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ANALYSIS OF THE EFFECT OF BANK CAPACTOR PLACEMENT AS VOLTAGE DROP INCREASE IN DISTRIBUTION NETWORK

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Abstract—The quality of electricity distribution in the distribution network is an important thing that must be considered. To maintain the quality of electrical energy, there are several parameters that must be considered in the distribution network, including voltage drop, power losses, power factor and other factors. One of the solutions used to improve the voltage drop and power factor is to install a capacitor bank in the distribution network. This paper will discuss the placement of capacitor banks using the fuzzy logic method with inputs in the form of voltage profiles, power losses and power flow calculations using Etap 12.6.0 software. In the Rao feeder, the final voltage is 16.806 kv or has passed the standard set by Pln (-10% and +5%). The Rao feeder has a power loss of 0.242 mw and a power factor of 0.7815. Fuzzy logic method is used to determine the optimal location of capacitor placement. After the installation of the capacitor bank, the terminal voltage increases and the total power loss decreases, while the power factor increases. From the results obtained, Pln as a supplier of electrical energy can reduce power losses by placing and installing capacitor banks in the distribution network.

Keywords : Capacitor Bank, Voltage Drop, Power Loss, Power Factor, Fuzzy Logic, Matlab, Etap.

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1. Introduction

Electrical energy is one of the energies that affect human life. Along with the development of science, humans produce many discoveries that basically require electrical energy as a source of energy. That way, the need for electrical energy will increase from time to time. Given the importance of electrical energy for life, the distribution system of electrical energy must be able to function both quantitatively and qualitatively. However, in practice, distribution errors often occur when the quality of service provided is not as expected. Therefore, improving the quality of service by the organizers (PLN) is the most important thing [1].

When distributing electrical energy, several problems often occur, including voltage drops. The amount of power losses and distribution line voltage drops depends on several factors, including the type and length of the distribution line, type of distribution network, type of load, power factor and installed power as well as the amount of use of inductive loads that cause an increase in the need for reactive loads [2]. If there is no reactive power source near the load on the distribution network, then the need for reactive loads will be borne directly by the substation supplied by the generator at the power plant, so that reactive current will flow in the distribution network which will result in a decrease in power factor, voltage drop and loss power loss will increase [3].

To repair power losses and voltage drops in distribution lines, one of the ways commonly used is to install a capacitor bank in the problematic distribution network [4]. The function of the capacitor bank installation is to improve the power factor so that it will reduce the magnitude of power losses and voltage drops in the distribution network [5].

2. Electrical Power System

An electric power system generally consists of three parts, namely a power generation system, an electric power transmission system, and an electric power distribution system. Electrical energy is

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generated by a power plant and with a step-up transformer the resulting voltage is in the range of 11 kV to 765 kV. Then it is connected between the generating center and the distribution system or consumers through a transmission line with a substation to lower the voltage using a step down transformer to medium voltage. In this distribution section, electrical energy is distributed to consumers for various purposes [6].

2.1 Electric Power

Electrical power can be defined as the rate at which electrical energy is transferred in a circuit. The international unit (SI) of electrical energy is the watt, which expresses the amount of electricity (joules/second) that flows per unit time.

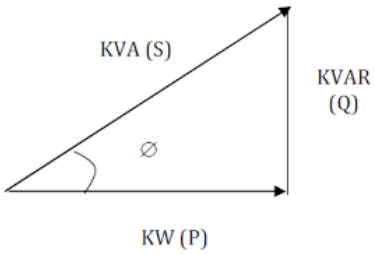


Figure 1. Power triangle

1. Active power (P) is the actual power required by the load. The unit of active power is the watt (W), which can be measured with a wattmeter. The active power in a resistive type (R) load does not have a voltage (V) waveform and a phase current inductance diagram, so the product of the voltage and current will produce two waves [7]. Both of these waves are positive, and the magnitude of the active power is P. The remaining peak is divided into two parts to fill the gap, so that both gaps are filled with two peaks that fill it. Active power in load impedance (Z) load impedance in circuit consists of resistance (R) and inductance (L). The product of the voltage and current waves produces two large positive peaks and two small negative peaks. The phase angle shift depends on the inductance of the component.

$$P = V\ x\ I\ x\ cos\ \varphi \quad (1)$$

where : P = Active power (W)
V = Voltage (V)
I = Electric current (A)
cos φ = Power factor

2. Reactive power (Q) Reactive power is the power required to form a magnetic field or the power generated from an inductive load. The unit of reactive power is Var (Reactive Volt Ampere). Reactive power can be saved by installing capacitors in circuits with inductive loads. The same thing is usually done in factories or other industries that use loads such as motors.

$$Q = V\ x\ I\ x\ sin\ \varphi \quad (2)$$

where : Q = Reactive power (VAr)

3. Apparent power (S) is the power produced by the product of current and voltage. The actual power is the power provided by PLN to the user [8]. The unit of apparent power is VA (Volt Ampere). Apparent power loads are resistive (R), such as incandescent lamps, dispensers, irons, televisions, and others. The resistance in an equipment or circuit cannot be eliminated, because the voltage and current are in phase, the phase angle difference is 0, and the power factor is 1.

$$S = V\ x\ I \quad (3)$$

where : S = Apparent power (VA)

2.2 Power Factor Correction

Increasing the power factor can be done by installing a capacitor bank on the network, capacitors have the natural nature to store electric charge when current flows so that the accumulated charge will

cause an electric voltage. Accumulated charge has a very high reactive power reserve. So if at any time the network needs a reactive power supply, the capacitor can provide backup to the network that needs it.

2.3 Capacitor Bank

A capacitor bank is a capacitive electrical device consisting of a collection of capacitors connected in series/parallel to obtain a certain capacitance capacity. A commonly used parameter is kVAr (kilovolt ampere reactive) although the capacitor itself lists the capacitance, specifically Farads (F) or microfarads (μF). The capacitor used to increase the power factor is installed in parallel with the load circuit. There are two ways to install capacitors, series and series/parallel. Installing capacitors in electrical systems generates reactive power to increase the power factor and voltage, thereby increasing system capacity and reducing losses. Capacitors are widely used to increase the power factor of alternating current. Meanwhile, direct current, especially in the power supply, increases the ripple current in the power supply and increases the amount of energy stored, because the main function of the capacitor is as a component that can store current. To improve the power factor and regulate mains voltage, engineers use block capacitors with the reactive power compensation system it provides. In power transmission lines, inductive loads will absorb reactive power, which in turn can cause a voltage drop on the receiving side. This is where the capacitor works by compensating for the reactive power and keeping the voltage at its full load. Installing a capacitor block is an attempt to provide reactive power. Thus, the use of compensating capacitors will reduce the reactive power of the load absorption system. This is done so that the voltage drop and network losses that occur can be reduced. [9]

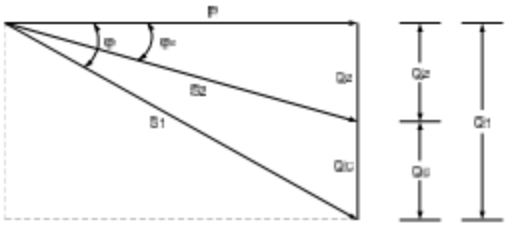


Figure 2. Reactive power triangle diagram

$$Q_c = Q_1 - Q_2 \quad (4)$$

where : Q_c = Required reactive power (VAR)
Q_1 = Initial reactive power (VAR)
Q_2 = Desired reactive power (VAR)

The required capacitor size can be calculated using the following formula :

$$C = \frac{Qc}{2\pi f\, V^2} \quad (5)$$

where : C = Kapasitor ($\boldsymbol{F}/\boldsymbol{\mu F}$)
Qc = Reactive power (Var)
$2\pi f$ = 2π frequency
V = Voltage (volt)

2.4 Fuzzy Logic

Fuzzy logic can be used in the fields of control theory, decision theory, and some areas of management science. The advantage of fuzzy logic is that it is able to perform linguistic reasoning, so that in its design there is no need for mathematical equations for the object being controlled.

Mamdani method is a fuzzy method that is useful for making the best decision from an uncertain problem. This method will later be used to determine the location of the capacitor bank. Here are the steps to get the output which in this case is the optimal location of the capacitor bank :

1. Pembentukan Formation of fuzzy sets

In this method, both input and output variables are divided into one or more fuzzy sets. One way that

can be used to get the membership value of a variable is through a function approach. In determining the location of the capacitor bank, the variables to be used are Power Loss Index (PLI) and Voltage (p.u) as input, and Capacitor Suitability Index (CSI) as output. The Power Loss Index (PLI) can be obtained using the following formula: [10]

$$PLI_{(n)} = \frac{(X_{(n)} - Y)}{Z - Y} \quad (6)$$

where : PLI = Power Loss Index
X = Reduction of active power loss
Y = Minimum active power loss reduction
Z = Maximum active power loss reduction
n = Bus number

2. Implication function

In this method, the implication function used is Min.

3. Composition of rules

Fuzzy rules show how the system operates. The general way of writing a rule is: If (X1 is A1) . … . (Xa is An) Then Y is B where (.) is an operator (OR or AND), X is a scalar and A is a linguistic variable.

The things that need to be considered in making rules are:

a. Group all the rules that have solutions on the same variable.
b. Sort the rules for easy reading.
c. Use identities to show the structure of the rules.
d. Use common names to identify variables in different classes.
e. Use comments to explain the purpose of a rule or rule group.
f. Give space between rules.
g. Write variables in uppercase, fuzzy sets in uppercase and other language elements in lowercase.

If the system consists of several rules, then the inference is obtained from the collection and correlation between the rules. There are methods used to perform fuzzy system inference, namely the Max method, the Additive method and the Probabilistic OR method. [11]

4. Defuzzification

The input of this process is a fuzzy set obtained from the arrangement of fuzzy rules, while the output generated is a number in the domain of the fuzzy set. So if given a fuzzy set within a certain range, it should be able to take certain sharp values as output.

2.5 Etap

Etap (*Electric Transient and Analysis Program*) is a software that supports the electric power system. The device is capable of working offline for power simulation, online for real-time data management or used to control the system in real-time. The features contained in it also vary, including features used to analyze electric power generation, transmission systems and electricity distribution systems. In this study, the modeling of the power generation system will be carried out to analyze its effect on the capacitor bank. One of the software that can be used to simulate the electric power system is ETAP 12.6.0. This software was developed by Operation Technology Inc., and underwent version changes from year to year [12].

Stress analysis that Etap can perform:

1. Power flow analysis
2. Short circuit analysis
3. Arc flash analysis
4. Temporary stability analysis

In analyzing electric power, a single line diagram is a simplified notation for a three-phase electric power system. Instead of representing separate three-phase lines, conductors are used. This makes it easier to read diagrams as well as in circuit analysis. Electrical elements such as circuit breakers, transformers, capacitors, bus bars or other conductors can be represented using symbols that have been standardized for single line diagrams.

Elements on a diagram do not represent the physical size or location of electrical equipment, but it is a common convention to arrange the diagram in the same left-to-right, top-down order as switches

or other equipment represented. In analyzing electric power, a single line diagram is a simplified notation for a three-phase electric power system. Instead of representing separate three-phase lines, conductors are used. This makes it easier to read diagrams as well as in circuit analysis. Electrical elements such as circuit breakers, transformers, capacitors, bus bars or other conductors can be represented using symbols that have been standardized for single line diagrams. The elements on a diagram do not represent the physical size or location of electrical equipment, but it is general agreement to arrange the diagram in the same left-to-right, top-down order as the switch or other device represented.

3. Research procedure

The procedure in this study is as follows:

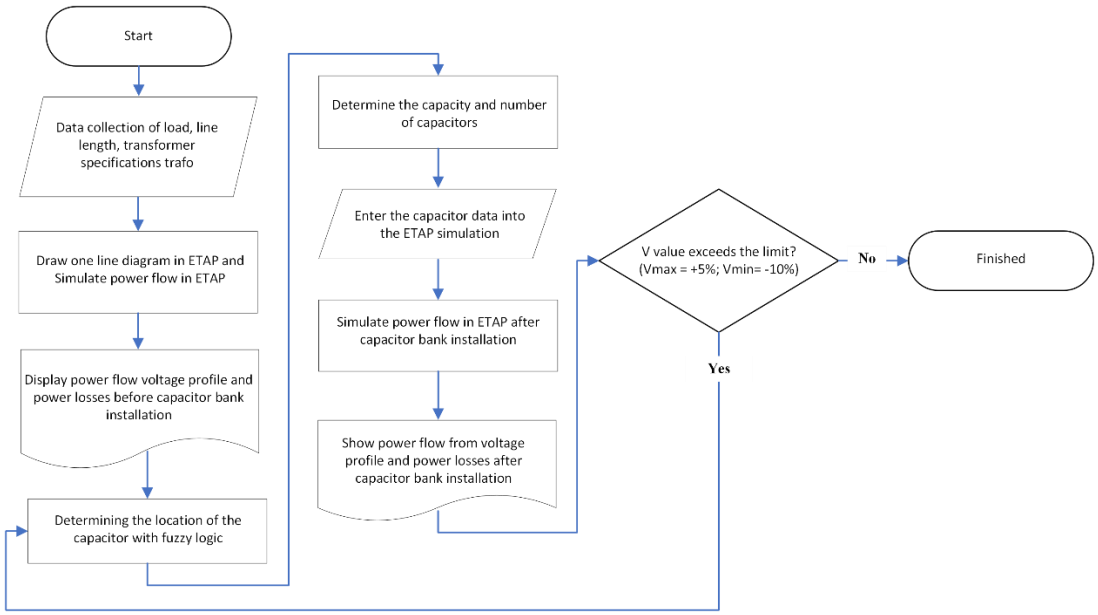


Figure 3. Research Flowchart

Based on the research flow chart in Figure 4, the research steps are as follows:

1. Data Collection
   The required data is taken from PT. PLN ULP Lubuk Sikaping, the data needed is in the form of transformer load data, cos phi, and line length.
2. Draw a one-line diagram
   After the data is obtained, then a one-line diagram is made and input the data of the electric power system on the Etap 12.6.0 software according to the 20 kV distribution network under study.
3. Run the simulation
   Once the one-line diagram has been created and the required data has been entered, run a power flow simulation.
4. Showing results
   After running a power flow simulation using Etap software, the results of the active and reactive power flows will be displayed, the voltage profile on the distribution network bus, and power losses on the 20 kV distribution network.
5. Determining the optimal location of the capacitor bank using the fuzzy logic method using Matlab software.
6. Capacitor Capacity Analysis

Capacity analysis on capacitor banks. This can be seen from the condition of the bus (voltage profile and power losses).

7. Run the simulation after the capacitor bank is installed again
8. Displaying the results after installing the capacitor bank
   The expected results from the simulation using the Etap software are active and reactive power flows, voltage profiles on the distribution network bus, and power losses in the 20 kV distribution network that has been connected to a capacitor bank.
9. Conclusion
   After getting the results of the power flow before and after the installation of the capacitor bank, conclusions can be drawn from the use of the capacitor bank.

4. Result and Discussion

4.1 Load Flow Before Installing Capacitor Bank

Table 1. Transformer data on feeder Rao

No. Substation	Location	Phase	Power (KVA)	Power Factor
TA.1	A. Gadang	3	150	0,9
TA.2	Bombai	3	150	0,85
TA.3	Lundar	3	173	0,85
TA.4	Kuamang	3	173	0,85
TA.5	Petok	3	277	0,85
TA.6	Panti	3	277	0,85
TP.1	Tanjung Aro	3	416	0,8
TP.2	Sontang	3	416	0,85
TP.3	Tapus	3	242	0,8
TK.1	Kauman	3	346	0,8
TK.2	Beringin	3	346	0,8
TK.3	Sorik	3	346	0,8
TR.1	Rao	3	520	0,75
TR.2	P. Rao	3	346	0,8
TR.3	Koto Nopan	3	693	0,75

Table 2. Rao feeder line length data

From Bus	To Bus	Channel Length (m)
Bus 01	Bus 02	5000
Bus 02	Bus 03	5000
Bus 01	Bus 04	10000
Bus 04	Bus 05	10000
Bus 01	Bus 06	8000
Bus 06	Bus 07	8000
Bus 07	Bus 08	8000
Bus 08	Bus 09	10000
Bus 09	Bus 010	4000
Bus 09	Bus 011	1000
Bus 08	Bus 012	8000
Bus 012	Bus 013	6000
Bus 013	Bus 014	8000
Bus 014	Bus 015	20000
Bus 015	Bus 016	5000
Bus 015	Bus 017	10000
Bus 015	Bus 018	10000

Tables 1 and 2 are the data of the Rao feeder distribution network obtained from the results of research at PT. PLN ULP Lubuk Sikaping. From the data obtained, a one-line diagram using Etap will be drawn and also the results of the power flow for more in-depth analysis.

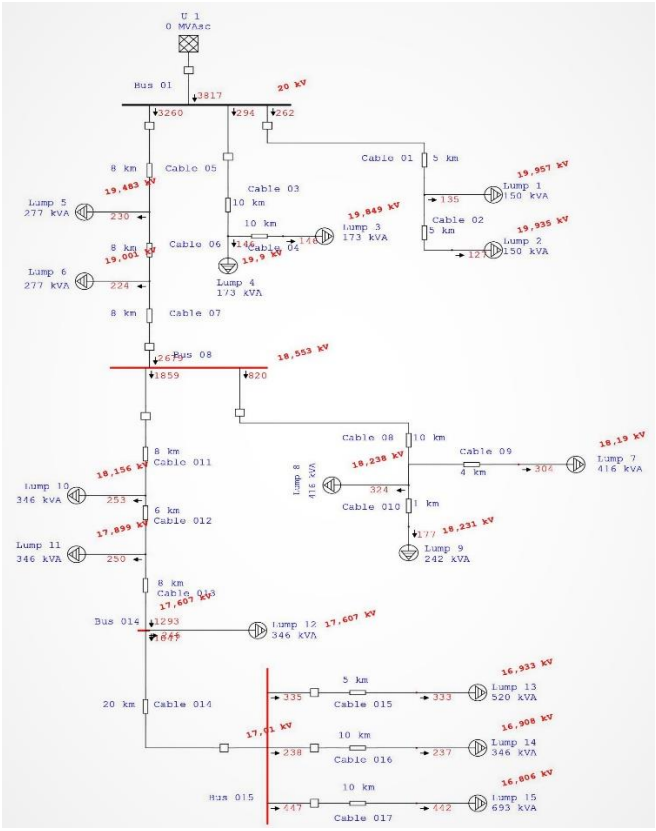


Figure 4. Single line diagram feeder Rao

Table 3. The results of running the program voltage, active power (P), and reactive power (Q) loading each bus before installing the capacitor bank (ETAP)

Bus ID	Voltage (%)	P Load (MW)	Q Load (Mvar)
Bus 01	100	3,817	3,047
Bus 02	99,78	0,262	0,144
Bus 03	99,68	0,127	0,079
Bus 04	99,5	0,293	0,182
Bus 05	99,25	0,146	0,091
Bus 06	97,41	3,211	2,606
Bus 07	95	2,94	2,364
Bus 08	92,76	2,679	2,139
Bus 09	91,19	0,807	0,563
Bus 010	90,95	0,304	0,228
Bus 011	91,16	0,177	0,133
Bus 012	90,78	1,829	1,521
Bus 013	89,49	1,559	1,305
Bus 014	88,04	1,293	1,093
Bus 015	85,05	1,021	0,868
Bus 016	84,67	0,333	0,294
Bus 017	84,54	0,237	0,178
Bus 018	84,03	0,442	0,39

Table 4. Results of active power flow (P flow) and reactive power (Q flow) as well as active and reactive power losses in each branch before installing capacitor bank (ETAP)

From Bus	To Bus	P Flow (kW)	Q Flow (kvar)	P Loss (kW)	Q Loss (kvar)
Bus 01	Bus 02	262	145	0,517	0,401
Bus 02	Bus 03	127	79	0,13	0,1
Bus 01	Bus 04	294	183	1,383	1,072
Bus 04	Bus 05	146	91	0,346	0,268
Bus 01	Bus 06	3260	2720	48,45	114
Bus 06	Bus 07	2982	2464	42,38	99,58
Bus 07	Bus 08	2715	2225	36,71	86,25
Bus 08	Bus 09	820	573	13,4	10,39
Bus 09	Bus 010	305	229	0,806	0,625
Bus 09	Bus 011	177	133	0,068	0,053
Bus 08	Bus 012	1859	1566	29,68	45,37
Bus 012	Bus 013	1576	1331	16,74	25,59
Bus 013	Bus 014	1309	1118	16	24,46
Bus 014	Bus 015	1047	909	26,82	41,0
Bus 015	Bus 016	335	295	1,59	1,231
Bus 015	Bus 017	238	179	1,41	1,095
Bus 015	Bus 018	447	394	5,66	4,387

Based on the PLN standard (SPLN) No. 72 of 1987 on distribution lines, the voltage should not be less than 10% and exceed 5% of the nominal source voltage which in this case is 20 kV. If referring to these standards, in this case the voltage should not be less than 18 kV and exceed 21 kV. So from the table above, it can be concluded that the bus that has a voltage below the PLN standard is bus 013 - bus 018.

4.2 Location of capacitor bank

In this final project research, the placement of the capacitor bank location is done using the fuzzy logic method by utilizing the tools in the Matlab R2015B application.

1. Formation of a set of fuzzy
   In determining the input and output, first determine the membership function. In this particular case, we use two input variable membership functions and one output variable membership function. The membership functions used are trapezoidal membership functions and triangular membership functions. In determining the location and value of the variable capacitors used are Power Loss Index (PLI) and Voltage (p.u) as input, and Capacitor Suitability Index (CSI) as output.

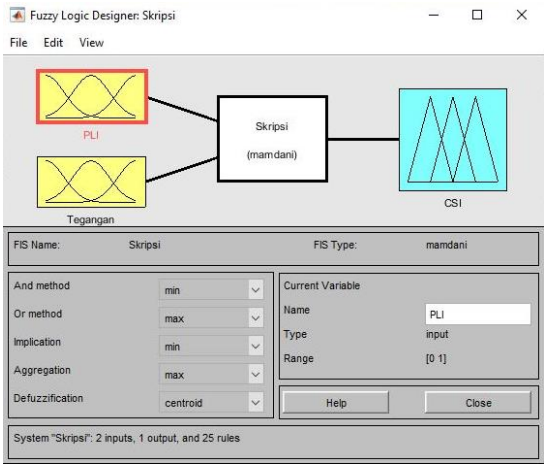


Figure 5. Fuzzy set

The PLI membership function is 0-1.

- Very Low : $\mu_{\text{Very Low}}[x]$ = {0-0,25}
- Low : $\mu_{\text{Low}}[x]$ = {0-0,5}
- Medium : $\mu_{\text{Medium}}[x]$ = {0,25-0,75}
- High : $\mu_{\text{High}}[x]$ = {0,5-1}
- Very High : $\mu_{\text{Very High}}[x]$ = {0,75-1}

The voltage membership function is 0.8403 p.u-1.05 p.u.

- Very Low : $\mu_{\text{Very Low}}[x]$ = {0,8403-0,8822}
- Low : $\mu_{\text{Low}}[x]$ = {0,8664-0,9189}
- Medium : $\mu_{\text{Medium}}[x]$ = {0,9032-0,9871}
- High : $\mu_{\text{High}}[x]$ = {0,9714 -1,024}
- Very High : $\mu_{\text{Very High}}[x]$ = {1,008-1,05}

Capacitor Suitability Index (CSI) membership function as an output variable, its membership function is 0-1.

- Very Low : $\mu_{\text{Very Low}}[x]$ = {0-0,25}
- Low : $\mu_{\text{Low}}[x]$ = {0-0,5}
- Medium : $\mu_{\text{Medium}}[x]$ = {0,25-0,75}
- High : $\mu_{\text{High}}[x]$ = {0,5-1}
- Very High : $\mu_{\text{Very High}}[x]$ = {0,75-1}

2. Formation of a set of fuzzy
   In this case, the fuzzy logic rules used are as follows:
   1. IF PLI Very Low AND Voltage Very Low THEN CLI Low
   2. IF PLI Very Low AND Voltage Low THEN CLI Low
   3. IF PLI Very Low AND Voltage Medium THEN CLI Low
   4. IF PLI Very Low AND Voltage High THEN CLI Very Low
   5. IF PLI Very Low AND Voltage Very High THEN CLI Very Low
   6. IF PLI Low AND Voltage Very Low THEN CLI Medium
   7. IF PLI Low AND Voltage Low THEN CLI Medium
   8. IF PLI Low AND Voltage Medium THEN CLI Low
   9. IF PLI Low AND Voltage High THEN CLI Very Low
   10. IF PLI Low AND Voltage Very High THEN CLI Low
   11. IF PLI Medium AND Voltage Very Low THEN CLI High
   12. IF PLI Medium AND Voltage Low THEN CLI Medium

13. IF PLI Medium AND Voltage Medium THEN CLI High
14. IF PLI Medium AND Voltage High THEN CLI Medium
15. IF PLI Medium AND Voltage Very High THEN CLI Low
16. IF PLI High AND Voltage Very Low THEN CLI High
17. IF PLI High AND Voltage Low THEN CLI High
18. IF PLI High AND Voltage Medium THEN CLI Medium
19. IF PLI High AND Voltage High THEN CLI Low
20. IF PLI High AND Voltage Very High THEN CLI High
21. IF PLI Very High AND Voltage Very Low THEN CLI Very High
22. IF PLI Very High AND Voltage Low THEN CLI High
23. IF PLI Very High AND Voltage Medium THEN CLI Medium
24. IF PLI Very High AND Voltage High THEN CLI Low
25. IF PLI Very High AND Voltage Very High THEN CLI Low

3. Defuzzification

Table 5. Defuzzification Result

Bus ID	P Loss (kW)	Voltage	PLI	CSI
Bus 01	242	1	1	0,25
Bus 02	0,517	0,9978	0,001855893	0,0801
Bus 03	0,13	0,9968	0,00025627	0,0801
Bus 04	1,383	0,995	0,005435412	0,0809
Bus 05	0,346	0,9925	0,001149083	0,0829
Bus 06	48,452	0,9741	0,19999008	0,248
Bus 07	42,382	0,95	0,174900385	0,25
Bus 08	36,709	0,9276	0,151451648	0,25
Bus 09	13,403	0,9119	0,055118794	0,337
Bus 010	0,806	0,9095	0,003050444	0,257
Bus 011	0,068	0,9116	0	0,25
Bus 012	29,681	0,9078	0,122402163	0,375
Bus 013	16,737	0,8949	0,068899525	0,328
Bus 014	16,003	0,8804	0,065865615	0,336
Bus 015	26,826	0,8505	0,110601326	0,363
Bus 016	1,588	0,8467	0,006282757	0,259
Bus 017	1,412	0,8454	0,00555528	0,258
Bus 018	5,66	0,8403	0,023113933	0,281

The most optimal bus candidate for placing capacitors is the one that has a CSI value greater than bus 01 which is the main reference bus, which is 0.25.

Table 6. Required reactive power and capacitor value

Bus ID	Reactive Power	Capacitor Value
Bus 09	200 kvar	3801 $\boldsymbol{\mu F}$
Bus 010	200 kvar	3184 $\boldsymbol{\mu F}$
Bus 012	200 kvar	3164 $\boldsymbol{\mu F}$
Bus 013	200 kvar	3164 $\boldsymbol{\mu F}$
Bus 014	200 kvar	3164 $\boldsymbol{\mu F}$
Bus 016	300 kvar	5394 $\boldsymbol{\mu F}$
Bus 017	200 kvar	3164 $\boldsymbol{\mu F}$
Bus 018	400 kvar	7185 $\boldsymbol{\mu F}$

4.3 Load Flow After Capacitor Bank Installation

Table 7. The results of running the program voltage, active power (P), and reactive power (Q) loading each bus after installing the capacitor bank (ETAP)

Bus ID	Voltage (%)	P Load (MW)	Q Load (Mvar)
Bus 01	100	3,898	1,051
Bus 02	99,78	0,262	0,144
Bus 03	99,68	0,127	0,079
Bus 04	99,5	0,293	0,182
Bus 05	99,25	0,146	0,091
Bus 06	98,66	3,31	0,65
Bus 07	97,52	3,051	0,443
Bus 08	96,59	2,798	0,247
Bus 09	95,39	0,841	0,375
Bus 010	95,23	0,317	0,238
Bus 011	95,36	0,185	0,139
Bus 012	95,64	1,931	0,265
Bus 013	95,05	1,655	0,262
Bus 014	94,38	1,382	0,258
Bus 015	93	1,105	0,046
Bus 016	92,77	0,362	0,319
Bus 017	92,69	0,257	0,201
Bus 018	92,38	0,481	0,424

Table 8. The results of active power flow (P flow) and reactive power (Q flow) as well as active and reactive power losses in each branch after capacitor bank installation (ETAP)

From Bus	To Bus	P Flow (kW)	Q Flow (kvar)	P Loss (kW)	Q Loss (kvar)
Bus 01	Bus 02	262	145	0,52	0,401
Bus 02	Bus 03	127	79	0,13	0,1
Bus 01	Bus 04	294	183	1,38	1,072
Bus 04	Bus 05	146	91	0,35	0,268
Bus 01	Bus 06	3341	724	31,4	73,83
Bus 06	Bus 07	3078	506	26,9	63,12
Bus 07	Bus 08	2821	301	22,8	53,45
Bus 08	Bus 09	850	169	9,28	7,194
Bus 09	Bus 010	318	26	0,52	0,399
Bus 09	Bus 011	185	-74	0,07	0,053
Bus 08	Bus 012	1948	78	17,6	26,95
Bus 012	Bus 013	1665	66	9,84	15,05
Bus 013	Bus 014	1391	64	9,29	14,2
Bus 014	Bus 015	1120	62	15,3	23,35
Bus 015	Bus 016	363	18	0,879	0,681
Bus 015	Bus 017	258	-7	0,888	0,688
Bus 015	Bus 018	484	27	3,129	2,425

It can be seen that after placing the capacitor bank in the distribution network, the voltage profile on the Rao feeder is getting better. Active power losses and reactive power losses have decreased, the power factor in the distribution network has increased after the installation of capacitor banks.

4.4 Effect of Capacitor Bank on Voltage, Power Losses and Power Factor

The following is a comparison of voltage, active power losses, reactive power losses and power factor before and after installing capacitors on the Rao feeder.

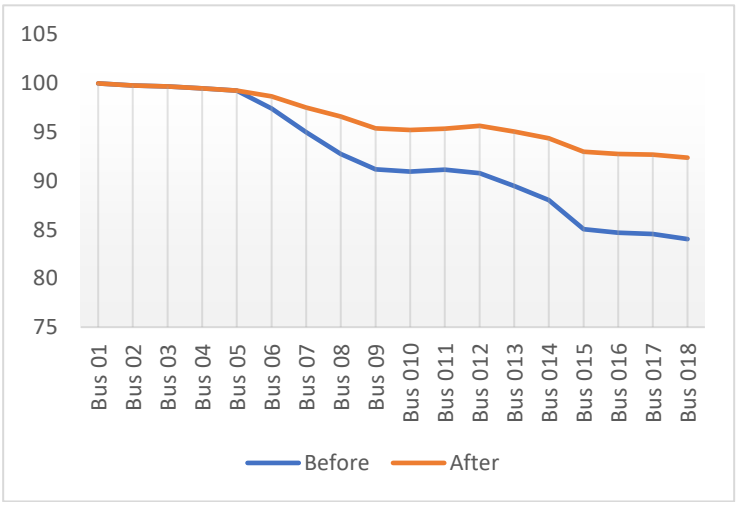


Figure 6. Voltage Before and After Installed Capacitor Bank

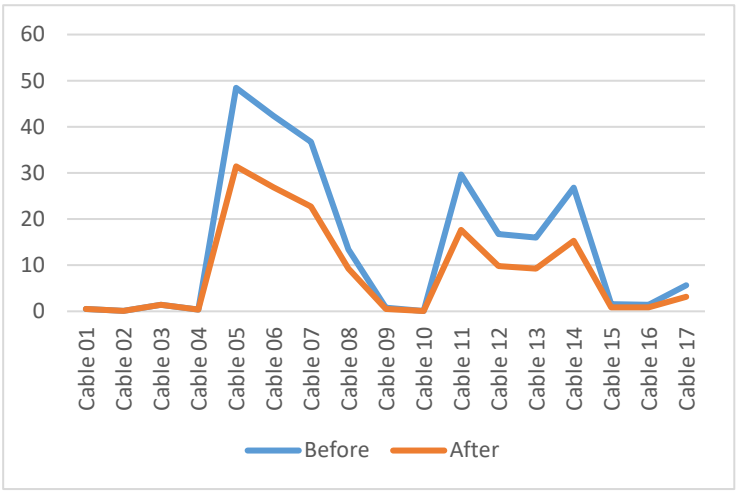


Figure 7. Active Power Loss Before and After Installing Tire Capacitors

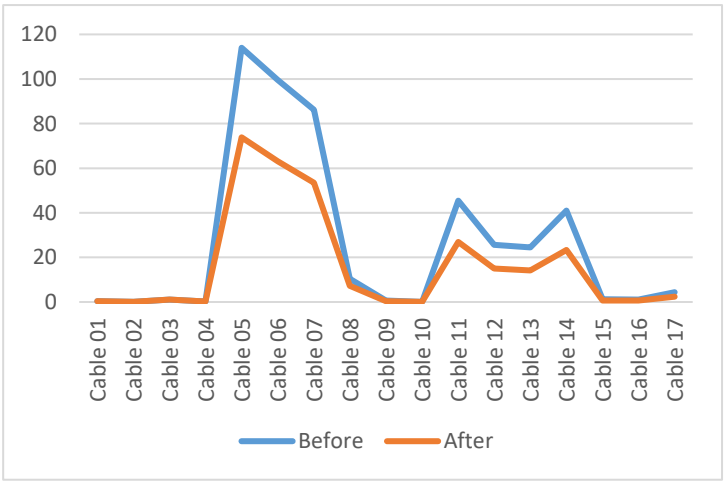


Figure 8. Reactive Power Loss Before and After Installation of Bank Capacitors

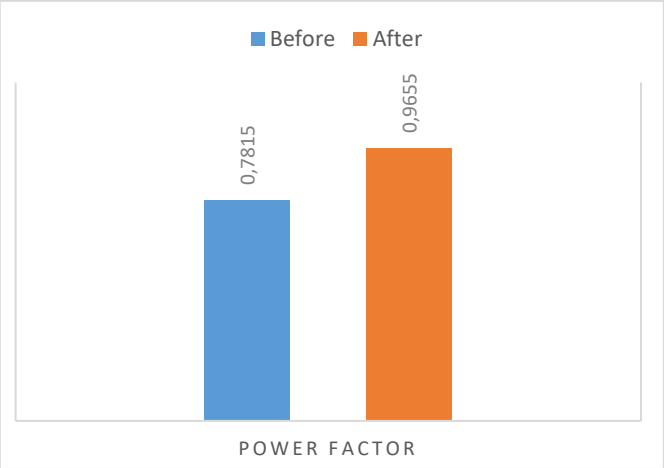


Figure 10. Comparison of Power Factor Before and After Capacitor Bank Installation

5. Conclusion

After conducting research and analyzing the data obtained during the research at PT. PLN ULP Lubuk Sikaping, the author can conclude several things, namely the results of calculations using fuzzy logic, the most optimal capacitor locations are on buses 09, 010, 012, 013, 014, 016, 017 and bus 018. Because these buses have a CSI value exceeding 0.25. After calculation, the reactive power required on buses 09, 010, 012, 013, 014, 016, 017 and bus 018 are 200 kVAr, 200 kVAr, 200 kVAr, 200 kVAr, 200 kVAr, respectively. 300 kVAr, 200 kVAr and 400 kVAr. The capacitor values to be paired are 3801 , 3184 , 3164 , 3164 , 3164 , 5394 , 3164 and 7185 . Based on the simulation results of the power flow on ETAP 12.6.0, the value of the tip voltage on the Rao feeder before the installation of the capacitor bank of 84.03 % can be increased to 92.38%. The power factor which was originally 0.7815 can be increased to 0.9655. The placement of capacitor banks using fuzzy logic can increase the total active power losses to 0.15 MW which was originally worth 0.242 MW. Likewise, the reactive power which was originally 0.456 Mvar can be increased to 0.283 Mvar.

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