Implementation of Placement and Determination of Capacitor Capacity in Medan City Medium Voltage Distribution Network Using The Electrical Transient Analysis Program

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ABSTRACT
The characteristics of an electric power distribution system, often radial in shape and distant from the generator, result in voltage drops. When these drops fall below tolerance levels, it adversely affects power quality for consumers connected to the distribution network. To address this issue, various methods such as network reconfiguration, distributed generator placement, and capacitor placement are employed. This study focuses on the use of capacitors to rectify voltage drops in the medium voltage distribution network in Medan city. The placement of capacitors and determination of their capacities were conducted using the Electrical Transient Analyzer Program (ETAP). Before the capacitor placement, the initial condition of the medium voltage distribution network showed an active power loss of 256.1 kW and a minimum voltage of 11.41 kV. Following the placement of capacitors on bus 18 and bus 34, each with a capacity of 600 kVAR, the power flow analysis revealed a reduction in power loss to 194.9 kW, representing a 23.90% decrease. Additionally, the minimum voltage increased to 11.891 kV, marking a 4.2% improvement.

Keywords: *capacitor, voltage drop, power loss, ETAP*

1. INTRODUCTION

The distribution of electrical energy, various issues arise, including voltage drops and low power factor. The distribution network experiences loads that can be capacitive or, more commonly, inductive. Higher inductive reactive loads lead to increased reactive load requirements and voltage drops. The quality of the voltage received by consumers significantly influences the effectiveness of an electric power distribution system. The ongoing development of electrical systems aims for efficiency in energy distribution. Minimizing voltage drop is a key aspect of achieving this efficiency. Several methods are commonly employed to address voltage drops, including increasing the cross-sectional surface area of the distribution network, transferring loads to other feeders, installing tap changers on transformers, and deploying capacitor banks. This study specifically focuses on the placement of capacitors in the medium voltage distribution network of the city of Medan across 34 buses. Hartono [1] proposed an optimal capacitor placement approach in a radial medium voltage distribution network using a genetic algorithm. The research's objective is to enhance voltage drops and reduce active power losses in the IEEE 118 bus distribution system. The method proved successful in correcting voltage drops and minimizing active power losses.

Costa [2] introduced an approach capacitor placement in radial distribution network system using quantum behaved particle swarm oprimization, Quantum Behaved Particle Swarm Optimization (QPSO) is a development of conventional Particle Swarm Optimization (PSO) and combined with quantum mechanical theory. the results of the placement capacitor using quantum behaved particle swarm oprimization compared to conventional particle swarm optimization, the result is that the improvement in voltage drop using QPSO increases the nominal voltage better than the capacitor placement method using conventional particle swarm optimization.

Ceylan [3] introduced capacitor placement and sizing using moth flame optimization algorithm, The research

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carried out two simulations, the first simulation of capacitor placement under constant load conditions, the second simulation under load conditions that changed over time. The simulation results using moth flame optimization show an increase voltage profile.

Julianus [4] proposed another method to improved voltage profil in medium voltage distribution network, Network reconfiguration is the process of opening and closing switches to find the most optimal network configuration. This research applies the Ant Colony algorithm to improve the voltage profile.

Alonso [5] suggests distribution network reconfiguration to minimize power losses in medium voltage distribution network, this research present artificial immune system to find optimal network reconfiguration with radial network constrain.

Mustafa [6] proposed minimum spanning tree algorithm to find optimal network configuration, in this method minimum spanning tree algorithm was tested on IEEE 118 bus distribution network system, The algorithm is proven to be able to find the most optimal network configuration so as to reduce active losses and increase voltage levels.

Sayed [7] proposed another method for reducing network losses and increasing voltage levels, in this method presents placement and sizing distributed generator to improve voltage drops, the particle swarm optimization algorithm is applied to placement and sizing distributed generators, this method is tested on an IEEE 14 bus distribution system.

Soma [8] proposed artificial bee colony algorithm to placement and sizing distributed generator, This method was tested on a 34 bus radial distribution system. This research considers the economic objective function in determining the location and size of distributed generators.

In this research, the proposal involves placing and sizing capacitors to increase voltage levels and reduce network losses using ETAP. This method was tested on the Medan city medium voltage distribution system.

2. PROBLEM FORMULATION

2.1 Current and Power Loss Formulation

The current flowing in the branches (k,l), which are connected to bus k and l is given in the following equation [1] ;

$$I_{kl} = \frac{P_{kl} - jQ_{kl}}{V_k} \quad (1)$$

Where

I_{kl} = Current on the branch (k,l)

P_{kl} = The number of real power flowing branch (k,l)

Q_{kl} = The number of reactive power flowing branch (k,l)

V_k = Voltage at bus k

The amount of power loss in tge distribution line is :

$$\text{APL} = \sum_{kl=1}^{n} I_{kl}^2 Z_{kl} \quad (2)$$

Where

APL = The amount power loss

n = current on branch (k,l)

Z_{kl} = Impedance of branch (k,l)

Reactive power and active power are two parts of branch current, equation 2 shows the amount of active power loss and reactive power loss

$$\text{APL} = APL^a + APL^b \quad (3)$$

Therefore

$$\text{APL} = \sum_{kl=1}^{n} Ia_{kl}^2 Z_{kl} + \sum_{kl=1}^{n} Ir_{kl}^2 Z_{kl} \quad (4)$$

Capacitors installed in the distribution system will reduce the reactive power in the network so the branch current equation is as follows ;

$$I_{rkl}^{new} = I_{kl}^r + G_{kl} I_{kl}^c \quad (5)$$

Where :

G_{kl}= 1, if branch $(k,l) \epsilon \alpha$

G_{kl} = 0, otherwise

From equation (4) and (5), the amount loss saving (ALS) can be expresses

$$\text{ALS} = \sum_{kl=1}^{n} (2G_{kl} I_{kl}^r + G_{kl} I_c^2) R_{kl} \quad (6)$$

Thus, the capacitor current for maximum loss saving is given by

$$I_c = \frac{-\sum_{kl\epsilon\alpha}^{n} I_{kl}^r R_{kl}}{\sum_{kl\epsilon\alpha}^{n} R_{kl}} \quad (7)$$

2.2 Capacitor Size Constraint

Capacitor size follows the following equation

$$Q_c = V_n I_c \quad (8)$$

Where ;

Q_c = Capacitor size (VAR)

I_c = Capacitor current (Ampere)

V_n = Nominal Voltage of bus n (Volt)

The injected reactive power must meet the minimum and maximum limits according to the following equation

$$Q_{cj}^{min} \leq Q_{cj} \leq Q_{cj}^{max} \quad (9)$$

reactive power injected at location j must be less than or equal to the total reactive power load

$$Q_C^{Total} \leq Q_L^{Total} \quad (10)$$

2.3 Electrical Transient Analyzer Program

ETAP (Electric Transient Analysis Program) is software used to analyze an electric power system. ETAP software can work offline (for electric power system simulations) or online with the aim of analyzing data in real time (such as SCADA). ETAP software is very useful in planning electrical systems. In ETAP, there are types of elements such as AC elements, instruments and DC elements.

Things that need to be considered when using ETAP, a single line diagram is a simple representation (depiction) of the relationships between components or electrical equipment that form an electric power system, a library is information or data regarding all components or equipment that will be used in an electric power system both electrical and mechanical data which aims to assist in determining unknown equipment specifications, study case is a parameter related to the study method carried out and the format of the analysis results, in operating ETAP there are several standards used, namely ANSI standards and IEC standards which are standards that commonly used in electrical equipment specifications. The difference between this standard is that IEC uses a frequency of 50 Hz while ANSI uses a frequency of 60 Hz [9].

ETAP Power Station makes it possible to work directly with image displays single-line diagrams. The operational system in the program is very similar to the operating system in real conditions. For example, when opening or closing a circuit breaker, placing an element in the system, changing the operating state of a motors, and for de-energized conditions on system elements and sub-elements. The ETAP Power Station combines information on electrical systems, logic systems, mechanical system, and physical data of an element included in the system same databases. For example, for a cable element, it does not only contain electrical data and about their physical dimensions, but also provide information through the raceways through which the cable passes. Thus, the data for one cable can be used to analyze the load flow (load flow analysis) and short-circuit analysis which requires parameters electricity [10].

3. RESEARCH METHOD

3.1 Research Methods

The two research methods used in this research are

1. The interview method is a method that used by the writer to get one line medium voltage distribution network diagram, impedance data, and loading data transformer. The author conducts discussions or interviews directly with the PT (PLN) technical supervisor.
2. The direct observation method is a method that used by the author to obtain data in field, data obtained directly from field is a direct measurement of the transformer distribution to get loading data.

3.2 Research Stage

After the single line diagram, impedance data, and transformer loading data are obtained through interviews and direct observation, The next step is the simulation stage using ETAP 12.6 and data analysis, the steps taken in this research:

1. Literature study aimed at understanding data required to be input into the device ETAP software, understand the installation concept capacitors and understand running the flow menu power and optimal capacitor placement on ETAP software.
2. Draw a single line feeder diagram NR8 to ETAP based on existing data obtained directly from the field.
3. Enter voltage parameters, parameters line length, line impedance, capacity transformer and distribution transformer loading, after that run the power flow to get initial condition of voltage and power loss.
4. Observe the power flow results to see the bus which has a value below the standard for used as a candidate for installing capacitors.
5. Carry out optimal capacitor placement on ETAP software to acquire buses which will be installed capacitors and capacity capacitor, after that install the appropriate capacitor location and capacity obtained.
6. Execute power flow to obtain voltage conditions and power loss conditions on feeder NR8 Medan city after instlling capastor.

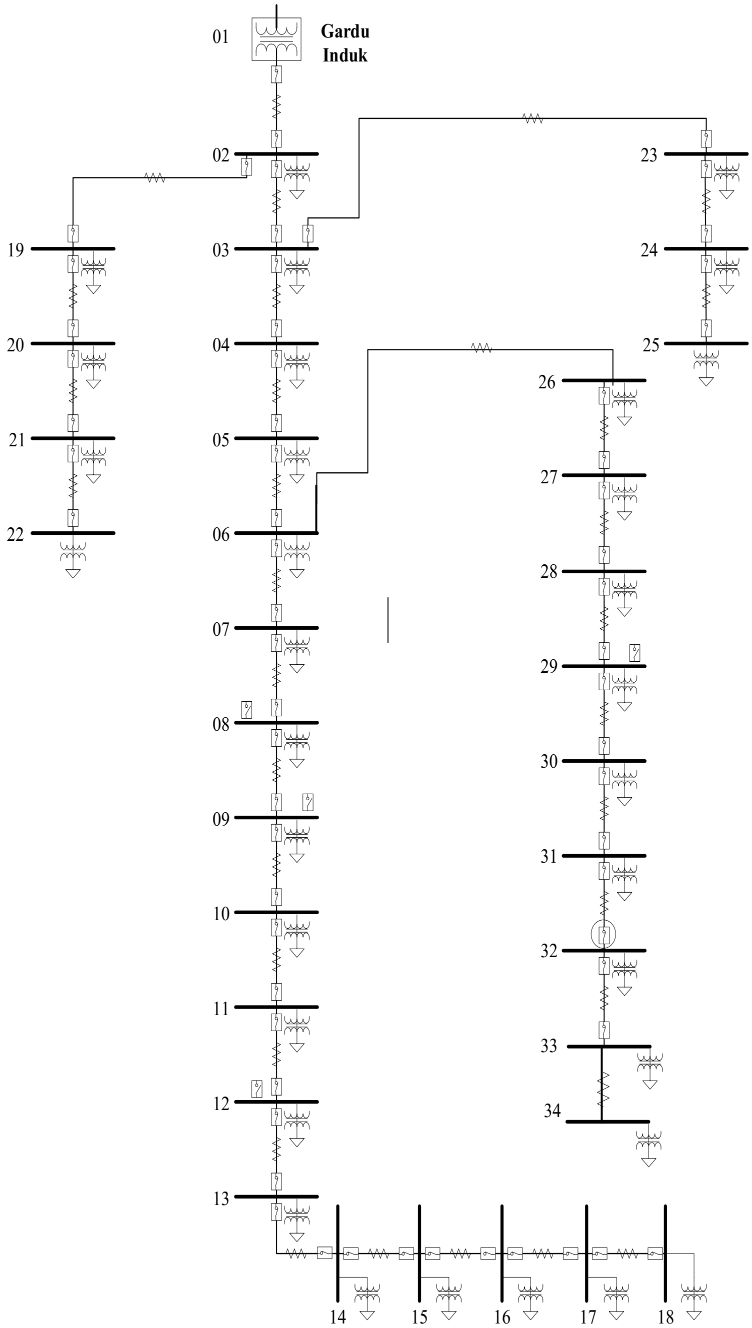

Figure 1. One Line Diagram NR8 Feeders

Figure 1 is a one line network diagram medium voltage distribution of the NR8 feeder in analysis to carry out placement optimization capacitors to improve the voltage profile and reduce my losses actively.

4. RESULT

Single line drawing of NR 08 feeders using ETAP 12.6, after drawing a single line step, the next step is to fill in the equipment rating in the ETAP 12.6 software according to the data that has been obtained from PT PLN Medan, namely data including power grids, transformers, buses, conductor length, cable impedance and also the load. The following are the components that need to be filled in ETAP 12.6

This study was tested on the Medan city medium voltage distribution Network, The feeder being analyzed is the NR8 34 bus feeder, this study still maintains voltage constrains and power factor constrains.

In this study, there are two cases. The first case is the initial condition before placement and sizing of the capacitor. The initial condition of the voltage and power loss will be obtained. The second case is placement and sizing capacitors with a candicate bus being a bus that has a nominal voltage below 0.95 p.u. After determining the location and size of the capacitor, a new nominal voltage and power losses are obtained, then compared with the nominal voltage and power losses in the first case

Table 1 explains the conditions before and after optimal capacitor placement. The initial conditions before optimal capacitor placement are minimum voltage 11.41 kV and power loss 256.1 kW. After carrying out optimal capacitor placement using the electrical transient analyzer program, the location of the capacitors on bus 18 and bus 34 with a capacity of 600 kVAR each was obtained. After optimal capacitor placement was carried out, the nominal voltage increased to 11.891 kV or increased by 4.2% and the power loss became 194.90 kW or decreased by 23.90%.

Figure 2 shows the nominal voltage before and after optimal capacitor placement, the initial minimum voltage condition on bus 18 is 11.41 kV, after optimal capacitor placement the nominal voltage on bus 18 increases to 11.891 kV or an increase of 4.2%.

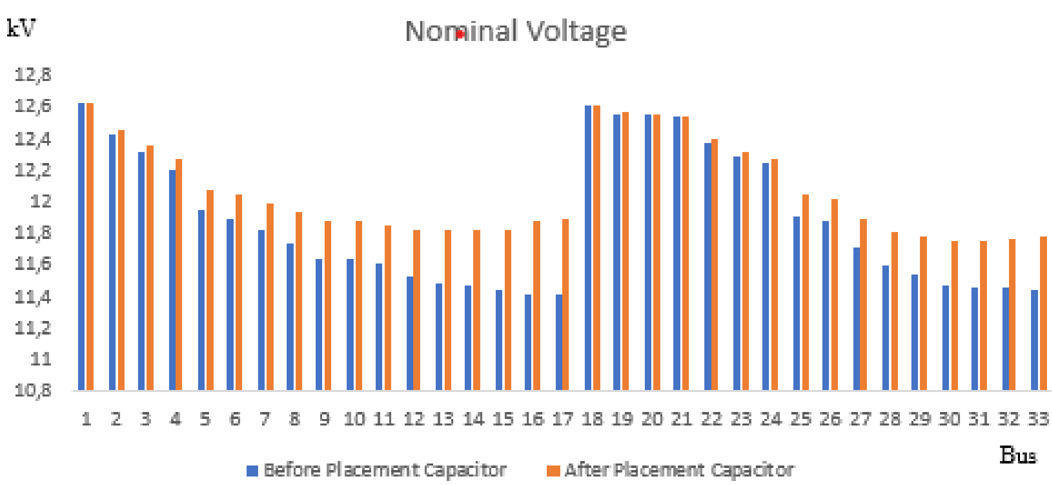

Figure. 2 Nominal Voltage before and after optimal capacitor placement

Table 1. Result of Optimal Capacitor Placement of Medium Voltage Distribution Network 34 BUS

Optimal Capacitor placment Condition	Before optimal Capacitor Placemet	Before optimal Capacitor Placemet
Capacitor Placement	-	34 & 18
Capacitor Capacity (kVAR)	-	600 & 600
Minimum Voltage (kV)	11, 41	11,891
Real Power Loss (kW)	256,1	194,9

5. CONCLUSION

In this paper, a study of placement and sizing of capacitors on a medium voltage distribution network of 34 buses has been carried out using an Electrical transient analysis program. From the results of the analysis before placing the capacitor, the initial conditions for power loss is 256.1 kW and a minimum voltage is 11.41 kV. After placing the capacitors using ETAP, the location of the capacitors was obtained on bus 18 and bus 34 with a capacitor capacity of 600 kVAR per bus , a power loss of 194.9 kW was obtained or a decrease of 23.9% and a minimum voltage of 11.891 kV or an increase of 4.2%

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