Improved Quality of using Voltage Static Var Compensator and Capacitor Bank on the Transmission Line

Surya Hardi*1, Muadzzah Rahmat2, Emerson P. Sinulingga3
1,2,3Departement of Electrical Engineering, Universitas Sumatera Utara

*Corresponding author : surya.hardi@usu.ac.id

Abstract. The increase in load which increases every year causes a decrease in voltage on the line which is getting bigger. The voltage drop on the transmission line greatly affects the quality of the voltage. The voltage that arrives at the electrical equipment will decrease which in turn reduces the performance of the equipment. The power flow study uses the Fast Decoupled method, the voltage on each bus can be determined. The performance parameters observed are the value of the power factor, voltage, active power, and reactive power to determine the parameters for the location and size of the capacitor bank capacities and the static var compensator (SVC). By increasing the power factor in the range of 0.85pu to 0.95pu, the bus voltage can fulfill the SPLN standard. Parameters are designed and simulated using the ETAP programming software version 12.6.0 by testing each bus that experiences a voltage drop in turn based on the voltage limit and the power factor value ≤ 0.85pu. Furthermore, several buses with the appropriate capacity rating are selected to increase the voltage on the system. The simulation results will show the effectiveness of the capacitor bank and static var compensator (SVC) to increase the voltage value on each bus.

1. Introduction

Increased load every year will cause a decrease in voltage in the channel. Drop voltage on the transmission line greatly affects the quality of the voltage. In electrical power systems, generator gain current-voltage and reactive power at load, on condenser and reactors. The need for greater reactive power by the load will increase the voltage. To ensure the safety of the operation of the system, the transmission system of the high voltage system operates under its thermal rating due to the voltage limit and stability limit. Transmission line parameters such as impedance, terminal voltage, and voltage angle can be controlled quickly and effectively using bank capacitors and Flexible AC Transmission System (FACTS) devices, one of which is with Static Var Compensator (SVC) to increase the voltage profile [1]. SVC on the power system is used to quickly control the voltage and reactive power of the terminal. These compensators used the Thyristor switch capacitor (TSC) or Thyristor Controlled Reactor (TCR) with a fixed power factor correcting capacitor. The SVC is afterward an emergency response for the dynamic compensation of the electric power system by utilizing the TCR coupled with the TSC [2].

Bank capacitors can usually be used to provide reactive power compensation, power, and voltage loss pressures, maintain voltage stability on buses, and improve system safety. The capacitor unit is parallely connected to meet the needs of reactive power in units (MVAR) and stabilizes the voltage while being
connected in series only to meet voltage improvements by compensating the inductive circuit [3]. Buses represent the nodes of the electrical system and can be classified based on the load and/or generation conditions. The bus data describes each bus as well as the loads and shunts connected to that bus.

The information includes the following [4]:
1. Bus ID, name, and number
2. Bus classification (swing/voltage controlled/load bus)
3. Bus service status (incoming/outgoing)
4. Bus nominal voltage
5. Bus/amp rating continuously
6. Initial voltage and angles (discussed later)

2. Static Var Compensator System

In transmission line compensation, the main objectives are [5]:
1. Correction of voltage regulation and reactive power control.
2. Improvement in system stability.

About the reactive components of a static compensator are shunt reactors and shunt capacitors. This diversity reactor uses a thyristor. The capacitor banks have a fixed or varying number of steps with the thyristor switching. Based on these principles various static compensators have been developed. This is characterized by fast response, reliability, low operating costs, and flexibility.

SVC can be one of the following types [2]:
1. Thyristor controlled Reactor
2. TCR plus Fixed Capacitor
3. Thyristor Switched Capacitor
4. TSC plus TCR

Figure 1 is a single line diagram of a typical static VAR system for the transmission application. TSC plus TCR are very popular and most effective. The idea is to sense the voltage of the line and keep it stable by introducing capacitance or inductance in the circuit, depending on the signal generated by the Automatic Voltage Regulator (AVR). So obviously, the gating signals to thyristor valves will have to be changed by AVR signal. Since control can be achieved in each cycle of the voltage wave by (controlling the conduction time of thyristors), control is very fast and accurate.

Figure 1: Typical Static Var Compensator

3. Bank Capacitor

Capacitors are commonly used within a lot of power systems, especially electronic constructed circuitry. In a three-phase power system, capacitors are normally installed within an isolating non-conductor metal box, which is called a capacitor bank. Fixed banks are connected permanently to the primary conductors through fused switches. Switch capacitors banks are tied to the primary system through the automated switch, allowing them to be put on the line and taken offline as needed. The distribution power system
usually connects the capacitor in parallel rather than connecting in series. The function of the shunt power capacitors is to provide leading KVAR to an electrical system when and where needed [6]. The amount of parameters that are often used is KVAR (Kilovolt ampere reactive) although in the capacitors themselves listed the capacitance size is Farad or microfarad. The electrical load consists of reactive load (R), inductive (L), and capacitive (C).

The following are some uses of bank capacitors:
1. Fix the Power Factor
2. Mensuply reactive power so that maximize the use of complex power (KVA)
3. Reduce voltage drop
4. Avoid overloaded transformers
5. Provides additional available power
6. Avoid rising current/temperature on cables
7. Save power/efficiency
8. Preserving installations & Electrical Equipment
9. Capacitor bank also reduces other losses on electrical installations.

4. Research Methods
The calculation of the power flow used is the Fast Decoupled method to determine which bus is experiencing a voltage drop that affects the stability of the transmission network. This research is designed to follow the following steps including identifying and preparing all data in the form of generation data, load data, line data on each bus. Analyze the network system to determine voltage changes using power flow equations. Then, confirm the placement of SVC (Static Var Compensator) and bank capacitors using Etap 12.6.0 on each bus that experiences a decrease in voltage.
Study of literature

Data collection in the form of channel data, generator data, and transmission line load data of 150 kV North Sumatra

Making a single line transmission diagram of North Sumatra using ETAP 12.6.0

Enter data for power flow simulation using the fast decoupled method using ETAP 12.6.0

Observe the power flow results and choose which bus to place the SVC and Capacitor banks

The SVC and capacitor banks were tested on each bus using ETAP 12.6.0 to obtain the observed values

Observe the desired power flow results

Finish

Figure 2. Flowchart of the research step

Simulations of single line diagram 18 bus 18 channels can be seen in Figure 3
5. Result and Discussion

5.1 Before installation of SVC
Early stages, to find out voltage on each bus, it is carried out power flow analysis with the help of Etap 12.6.0. in the Load Flow Analysis project. In our power flow Fast Decoupled method amounts to maximum iteration 5000 with a pre-sided 0.0001 and power flow results can be seen in table 1:

| ID BUS | NOMINAL (KV) | MVA   | %PF  | Amp   |
|--------|--------------|-------|------|-------|
| Bus 1  | 150          | 1336,363 | 83,8 | 5143,7 |
| Bus 2  | 150          | 106,452  | 94,4 | 409,7  |
| Bus 3  | 150          | 493,728  | 82,9 | 1901,2 |
| Bus 4  | 150          | 433,713  | 83,3 | 1670,6 |
| Bus 5  | 150          | 49,983   | 80,0 | 192,5  |

Figure 3. Simulation of single line diagram 18 bus 18 channels
From table 1 see the result of the power factor value then simulation done is by the placement of SVC and capacitor banks on the bus pf ≤0,85 alternating results are then obtained from each simulation that will be compared to the results before SVC placement.

5.2 After installation of SVC and Capacitor Bank

Based on program calculations power flow in Etap 12.6.0 by method Fast Decoupled can be seen in the amount of weight and power losses in table 3. and differences in voltage before and after the placement of the SVC (Static Var Compensator) and Capacitor Bank

|                  | Before         | After SVC      | After Capacitor banks |
|------------------|----------------|----------------|-----------------------|
| MW               | 1119.803       | 1120.136       | 1119.801              |
| Mvar             | 729.318        | 909.111        | 716.733               |
| MVA              | 1336.363       | 1442.633       | 1329.534              |
| %PF              | 83.7 Langging  | 77.65 Langging | 84.23 Langging        |

6. Conclusion

After the placement of SVC (Static Var Compensator), reduced power losses, namely real power loss decreased by approximately 0.08%, and reactive power loss decreased by approximately 19.8%, and active power loss increased by approximately 7.79%.

After the placement of the capacitor bank, there are reduced power losses that are losses - real power loss decreased by approximately 0.02%, and reactive power loss decreased by approximately 21.23%, and active power loss increased by approximately 9.08%.
7. Reference

[1] Khandani, S. Soleymani, and B. Mozafari., “Optimal Placement of SVC To Improve Voltage Profile Using Hybrid Genetics Algorithm And Sequential Quadratic Programming”, conference on electrical power distribution network (EPDC), 2011.

[2] IEEE Special stability controls working Group, "Static VAR Compensator Models for Power Flow and Dynamic Performance Simulation," IEEE Transactions on power systems, vol. 9, no.1 February 1994. pp. 229-240.

[3] Om Prakash Mahela., “Analysis of High Voltage Shunt Capacitor Bank on Reduced Capacity: The Case of RRVPN Power Grid”, Graduate Student Member IEEE & Junior Engineer-I, India, 2013.

[4] IEEE Std 3002.2™-2018, IEEE ‘‘IEEE Recommended Practice for Conducting Load-Flow Studies and Analysis of Industrial and Commercial Power Systems’’ Approved 27 September 2018

[5] Aboytes F., Arroyo.G. and Villa G., "Application of Static VAR Compensators in Longitudinal Power Systems", IEEE Trans on PAS, Vol.PAS-102, PP.3460-3466, Oct.1983.

[6] Praveen V.A, Sumaya Fathima, Sumalata I. A, Badiger K. D, Kandagal S. S., “Automatic Power Factor Correction Using Capacitor Banks and 8051 microcontroller”, ISSN: 2321-0869, Volume-3, Issue-6, June 2015