac 300 MVAac Bus423 20 kV Bus423 20 kV Bus423 20 kV Bus423 20 kV Bus423 20 kV

HAGU Bus420 20 kV Bus422 20 kV Bus422 20 kV Bus422 20 kV Bus422 20 kV

CUNDA Bus406 100 kV Bus408 100 kV Bus410 100 kV Bus410 100 kV Bus410 100 kV

BAYU U2 300 MVAac U3 300 MVAac Bus409 100 kV Bus409 100 kV Bus409 100 kV Bus409 100 kV Bus409 100 kV

LANCANG GARAM Bus409 100 kV Bus409 100 kV Bus409 100 kV Bus409 100 kV Bus409 100 kV

Load Flow Analysis Alert View - Output Report: Untitled

Study Case: LF Data Revision: Base

Configuration: Normal Date: 02-09-2023

☐ Zone Filter ☐ Area Filter

1 1

Marginal

Device ID	Type	Condition	Rating Limit	Operating	% Operating
-----------	------	-----------	--------------	-----------	-------------

After manual calculations were carried out at all points in the HG-08 feeder. To make it easier to compare manual calculations with ETAP after improvements were made to the HG-08 feeder of the Lhokseumawe City Hagu Connecting Substation, it can be observed in Figure 9.

This proves that the effect of changes in network operation patterns or load breakdown is quite significant

After improvements were made to the Lhokseumawe City medium voltage network, the power losses or technical shrinkage obtained have also decreased to 59.6 kW as presented in Table 2.

The change in Lhokseumawe City's losses decreased from 76.7 kW to 59.6 kW. So that, the changes loading operation patterns in the electric power system of Lhokseumawe City can be a solution to optimize technical shrinkage.

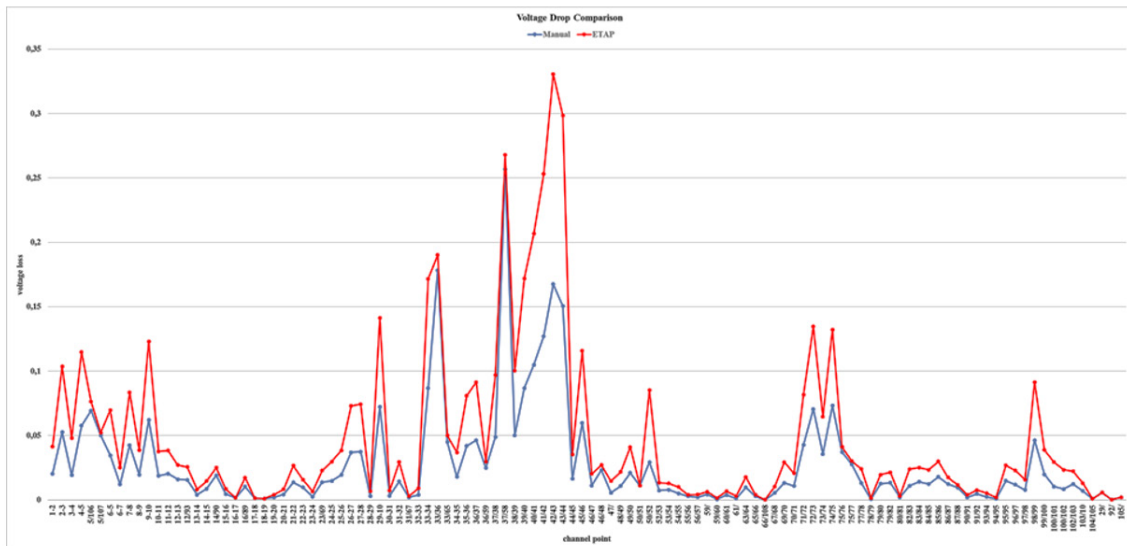


Figure 9. Comparison graph of manual calculations with ETAP

Table 2. Lhokseumawe City's power losses after repair

Branch IDE	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd% Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	
Line 1243	-0.063	-0.029	0.063	0.029	0.0	-0.1	99.8	99.8	0.00
BAS-476	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line 124	0.081	0.037	-0.081	-0.037	0.0	-0.4	99.8	99.8	0.00
Bas-463	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line 1245	-0.018	-0.009	0.018	0.008	0.0	-0.4	99.8	99.8	0.00
BAS-484	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
BAS-485	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line 1246	-0.27	-0.013	0.027	0.012	0.0	-0.4	99.8	99.8	0.00
BAS-483	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line 1247	-0.009	-0.004	0.009	0.004	0.0	-0.3	99.8	99.8	0.00
BAS-487	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line-1248	-0.018	-0.008	0.018	0.008	0.0	-0.1	99.8	99.8	0.00
BAS-488	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line-1249	-0.009	-0.004	0.009	0.004	0.0	-0.4	99.8	99.8	0.00
BAS-489	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line 1250	-0.027	-0.012	0.027	0.012	0.0	-0.1	99.8	99.8	0.00
Line 1251	-0.063	-0.029	0.063	0.029	0.0	-0.1	99.8	99.8	0.00
BAS-486	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line-1252	-0.009	-0.004	0.009	0.004	0.0	-0.3	99.8	99.8	0.00
BAS-490	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
Line-1253	-0.072	-0.033	0.072	0.033	0.0	-0.1	99.8	99.8	0.00
BAS-491	0.009	0.004	-0.009	-0.004	0.0	0.0	99.8	99.8	0.00
					59.6	-272.9			

V. CONCLUSION

The following is the conclusion of the results and analysis that has been carried out on the 20 kV MV Network of Lhokseumawe City. Technical depreciation calculation is carried out by dividing the load on the HG-08 feeder. The optimal step taken is to connect the Cunda

Substation Feeder load in the chamber by inserting the Hagu Substation Feeder load on the busbar connected to the HG-08 GH Hagu Feeder. Meanwhile, after repairing process, it was found that there was no voltage drop in the simulation. Basen on the calculation results after load breaking, it can be seen that the value of the HG-08 feeder voltage drop according to ETAP calculations dropped

from 3.277% or 655.4 V to 2.291% or 458.3 V. Based on manual calculations from 4.104% or 820.92 V to 3.079% or 615.98 V. So, for the feeder tip voltage it becomes 19541 V based on ETAP or 19384 V based on manual calculations. There was also a change in Lhokseumawe City's loss decreased from 76.7 kW to 59.6 kW. So that, the changes in loading operation patterns in the electric power system of Lhokseumawe City can be a solution to optimize technical shrinkage.

REFERENCE

- [1] P. S. Wibawa, A. S. P., Taringan, and S. Aryza, "Comparisional analysis study of power loss at the connection point of pierching connector with line tap connector on 220 V Low voltage network at PT. PLN (Persero) ULP Stabat," *J. INFOKUM*, vol. 10, no.3, pp. 398-404, 2022.
- [2] H. Stephen, *Electric Power Distribution System Engineering*, Columbia: Estados Unidos. Recuperado el, 1986.
- [3] A. Hasibuan, M. Isa, M. I. Yusoff, S. R. A. Rahim, and I. M. A. Nrartha, "Effect of installation of distributed generation at different points in the distribution system on voltage drops and power losses," in *AIP Conference Proceedings*, vol. 2339, no. 1, pp. 20134, 2021.
- [4] A. Hasibuan, F. Dani, and I. M. A. Nrartha, "Simulation and analysis of distributed generation installation on a 20 kV distribution system using ETAP 19.0," *Bull. Comput. Sci. Electr. Eng.*, vol. 3, no. 1, pp. 18–29, 2022.
- [5] S. Hardi, J. D. A. Tambunan, and A. Hasibuan, "Influence of static VAR compensator application for improving power quality in distribution lines supplied industry," in *IOP Conference Series: Materials Science and Engineering*, vol. 1003, no. 1, p. 12136, 2020.
- [6] R. Kurniawan, A. Nasution, A. Hasibuan, M. Isa, M. Gard, and S. V. Bhunte, "The effect of distributed generator injection with different numbers of units on power quality in the electric power system," *J. Renew. Energy, Electr. Comput. Eng.*, vol. 1, no. 2, pp. 71–78, 2021.
- [7] R. R. Maulana, S. Salahuddin, E. Ezwarsyah, B. Ismail, A. Shrestha, and D.V. Astonkar, "Analysis of technical loss calculation using load curve approach on 20 kV distribution network," *J. Renew. Energy, Electr. Comput. Eng.*, vol. 1, no. 2, pp. 85-93, 2021.
- [8] F. M. Gonzalez-Longatt, "Impact of distributed generation over power losses on distribution system," in *Proc. 9th Int. Conf. Electr. power Qual. Util.*, 2007, pp. 9-11.
- [9] B. Menu, A. P. Beaudet, M. Jolin, and B. Bissonnette, "Experimental study on the effect of key mix design parameters on shrinkage and cracking resistance of dry-mix shotcrete," *Constr. Build. Mater.*, vol. 320, pp. 126216, 2022.
- [10] A. Hasibuan, K. Kartika, S. Mahfudz, and M. Daud, "Network reconfiguration of 20 kV sample connection substance LG-04 Lhokseumawe City using Digsilent Power Factory software simulation 15.1," *Int. J. Adv. Data Inf. Syst.*, vol. 3, no. 1, pp. 20–29, 2022.
- [11] A. Hasibuan, M. Isa, I. M. Nrartha, and S. Hardi, "Improving voltage profile of 150 kV transmission line in Aceh subsystem with capacitor bank installation," in *Proc. 2019 3rd Int. Conf. Electr. Telecommun. Comput. Eng.*, 2019, pp. 140-144.
- [12] D. Dasman, "Analysis of power loss of 20 kV power distribution," in *MATEC Web Conference*, vol. 215, pp. 1-4, 16, 2018.
- [13] M. Y. Rofandy, A. Hasibuan, and R. Rosdiana, "Analysis of the effect of bank capacitor placement as voltage drop increase in distribution network," *Andalasian Int. J. Appl. Sci. Eng. Technol.*, vol. 2, no. 1, pp. 11–24, 2022.
- [14] A. Hasibuan, W. V. Siregar, E. S. Nasution, and R. Ismail, "Calculation of consumption and expenditures for electricity energy costs at Lido Graha Hotel Lhokseumawe City based on electrical power measurement," *Bull. Comput. Sci. Electr. Eng.*, vol. 1, no. 2, pp. 73–79, 2020.
- [15] R. Putri, D. Pratama, A. Hasibuan, M. A. Muthalib, and N. S. Nurfebruary, "Evaluation of technical shrinkage of express extension PL 03 and LW 09 at PLN Lhoksukon using ETAP software," *Int. J. Eng. Sci. Inf. Technol.*, vol. 3, no. 2, pp. 88–96, 2023.
- [16] F. S. Lukman, "Penurunan gangguan penyulang BR-10 dengan inspeksi camera stick pada PLN UP3 Lhokseumawe," *Rekayasa Elektr. dan Energi: J. Tek. Elektro*, vol. 5, no. 2, pp. 103-108, 2023.
- [17] R. K. Putra, M. Daud, A. Setiawan, and A. Hasibuan, "Penetration impact of distributed generation of wind turbines on PLN's electric distribution network at Krueng Raya Aceh Besar," *Motiv. J. Mech. Electr. Ind. Eng.*, vol. 5, no. 2, pp. 245–260, 2023.
- [18] M. Mahmood, O. Shivam, P. Kumar, and G. Krishnan, "Real time study on technical losses in distribution system," *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.*, vol. 3, no. 1, pp. 131-137, 2014.
- [19] O. J. Egwaile, K. O. Ogbeide, and A. Osahenvemwen, "Technical loss estimation and reduction in a typical nigerian distribution system: a case study," *J. Electr. Eng. Electron. Control Comput. Sci. – JEECCS*, vol. 4, no. 3, pp. 1-8, 2018.