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Analysis of The Kalasan Feeders Quality performance when New Big Customers are Connected to PT PLN (Persero) ULP Pangkalan Balai Electrical System

By

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Abstract

In 2022, it's planned that big customers will be connected to PLN ULP Pangkalan Balai electric system, and this condition can increase revenue. But another condition is the feeder to supply new customers have bad performance. The feeder to supply new customers is the Kalasan feeder. Kalasan feeder has a voltage drop of more than 15%. To analyze how to repair the kalasan feeder was used with ETAP. ETAP is software for electrical power system load flow analysis that is used to simulate the actual condition. Based on the existing condition of the electrical system on the kalasan feeder, do simulations with ETAP. This simulation is carried out with various scenarios, including repairing with AVR, repairing with capacitors, repairing by uprating conductors, repairing by uprating distribution transformers, simulation with express feeder, simulation to the construction of a new substation, and connected solar power system to 20 kV grid. Based on the simulations of several scenarios, the best alternative is to connect the solar power system to a 20 kV grid. The result is a voltage drop decrease below 5%, a power factor of more than 95%, losses are smaller than before, and revenue increases.

Index Terms: Voltage drops, Grid loss, Electric power system analysis, Solar power generation, 20 kV feeder.

I. Introduction

One of the strategic targets proclaimed by the Sumatra operations director of PT PLN (Persero) in 2022 is to increase PLN's income and service quality improvement in the form of voltage improvement on the side of big customers. One of the PLN customer service units at PLN WS2JB that will serve big customers is PT PLN (Persero) ULP Pangkalan Balai. It is planned that the big prospective customers will be supplied by the Kalasan feeder. Figure 1. The following is a geographical picture of the Kalasan feeder supplied by the Sungai Lilin Substation.

Based on the measurements made, it is known that the kalasan feeder voltage is very low at only 11 kV and the network shrinkage is 10%. Currently, the Kalasan feeder does not meet PLN's service quality criteria. You can imagine what might happen if a new big customer were connected to a kalasan feeder.

Figure 1. *Kalasan Feeder in GIS*

II. Restricting the Problem

The research is limited to the analysis of performance quality improvements to the kalasan feeder if new big customers are connected at PT PLN (Persero) ULP Pangkalan Balai.

Based on this background, the problems to be studied can be formulated:

a. What technology can be a solution to improve the voltage on the feeder kalasan if a big customer is connected?
b. How much is the reduction in network losses if voltage increases?

III. Purpose

The purpose of this research is to find out a more optimal solution for voltage improvement on the Kalasan feeder if big customers connected

IV. Methodology

In this study, the methodology used was a descriptive exploratory research design. Descriptive exploratory research aims to describe the state of a phenomenon, in this study is not intended to test certain hypotheses but only describe what a variable, symptom, or situation is (Arikunto, 2002).

The author conducted research by observing and analyzing the data and then carried out a simulation of the electricity network using a power system analysis application, while the application used was ETAP (Electrical Transient Analysis Program).

The methods used in this research include:

1. Study of Literature
2. Learn the calculation of voltage drop with ETAP.
3. Learn how to calculate losses with ETAP.
4. Data analysis
5. Analyzing the calculation results of the voltage drop of the kalasan feeder and then comparing the calculation results of the voltage drop with the standard 5% using ETAP.
6. Comparing the calculation results of the voltage drop of the kalasan feeder with losses using ETAP.

V. Research Data

The source of data in this research is secondarily obtained from PLN ULP (Persero) Pangkalan Balai. Sources of secondary data in this study that will be collected are Single line diagrams, distribution transformer loading data (transformer capacity and transformer loading measurement results), conductor data (distance between sections, size, type, and type), and other accessories data.

VI. Literature Review

A. Power Flow Study

Power flow analysis is an analysis used to determine the condition of the system under normal conditions, so it is needed in planning the system for the future and is an evaluation material for the existing system. This analysis includes determining the value of the voltage (V), active power (P), reactive power (Q), and the phase angle (θ) of each bus in the system [1].

Power flow analysis studies can be calculated manually or using computer software.

B. The objectives of the power flow study are

1. To find out the components of the electric power system network in general.
2. To find out the magnitude of the voltage on each bus of an electric power system.
3. Calculate the flow of power, both real power and reactive power that flows in each channel.

4. Optimal system losses.

C. Power Factor

In equations and power calculations, the main thing that must be understood is to understand the concept of a power triangle. The following will explain the power triangle using pictures along with explanations and calculations. The Triangle power factorshown in Figure 2.

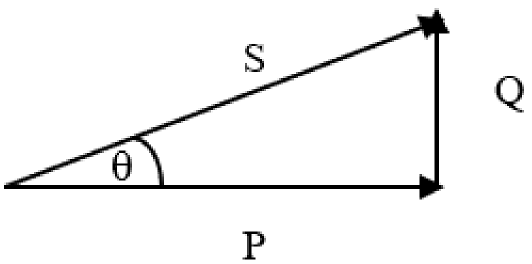


Figure 2 *Triangle power factor*

Information

P : Active power
Q : Reactive power
S : Apparent power
Cos φ : Power factor

In the electric power system, there are three types of power, namely active power (P), reactive power (Q), and apparent power (S). Active power (P) is electrical power generated at the generator output side, and then it can be used by consumers, can be converted to other forms of energy such as motion energy in motors, can also be heat energy in the heater, or can be converted into other forms of electrical energy [2].

The average power is no longer a function of RMS (root mean square) of current and voltage only, but there is an element of difference in the current and voltage phase angles from the phase angle equation and φ = 0°. The power equation becomes [3]:

$$P = V.\mathrm{I}\cos\varphi \quad (1)$$

For:

$$\varphi = 60^0; so\ P = V.I\cos\ (60^0) = 0{,}3\ V.I \quad (2)$$

$$\varphi = 90^0; so\ P = V.I\cos\ (90^0) = 0 \quad (3)$$

The current flowing in resistance will cause a voltage on the resistance, which is equal to:

$$P = Vr.Im\cos\varphi \quad (4)$$

Information

P : active power (watts)
Vr : voltage (volts)
Im : maximum current (amperes)
Cos φ : power factor

Since there is no phase angle between the current and the voltage across the resistance, the angle = 0°, so:

$$P = V \quad (5)$$

Voltage multiplied by the current is called apparent power.

The average power divided by the apparent power is called the power factor. For sinusoidal currents and voltages, the power factor can be calculated:

$$Power\ factor = \frac{P}{V.I} = \frac{J.Cos\ \varphi}{V.I} = \cos\varphi \quad (6)$$

φ is the power factor angle, this angle determines the previous or lagging state of the voltage to the current

D. Losses

The conductor in the distribution section of electrical energy has resistance to electric current, so when the system operates in this distribution section there will be a power loss that turns into heat energy. Power losses at substations are relatively small, so power losses in the electric power system can be considered to consist of power losses in the transmission and distribution networks [4].

If electrical energy is channeled through a three-phase alternating current network, then the power loss in the network is:

$$\Delta P1 = 3.I^2.R\ (Watt) \quad (7)$$

Information

I: conductor current (amperes)
R: conductor resistance (ohms)

E. Basic Methods of Solving Power Flow Studies

To complete the study of power flow the iteration method (numeric) has been developed using a digital computer. Various methods of completing power flow studies have been developed in line with the development of power system network configurations, both in planning, development, and operation. Until now, several methods that are often studied are the Gauss-Seidel method, the Newton-Raphson method, the decoupled method, and the fast decoupled method. Each method for power flow analysis has advantages and disadvantages to each other [5].

VII. Analysis Of Existing Conditions

Kalasan feeder is supplied from the Sungai lilin substation with a length of 316,34 kms. The kalasan feeder conductor uses a cross-sectional is 70 mm^2. Based on the measurements in real-time, the peak load of the kalasan feeder is 5,70 MVA and the voltage at the end of kalasan feeder is 14 kV and the operating voltage at the substation outgoing kalasan feeder is 21 kV. The current condition of the feeder loading is spread and the biggest load is at the end. With the current loading conditions, the loss of kalasan feeder is 800 kW.

The condition of the kalasan feeder is simulated again by using the ETAP. Figure 3 is shown a kalasan feeder by ETAP. Based on the load flow analysis performed with ETAP, the network performance results are shown in Table 1.

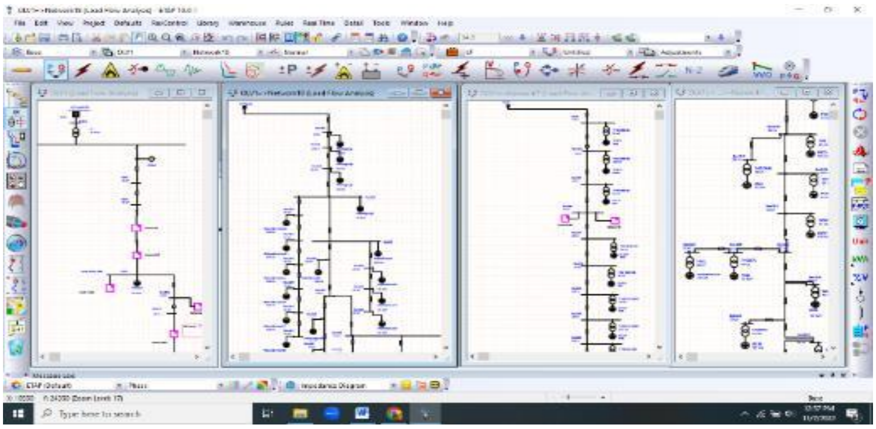


Figure 3 *Kalasan Feeder in ETAP*

Table 1 *Existing condition load flow analysis results*

Existing	Result	Unit
Power (S)	5844	kVA
Power (P)	4916	kW
Power (Q)	3160	kVAR
Current	163	A
Lowest Voltage	14,05	kV
Power factor	84,12	%
Losses	796,85	kW

The simulation results and measurement results are almost the same, so it can be ascertained that the simulation results in ETAP can be declared accurate.

Based on the results of measurements and simulations, it is stated that the current condition of the Kalasan feeder is very alarming because it still does not meet the quality of service, both voltage, and losses.

VIII. New big Customers connected to kalasan feeder

It is planned that new big customers will connect to kalasan feeder, the new big customer is the form of industrial customers with a power of 2 MVA and these new customers will be supplied with an operating voltage of 20 kV and will be served with kalasan feeder.

it's can imagine what will happen if the new customer is connected to the kalasan feeder, which currently conditions the kalasan feeder does not meet the quality of service.
The location of the new customer is at the end of the kalasan feeder as shown in Figures 4 and 5.

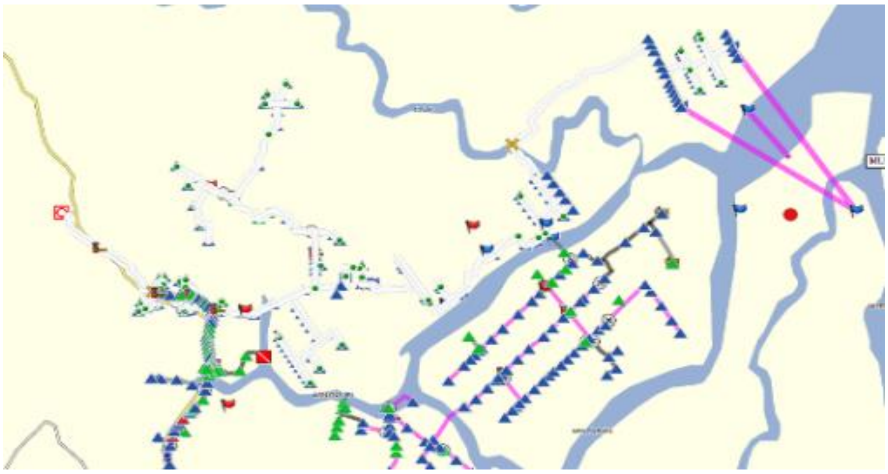


Figure *4 New big customer location in GIS*

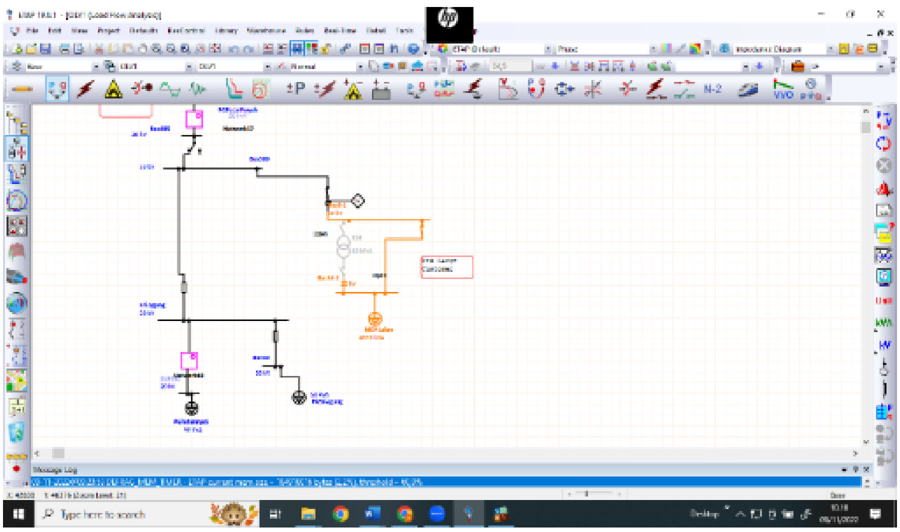


Figure 5 *New big customer location in ETAP*

If a new big customer is connected to the feeder, the simulation results can be seen in table 2.

Table 2 *Load flow analysis results with new big customer*

Capacitor Instalation	Result	Unit
Power (S)	6798	kVA
Power (P)	5610	kW
Power (Q)	3839	kVAR
Current	190,1	A
Lowest Voltage	10,89	kV
Power factor	82,53	%
Losses	13776,7	kW

IX. Analysis results of repairs to kalasan feeder after new customers are connected

A. Optimal Capacitor Placement

Power flow simulation requires a voltage limit value using critical and marginal limits, critical is a state of an electrical component that is dangerous and is immediately handled, while marginal is a state of an electrical component that is almost close to critical but still tolerable but still needs attention [6]. ETAP can calculate capacitor requirements based on the type of voltage improvement or power factor improvement with the Optimal Capacitor Placement feature in ETAP. Etap has an optimal capacitor placement feature that can be utilized for the needs of voltage correction and improvement of the power factor angle [7].

Recommendations that will be given by the optimal capacitor placement can be seen in Figure 6.

Based on the recommendations from the optimal capacitor placement result, try to simulate it by installing the capacitor according to the recommendations on the Kalasan feeder, the results of the load flow analysis are shown in table 3.

For the case of this kalasan feeder, we can't do a simulation to improve the voltage and power factor at the same time, we can only choose one.

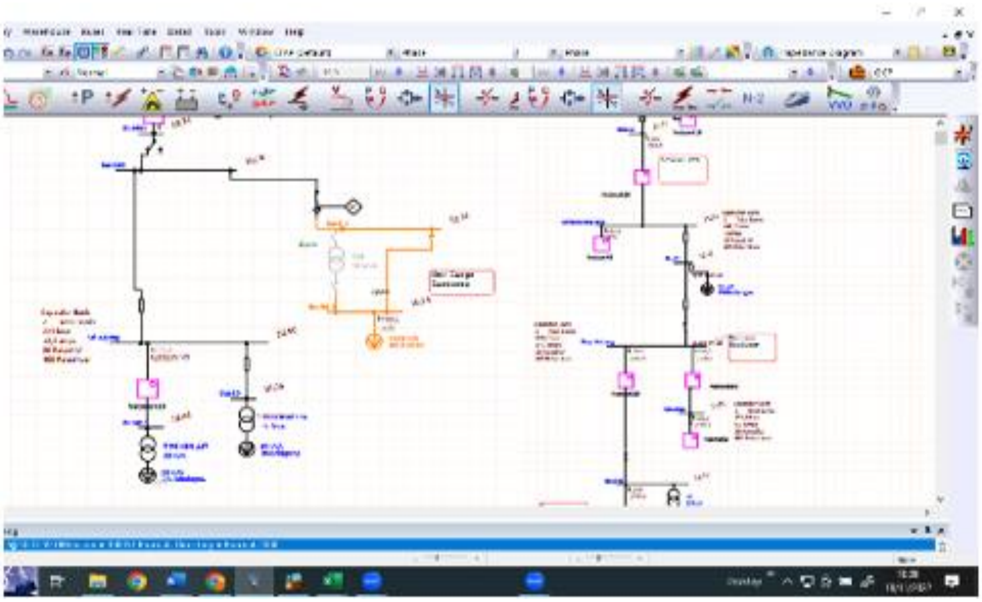


Figure 6 *Result Optimal Capacitor Placement in ETAP*

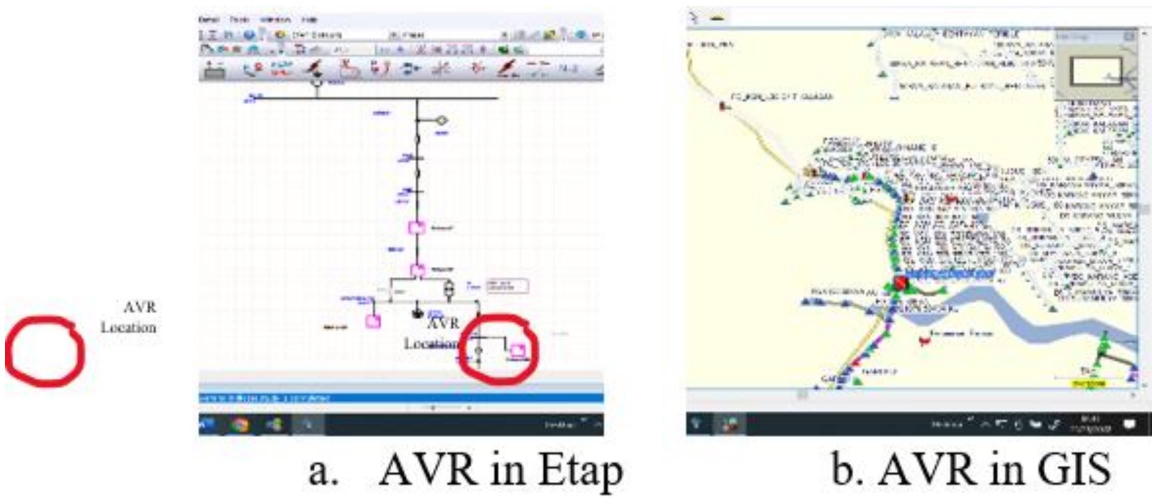
Table 3 *Load flow analysis results after capacitor installations in kalasan feeder*

Capacitor Instalation	Result	Unit
Power (S)	6595	kVA
Power (P)	5750	kW
Power (Q)	3229	kVAR
Current	184	A
Lowest Voltage	11,58	kV
Power factor	99,16	%
Losses	1288,94	kW

Table 3 the simulation results of load flow analysis after installing the capacitor according to the recommendations, the results of load factor increase from 82.52 to 99.16 % and voltage increase from 10,89 kV to 14.05 kV. the voltage obtained still does not meet the network service quality criteria, but the power factor is excellent.

B. Automatic Voltage Regulator (AVR)

Simulation is carried out by adding one AVR in the middle of main the network. The installed AVR capacity is 5 MVA, the installation location can be seen in Figure 7. So that the simulation results are obtained as in table 4.



a. AVR in Etap b. AVR in GIS

Figure 7 *AVR Installation Location*

Table 4 *Load flow analysis results after capacitor installation in kalasan feeder*

Capacitor Instalation	Result	Unit
Power (S)	8648	kVA
Power (P)	6810	kW
Power (Q)	5331	kVAR
Current	243,6	A
Lowest Voltage	12,41	kV
Power factor	78,74	%
Losses	2059,49	kW

The simulation results shown in table 4, it is found that the voltage value increases but still does not meet service quality standards. As the voltage increases, the power also increases, but on the one hand, the network losses also increase.

C. Condutor Uprating Sizes

A simulation is carried out by replacing a conductor that still has a cross-sectional area below 70 mm with a conductor with a cross-section of 150 mm. The simulation results can be seen in table 5.

Table 5 *Load flow analysis results after Uprating Sizes of Conductor*

Capacitor Instalation	Result	Unit
Power (S)	6989	kVA
Power (P)	5656	kW
Power (Q)	4106	kVAR
Current	195,7	A
Lowest Voltage	12,31	kV
Power factor	80,92	%
Losses	1164,6	kW

Based on the simulation results in table 5 is still below the quality of network services. the quality of service for the medium voltage network is still not fulfilled because the voltage is 12.31 kV and the power factor is 80.92%.

D. Exspress Feeder for splite kalasan feeder

Simulated by adding the express feeder side by side with the kasalan feeder and will take the load of the kalasan feeder after the Lilin River connecting substation, the length of the express feeder built is 33 kms with a conductor cross-sectional area of 150 mm.

The reason for choosing the location of the express feeder connection at the candle river substation is because the middle starts below 17 kV after the location of the connecting substation.

Table 6 *Load flow analysis results after express feeder install in kalasan feeder*

Capacitor Instalation	Result	Unit
Power (S)	7010	kVA
Power (P)	5855	kW
Power (Q)	3850	kVAR
Current	196,1	A
Lowest Voltage	11,69	kV
Power factor	82,35	%
Losses	1224,1	kW

Based on the simulation results in table 6 is still below the quality of network services. the quality of service for the medium voltage network is still not fulfilled because the voltage is 11.69 kV, and the power factor is 82.35%.

E. Sollar Pannel Install

Simulations were carried out by installing a solar panel with a capacity of 2 MVA. the installation location is planned to be close to the location of *big* customers as shown in Figure *8*. The results of the ETAP simulation can be seen in table *7*.

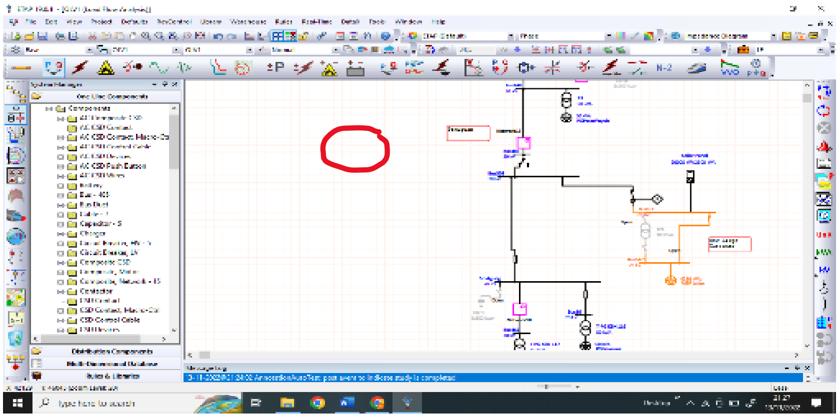


Figure 8 *Solar Panel Installation Location*

Table 7 *Load flow analysis results from solar panel installation in kalasan feeder*

Capacitor Instalation	Result	Unit
Power (S)	8299	kVA
Power (P)	7682	kW
Power (Q)	2605,5	kVAR
Current	235,7	A
Lowest Voltage	18,067	kV
Power factor	82,94	%
Losses	657,3	kW

By installing solar panels, better network performance is produced compared to other repair methods. all network performance indicators are met, such as the voltage increases to 18,06 kV, the power increases to 7682 kW, and network losses become smaller, which is only 657,3 kW.

X. Conclusion

After conducting simulations to improve the quality of service for the feeders, the best alternative is obtained by installing a solar panel system on the feeders to improve the quality of the feeders. the installation of solar panels must also be equipped with a battery system to meet power needs at night when the sun is not available.

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