

Study of Capacitor Placement to Improve the Voltage Profile in Contingency Conditions of the 150 kV Madura Electricity Power System

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ABSTRACT

The contingency is a very important issue in the electricity power system security. The contingency impact can change voltage, particularly the voltage drop on the load bus. This condition can have an impact on the quality of power supplied to the load, system reliability, and system security. The solution to overcome the voltage drop is to improve the voltage profile through the injection of reactive power sources into the system. This study focuses on improving the stress profile when a contingency occurs in the electricity power system. The stabilization profile is improved by placing the capacitor in distribution and centrally on the electricity power system. Newton Raphson method is used to determine the power flow and voltage on each bus normal and contingency conditions. The results showed that the worst undervoltage impact occurred in scenario 7 where the value of the Sumenep bus voltage decreased to 132.4 kV and the value of the bus voltage of Pamekasan was 131.8 kV. the centralized capacitor placement method is carried out on the Sumenep bus with an injection of a negative power of 24.93 MVAR. the centralized capacitor placement method can increase the bus voltage profile above the standard minimum value used. the distributed capacitor placement method is carried out by measuring the reactive power on each bus Sumenep 24.93 MVAR, Sampang 29.78 MVAR, Bangkalan 50.85 MVAR, Gilitimur 67.41 MVAR. The results of the voltage profile show that the voltages of all load buses are above the standard. The voltage standard used is the Regulation of the Minister of Energy and Mineral Resources CC2.0: 2007 with a minimum voltage limit of -10%.

Keywords: Contingency Analysis, Voltage Profile, The Centralized Capacitor Placement Method, The Distributed Capacitor Placement Method

1. INTRODUCTION

The problem of voltage stability is very important issue in terms of planning and operation in the power system [1]. Voltage instability will result in the system's inability to supply the power required by the load. Voltage instability in the power system can make a voltage drop.

A voltage drop in the electric power system is a continuation of the voltage instability when the voltage drops rapidly and uncontrollably. The issue of voltage drop can happen by inappropriate reactive power sources, unexpected increases in load levels due to unusual conditions in the power system, or due to the influence of disturbances in the power system such as contingency disturbances for disconnection of the transmission lines, transformers, or generator [2]. the

best system performance voltage stability is based on SPLN No. 1: 1995 Article 4 regarding the provision of service voltage variations where the allowable voltage drop is only -10% to + 5% [3].

One of the anticipations of these disturbances can be done by using a contingency analysis to maintain service continuity, and the system can survive when a disturbance occurs [4] - [6]. Contingency analysis is an analysis used to predict power flow and bus voltage conditions in the event of disturbances which include: transmission line outage, transformer outage, load outage, generator unit outage, capacitor/reactor outage, etc. [7] - [11]. Efforts to reduce the damages that occur due to these disturbances can be done by using a contingency analysis, because contingency analysis is an analysis to determine changes of power flow and changes of voltage for each bus when the transmission

line is disconnected [12]. Indication of system instability is the occurrence of voltage drop and undervoltage. the solution to prevent undervoltage is by injecting a reactive power source for the capacitor to improve the voltage profile [13] - [21].

This study discusses of capacitor placement to improve the voltage profile when the contingency of Madura 150 kV electricity power system happened. contingency analysis in Madura 150 kV electricity power system carried out with 8 contingency scenarios. Each scenario consists of an outage transmission line on Madura 150 kV electricity power system. The Newton Raphson method is used to calculate the power flow in Madura 150 kV electricity power system. This function is to determine the voltage drop that results in undervoltage when an element of the power system outages. The worst impact of undervoltage then calculate to voltage profile which is then followed by placing the capacitor to inject the reactive power bus. The capacitor placement method in this study to optimal capacitor placement is a centralized capacitor placement method and distributed capacitor placement method. Where the centralized placement method focuses on placing capacitors on the worst bus, while the distributed placement method places capacitors on each of the other buses.

2. MATERIAL AND METHOD

2.1. Newton Raphson Methods

The solution to select a release case or contingency condition scenario is to use the newton raphson power flow method. The electricity power system not only consists of two buses but consists of several buses that are interconnected with each other. The electricity injected from the generator to the bus is not only absorbed by the load bus but also absorbed by other buses that are also connected or interconnected. A Diagram of one line of several buses from a power system is shown in figure 1:

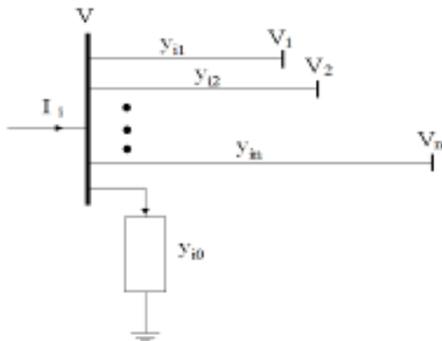


Figure 1 One Line Diagram of n-bus in an Electricity Power System

The current on bus i is a multiplication admittance y and V voltage, and there can be written in the form of the following equations:

$$I_i = V_i \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j \tag{1}$$

Description:

I_i = current on bus i .

V_i = voltage line i .

V_j = voltage line j .

y_{ij} = admittance on line i .

$$I_i = y_{i0}V_i + y_{i1}(V_i - V_2) + \dots + y_{in}(V_i - V_n) \tag{2}$$

$$I_i = (y_{i0} + y_{i1} + y_{i2} + \dots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - \dots - y_{in}V_n \tag{3}$$

For the active power and reactive power values on bus i are as follows:

$$P_i + jQ_i = V_i I_i \tag{4}$$

or

$$I_i = \frac{P_i + jQ_i}{V_i} \tag{5}$$

Description:

I_i = current on bus i

P_i = active power value on line i .

jQ_i = reactive power value on line i .

V_i = voltage value line i .

Then substitution I_i :

$$\frac{P_i + jQ_i}{V_i} = V_i \sum_{j=0}^n y_{ij} - \sum_{j=1}^n y_{ij} V_j \tag{6}$$

2.2. Shunt Capacitor

Solution to regulating the voltage profile on the bus is to inject shunt capacitors in the transmission, distribution system, or the main substation and load. Basically the capacitor is a tool to inject reactive power (VAR). In figure 2 bus 1 is the sending bus and bus 2 is the receiving bus. The channel has Ω impedance ($R+jX$).

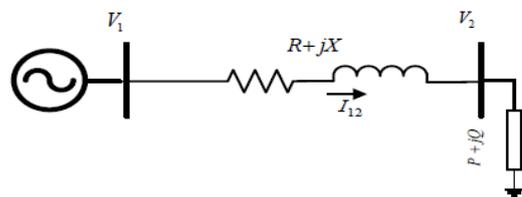


Figure 2 Transmission Line to Load

Based on V_2 as the reference, the current value that appears different phase angle is V_1 , while $R+jX$ value is the transmission line impedance value, and the $P+jQ$ value is the load impedance value, so the ΔV and $\Delta \delta$

values are obtained [22], so that phasor diagrams are obtained as shown below:



Figure 3 Phasor diagram

$$V1^2 = (V2 + \Delta V)^2 + \Delta\delta^2 \tag{7}$$

When:

$$\Delta V = \frac{RP}{V2} + \frac{XQ}{V2} \tag{8}$$

$$\Delta\delta = \frac{XP}{V2} + \frac{RQ}{V2} \tag{9}$$

$\Delta\delta$ usually will be smaller than $V2 + \Delta V$, so we get the following equation:

$$V1^2 = (V2 + \Delta V)^2 \text{ atau } V1 = (V2 + \Delta V) \tag{10}$$

Then, the voltage on the transmission line is:

$$V1 - V2 = \Delta V = \frac{RP}{V2} + \frac{XQ}{V2} \tag{11}$$

Description:

- V1 = send of voltage..
- V2 = receiver of voltage..
- P = active power.
- Q = Reactive power..
- ΔV = between V1 and V2

Based on the formula above the Q value can be categorized as shunt capacitor.

2.3. Flowchart

Model the problem with ETAP 12.6 application to calculate newton rapsion power flow on madura 150 kV electricity power system. The research phase of the capacitor placement study for voltage profile at the time of contingency at Madura 150 kV electricity power system includes the flow chart in figure 4 below.

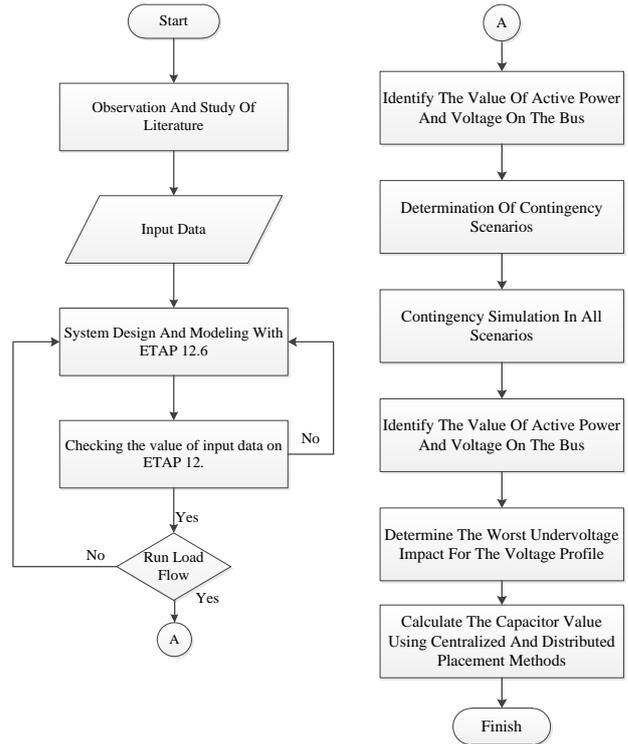


Figure 4 Capacitor Placement Flowchart For Voltage Profile When contingency at Madura 150 kV electricity power system.

2.4. Research data

This research data is electricity system 150 KV Madura includes a Single line diagram of Madura 150 kV electricity power system with region sub-system Krian 1,2 Gresik, Data transmission line parameters, Data transformer, Bus data, Peak-load data.

3. RESULT AND DISCUSSION

3.1. Madura 150 kV electricity power system

Madura island included in region krian subsystem – 1.2 – gresik consisting of 5 substations (GI) with GI Bangkalan, GI Gilitimur, GI Sampang, GI Pamekasan, GI Sumenep to meet the load needs of Madura island which when peak load happens can reach 200 MW (PT. PLN APB REGION 4). Single line is shown in figure 5 below:

Power flow at the normal condition (before contingency) shows Madura 150 kV electricity power system in good condition, each bus connected to the system works well to deliver electrical energy according to the demand of each bus without overload or undervoltage. There show the table of results from the simulation of load flow during normal conditions (before contingency) with peak load in table 2:

Table 2. Voltage result of Madura 150 kV electricity power system Before Contingency (Normal)

No.	Bus ID	Voltage (kV)
1	Infinity (Kenjeran)	145.08
2	Infinity (Ujung)	144.72
3	Gilitimur	143.8
4	Bangkalan	142
5	Sampang	138.9
6	Pamekasan	137.9
7	Sumenep	136.8

Based on table 2 and there show Madura 150 kV electricity power system is in good condition because it is still within the threshold or standard regulation of the Minister of Energy and Mineral Resources CC2.0:2007 where the minimum voltage limit is -10% and the maximum voltage limit is +5%.

3.2. Madura 150 kV electricity power system contingency scenario

Contingencies on transmission lines in this study consist of eight outage scenarios. The outages modeled on every transmission line in Madura 150 kV electricity power system. The following contingency scenarios in the study are shown in table 3 below:

Table 3. Scenario contingency

Scenario	Gili Timur
1	Infinity – Gilitimur A
2	Infinity – Bangkalan A
3	Gilitimur B – Bangkalan B
4	Bangkalan A – Sampang A
5	Bangkalan B – Sampang B
6	Sampang B – Sumenep
7	Sampang A– Pamekasan
8	Sumenep – Pamekasan

From the result scenario contingency, especially on the Sumenep bus is always undervoltage when a contingency scenario occurs and the Pamekasan bus is the next worst sequence with undervoltage occurring in all scenarios except scenarios 6 and 8. The Worst undervoltage occurred is scenario 7 where the Sumenep bus voltage value was 132.4 kV and the Pamekasan bus voltage value was 131.8 kV. Therefore, it is necessary to place a capacitor to improve the bus voltage and by the optimal placement of the capacitor.

3.2.1. Scenario of the centralized capacitor placement method on the worst bus sumenep

Based on equation 8 the result of shunt capacitor is 39 MVAR for bus sumenep, and the result of scenario contingency show from table 4.

Table 4. Result Voltage On Each Bus Madura 150 kV electricity power system of the centralized capacitor placement method

No.	Bus ID	Before Capacitor placement		After capacitor placement	
		Normal	Contingency	Normal	Contingency
1	Infinity (Kenjeran)	145.08	145.08	145.08	145.08
2	Infinity (Ujung)	144.72	144.72	144.72	144.72
3	Gilitimur	143.8	143.6	144.2	144
4	Bangkalan	142	141.7	143.1	142.7
5	Sampang	138.9	138	142.3	140.9
6	Pamekasan	136.8	131.8	142.7	141.1
7	Sumenep	137.9	132.4	143.7	141.6

From table 4, that shows the undervoltage of several buses in the scenario, especially on the Sumenep bus is always undervoltage when a contingency scenario occurs and the Pamekasan bus is the next worst sequence with undervoltage occurring in all scenarios except scenarios 6 and 8. The Worst undervoltage occurred is scenario 7 where the Sumenep bus voltage value was 132.4 kV and the Pamekasan bus voltage value was 131.8 kV.

3.2.2. Scenario of the distributed capacitor placement method

Based on equation 8 the result equation 11 of shunt capacitor is 39 MVAR for sumenep, 29.78 MVAR for Sampang, 50.85 MVAR for Bangkalan, 67.41 MVAR Gilitimur and the result of scenario contingency show from table 5.

Table 5. Result Voltage On Each Bus Madura 150 kV electricity power system of the distributed capacitor placement method

No.	Bus ID	Before Capacitor placement		After capacitor placement	
		Normal	Contingency	Normal	Contingency
1	Infinity (Kenjeran)	145.08	145.08	145.08	145.08
2	Infinity (Ujung)	144.72	144.72	144.72	144.72
3	Gilitimur	143.8	143.6	146.8	146.6
4	Bangkalan	142	141.7	146.8	146.3
5	Sampang	138.9	138	148	146.5
6	Pamekasan	136.8	132.4	148.4	146.6
7	Sumenep	137.9	131.8	149.4	147.2

Based on table 4 and table 5, that shows the best capacitor placement is the capacitor placement distribution method with the value of each bus of the Madura electricity power system being more optimal than the centralized capacitor placement method. From the result this paper uses the distribution capacitor placement method, the value of distribution capacitor placement method is Sumenep 24.93 MVAR, Sampang of 29.78 MVAR, Bangkalan of 50.85 MVAR, Gilitimur of 67.41 MVAR with the voltage on each bus that was still by the threshold or standard Regulation of the Minister of Energy and Mineral Resources CC2.0: 2007 with a minimum voltage limit of -10%.

4. CONCLUSION

Based on the results of the contingency scenario carried out on the Madura 150 kV Electricity power System, the voltage and active power flow on each bus have changed. The results showed that the worst undervoltage impact occurred in scenario 7 where the value of the Sumenep bus voltage decreased to 132.4 kV and the value of the bus voltage of Pamekasan was 131.8 kV. The centralized capacitor placement method is carried out on the Sumenep bus with an injection of a negative power of 24.93 MVAR. The centralized capacitor placement method can increase the bus voltage profile above the standard minimum value used. The distributed capacitor placement method is carried out by measuring the reactive power on each bus Sumenep 39 MVAR, Sampang 29.78 MVAR, Bangkalan 50.85 MVAR, Gilitimur 67.41 MVAR. The results of the voltage profile show that the voltages of all load buses are above the standard. The voltage standard used is the Regulation of the Minister of

Energy and Mineral Resources CC2.0: 2007 with a minimum voltage limit of -10%.

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