



Analysis of Energy Losses in Medium Voltage Distribution Conductors Based on Load Curve: A Case Study on the Sindanglaut Feeder

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ABSTRACT

Power losses in electrical distribution systems are a major challenge that can reduce the efficiency of energy delivery. This study focuses on reducing such losses in medium-voltage distribution networks, particularly on the Sindanglaut Feeder at the Ciledug customer service unit of the State Electricity Company. The analysis employed load flow simulations using ETAP 12.6.0 software, with an optimization strategy of increasing the cable cross-section from 150 mm² to 240 mm² to assess its impact on voltage drop and distribution efficiency. Simulation results indicated that, prior to optimization, the average active power was 1.40 kW, reactive power was 5.75 kVar, and voltage drop was 3.28%. After optimization, these values decreased to 1.13 kW, 5.16 kVar, and 2.76%, accompanied by a significant reduction in total power losses. These findings demonstrate that cable size adjustment based on technical analysis is effective in improving distribution system performance and can serve as a reference for developing efficient, data-driven distribution networks.

INTRODUCTION

Reliable and efficient electrical energy is a fundamental component in supporting public activities and industrial operations. In the context of national development, electricity plays a vital role as a key driver of social and economic growth(Wahyudi, 2024). However, one of the major challenges in power distribution systems is the occurrence of energy losses, particularly in medium-voltage distribution networks(Celik, 2024)(Liu & Zhao, 2024). These losses are mainly caused by factors such as long distribution lines, unbalanced loads, and inadequate conductor sizing. Such inefficiencies can hinder the overall performance of the system and reduce the quality of electricity supplied to consumers(Girigoudar & Roald, 2020)(Jamil, 2023).

In the operational area of the State Electricity Company Customer Service Unit in Ciledug, several medium-voltage distribution feeders are in service, including the Sindanglaut feeder, which is supplied from the Babakan Substation. This feeder serves a wide geographic area with varying load characteristics, which contributes to a significant potential for energy losses. Initial assessments and technical data reveal that this feeder has a complex network, yet it presents opportunities for performance improvements through proper technical measures. The scale and complexity of the Sindanglaut feeder make it a distinctive and relevant case for exploring efficiency improvements in power distribution systems(Masdzarif et al., 2023).

One technical approach considered effective in reducing power losses is conductor resizing, or upgrading the cross-sectional area of distribution cables. This method enhances the current-carrying capacity and reduces resistance in the lines, allowing for more efficient power delivery with minimal energy loss. It also plays a role in optimizing distribution network performance by aligning conductor capacity with actual load demand(Ponce et al., 2023).

Based on this context, the objective of this study is to evaluate and optimize energy losses in the Sindanglaut feeder at the State Electricity Company Ciledug Customer Service Unit by applying a conductor resizing strategy. This study is expected to identify the most efficient cable sizing configuration in quantitative terms and contribute strategically to improving the overall quality and reliability of electricity distribution(Aziz et al., 2025).

LITERATURE REVIEW

Feeder Sindanglaut

The Sindanglaut feeder has a total length of 23.2 kilometers, and there are 5 types of cables used with different lengths, namely the A3CS 3x70mm type with a length of 0.922 km, the A3CS 3x150mm cable type with a length of 1.944 km, the A3C 3x50mm cable type with a length of 0.045 km, the A3C 3x70mm cable type with a length of 8.475 km, the A3C 3x150mm cable type with a length of 7.0868 km.

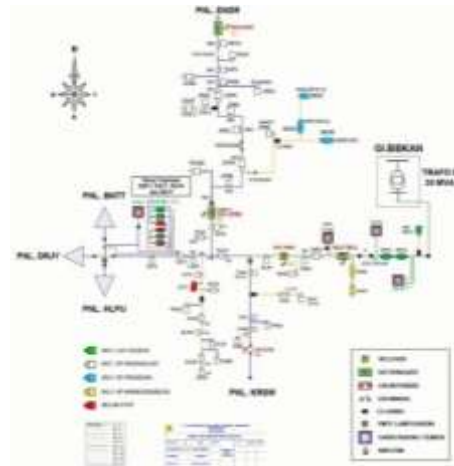


Figure 1. Single Line Diagram System Distribution Feeder Sindanglaut

Literature studies are carried out by collecting theories and references from various relevant sources. The research began with the collection of network data from the Sindanglaut Feeder connected to the Babakan Substation, part of the 20 kV distribution system of the Customer Service Unit of the Ciledug State Electricity Company(Gao et al., 2023). The data collected includes load characteristics, feeder length, transformer capacity, and cable specifications. The network model was created in the form of a single line diagram using the ETAP Power Station software version 12.6.0(Techane et al., 2022)(Putri et al., 2024). Load flow analysis is performed to identify overvoltage drops and potential power loss(Wang et al., 2024). The results of the initial simulation showed a total voltage decrease of 3.27%. As an optimization step, the size of the cable cross-section was changed from 150 mm² to 240 mm² on certain parts of the network. Adjustments are made gradually until all substations meet the permissible voltage limits. After the resimulation, the results showed that the voltage decrease decreased to 2.75%. All analyses were conducted at peak load conditions to reflect the worst-case scenario(Putri et al., 2024).

Table 1. Conductor specifications

Specifications	Value
Nominal Cross-Section (mm ²)	150
Radius (mm)	81250
Urat	19
GMR (mm)	3,3
KHA (A)	425

Table 1, shows the size and describes the specification of one of the cable cross-sections whose network length is experiencing a voltage drop.

Figure 3 shows the stages of simulating the cross-section change of the network cable using the Load Current Analysis method, with the following procedure:

1. Use data from the Sindanglaut Feeder at peak load.
2. Run the initial load flow (base condition).
3. Check if there is a voltage limit violation.
4. If applicable, adjust the transformer tap.
5. If that hasn't worked, proceed to the cable cross-section replacement.
6. Re-simulate with the new cable in ETAP Power Station 12.6.0.
7. Compare power losses before and after changes.
8. The simulation is complete.

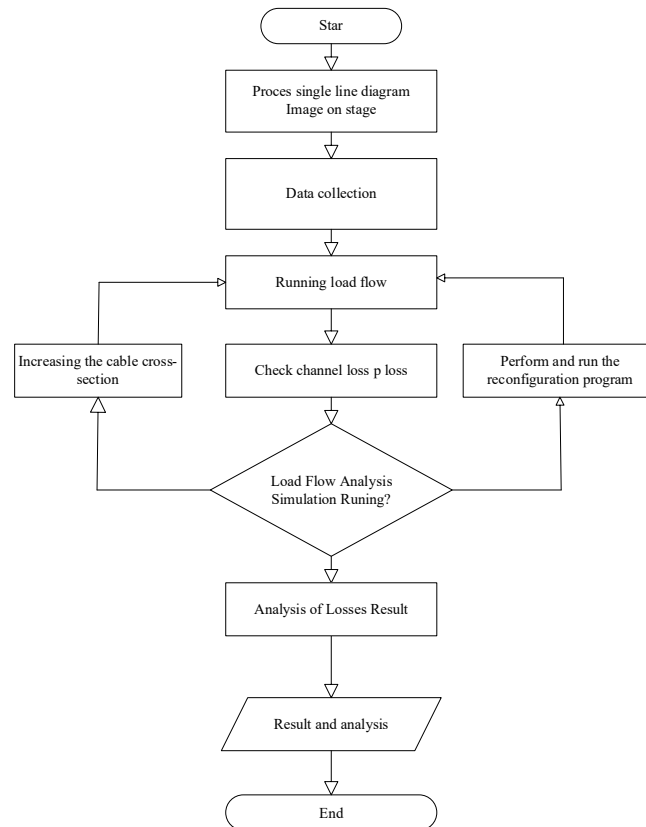


Figure 3. Research scheme

RESEARCH RESULTS

Simulation testing using ETAP has been performed. From the test results, the values of voltage reduction, kW, kVar, and voltage decrease were obtained. The output before the reconfiguration and after the reconfiguration was carried out using ETAP software version 12.6.0 and performed a manual calculation by changing the cable cross-section from 150mm² to 240mm²(Putri Politeknik Negeri Medan et al., 2021)(Aziz et al., 2024).

Table 2. Conductor Data	
Specifications	Value
Substation	Babakan
Transformer	3

Feeder	Sindanglaut
Feeder type	SUTM
ACCCS 3X70	0,922 km
ACCCS 3X150	1,944 km
ACCC 3x50	0,045 km
ACCC 3x70	8,475 km
ACCC 3x150	7,0868 km

At this stage, data collection related to the research was carried out, to improve the voltage profile and reduce power loss with load flow analysis, in this study data was used from the Sindanglaut Feeder where this feeder got supply from the Babakan Substation and the data used in this study was data from the 20 kV distribution line system at the Customer Service Unit of the Ciledug State Electricity Company. In order to optimize the power flow, the Single Line Diagram is first defined according to the figure below. It is then analyzed using ETAP Power Station 12.6.0 software with the aim of determining the system status or character.

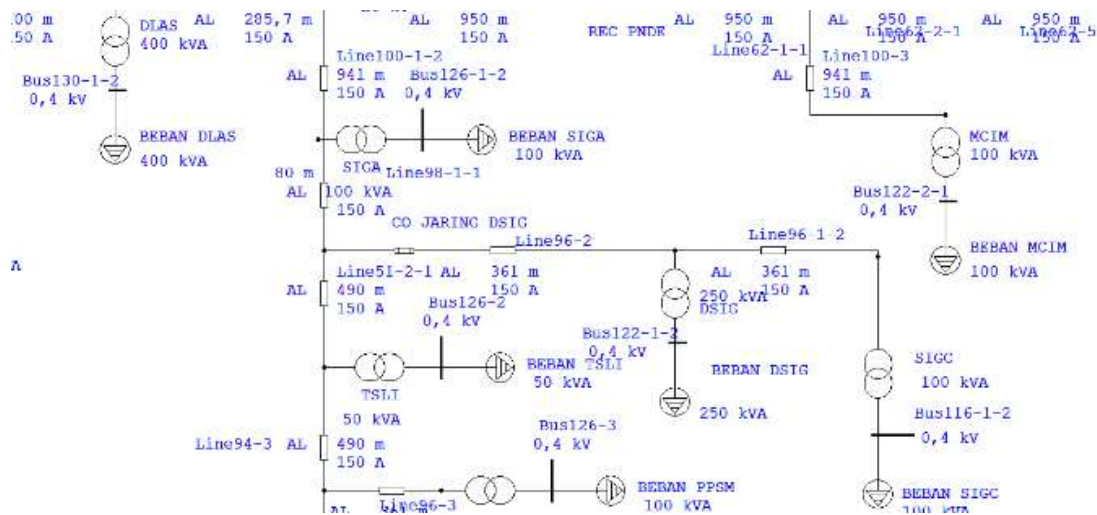


Figure 4. Results of Single Line Diagram of Distribution Network from Feeder using ETAP Power Plant version 12.6.0

The image shows the results of load flow analysis using ETAP software version 12.6.0 at the Sindanglaut Feeder, where the system voltage decrease was recorded by 3.27% when using a 150 mm² cross-sectional cable under peak load conditions.

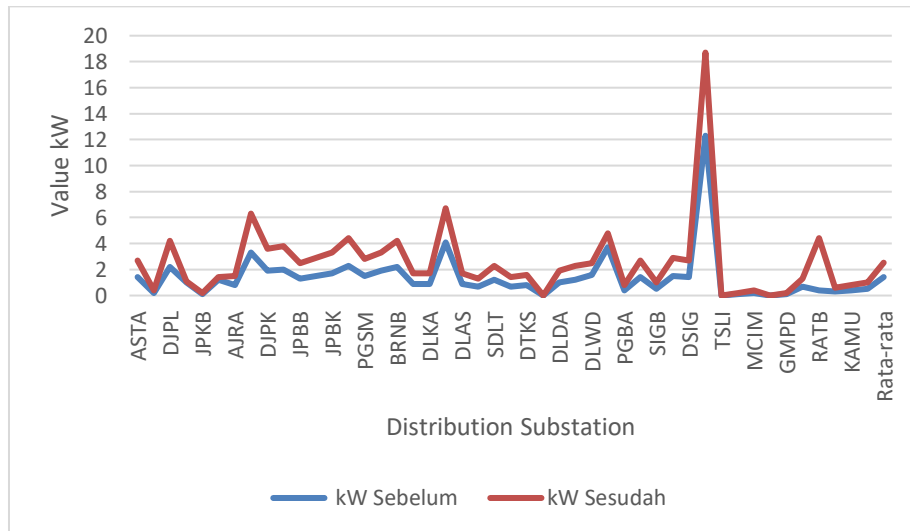


Figure 5. Before the change of cable cross-section

Based on the graph, the total kW voltage drop obtained for the load flow analysis simulation measurement with a value of 1.4 kW before and after 1.3 kW.



Figure 6. Results of Single Line Diagram of Distribution Network from Feeder using ETAP Power Station 12.6.0

The image shows the results of load flow simulation using ETAP 12.6.0 software on the Sindanglaut Feeder after the cable replacement from 150 mm² to 240 mm², with a voltage reduction of 2.75% under peak load conditions.

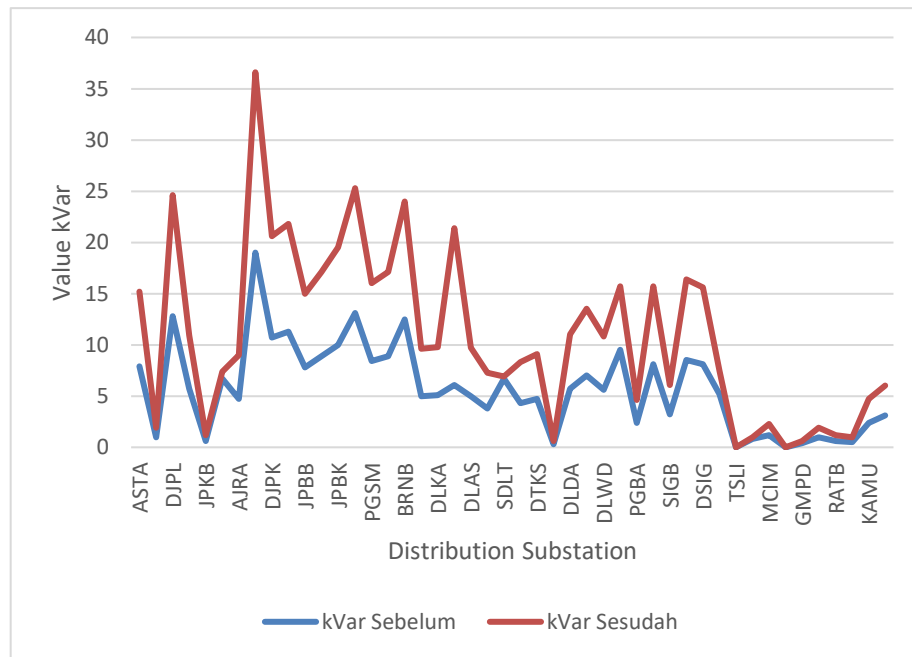


Figure 7. After the change in cable cross-section

Based on the graph, it shows the total kVar voltage drop obtained for the simulated measurement of power flow analysis after the original reconfiguration with values of 5.75 kVar to 5.15 kVar.

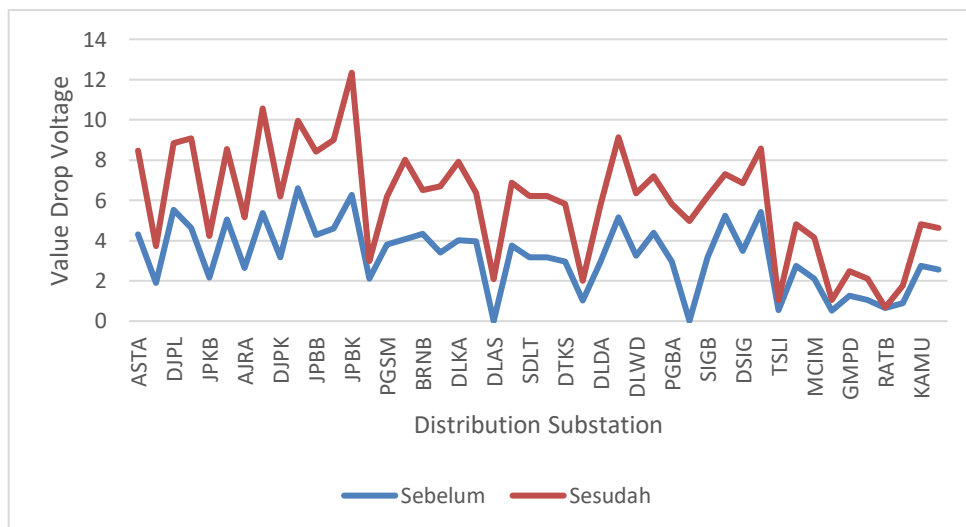


Figure 8. Optimal voltage drop results

As seen in graph 3, the voltage drop obtained before 3.27% becomes optimal with a value of 2.75%.

DISCUSSION

Efforts to reduce power losses in the electricity distribution system are an important step in improving the efficiency of energy distribution and ensuring the stability of electricity supply to consumers. Based on the results of the simulation conducted using ETAP software version 12.6.0, the change in the size of the cable cross-section from 150 mm² to 240 mm² in certain parts of the

network was proven to have a positive impact on system performance, especially in reducing the voltage drop and reducing reactive power. Technically, the increase in the area of the conductor's cross-section reduces the electrical resistance on the distribution line, thereby minimizing energy losses due to heat (losses) in the conductor. This increase in cross-section also has a direct effect on the voltage stability at various load points. At peak loads, the distribution system is often under pressure due to an increase in current that causes the voltage to drop significantly.

With cable optimization, the voltage profile becomes more even and within the permissible tolerance limits, which indicates an overall improvement in the performance of the distribution system. In addition, the decrease in reactive power consumption indicates that the network power factor has improved. This means that the system works more efficiently because less energy is wasted on overcoming power that doesn't produce real work.

These findings are in line with previous studies that have shown that conductor size engineering is one of the most effective strategies in reducing power losses in distribution systems. From a technical and implementation perspective, this strategy is feasible to implement, especially in long networks that have the characteristics of spreading loads such as the Sindanglaut Feeder. Load flow simulation-based analysis enables more precise and responsive network planning to actual conditions in the field, and supports the achievement of a reliable, efficient, and sustainable distribution system.

CONCLUSIONS AND RECOMMENDATIONS

This study shows that efforts to reduce power loss in medium-voltage distribution networks can be effectively carried out through the optimization of the cable cross-section size, with a power flow analysis approach. The simulation process was carried out using ETAP software version 12.6.0 at the Sindanglaut Feeder owned by the State Electricity Company of the Ciledug Customer Service Unit under maximum load conditions.

From the simulation results, it is known that the change in cable size from 150 mm² to 240 mm² has a positive impact on the voltage profile of the system, with a decrease in the rate of voltage decrease from 3.27% to 2.75%. This achievement shows an increase in energy distribution efficiency and a real reduction in power losses. Therefore, this approach can be recommended as an efficient and scalable technical solution to improve the performance of electricity distribution systems, especially in networks with complex and dispersed load characteristics such as the Sindanglaut Feeder.

ADVANCED RESEARCH

Every study certainly has limitations, and so does this study. One of its limitations lies in the scope of the analysis that focuses only on changing the cross-section of the cable without considering other technical alternatives, such as network reconfiguration, the use of capacitor banks, or the integration of decentralized energy plants. In addition, simulations are only conducted based

on peak load conditions, so they do not fully represent load dynamics that vary over time.

Therefore, in future research, it is recommended to evaluate the distribution system with an approach that takes into account daily and seasonal load fluctuations so that the results obtained are more comprehensive. The use of artificial intelligence-based optimization methods, such as genetic algorithms or particle swarm optimization, also has the potential to provide more optimal technical solutions. No less important, considering the environmental aspects and the actual physical condition of the network in the field will strengthen the accuracy of the simulation and analysis results.

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