# Analysis of Electric Power Distribution System Planning (Case Study at PLN ULP East Binjai)

**Agus Wirya Nata, Rahmaniar, Dino Erivianto**


## Abstract

Voltage quality is one of the main indicators in the reliability of the electric power distribution system, where excessive voltage drops can reduce the quality of service and directly impact the performance of customer electrical equipment. This study was conducted on the distribution network of PLN ULP Binjai Timur with the analysis focus on the outgoing line of a 100 kVA distribution transformer that supplies the load through aluminum conductor cables with a cross section of 35 mm² and 70 mm² with a length of 400 meters. The load current data obtained on each phase is 53 A for phase R, 50 A for phase S, and 51 A for phase T, with an average power factor of 0.85. Based on calculations, the use of 35 mm² cables results in a phase-neutral voltage drop of 8.50%–9.01% and a phase-phase voltage of 8.56%–9.07%, which clearly exceeds the maximum technical standard limit of 5%. This condition has the potential to cause higher power losses and voltage instability on the customer side. In contrast, the use of 70 mm² cables showed significant improvements, with phase-neutral voltage drops ranging from 4.51%–4.78% and phase-to-phase voltage drops of 4.53%–4.81%, thus still meeting voltage service standards. These results confirm that selecting larger cable cross-sectional sizes in distribution networks not only reduces voltage drops but also supports energy efficiency, extends equipment lifespan, and improves customer satisfaction. These findings can be used as a basis for technical considerations in the planning and development of electricity distribution systems in PLN's operational areas, particularly in areas with rapid load growth.


***Keywords***: Power Distribution, Voltage Drop, Power Factor, Aluminum Cable, PLN ULP Binjai Timur


Agus Wirya Nata
Department of Electrical Engineering, Faculty of Science and Technology, Panca Budi Development University, Indonesia
e-mail: nataaguswirya@gmail.com

Rahmaniar, Dino Erivianto
e-mail: rahmaniar@dosen.pancabudi.ac.id, derivianto@gmail.com.

## Introduction

The growth of electricity users increases in line with the growth of customers every year, this situation ensures that electricity suppliers continue to increase the number of generators [1]. Along with growth and development, the need for facilities and infrastructure also increases, for example, the provision of electricity [2]. The need for electricity is always increasing, electricity is needed to support development and encourage community progress [3]. PT. PLN (Persero) is a State-Owned Enterprise (BUMN) that is committed to providing electricity to all Indonesian people. Along with the increasing population and accompanied by current technological advances, the basic need for electricity continues to increase, so that the basic need for electricity has become a basic need for Indonesian citizens. Electricity includes a generation system, a transmission system, and a distribution system. The distribution system is divided into 2, namely medium voltage distribution (Primary Distribution) with a voltage of 20 KV and voltage distribution (Secondary Distribution) with a voltage of 220/380 V. Feeders coming out of the GI (main substation) usually have a voltage of 20 kV. Then it is split and directed to the ULP (Customer Service Unit). The long distance of electricity transmission from the grid causes a loss of voltage and current (also known as voltage drop) [4]. Electricity is a primary need in today's life, be it social, economic, religious, educational, business, and various other fields. In Indonesia, the electricity business process is managed by PT PLN (Persero) as the main party responsible for ensuring that all communities are supplied with electrical energy [5]. The East Binjai PLN Service Unit as the operational entity responsible for electricity distribution in this region faces a major challenge in ensuring the availability of sufficient and quality energy. One of the main challenges faced is the limited distribution network infrastructure, technical disruptions, and voltage drops. Without careful and data-based planning, the distribution system is feared to be unable to meet the ever-increasing energy needs. Electrical installations have three main parts, namely, voltage sources, conductors, and resistance. The voltage source originating from the power plant is distributed through conductors [6].

Power generation centers are located far from the load center, this results in significant losses in the distribution of electrical power. These losses are caused by the long lines [7]. The electric power distribution network plays an important role in channeling electrical energy from distribution substations to consumers, both for household and industrial purposes. The quality of electricity supply received by customers is greatly influenced by the condition of the distribution network, especially the low voltage network (JTR) which operates at a nominal voltage of 220 V [8]. In the electric power distribution system, conductors play an important role in delivering electrical energy from the source to consumers. Conductors with high resistance cause greater power losses, resulting in a voltage drop at the end point of the line, which in turn affects the quality of electricity received by consumers and the efficiency of the distribution system [9]. The low quality of the electric power distribution system can cause voltage drops. Therefore, a method is needed to improve voltage drops, where the method used in this study uses the distribution network up-rating method [10]. In general, the voltage drop that occurs along the electric power network is directly proportional to the length of the line and inversely proportional to the cross-sectional area of the conductor used in the line/network. Voltage drop can also be defined as the difference between the voltage at the sending end and the voltage at the receiving end [11]. The causes of voltage drop are due to the length of the electric power distribution system, the diameter of the conductor wire used, the type of conductor wire, the resistance size of the conductor wire [12]. Technological developments in various sectors demand optimal electricity provision through adequate supply and quality distribution systems. This is a challenge for electricity providers to continue to improve the quality of service and continuity of energy supply to consumers. One indicator of the quality of electric energy service is voltage drop. The smaller the value of these two parameters, the better the quality of the electric power system [13]. Safety feasibility related to the use of cables in high-rise buildings refers to the standards set out in the IEC (International Electrotechnical Commission), as a usage time limit, where the standardization of installed electrical cables has a usage time limit [14].

One of the problems in the distribution of electricity at PT. PLN (Persero) is voltage drop. The condition of voltage drop is the difference between the sent voltage and the received voltage. Voltage drop can occur due to several things including inappropriate conductor cross-sectional size, flowing current and network lines that are too long so that the voltage at the end of the network leading to the customer is below the tolerance value. The good or bad of the electricity distribution and distribution system is primarily reviewed from the quality of the voltage received by consumers / customers. PT PLN has set a voltage drop tolerance limit in SPLN 1: 1995 of 5% - 10%, in the medium voltage network (JTM). To reduce the voltage drop is by replacing the conductor cross-section size with a larger cross-section size. In this study, researchers conducted manual calculations and simulations to analyze the estimated voltage drop. In this analysis process, the estimated effect of uprating the conductor cross-section on improving the voltage drop can be known. The use of ETAP software is used to facilitate the calculation of voltage drop [15].

## Literature Review

Electric Power Distribution is the process of sending electrical power from the electrical transmission system to consumers. Distribution substations are connected to the transmission system, and the voltage is stepped down using transformers.

### 2.1 Distribution Substation

Distribution Substation is an electrical substation building that contains or consists of installations of Medium Voltage Equipment (PHB-TM) and Low Voltage Connection Equipment (PHB-TR) to supply electricity needs for customers both Medium Voltage (TM 20 kV) and Low Voltage (TR 220/380V). The type of connection equipment for medium voltage in a distribution substation differs according to the type of substation construction [12].

2.2 Primary Distribution Network

Primary Distribution is a transmission network whose voltage is reduced at the Main Substation (GI) to medium voltage (TM) with a nominal voltage of 20 KV which is called the medium voltage network (JTM) then distributed to the transformer at the Distribution Substation and the voltage is increased/decreased then distributed to customers [12].

2.3 Secondary Distribution Network

Secondary distribution is a distribution network from the distribution substation and is distributed to customers with a voltage classification of 220 V or 380 V (Inter-Phase). The network from the Distribution Substation is called a low voltage network (JTR), then distributed to customers' homes which is called a house connection (SR) [12].

2.4 Voltage Drop

Voltage drop is the decrease in voltage that occurs in a conductor during the process of distributing electrical energy from the source to the load. This drop occurs due to resistance (R) and reactance (X) in the conductor, which causes a difference between the voltage at the sending and receiving end [15]. This phenomenon occurs not only at the customer end but also in the electricity company's network, significantly impacting the quality of energy received by consumers. In distribution system design, standards such as those stipulated in the voltage rating standard (SPLN) and IEEE Std. 141-1993 recommend that the voltage drop at the receiving end not exceed 10% of the nominal voltage. This limit is important to ensure optimal operation of electrical equipment at the consumer end without damage due to unstable voltage. To achieve this limit, network design must accommodate conductor characteristics, including R and X values, and consider other factors such as transmission distance and environmental conditions that can affect conductor performance in both transmission and distribution lines [13].

## Research Methodology

This research was conducted using a quantitative approach based on technical calculations to determine the magnitude of voltage drop in the distribution network. The primary data used came from direct field measurements, including the current in each phase (R, S, and T), the length of the conductor cable, the type and cross-sectional area of the cable, and the load power factor. Additional information regarding voltage standards and tolerance limits refers to PLN and SNI regulations.

The first step began with collecting technical data at the distribution substation, particularly on the left outgoing section. Once the data was collected, it was processed using a three-phase voltage drop calculation formula that includes the resistance (R) and reactance (X) values of the cable per kilometer. To ensure the accuracy of the results, each resistance and reactance value was recalculated by adjusting for the actual cable length in the field.

Next, calculations were performed for two scenarios: using 35 $mm^2$ aluminum cables and 70 $mm^2$ aluminum cables, each with a conductor length of 400 meters. From these two scenarios, voltage drop values were obtained for both phase-neutral and phase-phase systems. The calculation results were then compared with the maximum voltage drop limit (5%) to assess the feasibility of using each cable type.

The final stage was analysis of the results. In this section, the researchers not only presented figures but also interpreted their impact on the quality of electricity supply, distribution network reliability, and customer comfort. With this approach, the research went beyond calculations but also provided practical insights that could be used as a basis for decision-making in the field.

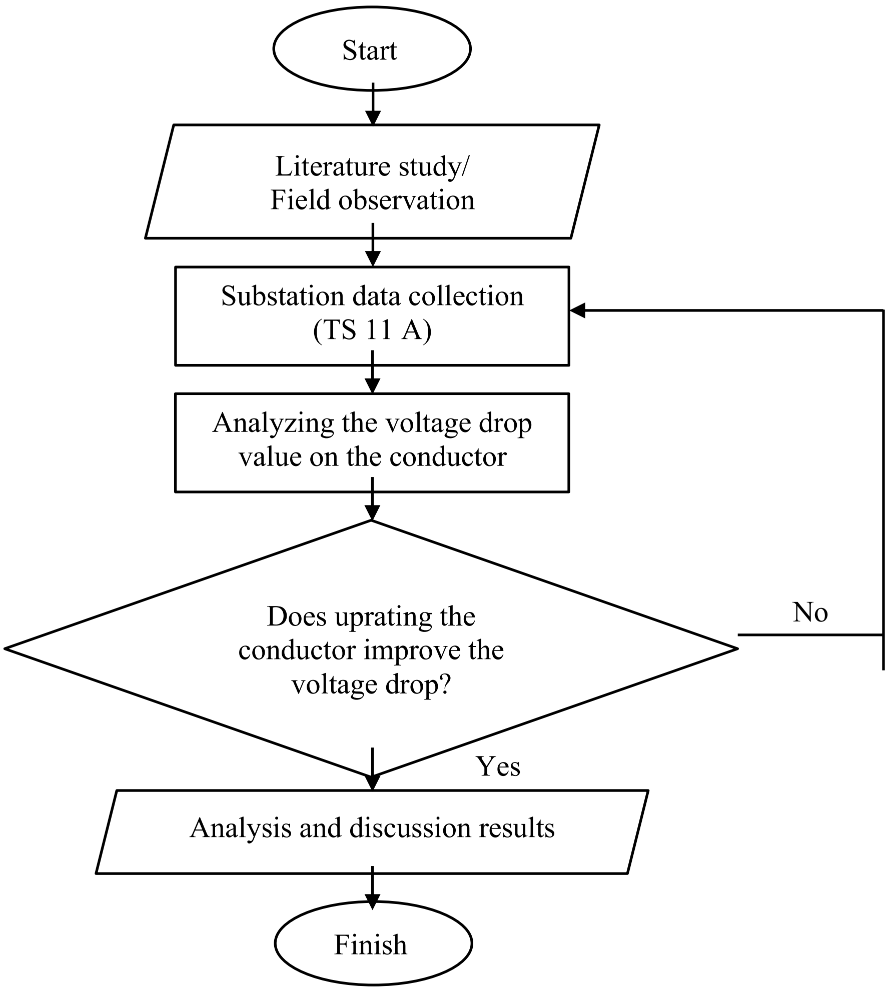



Figure 1. Flowchart

### 3.1 Distribution Substation Measurements

Field measurement data from the TS 11 A distribution substation in the PR Griya Sirsak 1 area provides a clear picture of the load conditions and voltage quality distributed to customers. Recorded information includes incoming current from the main feeder, outgoing current to the left and right side of the network, and phase-to-phase and phase-to-neutral voltages. Furthermore, substation protection features, such as the LVC, FCO, and grounding system, were inspected to ensure operational reliability. This data set provides a critical basis for assessing load balance, voltage stability, and the potential for voltage drops in the substation's outgoing conductors.

Table 1: Measurement Data from TS 11 A Distribution Substation

| Data Summary | | | |
|---|---|---|---|
| Substation Code | TS 11 A | | |
| Location | PR Griya Sirsak 1 | | |
| Transformer Brand | Starlite | | |
| Capacity | 100 kVA | | |
| Feeder | PI 6 | | |
| Date/Time | 25-07-2025, 10:58 WIB | | |
| INCOMING (A3CS 70 mm²) | | | |
| Current | | | |
| R = 73 A | S = 63 A | T = 66 A | N = 20 A |
| OUTGOING - Left (TIC 70 mm²) | | | |
| Current | | | |
| R = 53 A | S = 50 A | T = 51 A | N = 8 A |
| Fuse | | | |
| R = 125 A | S = 125 A | T = 160 A | |
| OUTGOING - Right (TIC 70 mm²) | | | |
| Current | | | |
| R = 17 A | S = 14 A | T = 11 A | N = 5 A |
| Fuse | | | |
| R = 125 A | S = 125 A | T = 125 A | |
| Voltage | | | |
| Phase-Neutral Voltage | RN = 225 V | SN = 224 V | TN = 224 V |
| Phase-to-Phase Voltage | RS = 387 V | RT = 388 V | ST = 387 V |
| Neutral - Earth = 1.9 V | | | |

Protection Equipment

a. LVC: Reliable
b. FCO: Reliable
c. LA (Lightning Arrester): Available
d. APG (Substation Protective Arrester): Available
e. Mimir: Not Available

Grounding:

a. LA Ground: Available
b. Transformer Body Ground: Available
c. Neutral Ground: Available

Initial Analysis

a. Incoming currents (R, S, T) are relatively balanced, although there is a difference of approximately 10 A.
b. Outgoing current on the left is greater than outgoing current on the right, with the dominant load on the left side.
c. Phase-neutral voltages (225 V, 224 V, 224 V) are within normal limits (±5% of 220–230 V).
d. Interphase voltage (387–388 V) meets 3-phase system standards (ideal 380–400 V).
e. Neutral-to-ground voltage (1.9 V) is still considered good (<5 V).
f. Protection is complete and the condition is considered reliable.

2. Calculation of Voltage Drop Value Going Left Out

Parameter out going left
$I_R$ = 53 A
$I_S$ = 50 A
$I_T$ = 51 A
L = 400 m = 0,4 km
$Cos\varphi$ = 0,85
$Sin\varphi = \sqrt{1 - 0{,}85^2} \approx 0{,}5267827$
$V_{L-N}$ = 225 V
$V_{L-L}$ = 387,3 V
$\sqrt{3} \approx 1{,}73205$

Formula:
For a phase-neutral system, the approximate voltage drop magnitude is:

$$\Delta V = I\,(R_L\, Cos\varphi + X_L\, Sin\varphi)$$

For a phase-phase system, the approximate voltage drop magnitude is:

$$\Delta V = \sqrt{3}\, I\,(R_L\, Cos\varphi + X_L\, Sin\varphi)$$

with, $R_L = R_{per\ km} \times L_{km}$ dan $X_L = X_{per\ km} \times L_{km}$

Percentage of voltage (phase – neutral):

$$\%\Delta V = \frac{\Delta V}{V_{L-N}}\ x\ 100\%$$

Percentage to voltage (phase – phase):

$$\%\Delta V = \frac{\Delta V}{V_{L-L}}\ x\ 100\%$$

The 35 $mm^2$ cable
Kilometer value: R = 1.077 Ω/km, X = 0.0783 Ω/km
For 0.4 km:
R = 1,077 Ω/km
X = 0,0783 Ω/km
$R_L$ = 1,077 x 0,4 = 0,4308 Ω
$X_L$ = 0,0783 x 0,4 = 0,03132 Ω

Calculation of voltage drop value (phase – neutral)

1. Phase R (I = 53 A)
   $\Delta V_R = I\,(R_L\, Cos\varphi + X_L\, Sin\varphi)$

$\Delta V_R = 53 \times (0{,}4308 \times 0{,}85 + 0{,}03132 \times 0{,}52678)$
$\Delta V_R = 20{,}28$ V

Percentage of phase – neutral voltage:

$$\%\Delta V_R = \frac{\Delta V_R}{V_{L-N}} \, x \, 100\%$$
$$\%\Delta V_R = \frac{20{,}28}{225} \, x \, 100\%$$
$$\%\Delta V_R = 9{,}01\%$$

2. Phase S (I = 50 A)
$\Delta V_S = I\,(R_L\, Cos\varphi + X_L\, Sin\varphi)$
$\Delta V_S = 50 \times (0{,}4308 \times 0{,}85 + 0{,}03132 \times 0{,}52678)$
$\Delta V_S = 19{,}13$ V

Percentage of phase – neutral voltage:

$$\%\Delta V_S = \frac{\Delta V_S}{V_{L-N}} \, x \, 100\%$$
$$\%\Delta V_S = \frac{19{,}13}{225} \, x \, 100\%$$
$$\%\Delta V_S = 8{,}50\%$$

3. Phase T (I = 51 A)
$\Delta V_T = I\,(R_L\, Cos\varphi + X_L\, Sin\varphi)$
$\Delta V_T = 51 \times (0{,}4308 \times 0{,}85 + 0{,}03132 \times 0{,}52678)$
$\Delta V_T = 19{,}51$ V

Percentage of phase – neutral voltage:

$$\%\Delta V_T = \frac{\Delta V_T}{V_{L-N}} \, x \, 100\%$$
$$\%\Delta V_T = \frac{19{,}51}{225} \, x \, 100\%$$
$$\%\Delta V_T = 8{,}67\%$$

Voltage drop value calculation (phase – phase)

1. Phase R (I = 53 A)
$\Delta V_R = \sqrt{3}\, I\,(R_L\, Cos\varphi + X_L\, Sin\varphi)$
$\Delta V_R = \sqrt{3} \times 53 \times (0{,}4308 \times 0{,}85 + 0{,}03132 \times 0{,}52678)$
$\Delta V_R = 35{,}13$ V

Percentage of phase-to-phase voltage:

$$\%\Delta V_R = \frac{\Delta V_R}{V_{L-L}} \, x \, 100\%$$
$$\%\Delta V_R = \frac{35{,}13}{387{,}3} \, x \, 100\%$$
$$\%\Delta V_R = 9{,}07\%$$

2. Phase S (I = 50 A)
$\Delta V_S = \sqrt{3}\, I\,(R_L\, Cos\varphi + X_L\, Sin\varphi)$
$\Delta V_S = \sqrt{3} \times 50 \times (0{,}4308 \times 0{,}85 + 0{,}03132 \times 0{,}52678)$

$\Delta V_S = 33{,}13$ V

Percentage of phase-to-phase voltage:

$$\%\Delta V_S = \frac{\Delta V_S}{V_{L-L}}\ x\ 100\%$$
$$\%\Delta V_S = \frac{33{,}13}{387{,}3}\ x\ 100\%$$
$$\%\Delta V_S = 8{,}56\%$$

3. Phase T (I = 51 A)
   $\Delta V_T = \sqrt{3}\ I\ (R_L\ Cos\varphi + X_L\ Sin\varphi)$
   $\Delta V_T = \sqrt{3}$ x 51 x (0,4308 x 0,85 + 0,03132 x 0,52678)
   $\Delta V_T = 33{,}81$ V

   Percentage of phase-to-phase voltage:

$$\%\Delta V_T = \frac{\Delta V_T}{V_{L-L}}\ x\ 100\%$$
$$\%\Delta V_T = \frac{33{,}81}{387{,}3}\ x\ 100\%$$
$$\%\Delta V_T = 8{,}73\%$$

The 70 mm$^2$ cable
Kilometer value: R = 0.550 Ω/km, X = 0.0751 Ω/km
For 0.4 km:
R = 0,550 Ω/km
X = 0,0751 Ω/km
$R_L$ = 0,550 x 0,4 = 0,220 Ω
$X_L$ = 0,0751 x 0,4 = 0,03004 Ω

Calculation of voltage drop value (phase – neutral)

1. Phase R (I = 53 A)
   $\Delta V_R = I\ (R_L\ Cos\varphi + X_L\ Sin\varphi)$
   $\Delta V_R$ = 53 x (0,220 x 0,85 + 0,03004 x 0,52678)
   $\Delta V_R = 10{,}75$ V

   Percentage of phase – neutral voltage:

$$\%\Delta V_R = \frac{\Delta V_R}{V_{L-N}}\ x\ 100\%$$
$$\%\Delta V_R = \frac{10{,}75}{225}\ x\ 100\%$$
$$\%\Delta V_R = 4{,}78\%$$

2. Phase S (I = 50 A)
   $\Delta V_S = I\ (R_L\ Cos\varphi + X_L\ Sin\varphi)$
   $\Delta V_S$ = 50 x (0,220 x 0,85 + 0,03004 x 0,52678)
   $\Delta V_S = 10{,}14$ V

   Percentage of phase – neutral voltage:

$$\%\Delta V_S = \frac{\Delta V_S}{V_{L-N}}\ x\ 100\%$$
$$\%\Delta V_S = \frac{10{,}14}{225}\ x\ 100\%$$
$$\%\Delta V_S = 4{,}51\%$$

3. Phase T (I = 51 A)
   $\Delta V_T = I\ (R_L\ Cos\varphi + X_L\ Sin\varphi)$
   $\Delta V_T = 51\ x\ (0{,}220\ x\ 0{,}85 + 0{,}03004\ x\ 0{,}52678)$
   $\Delta V_T = 10{,}34\ V$

   Percentage of phase – neutral voltage:
   $$\%\Delta V_T = \frac{\Delta V_T}{V_{L-N}}\ x\ 100\%$$
   $$\%\Delta V_T = \frac{10{,}34}{225}\ x\ 100\%$$
   $$\%\Delta V_T = 4{,}60\%$$

Voltage drop value calculation (phase – phase)

1. Phase R (I = 53 A)
   $\Delta V_R = \sqrt{3}\ I\ (R_L\ Cos\varphi + X_L\ Sin\varphi)$
   $\Delta V_R = \sqrt{3}\ x\ 53\ x\ (0{,}220\ x\ 0{,}85 + 0{,}03004\ x\ 0{,}52678)$
   $\Delta V_R = 18{,}61\ V$

   Percentage of phase-to-phase voltage:
   $$\%\Delta V_R = \frac{\Delta V_R}{V_{L-L}}\ x\ 100\%$$
   $$\%\Delta V_R = \frac{18{,}61}{387{,}3}\ x\ 100\%$$
   $$\%\Delta V_R = 4{,}81\%$$

2. Phase S (I = 50 A)
   $\Delta V_S = \sqrt{3}\ I\ (R_L\ Cos\varphi + X_L\ Sin\varphi)$
   $\Delta V_S = \sqrt{3}\ x\ 50\ x\ (0{,}220\ x\ 0{,}85 + 0{,}03004\ x\ 0{,}52678)$
   $\Delta V_S = 17{,}55\ V$

   Percentage of phase-to-phase voltage:
   $$\%\Delta V_S = \frac{\Delta V_S}{V_{L-L}}\ x\ 100\%$$
   $$\%\Delta V_S = \frac{17{,}55}{387{,}3}\ x\ 100\%$$
   $$\%\Delta V_S = 4{,}53\%$$

3. Phase T (I = 51 A)
   $\Delta V_T = \sqrt{3}\ I\ (R_L\ Cos\varphi + X_L\ Sin\varphi)$
   $\Delta V_T = \sqrt{3}\ x\ 51\ x\ (0{,}220\ x\ 0{,}85 + 0{,}03004\ x\ 0{,}52678)$
   $\Delta V_T = 17{,}91\ V$

   Percentage of phase-to-phase voltage:

$$\%\Delta V_T = \frac{\Delta V_T}{V_{L-L}} x\ 100\%$$
$$\%\Delta V_T = \frac{17{,}91}{387{,}3} x\ 100\%$$
$$\%\Delta V_T = 4{,}62\%$$

**Results**

The results of the voltage drop calculations on the left outgoing for two types of cables, namely 35 mm² and 70 mm², show quite striking differences.

Table 2: Calculation results of the voltage drop value going out left on a 35 mm$^2$ cable

| Phase | I (A) | $\Delta V_{L-N}$ (V) | $\%\Delta V_{L-N}$ (%) | $\Delta V_{L-L}$ (V) | $\%\Delta V_{L-L}$ (%) |
|---|---|---|---|---|---|
| R | 53 | 20,28 | 9,01 | 35,13 | 9,07 |
| S | 50 | 19,13 | 8,50 | 33,13 | 8,56 |
| T | 51 | 19,51 | 8,67 | 33,81 | 8,73 |

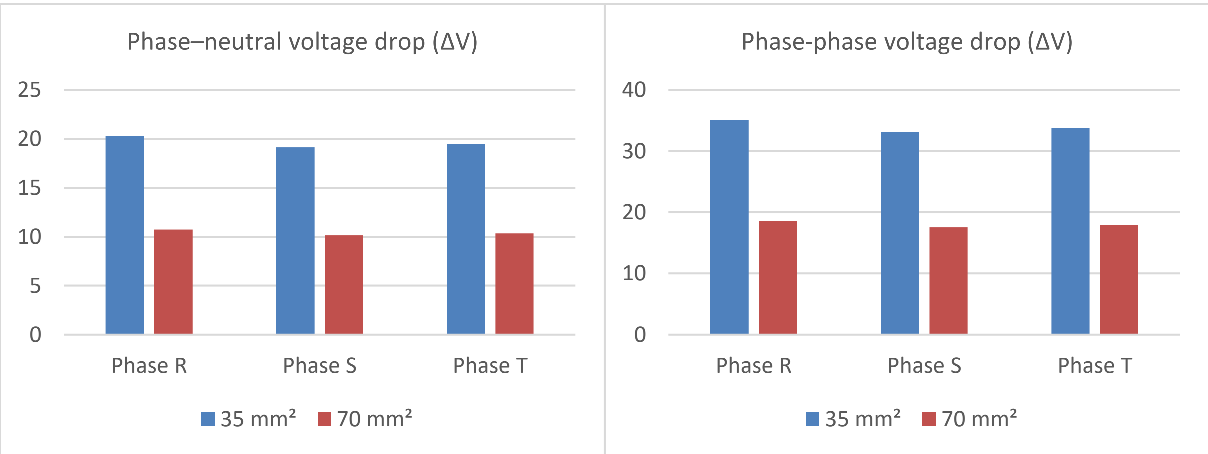
On a 35 mm² cable, the average voltage drop is in the range of 19–20 V for the phase–neutral connection (approximately 8.5–9.0% of the nominal voltage), and 33–35 V for the phase–phase connection (approximately 8.5–9.1%). This figure clearly exceeds the 5% tolerance limit commonly used in SPLN/SNI standards. This means that if this cable is used in real conditions, the voltage at the end of the line can drop too low, causing lights to dim, induction motors to overheat, and even potentially causing electronic equipment to malfunction.

Table 3: Results of the calculation of the voltage drop value going out to the left on a 70 mm$^2$ cable

| Phase | I (A) | $\Delta V_{L-N}$ (V) | $\%\Delta V_{L-N}$ (%) | $\Delta V_{L-L}$ (V) | $\%\Delta V_{L-L}$ (%) |
|---|---|---|---|---|---|
| R | 53 | 10,75 | 4,78 | 18,61 | 4,81 |
| S | 50 | 10,14 | 4,51 | 17,55 | 4,53 |
| T | 51 | 10,34 | 4,60 | 17,91 | 4,62 |

Meanwhile, the 70 mm² cable performed much better. Voltage drops were recorded at only around 10–11 V between phase and neutral (4.5–4.8%) and 17–19 V between phase and phase (4.5–4.8%). All these values are safely below 5%, ensuring that voltage quality is maintained. Therefore, the 70 mm² cable is more suitable for use with a 400-meter long left-hand outgoing load with a current of 50–53 A.

This difference occurs because cable resistance is inversely proportional to cross-sectional area. The larger the cross-section (from 35 to 70 mm²), the smaller the resistance, and the correspondingly lower voltage drop. These results also show that the slight difference in current between phases (53 A, 50 A, and 51 A) does have an impact, but it is not a dominant



factor compared to the choice of cable size. Technically, the use of a 35 mm² cable in these conditions is not recommended, as it degrades voltage quality beyond standard limits. On the other hand, 70 mm² cable not only meets the requirements, but is also more efficient in reducing power losses and maintaining customer comfort.

Figure 2. Voltage drop (ΔV) phase – neutral and phase – phase

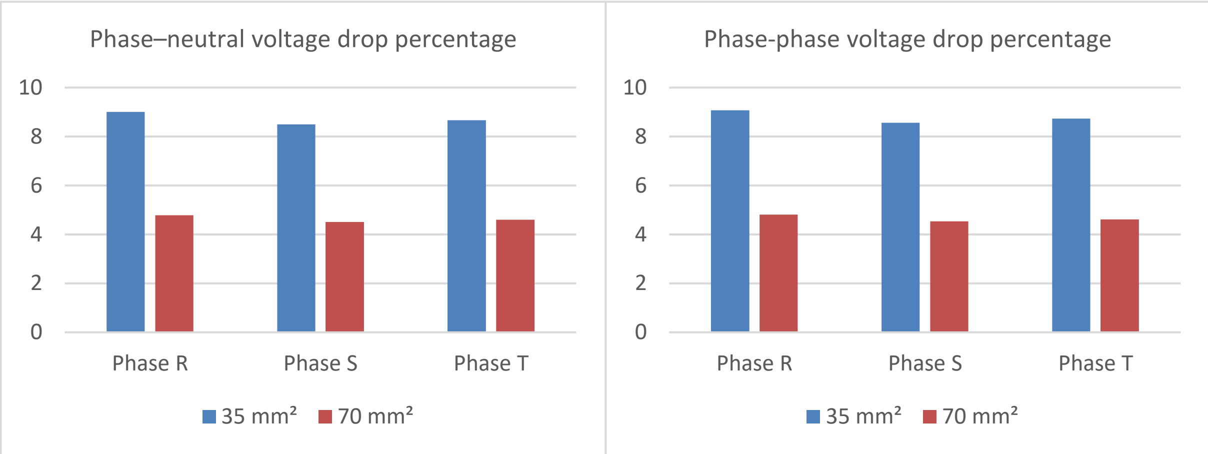



Figure 3. Percentage of phase-neutral and phase-phase voltage drops

The following graphs show the voltage drop calculations for 35 mm² and 70 mm² cables:

a. The first graph shows the phase-neutral voltage drop (ΔV).
b. The second graph displays the phase-phase voltage drop (ΔV).
c. The third graph compares the phase-neutral voltage drop percentage.
d. The fourth graph shows the phase-phase voltage drop percentage.

These graphs clearly demonstrate that using 70 mm² cables consistently results in lower voltage drop than using 35 mm² cables.

From the comparison graph, it's clear that 70 mm² cables are far superior in suppressing voltage drop compared to 35 mm² cables. In the phase-neutral voltage drop graph, the ΔV value for a 35 mm² cable is in the range of 19–20 V, while for a 70 mm² cable it's only around 10 V. This means that the current flowing in a conductor with a larger cross-section experiences almost half the voltage loss.

A similar trend is observed in the phase-phase graph. A 35 mm² cable produces a voltage drop of around 33–35 V, while a 70 mm² cable produces only 17–18 V. In other words, customer loads connected through smaller cables (35 mm²) are more susceptible to low voltage, especially as the conductor distance increases or the load increases.

The percentage graph further clarifies the situation. A 35 mm² cable produces a phase-neutral voltage drop of around 8.5–9%, and a phase-phase voltage drop of around 8.5–9.1%. This figure clearly exceeds the standard tolerance limit of 5%. In contrast, a 70 mm² cable yields a safe result, at only 4.5–4.8% for phase-neutral and 4.5–4.8% for phase-phase.

Simply put, this graph shows that cable size selection plays a significant role in maintaining voltage quality. Cables with a larger cross-section not only reduce voltage drop but also make the power supply more stable, efficient, and safe in the long term.

## Conclusion

Analysis of the voltage drop at the left output of a 100 kVA distribution transformer with a conductor length of 400 meters shows that cable size selection significantly impacts voltage quality. Using 35 mm² aluminum cable, the voltage drop was recorded as quite high, at 8.50%–9.01% for phase-neutral and 8.56%–9.07% for phase-to-phase. These values clearly exceed the

5% maximum tolerance limit set by the voltage service standard. This makes it unsuitable for use due to the potential for significant power losses, voltage instability, and reduced quality of electricity service to customers.

Conversely, using 70 mm² aluminum cable resulted in significant improvements, with voltage drops of 4.51%–4.78% (phase-to-neutral) and 4.53%–4.81% (phase-to-phase). These results are still within the technical standard range, indicating that using larger cable cross-sections is effective in reducing voltage drop. Thus, the selection of 70 mm² cable is more suitable for application in the low voltage distribution network at ULP Binjai Timur, because it can increase energy efficiency, extend the life of electrical equipment, and maintain customer satisfaction with the quality of electricity supply.

## References

[1] Rahmaniar, A. Junaidi, R. Salman, and J. S. Rambey, "Fundamental Study of Symmetrical Short Circuit Calculation (S-SCC) on 14 Bus IEEE-Power Systems," in *Proceedings of SEMNASTEK UISU 2021*.

[2] J. F. Sam, Rahmaniar, and H. Gunawan, "Analysis and Simulation of Load Unbalance of Distribution Transformer Feeder Lk.10 in ULP Medan City," *Jurnal Nasional Holistic Science*, vol. 5, no. 2, Aug. 2025.

[3] D. Y. Nurzaman and Waluyo, "Comparative Analysis of Power Losses and Voltage Drop on Overhead Distribution Lines and 20 kV Medium Voltage Cables," in *Proceedings of Diseminasi FTI Genap 2021/2022*.

[4] I. Apriliyanto, R. M. Utomo, A. P. Wirawan, A. Hardjanto, and F. H. Rumawan, "Voltage Drop Analysis on S-1 Feeder at Manggar Sari Substation Balikpapan," in *Proceedings of SNITT, Politeknik Negeri Balikpapan*, 2023.

[5] R. C. Pramudita, Hamdani, and Rahmaniar, "Analysis of the Impact of Electricity Usage Regulation on Reducing Non-Technical Losses at PT PLN (Persero) ULP Tapaktuan," *Jurnal Riset Rumpun Ilmu Teknik*, vol. 4, no. 1, Apr. 2025.

[6] Rahmaniar, M. R. Syahputra, D. Lesmana, and A. Junaidi, "Community Education on the Hazards of Touch Voltage and Short Circuit in Electrical Systems at Kota Pari Village," *Reswara: Jurnal Pengabdian Kepada Masyarakat*, vol. 3, no. 2, Jul. 2022.

[7] M. Masri, Z. Pelawi, R. Harahap, F. H. Pulungan, and A. Komaini, "Analysis of Distribution Transformer Placement Based on Voltage Drop in 20 kV Primary Distribution Line," *Journal of Electrical Technology*, vol. 9, no. 1, Feb. 2024.

[8] M. Syekhurohim, A. Triyanto, and M. Firdaus, "Analysis of Voltage Drop Effect on JTR at Substation KDR86P Cengkareng," *JTE UNIBA*, vol. 9, no. 2, Apr. 2025.

[9] R. B. Pratama, P. Wibowo, and S. Anisah, "Analysis of Conductor Replacement Impact on Voltage Drop in 20 kV Medium Voltage Overhead Lines at PT PLN (Persero) UP3 Bangkinang," *Jurnal Penelitian Inovatif (JUPIN)*, vol. 5, no. 2, May 2025.

[10] Y. A. Deavy, A. B. Fakhri, and M. Putri, "Voltage Drop Improvement through Conductor Uprating in Nr.06 Using ETAP Software," in *Proceedings of the National Conference on Social and Engineering, Politeknik Negeri Medan*, 2022.

[11] E. H. Harun, M. T. Adam, and J. Ilham, "Improvement of 20 kV Distribution Voltage Quality at Lemito Switching Station through Power Flow Study," *Jambura Journal of Electrical and Electronics Engineering*, vol. 4, no. 2, Jul. 2022.

[12] J. P. Pilat, H. Tumaliang, and S. Silimang, "Analysis of Power Losses in 20 kV Distribution Lines in Sangihe Islands Regency," *Jurnal Universitas Borneo Tarakan*, 2022.

[13] P. Julianto and N. Fadila, "Analysis of Power Losses and Voltage Drop in the Distribution System of PT Pertamina Hulu Indonesia Regional 3 Zone 10 Tarakan Field," *Elektrika Borneo Journal (JEB)*, vol. 11, no. 1, Apr. 2025.

[14] Rahmaniar, S. Anisah, and A. Junaidi, "Enhancing Understanding of PUIL 2000 and Illumination Calculation at Deli Serdang Museum," *Jurnal Abdidas*, vol. 2, no. 3, 2021.
[15] K. M. Habsari, L. Kharirroh, Y. Prasetyo, and R. J. K. Haryo, "Voltage Drop Correction Analysis Using Conductor Uprating from A3C to A3CS on West Feeder of 70 kV Mranggen Substation," in *Proceedings of Seminar Nasional FORTEI7-6, Forum Pendidikan Tinggi Teknik Elektro Indonesia Regional VII*.