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Optimization of Switching Substation Performance for Power Network Stability Against Voltage Drop Effects at ULP Kutacane

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and Performance Optimization.

ABSTRACT

This study aims to optimize the performance of the distribution substation in maintaining the stability of the electricity network, especially in reducing the effects of voltage drops in the Kuta-cane Customer Service Unit (ULP). Significant voltage drops can affect the quality of electricity supply and cause instability that impacts the performance of customers' electrical equipment. This study includes data collection on distribution substations and network conditions, voltage drop measurements at critical points in the network, and voltage distribution simulations using electrical analysis software. Based on the results of the analysis, optimization of the distribution substation was carried out by adjusting the transformer capacity, installing load balancing devices, and rearranging the load distribution to reduce voltage drops. The optimization results showed an increase in voltage stability in the Kuta-cane ULP electricity network, as indicated by a decrease in voltage drops in previously problematic areas. This optimization has proven effective in maintaining distribution stability and improving the quality of electricity supply to customers. This study produces technical recommendations that can be implemented by the Kutacane ULP in maintaining the performance of distribution substations sustainably, so as to improve the reliability of the electricity network in the region.

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INTRODUCTION

The electricity distribution network plays an important role in ensuring reliable and stable electricity availability for the community. One of the main challenges in the distribution network, especially in low and medium voltage systems, is the phenomenon of voltage drop, which refers to a decrease in the electric voltage from the standard value caused by load factors, cable length, and network equipment conditions. Significant voltage drops can result in voltage instability, which impacts the performance of customers' electrical equipment and reduces the quality of electricity supply.

In Kutacane Customer Service Unit (ULP), voltage drop problems often occur at various points in the distribution network, especially in areas far from the main substation or switching substation. This results in customer dissatisfaction because unstable voltage can cause interference to their electronic and electrical equipment. To face this challenge, efforts

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are needed to optimize the performance of switching substations that function as medium voltage distribution points that distribute energy to wide areas.

The increasing need of the community for electrical energy from year to year, along with the increase in population will lead to the development of settlements, the development of trade centers and industrial development so that the level of the community's economy will change, thus affecting the stock of electrical energy supply managed by the State Electricity Company. In general, consumers expect a continuous electrical power service system with good quality. One of the requirements for the reliability of the power supply system is good and stable voltage quality. Although the continuity of the supply of electrical energy is guaranteed, it is not necessarily able to maintain voltage stability.

Distribution substation is a means of distributing electricity from PLN to customers. with a primary voltage of 20 KV then converted by a transformer into a secondary voltage of 380 V (between phases) or 220 V (phase - neutral). Customers who use this are TR customers, both industrial and household.

One of the problems faced in the distribution of low-voltage power networks is voltage drop. Voltage drop is the difference in voltage on the sending side and the voltage on the receiving side. Communities in areas far from distribution substations tend to receive lower voltages than those in areas close to distribution substations. According to SPLN 1:1995, the Service Channel (SP) voltage tolerance is +5% of the low voltage standard voltage at the base and -10% at the end.

The magnitude of the current flowing along the low voltage twisted cable (LVTC) is not the same, because the loads are only connected to the network support poles. So it can be said that the magnitude of the current on the first pole is greater than the magnitude of the current on the second pole, and so on, getting smaller until the last pole. While the magnitude of the losses that occur along the network is the square of the current multiplied by the total resistance of the network cable. Because the magnitude of the current varies along the network, it is very difficult to calculate the overall voltage drop of the wire.

As a result of the unevenly distributed load, the length of the conductor is too far, so the sum of the three phase currents is no longer equal to zero, because the load is not balanced so that a current will flow from the neutral conductor to the earth electrode in the neutral wire (grounding rod), so that there is a voltage drop on the conductor line and power losses on the conductor. Based on the background that has been described above, a discussion was conducted on the Analysis of Voltage Drop on the Low Voltage Network of PT. PLN (Persero) ULP Kutacane.

Switching substations play a vital role in maintaining voltage stability in the distribution network. By optimizing the performance of switching substations, such as increasing transformer capacity, installing load balancing devices, and adjusting distribution configurations, voltage stability can be maintained so that voltage drops can be minimized. This optimization can also increase the efficiency of the electricity distribution system at ULP Kutacane, and support PT PLN (Persero) in providing the best service to customers.

This study aims to analyze the factors that affect the voltage drop in the distribution network at ULP Kutacane and formulate optimization solutions at the substation in order to minimize the impact of the voltage drop. Thus, the results of this study are expected to provide technical recommendations for improving the quality of electricity supply and increasing network reliability in the ULP Kutacane area.

Literature Review

Electric Power

Power is the energy needed to do work / work. Electrical power is usually expressed in Watts. Mathematically, the amount of electrical power can be written as follows:

Where :

$$P = V.I$$

Q:is electrical power (Watts)
V: is voltage (volts)
I :is electric current (amperes)

However, in an alternating current power system where voltage and current change over time, the simple formula above becomes a little more complicated. The quantities of power, current and voltage are complex numbers and the equation above becomes:

$$S = I^*V$$

where S is an apparent power and the asterisk (*) indicates the current conjugate of the complex number I, which means that in the calculation, the sign (positive or negative) of the imaginary component of the complex number must be reversed (positive to negative and vice versa).

While the actual power consumed by a load or electrical equipment is the real power (P) expressed in watts. In mathematical form, it is formulated:

$$P = Irms\ Vrms\ \cos\varphi$$

Where :
P : apparent power/active power (Watt)
φ : the angle formed between current and voltage.

There is another power component called reactive power, which is the power required to form a magnetic field.
Symbolized by Q, expressed in Var and mathematically written as:
Where :

$$Q = Irms\ Vrms\ \sin\varphi$$

Q : reactive power (Var)
φ : the angle formed by the current and voltage.

The relationship between apparent power, active power and reactive power can be seen through the power triangle, as shown in Figure 2.1.

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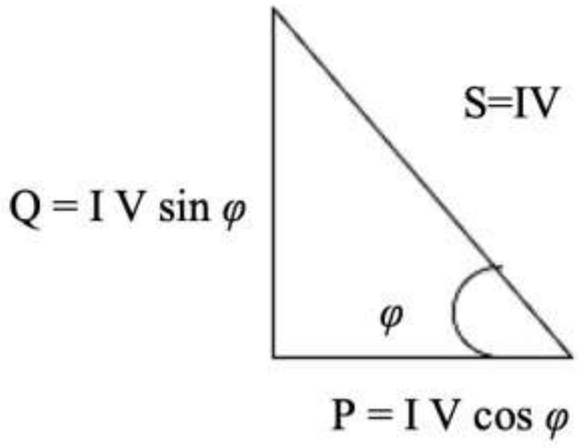

Figure 1. Triangle of Forces.

Electric Power System

A complete electric power system contains four elements. First, the power plant. Second, transmission, complete with substations. Because of the long distance, it is necessary to use high voltage (TT), or extra high voltage (TET). Third, distribution, which usually consists of a primary distribution channel of medium voltage (TM) and a secondary distribution channel of low voltage (TR). Fourth, usage (utilization), which consists of installations for using electric power. Household installations use low voltage, while large users such as industry use medium voltage.

Electrical energy is generated in a power plant (PTL) which can be a steam power plant (PLTU), hydro power plant (PLTA), gas power plant (PLTG), diesel power plant (PLTD), or nuclear power plant (PLTN). PTL usually generates electrical energy at medium voltage (TM), which is generally between 6 and 20 KV.

In a large power system, or if the PTL is located far from the user, then the electric power needs to be transported through a transmission line, and its voltage must be increased from TM to high voltage (TT). At very long distances, extra high voltage (TET) is even needed. Increasing the voltage is done at the substation (GI) using a step-up transformer.

Approaching the center of electricity consumption, which can be an industry or a city, the high voltage is lowered to medium voltage (TM). This is also done in a GI by using a step down transformer. In Indonesia, the medium voltage is 20 KV. This 20 KV line runs through the streets throughout the city, and is the primary distribution system.

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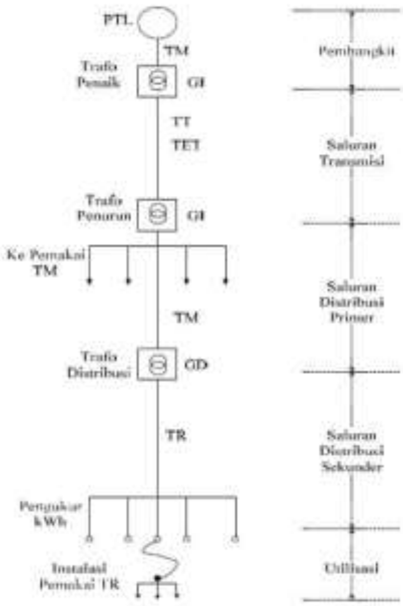

Figure 2. Electric Power System

Low voltage power distribution network is the downstream part of an electric power system, on the sides of the road, usually close to intersections there are distribution substations (GD). Which converts medium voltage to low voltage through distribution transformers.

Through the electric poles visible on the side of the road, low voltage electricity is distributed to consumers. In Indonesia, low voltage is 220/380 volts, and is a secondary distribution system, called a low voltage network (JTR). The Low Voltage Network is the distribution of electricity starting from the secondary side of the distribution transformer which covers all parts of the network and its equipment, up to the load Measuring and Limiting Device (APP).

The amount of current flowing along the conductor is not the same, because the house connection point (SR) at each TR pole is different. The amount of current at the first pole is greater than the current at the second pole, and so on gets smaller until the end pole. Voltage drop is the voltage sent is not the same as the voltage received by the load, because the current (I) flowing along the conductor is directly proportional to the resistance (R), while the amount of power loss along the network is the square of the current (I2) multiplied by the resistance of the network conductor (R).

Because the magnitude of the load current varies in each phase R, S, T throughout the network, causing the loading on the secondary transformer is an unbalanced load, the neutral current will flow to the earth through the grounding conductor. then it is difficult to calculate the overall power losses of the conductor. this study uses several assumptions and the calculation results obtained are not the actual results but are the results of the approach.

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Secondary Distribution.

A good secondary network system currently provides a level of reliability on a low voltage network with a high load density, so that its high costs can be justified and this level of reliability is considered necessary.

In general, the secondary network occurs by connecting all low-voltage sides of transformer substations filled by two or more medium-voltage feeders. On the low-voltage side of the distribution substation there is a power switch that is operated automatically and is known as automatic protection.

This protection will disconnect the transformer from the secondary network when the primary charging is lost from the low voltage side to the medium voltage side. The power switch is supported by a fuse so that when the automatic protection fails the fuse will work and disconnect the transformer from the secondary network. This will avoid a reverse current from another phase.

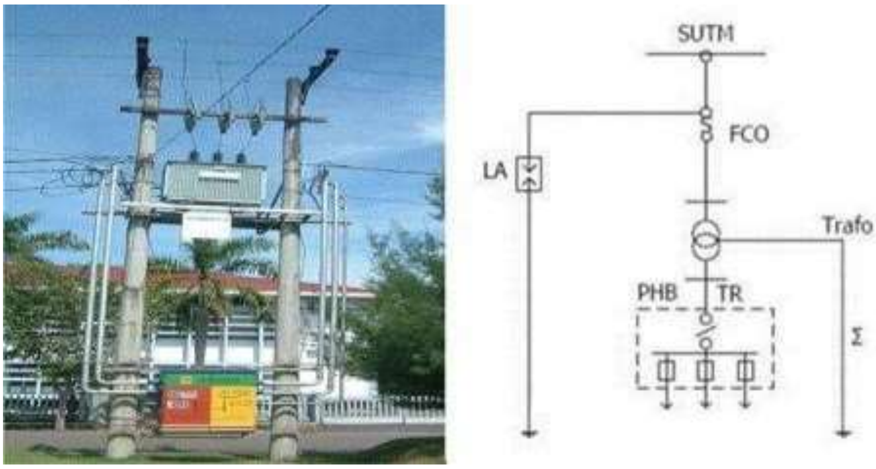

Figure 3. Switchgear

The number of primary feeders on the medium voltage side is important. If for example there are only two feeders, it can happen that one feeder is disturbed, then there will need to be sufficient transformer reserve capacity so that the system that is still working does not experience overload. The low voltage secondary network gets the most filling from three or more feeders, so that if one of the primary feeders is disturbed, the rest of the secondary network will be able to easily accommodate the load from the disturbed feeder. The low voltage secondary network must be designed in such a way that there is load sharing and voltage regulation.*(voltage regulation)*which is good on all transformers, also in the event that one of the medium voltage chargers is disturbed.

The secondary distribution system is used to distribute electric power from the distribution substation to the loads at the consumer. In the secondary distribution system, the most widely used channel form is the radial system. This system can use insulated cables or conductors without insulation. This system is usually called a low voltage system that will be directly connected to consumers/users of electric power through the following equipment:

1. Distribution transformer splitter board,

2. Low voltage transmission (secondary distribution lines).
3. Customer Service Channel (CSP) (to consumers/users)
4. Power limiting and measuring devices (kWH. meters) and fuses or security for customers.

   There are various secondary distribution voltage systems according to standards; (
   EEI : Edison Electric Institute,
   NEMA (National Electrical Manufacturers Association).

Basically no different from the DC distribution system, the main factor that needs to be considered is the amount of voltage received at the load point approaching the nominal value, so that the equipment/load can be operated optimally. Reviewed from the wiring method. AC distribution channels are divided into several types, and this wiring method also depends on the number of phases, namely:

1. One phase two wire 120 Volt system
2. Single phase three wire 120/240 Volt system
3. Three phase four wire 120/208 Volt system
4. Three phase four wire 120/240 Volt system
5. 240 Volt three phase three wire system
6. Systemthreephasethreewire480Volt
7. Three phase four wire system 240/416 Volt
8. Three phase four wire system 265/460 Volt
9. Three phase four wire system 220/380 Volt

In Indonesia, in this case, PT. PLN uses a 220/380 Volt voltage system. Meanwhile, electricity users who do not use electricity from PT. PLN, use one of the above systems according to existing standards. The electricity users in question generally depend on the lending country or in the framework of cooperation, where all electrical equipment from generator sets to work equipment (electric motors) are supplied by the lending/collaborating country. As a member of the IEC (International Electrotechnical Commission), Indonesia has begun to adjust the voltage system to 220/380 Volts only, because the IEC has not listed 127 Volts since 1967.

Low Voltage Network

Low voltage networks have several general criteria, namely a maximum goal distance of 40 meters for semi-underbuilt low voltage networks. For remote areas and few consumers. directly networked with a small transformer medium voltage network, so it does not require a low voltage network. Maximum 50 meters for pure low voltage networks and underbuilt low voltage networks. The component specifications include:

1. Pole Type of pole: Concrete pole, Iron pole. Wooden pole or pole from other materials is possible if available locally and cheaper/economical when compared to concrete pole or iron pole, and has an economic life of not less than 10 years. Strength: Working load 100 daN. Able to withstand the load pull on a straight path (angle <5°). For bends with an angle> 5° used tensile support/guy wire or compression support. Length: 7 meters
2. Aerial stranded cable.

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Aerial stranded cables for AAC phase conductors with insulation made of crosslink polyethylene (XLPE) and neutral as a hanger consisting of solid round twisted aluminum compound wire (AAAC) (SPLN 42-10: 1986 and its revisions).

The size of the twisted stranded cable selected according to SPLN 74: 1987 is as follows:

1. Aerial stranded cable hanging equipment, consisting of: Hangers on support poles/supports, function only as hangers for stranded cables. Hangers for small turns/angles and right angles/large. Equipment for pulling on the initial/final pole or pull pole. Pulling Support (Guy wire) used on the initial/final pole and pole on the bend is made of steel with a quality equivalent to steel st 37 with a right twist direction.
2. Tapping clamps for branching from the conductor.
3. Conductor end caps to protect the ends/tips on conductor at the end of the final pole.

Transformer

A transformer is a static electrical device that can transfer and change alternating voltage and current from one or more electrical circuits to another electrical circuit with the same value or a different value at the same frequency, through magnetic coupling and based on the principle of electromagnetic induction.

In general, a transformer consists of a core made of coated iron, and two coils, namely the primary coil and the secondary coil. The ratio of voltage changes will depend on the ratio of the number of turns on the coil. Usually the coil is made of copper or aluminum wire wrapped around the legs of the transformer core. Transformers are widely used in both electrical power and electronics.

The use of transformers in power systems allows the selection of appropriate and economical voltages for each requirement, for example, the need for high voltages in long-distance power transmission. The use of a very simple and reliable transformer is one of the important reasons for its use in the distribution of alternating current electricity, because alternating current is widely used for the generation and distribution of electricity.

In the distribution of alternating current electricity, there is an energy loss of R watts. This loss will be greatly reduced if the voltage is raised as high as possible. Thus, the electric power transmission lines always use high voltage. This is done mainly to reduce the energy losses that occur, by using a transformer to increase the electric voltage at the power plant from the generator voltage which is usually 6 kV - 20 kV at the beginning of the transmission to the transmission line voltage between 100 kV - 1000 kV, then lowering it again at the end of the lower tension line.

Transformers used in electric power networks are power transformers. In addition, there are other types of transformers that are widely used and are generally much smaller transformers. For example, transformers used in households to adjust the voltage from the refrigerator to the voltage from the general electric network, transformers used in fluorescent lamps and "mini" transformers used in various electronic devices, such as radio receivers, televisions and so on.

METHODS

This study uses a quantitative approach to analyze and optimize the performance of the substation in maintaining the stability of the electricity network, especially in reducing the effects of voltage drops in the Kutacane ULP area. The research stages are carried out through the following steps:

1. Literature Study.
   Literature study was conducted to understand the basic concepts and techniques of substation optimization, voltage drop analysis, and theories related to voltage stability in the electricity distribution network. This information was taken from various references, such as journals, books, PLN standards, and relevant previous research.
2. Data collection.
   Data collection is carried out in two ways:
   a. Primary Data: Direct field measurements at critical points of the Kutacane ULP distribution network, especially areas that often experience voltage drops. Measurements include voltage, current, load, and network length values.
   b. Secondary Data: Operational data and conditions of the substation obtained from ULP Kutacane records, such as transformer capacity, network configuration, and customer complaint data related to voltage.
3. Identify Critical Voltage Drop Points.
   Based on field measurement data, identification was carried out at network points that experienced significant voltage drops. These results were used to determine areas that require optimization and repair at the switchgear.
4. Network Simulation and Analysis.
   Network simulation is performed using electrical analysis software to model the voltage and current distribution in the Kutacane ULP network. This simulation aims to see the effect of distance, transformer capacity, and load on the voltage drop that occurs.
5. Switchgear Performance Optimization.
   Based on the analysis results, optimization was carried out on the switching substation using several methods, such as:
   a. Transformer Capacity Addition: To adapt to high loads in certain areas.
   b. Load Distribution Reset: Distributes the load evenly to reduce voltage drop at a particular point.
   c. Load Balancing Device Installation: Balances current and voltage across the network to reduce voltage fluctuations.
6. Evaluation and Validation of Results.
   After the optimization implementation, re-measurements are performed to evaluate the reduction in voltage drop and the improvement in voltage stability in the network. The results of these measurements are compared with the data before the optimization to assess the effectiveness of the implemented solution.
7. Data Analysis and Interpretation.

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Data obtained from measurement, simulation, and optimization results are analyzed quantitatively to see the correlation between optimization performed and changes in voltage stability. This data is then interpreted to provide relevant recommendations for ULP Kutacane.

This research method is expected to be able to provide an appropriate solution to overcome the problem of voltage drops in the distribution network at ULP Kutacane and support the improvement of the quality of PLN services for customers.

The result is the solution of the problems in this study. The problem will be solved mathematically using existing equations manually. The results of this study are in the form of conclusions that show whether the distribution transformer at low voltage in the Kutacane ULP Distribution Substation is experiencing excessive loading or not.

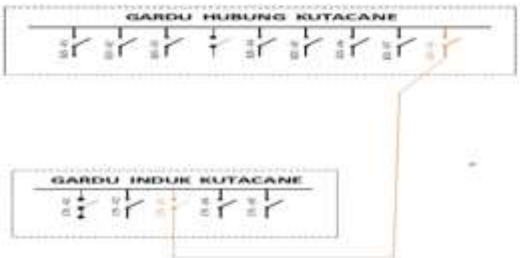

Figure 4. Flow Diagram of Main Substation to Switching Substation

RESULT

Steps to Calculate Voltage Drop Network Low Voltage

The amount of electric voltage flowing through a conductor cable will decrease or what is commonly called a drop voltage when it passes through a conductor and receives an electric load. In calculating the Distribution Substation Voltage Drop on the KN feeder 08-48, materials are needed in the form of data including:

a. Length of Conductor
   The length used is the length of the KN 08 feeder conductor.
b. Conductor Resistance
   The resistance value of the conductor on the KN 08 feeder has been determined from factory data (manufactures data) with units of Q/km.
c. Conductor Reactance
   The reactance value of the conductor in the KN 08 feeder.
d. Sender Voltage
   Operating voltage on the medium voltage network supplied from the Kutacane Main Substation to the KN 08-48 feeder.

Voltage Drop Calculation

Voltage Drop Voltage drop is the difference between the voltage at the sending end and the receiving end. This causes losses to consumers, because it can reduce the life of the electronic devices used. For to ensure the continuity of electricity distribution to consumers, the voltage drop needs to be limited to a certain price. So the permissible voltage tolerance limit is a minimum of 5% and a maximum of 10% of the nominal voltage.

In this study we analyze the Voltage Drop that occurs around Kutacane which is located close to the office of PT PLN (Persero) Rayon Kutacane. The things we examine include: The voltage on the panel, and the voltage at the end of the network and then compare them to find out what percentage of voltage drop is experienced by each distribution transformer. The tool we use in this study is Tang Amper. Here are some distribution substations that we examined on this occasion:

Table 1. Results of voltage measurements at the KN08-51 Distribution Substation.

SUBSTATION CODE	LOCATION	PHAS	VOLTAGE ON PANEL(V)	VOLTAGE ON END OF THE NET (V)
		R	229	222
KN08-51	GULO II	S	232	218
		T	232	219

From the calculation results, the voltage drop that occurs in phase R at the KN08-51 Distribution Substation is very low.

Table 2. Results of voltage measurements at the KN08-50 Distribution Substation

SUBSTATION CODE	LOCATION	PHAS	VOLTAGE ON PANEL (V)	VOLTAGE ON END OF THE NET (V)
		R	220	200
KN08-50	GULO I	S	220	194
		T	220	197

From the calculation results, the voltage drop that occurs in each phase at the KN08-50 Distribution Substation is quite large.

Table 2. Results of voltage measurements at the KN08-48 distribution substation

SUBSTATION CODE	LOCATION	PHASA	VOLTAGE ON PANEL (V)	VOLTAGE ON END OF THE NET (V)
		R	222	205
KN08-48	Rumah	S	225	212
	Bundar	T	224	195

From the calculation results, the voltage drop that occurs in phase T at the KN08-48 substation is quite large.

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Distribution Substatio.

Table 3. Results of voltage measurements at the KN08-47 distribution substation

SUBSTATION CODE	LOCATION	PHAS	VOLTAGE ON PANEL (V)	VOLTAGE ON END OF THE NET (V)
KN08-47	SIMPUR	R	224	215
		S	225	212
		T	221	212

From the calculation results, the voltage drop that occurs in the R, T phase at the KN08-47 substation is quite low below the voltage tolerance.

Voltage Drop Calculation Results:

$$\Delta V_R = \frac{220-200}{220} x100\% = 9\%$$

$$\Delta V_S = \frac{230-198}{230} x100\% = 13\%$$

$$\Delta V_T = \frac{230-197}{230} x100\% = 14\%$$

From the calculation results, the voltage drop that occurs in each phase at the KN08-41 Distribution Substation is quite large.

Table 4. Results of voltage measurements at the KN08-40 Distribution Substation

SUBSTATION CODE	LOCATION	PHAS	VOLTAGE ON PANEL(V)	VOLTAGE ON END OF THE NET (V)
KN08-40	LAK LAK	R	229	222
		S	232	218
		T	232	218

From the calculation results, the voltage drop that occurs in phase S at the KN08-40 Distribution Substation is very low.

Table 5 Results of voltage measurements at the KN08-39 Distribution Substation

SUBSTATION CODE	LOCATION	PHAS	VOLTAGE ON PANEL(V)	VOLTAGE ON END OF THE NET(V)
KN08-39	SHORT	R	222	205
		S	225	212
		T	224	195

Voltage Drop Calculation Results:

$$\Delta V_R = \frac{222-205}{222} x100\% = 7\%$$

$$\Delta V_S = \frac{225-212}{225} x100\% = 5\%$$

$$\Delta V_T = \frac{224-195}{224} x100\% = 12\%$$

From the calculation results, the voltage drop that occurs in phase T at the KN08-39 Distribution Substation is quite large.

Table 6. Results of voltage measurements at the KN08-38 Distribution Substation

SUBSTATION CODE	LOCATION	PHAS	VOLTAGE ON PANEL (V)	VOLTAGE AT THE END NETWORK (V)
		R	220	200
KN08-38	LAW CALENDAR	S	222	195
		T	222	198

Voltage Drop Calculation Results:

$$\Delta V_R = \frac{220-200}{220} x100\% = 9\%$$

$$\Delta V_S = \frac{222-195}{222} x100\% = 12\%$$

$$\Delta V_T = \frac{222-198}{222} x100\% = 10\%$$

From the calculation results, the voltage drop that occurs in each phase at the KN08-38 Distribution Substation is still within the specified tolerance limits.

Factors Affecting Voltage Drop

There are several factors that cause voltage drops in PT PLN (Persero) ULP Kutacane, namely: Several distribution transformers at PT PLN (Persero) Rayon Kutacane have experienced overload. Ideally, the workload of a transformer is only up to 80%. However, in reality in the field there are still several distribution transformers that work above 80%, so it is necessary to carry out transformer management or add insert transformers to maintain the ideal workload of a distribution transformer.

This incident also happens quite a lot. Tree branches attached to the distribution network will be an obstacle that can reduce the amount of voltage. Therefore, it is necessary to prune tree branches that have spread and attached to the distribution network. From the results of interviews with the party handling the distribution at PT PLN (Persero) ULP Kutacane, this is also one of the causes of voltage drops. So to improve the quality of voltage, it is necessary to do joinization at each connection/connector.

CONCLUSION

Based on the results of analysis and evaluation, it can be concluded that the optimization of switching substation performance at ULP Kutacane has a significant impact on improving p ower grid stability, particularly in reducing voltage drop effects. The key conclusions are as f ollows: Identification of the highest voltage drop points revealed that major issues occur duri ng peak loads and in distribution lines with long conductor distances and suboptimal condu ctor conditions. Implementation of optimization methods such as tap changer adjustments o n transformers, phase load balancing, and the installation of capacitor banks at strategic loc ations proved effective in reducing voltage drops to within acceptable SPLN standards. Sim ulation results and field measurements indicate that after optimization, voltage values at sev eral critical points increased from an average of 195 V to 218 V (in a 220 V system), approa ching the desired nominal value. The optimized switching substation performance also impr oved power distribution efficiency, reduced active power losses, and enhanced the reliability of the distribution system in maintaining continuous electricity supply to customers. This op timization also supports economic aspects, by reducing service interruptions and minimizing customer complaints caused by voltage instability. Thus, the optimization of switching subs tations is highly recommended as an ongoing program at ULP Kutacane and can be adopte d by other operational areas to improve the quality of electrical service delivery.

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