Analysis of the Impact of the Development of HUTM Network Expansion in Overcoming Drop Voltage at PLN Binjai

Dicky Arya Duta, Rahmaniar, Zuraidah Tharo

Abstract:
This research was carried out in the PLN Binjai area, precisely in the BJ feeder network. 01 Stabat, to analyze the impact of the development of the HUTM (Medium Voltage Air Conduction) network in overcoming the problem of drop voltage. The calculation was carried out using the standard formula of a three-phase system and considered the voltage tolerance limit according to PUIL 2011 and SPLN 72-1987, which is ±5% of the nominal voltage. The measurement results showed that at substation SC 84, the existing voltage dropped to 336.5 V, resulting in a voltage drop of 63.5 V. After analysis of the length of channel 4.95 km with a load current of 214.47 A, the total allowable resistance of 0.2137 Ω was obtained. From the calculations, the minimum cross-section of a copper conductor required to maintain a voltage within the standard limit is about 400 mm², while for aluminum conductors a cross-section of about 650 mm² is required. After the expansion of the new network of 420V using an insert transformer with a power of 50kVA using a cross-section of the distribution network conductor along 4.95 km, and 34 poles as many as 34 rods.

***Keywords**:* Voltage Drop, HUTM, Distribution Network, Conductor, PLN Binjai.

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Introduction

Today, electricity is essential for various social, economic, religious, educational, business, and other fields. PT PLN (Persero) is responsible for managing electrical operations in Indonesia and is responsible for providing electrical energy to the entire community. However, there are a few things to consider when managing these electrical operations, including the quality of the components used and the standards that have been established to prevent a decrease in the amount of energy produced. (Repka Cipta Pramudita1*, Hamdani2, 2025)

One of them is the drop voltage problem. Several factors can cause self-drop voltage in a low-voltage or JTR network. Some of these factors include imperfect connections between the SR (Home Connection) cable and the JTR cable, too long a distance between the distribution substation and the customer's home being supplied, a high load on the network, and a carrier cross-section area that is too small.(Ilyas & Yulianto, 2022)

So that in this journal, the calculation of load current and drop voltage will be carried out so that there is an impact on the construction of a new HUTM (Medium Voltage Air Transmission) network in overcoming the drop voltage at PLN BINJAI.

Literature Riview

2.1 Electric Power Distribution System

The electric power distribution system is the final part of the electrical energy distribution process which is in charge of delivering power from the distribution substation to consumers. This system has an important role because it is directly connected to electricity needs society, industry, and other sectors. In an electricity network, the distribution system functions to provide energy to the end user safely and reliably from the transmission network. As a result, service providers have a strong incentive to continuously improve the quality of the goods and services they offer. PT. PLN (Persero) is a national company that focuses on providing and distributing clean energy to customers. (Abendanon Siagian et al., 2023)
In general, distribution systems are divided into two main types:

1. Primary Distribution: Using medium voltage (about 20 kV) for Distribute electricity from the substation to the distribution substation.
2. Secondary Distribution: Distributing electricity from the distribution substation to the customer using low voltage (usually 220–380 V).

These two types of distribution are interconnected in maintaining the continuity and quality of the electricity supply that customers receive. Therefore, the most important thing to always maintain is a constant and stable supply of electricity. Distribution transformers are one of the main equipment used to deliver electrical energy to low-voltage grids.(Muhammad et al., 2024)

2.2 Medium Voltage Air Supply (HUTM)

An Air Medium Voltage Network (HUTM) is a type of distribution network that distributes electrical energy through an overhead cable with a voltage of about 20 kV. It is generally used by PLN to reach widespread areas, especially in urban and rural areas. PLN as an integral part of the electricity distribution system has an important role in distributing electricity to various sectors, ranging from households to industry. The reliability of the power grid in this region not only has an impact on the comfort of the community but also on the productivity of the regional economy and other electricity distribution systems. (Solin et al., 2024)

HUTM consists of various components that are integrated with each other, including:

1. Conductor: The main media of the electric conductor, such as AAAC and ACSR types.
2. Power Pole: Grid support to keep it sturdy and stable.
3. Isolator: Functions to prevent current leakage and maintain system security.
4. Arrester and Fuse Cut Out: As protection against lightning and current interference More.
5. Load disconnect switch: Used to regulate the power supply at the condition certain.
6. Distribution transformer: Converting medium voltage to low voltage according to customer needs

The structure of the HUTM network can be radial (flowing in one direction) or loop (closed circuit), depending on the distribution scheme applied in a region.

2.3 Voltage Drop

Drop voltage is the phenomenon of reduced electrical voltage when it is passed through a conductor to the load. This voltage decrease occurs due to the presence of resistance (resistance) and inductance (reactance) in the conductor through which the current passes.(Dewi et al., 2023)

Some common causes of voltage drop include:

1. Too long network spacing, so that the voltage reaches the end become weak.
2. Overload on one distribution line.
3. Conductor with small cross-sectional area, which increases the resistance.
4. Poor connection quality, causing power loss.
5. Environmental conditions and network age, which may affect performance.

The consequences of untreated voltage drop are decreased performance of electrical equipment, waste of energy, and customer discomfort due to voltage not up to standard. The calculation of current and voltage is as follows:

1. Load Current Calculation

To calculate the load current on a 3-speed distribution network, the following formula is used:

$$I = \frac{P}{\sqrt{3} \times V \times \cos \emptyset}$$

Information:

I =Load Current (Ampere)
P =Active Power (Watts)
V =Interphase Voltage (Volts)
Cos ∅ = Power Factor, usually assumed to be 0.8-0.95 depending on the type of load.

This formula is used to determine the amount of current flowing through the conductor for a given load. The larger the current, the greater the voltage loss will also be greater, especially if the conductor has a high length and resistance.

2. Calculation of Drop Voltage

The drop voltage is calculated by taking into account the current value and the impedance of the line (which consists of resistance and reactance). The general formula of drop voltage in a 3-phase system is:

$$\Delta V = \sqrt{3}\ x\ I\ x\ (R \cos \emptyset + X \sin \emptyset)$$

Information :

ΔV = Voltage Drop (Volt)

I = Load Current (Ampere)

R = Conductive Resistloadance (Ohm)

X = Conductive Reactance (Ohm)

Cos ∅ = Force Factor

Sin ∅ = $\sqrt{(1 - cos^2\varphi)}$

The values of R and X can be calculated from the length of the cable and the type of conductor used.

$$R = \rho\ x \frac{L}{A}$$

Where :

ρ = Conductive Material Resistivity (Ohm)

L = Conductor Length (meter)

A = Cross-sectional Area (mm)

2.4 Service Voltage Standard

In the provision of electricity, service quality standards cannot be ignored. Based on the reference of PUIL 2011 and PLN Standard (SPLN) 72-1987, the maximum voltage drop in the Medium Voltage Network (JTM) is 5% of the nominal voltage, the voltage tolerance limit for the distribution system is set at ±5% of the nominal voltage. (Erhaneli, 2020). For medium-voltage networks with nominal voltage, then:

1. The minimum allowable voltage is 380V
2. Maximum voltage is 420V

If the voltage received by the customer is outside this range, it is considered not in accordance with the standard and has the potential to cause service interruptions.

2.5 Solutions to Overcome Drop Voltage

If the voltage received by the customer is outside this range, it is considered not in accordance with the standard and has the potential to cause service interruptions. Some technical steps that can be taken to reduce or overcome the problem of drop voltage in the distribution network include:

1. Expansion of distribution network

By extending the network or adding new lines, the power distribution becomes more even and the load between the networks can be shared, reducing excessive drop voltage. With a network that is also required for reliability, the reliability of each component's system depends on the conditions in each environment, such as when it is operated and stored, and it can be said that it will decrease as the device ages. (Noufanda et al., 2021)

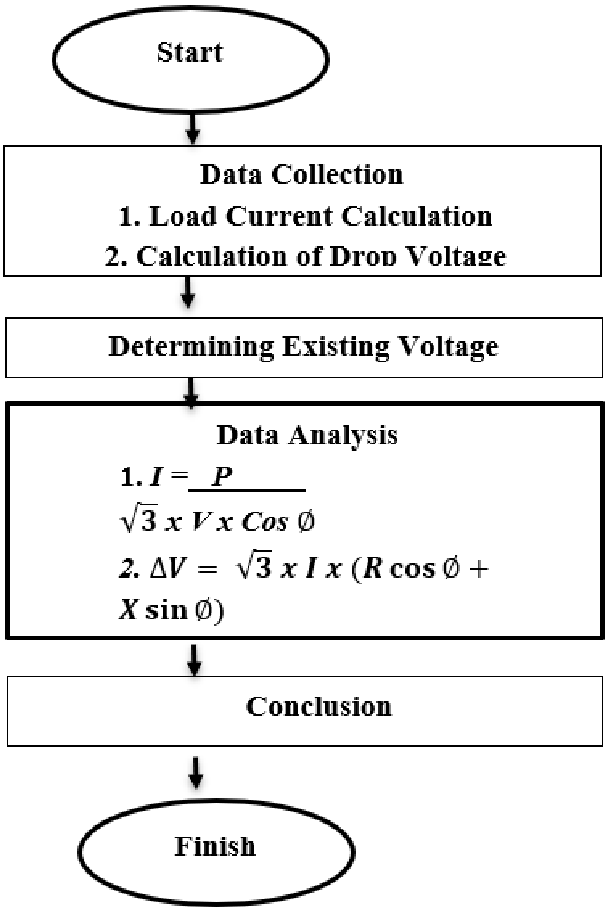
2. Conductor Replacement

Replacing the old conductor with a new conductor that has a larger cross-sectional area or higher conductivity will lower the resistance, so that voltage losses can be suppressed. In an electrical power distribution system, conductors play a crucial role in delivering energy from the source to the consumer. Conductors with high resistance experience greater power loss, which leads to voltage drop or voltage drop at the end point of the line. As a result, the quality of energy that consumers receive and the efficiency of the distribution system are affected. (Pratama et al., 2025)

3. Addition of Distribution Substations

Placing additional distribution substations in strategic locations can shorten the distance of power distribution to the load. Thus, the voltage received by the customer will be more stable and within the permissible limits. The load level of each substation department is different, and because the load of the substation department automatically increases at the same rate, overload (greater load) on the substation department that is overloaded more than its capacity can occur. With the longer the length of the load line, the load current becomes larger, which can lead to voltage and reference drops. In addition, unavoidable damage ranging from distribution substation components to low-voltage networks will continue to increase, and PT. PLN (Persero) will continue to increase. Load sharing is a way to reduce the possibility of overload in the distribution substation department, correct voltage drops and power losses in low-voltage network distribution, and maintain reliable distribution substation components in low-voltage networks. (Marniati, 2023)

Methode



Results

4.1 Existing Tissue Conditions

1. Description of the Analyzed HUTM Network

    1. Network Overview

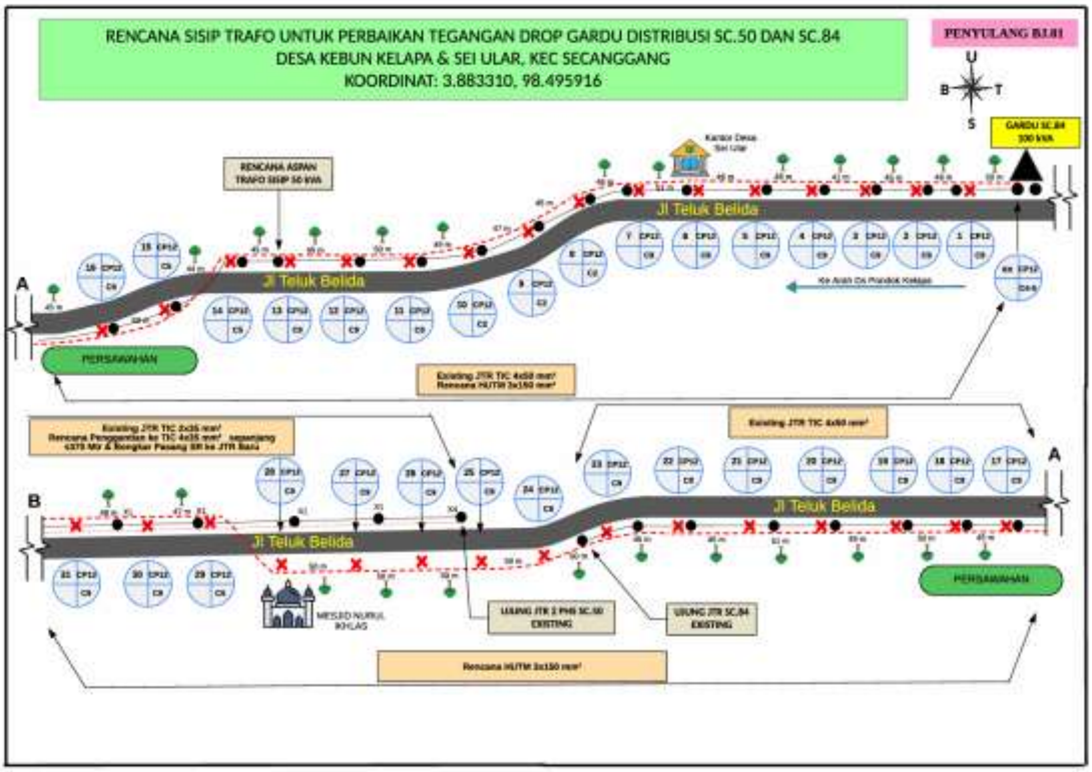


Figure 1: Drop Voltage Repair Network Overview

1. Network Location

For the location in the Langkat area, namely Jl. Tlk Belida, Lalat Regency, Secanggang District, Sungai Snake Village. With latitude: 3. 883310 and longitude: 98. 495916.

2. Network Function

This distribution network functions as a distribution of electricity to the community such as the general public, industry, livestock and so on.

3. Total Network Length

For the total length of the BJ feeder network. 01 is 120 kms. For additional networks, the network is increased by 4.95kms. By using JTR TIC 4x50 $mm^2$to 3x150 mm^2. For the type of distribution system, use a loop distribution system.

2. Network Technical Specifications
    1. Nominal voltage: 20KV
    2. Channel Length and Configuration: 3phase 120kms
    3. Feeder and Distribution Transformer: BJ Feeder. 01 Stabat
    4. Number of Distribution Substations

    For the number of distribution substations at BJ feeders. 01 Stabat as many as 60 Distribution Substations but the data writer only has 2 distribution substations with specifications: Code : SC 84 Power : 100 kVA

    And coupled with a new insert transformer with a power of 50kVA

5. Network Performance Conditions For the condition of network performance at the beginning of the voltage drop, namely at the substation with the code SC 84 and the solution to repair the drop voltage is by adding a distribution network.
6. Existing Voltage (at the end of the load
   For the voltage that occurs in the field in the drop part, namely at the SC 84 substation, it gets a voltage that is quite very dropped, which is 336.5Volts as in the following figure:

Figur 2 : Initial Voltage During Drop

Use the formula for calculating the load current:

$$I = \frac{P}{\sqrt{3} \times V \times Cos\ \emptyset}$$

$$I = \frac{100.000}{1{,}732 \times 336{,}5 \times 0{,}8}$$

$$\approx \mathbf{214{,}47A}$$

Required Drop Voltage: ΔV=Vnom−Vtarget = 400−336,5 = 63,5 V

3. Diagram SLD (Single Line Diagram)

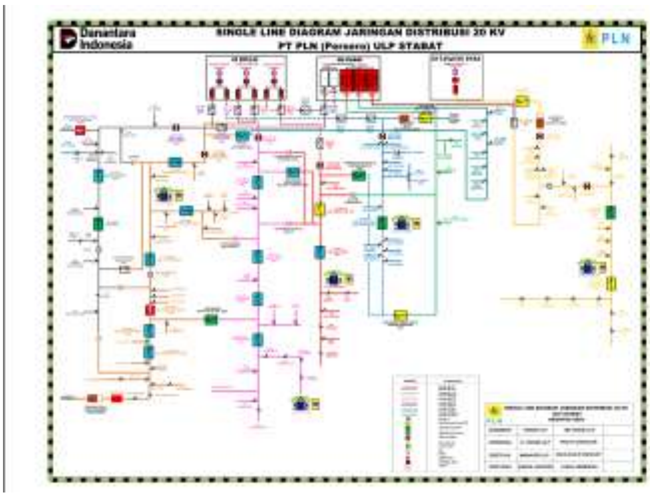


Figure 3: Single Line Diagram

4. Network Expansion
   1. New network design

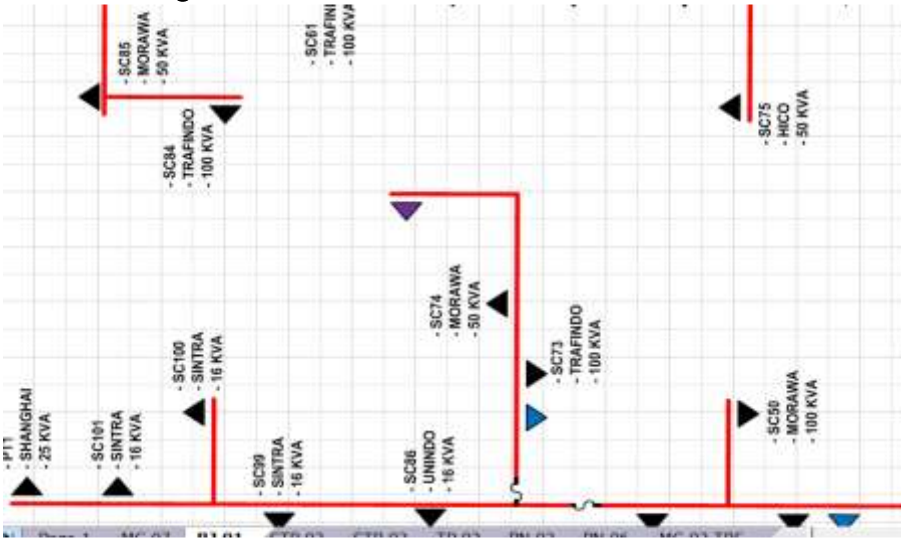


Figure 4 : Single Line After Addition of Distribution Substation

   2. Documentation of Installation of Transformers and Distribution Networks

Figure 5: Documentation

3. Calculation Results

   Use the formula for calculating the load current:

$$I = \frac{P}{\sqrt{3}\ x\ V\ x\ Cos\ \emptyset}$$

$$I = \frac{100.000}{1{,}732\ x\ 336{,}5\ x\ 0{,}8}$$

$$\approx \mathbf{214{,}47A}$$

Required Drop Voltage :

$$\mathbf{\Delta V = Vnom - Vtarget = 400 - 336{,}5 = 63{,}5\ V}$$

Use the formula of drop voltage :

$$\Delta V = \sqrt{3}\ x\ I\ x\ (R \cos \emptyset + X \sin \emptyset)$$

We can solve for linear impedance combinations :

$$R \cos \emptyset + X \sin \emptyset = \Delta V\ /\ \sqrt{3}\ I$$

Enter numbers : $\mathbf{63{,}5\ /\ 1{,}732}$ x $\mathbf{214{,}47 \approx 0{,}17094}$

So : $R \cos \emptyset + X \sin \emptyset \approx \mathbf{0{,}17094}$

$\mathbf{R \approx 0{,}17094/\cos \varphi = 0{,}17094/0{,}8 \approx 0{,}213\ \Omega}$

So the total resistance of a single-phase conductor for 4.95 km is a maximum of 0.2137Ω.

Find the conductor cross-sectional area (A)

Use $\mathbf{R} = \rho\ x \frac{L}{A} \longrightarrow \mathbf{A} = \rho\ x \frac{L}{R}$

Lenght L = **4,95 km = 4.950 m**

P copper = $\mathbf{1{,}724\ x\ 10^{-8}\ \Omega.\ m}$

For copper $\mathbf{A} = \frac{1{,}724 \text{ x } 10^{-8}\ 4.950}{0{,}2137}\ m^2$

$$\mathbf{A} \approx 3{,}99 \text{ x } 10^{-4} m^2 = 399\ mm^2$$

So for copper, conductor cross-section area: A ≈ $\mathbf{400 mm^2}$

For aluminium $\rho \approx 2{,}82 \text{ x } 10^{-8}$

$$\mathbf{A} = \frac{2{,}82 \text{ x } 10^{-8}\ 4.950}{0{,}2137}\ m^2$$

$$\mathbf{A} \approx 6{,}53 \text{ x } 10^{-4} m^2 = 653\ mm^2$$

So for aluminum, cross-section area: **A** ≈ $\mathbf{653 mm^2}$

Figure 6: Measurement Results After Network Expansion

The calculation obtained after the installation of the new network is 420V, which was initially 336.5V to 420V which has increased to 83.5V. By using an insert transformer with a power of 50kVA using a distribution network conductor cross-section of 4.95 km, and 34 poles.

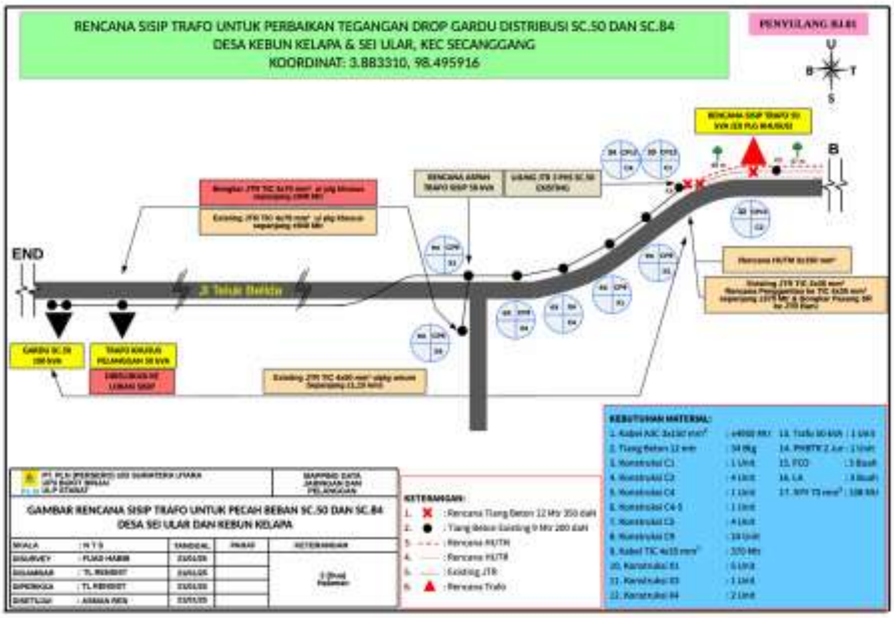


Figure 7: Material Description

Conclusion

Based on the results of the calculation of the determination of the conductor cross-section on a distribution network along 4.95 km with a load current of 214.47 A and a voltage drop limit (ΔV) of 63.5 V, the following results were obtained:

1. For copper conductors, the total allowable resistance 0.2137 Ω, so the minimum cross-section of the required conductor is about 400 mm².
2. For aluminum conductors, with the same total resistance 0.2137 Ω, a larger minimum cross-section is required which is about 650 mm².

After the expansion of the new network using an insert transformer with a power of 50Kva to create a new voltage which initially the drop voltage of 336, 5V changed to 420V where the difference was quite large, namely 83.5V by using a cross-section of the distribution network conductor along 4.95 km, and a pole of 34 rods.

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