Comparison of STATCOMs and SVCs in Voltage Support at the Fringe of the Power System

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Abstract

Electrical transmission and distribution networks are currently stretched to the limit due to the ever increasing demand for electricity. As the distance from load demand from a large generation source is increased, the capacity, security and reliability of supply decreases. This problem has been prevalent in distribution networks at remote locations at the fringe of the power system.

The use of shunt dynamic reactive power compensation devices such as STATCOMs and SVCs are emerging as cost effective alternative solutions to these problems. The purpose of this study is to examine the pros and cons of using these devices in remote locations of the network. This will be achieved by modelling and simulating these devices on an existing network model and comparing their performance.

1.0 Project Outline

This project has been initiated to explore a possible network reinforcement solution to voltage control, power transmission capacity, voltage stability and flicker issues in power distribution networks at the edge of the grid. The aim of this project is to produce a comprehensive, proven list of advantages and disadvantages of using either STATCOM or SVC technology to provide support at the edge of the grid with respect to the following issues:

- The effectiveness of these devices in improving voltage stability (main issue)
- The effectiveness of these devices in the mitigation of flicker
- The impact of harmonics and resonance introduced by these devices on the network

2.0 Background on SVC and STATCOM

2.1 Introduction to SVC and STATCOM

The Static Var Compensator (SVC) and Static Synchronous Compensator (STATCOM) are power electronic devices that are utilized in power systems to improve network efficiency and utilization in a variety of technical areas. In the context of this project these include:

- Voltage control and regulation
- Improving voltage stability
- Flicker mitigation

The term "static" indicates that the devices have no mechanically moving parts and no inertia. Both devices achieve the tasks listed above by providing dynamic reactive power compensation to the power system they are connected to. Reactive power is closely coupled with voltage. As the amount of reactive power supplied increases voltage magnitude increases and vice versa. Thus dynamic reactive power compensation provides fast, accurate voltage control [1].

There are many possible configurations of these devices. A brief overview of working principles behind common basic configurations and the main elements for each device will now be presented.

2.2 Static Var Compensator (SVC)

SVCs provide fast dynamic reactive compensation by supplying a variable susceptance. The main elements of a SVC are the Thyristor Controlled Reactor (TCR), Thyristor Switched Capacitor (TSC) and a control system. The advantage of using thyristor switches and controllers is that they have a fast response time and have an almost unlimited switching capability (no mechanical moving parts – low maintenance). The TCR and TSCs operate in combination to provide an overall SVC susceptance.

A control system is used to control overall susceptance by controlling the thyristor controllers and switches according to the required reactive power compensation needs of the power system. A single line diagram of a SVC and a basic block diagram of its control system are shown below.

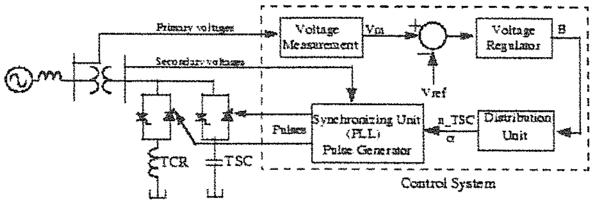

Figure 1 - Single line diagram of SVC and control system [2].

2.3 Static Synchronous Compensator (STATCOM)

STATCOMs provide dynamic reactive power compensation by variable current injection. The main elements of a STATCOM are a voltage source converter (VSC), DC link capacitor and a control system. The VSC operates as an inverter and uses a capacitor as its DC energy source. The STATCOM control system exhibits greater complexity as more variable quantities must be controlled to actuate the desired current injection into the system.

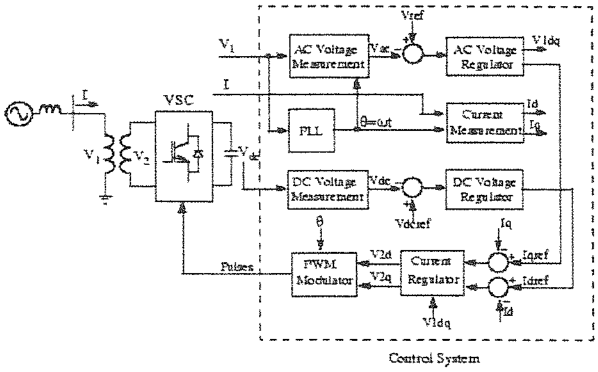

Figure 2 - Single line diagram of STATCOM and control system [2].

The VSC may utilize either Integrated Gate Bipolar Transistor (IGBT) or Gate Turn Off thyristor (GTO) switches on its bridges. Pulse Width Modulation (PWM) is also commonly used. These components allow the STATCOM to have a fast response time and accurate control [3].

3.0 Analysis

3.1 Introduction

All analysis was conducted using computer simulation. The computer program used was SimPowerSystems. There are many analytical techniques available for power system analysis using computer simulation. These techniques fall in two main categories of analysis: steady state and dynamic.

The technical component we are considering throughout the following analysis is voltage stability. *Voltage stability* is concerned with the ability of a power system to maintain acceptable voltages at all nodes (buses) in the system under normal and contingent conditions [4]. By contingencies we are referring to the loss of system elements. Voltage magnitudes are presented in per unit (pu) values which represent a fraction/percentage of nominal voltage. The acceptable range of distribution system voltage magnitudes at any node of the network is between 0.9 and 1.1 pu.

3.2 Network Model

The distribution system network model was constructed using data from a selected edge of grid network.

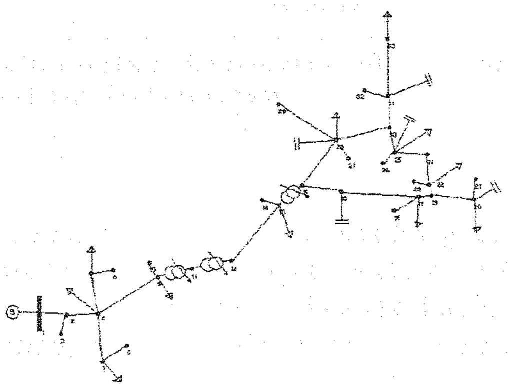

Figure 3 - Single line diagram of the network model.

The base case load level provided is for peak summer load. This load level provides a good starting point for credible worst case studies. Voltage magnitudes for buses along the backbone of the network will be considered. Also note that bus 20 is the node at the very edge of the network – we will be referring to this bus for most analyses.

3.3 Steady State Analysis

3.3.1 Modeling and Simulation Details

Steady state analysis involves simulation where time is not a factor. The term steady-state is used to indicate that the system solution is specified as being in an equilibrium (or final) state.

In this case all generation and loads are static models (no time variance). A manually varied capacitive load is used to simulate the SVC. We will just model the SVC to demonstrate how variable reactive compensation can improve system performance in steady state conditions. In steady state analysis we will simply refer to the modelled SVC as reactive compensation. Actual comparisons in performance between the STATCOM and SVC will be explored in dynamic analysis.

3.3.2 Power flow

Power flow involves finding solutions of nodal voltages, currents, active and reactive powers for a specified system operating condition. We are mainly interested in the steady state voltage magnitudes. The bus voltages can then be plotted to provide a voltage profile of the system [5].

For the figure below the system is at heavy load and voltage magnitudes at buses along the backbone of the network (buses 9, 17, 19 and 20) drop below the acceptable range. However when reactive compensation is connected, the voltages are supported to the acceptable range.

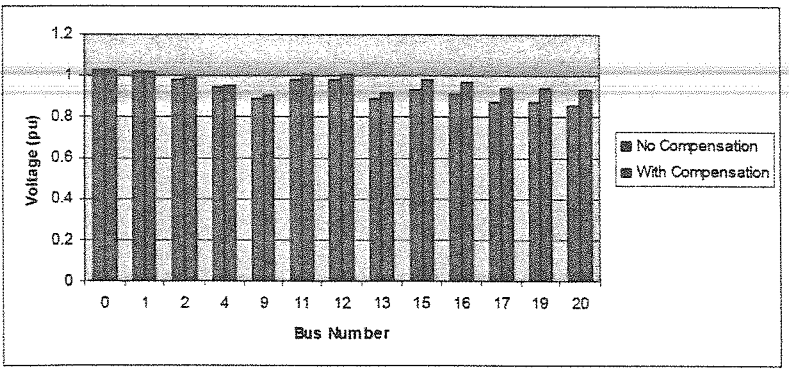

Figure 4 - Comparison of voltage profiles for buses along the backbone of the network with and without reactive compensation under heavy load conditions.

3.3.3 PV curves

PV curves are useful in estimating voltage stability limits as active power transfer is increased. Active Power (P), Voltage (V). A series of power flow simulations are run with increasing active power transfer at a specified bus and the variation in bus voltage is observed. Active power transfer and corresponding bus voltage values are then plotted on axes resulting in a PV curve. The knee of the curve is the point of instability, as the part of the curve under the knee indicates a decrease in voltage for a decrease in active power transfer – an indicator of voltage instability [6]. In the figure below you can clearly see that with compensation the knee moves further to the right – increasing the active power transfer and voltage stability limit.

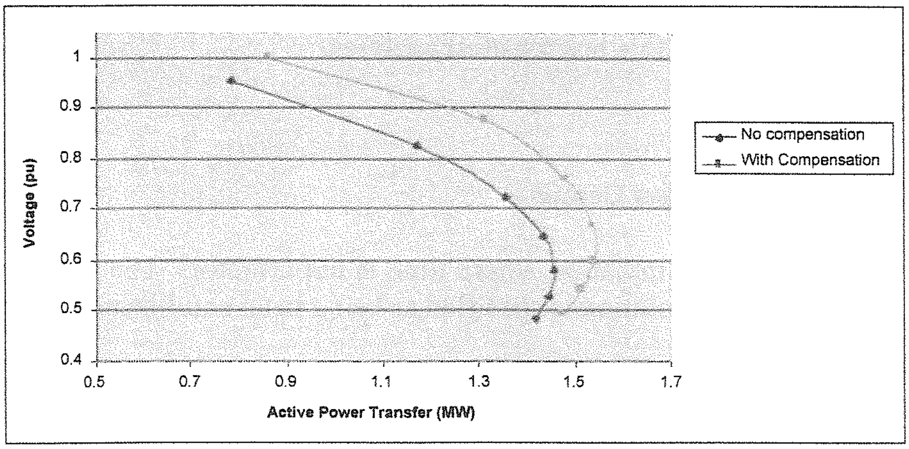

Figure 5 - PV curve comparison for system with and without compensation, obtained at bus 20.

3.4 Dynamic Analysis

3.4.1 Modeling and Simulation Details

Dynamic analysis includes time varying elements into the simulation process. Thus you can actually observe how a quantity varies with time as the system is transitioning from one state to another. The only dynamic elements are chosen to be STATCOM, SVC and the loads. The generation source is chosen to be constant.

All models have been chosen from the existing SimPowerSystems block library. These models are generic and are designed to represent typical device configurations. Reactive power limits of the devices were chosen according to QV curve analysis (not discussed due to space constraints). The SVC and STATCOM are connected to the network at bus 20. The loads have been modelled as part induction motor and part static load to provide a more realistic system response as recommended in [7].

We are interested in seeing how the devices will aid the system in recovering from larger disturbances such as faults. As we are interested in transient behaviour, the time range of interest is in the short term (a few seconds).

3.4.2 Response to faults

Single phase to earth faults are the most common type of fault to occur in electrical transmission and distribution systems (80 to 90% of all faults). They are most often transitory and mainly caused by physical disturbances on distribution lines. In particular this network is at increased risk of these faults due to the long length of the distribution lines. In the case below the system is stressed and a single phase fault is applied for one second from 2-3 seconds on a line close to bus 20. We will just assume that when the fault occurs supply is lost from the affected phase conductors – protection is not strictly modelled.

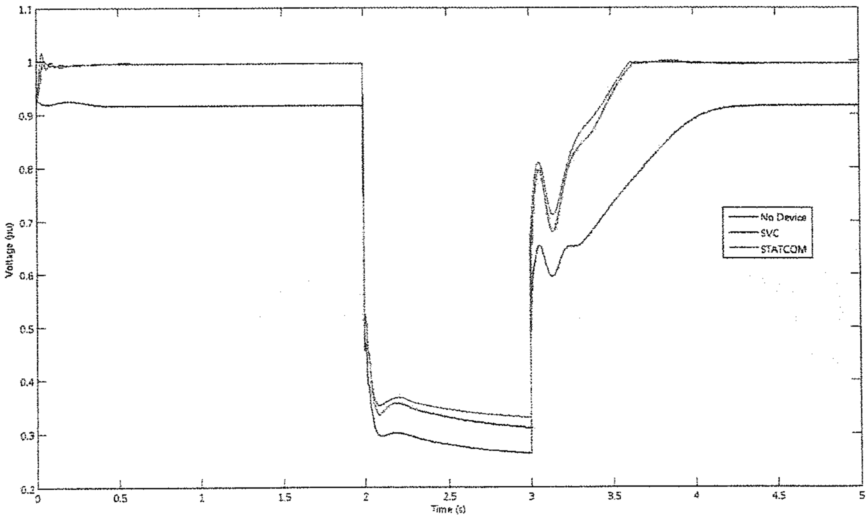

Figure 6 - Response to single phase fault at bus 20. Voltage magnitude vs time.

Consider the response from the system with no compensation device connected. Before the fault, system is at steady state (after a short transient at the start of simulation). During the fault, the voltage is greatly reduced due to the loss of supply on a phase conductor. This reduced voltage causes induction motors in the load to decelerate. When the fault is cleared, supply is reestablished from the affected phase conductor. When this occurs, the induction motors draw large amounts of current (and reactive power) to re-accelerate their rotors. This causes the voltage to sag upon reconnection - i.e. the voltage is decreased and does not immediately return to its pre-fault value. As the motors re-accelerate, they draw less current and the voltage slowly recovers. This continues until the motors reach their pre-fault speed and the voltage is fully recovered. It can be observed that this takes over one second to occur post-fault – this is called the voltage recovery time. This time is significant because voltages during this time are mostly outside acceptable limits and as this time increases more electrical equipment in the load may malfunction – i.e. stalling of induction motors. Thus it is desirable to reduce this time and return voltages to within acceptable limits as soon as possible.

Now consider the response when the SVC or STATCOM is applied. The pre-fault voltage is now supported to a more desirable level. During the fault the devices provide support to reduce the severity of the voltage sag. Post-fault, the devices quickly act to support supply reactive power and support the voltage from the sag caused by the re-acceleration of the motors. The voltage is at more desirable levels during the recovery time and voltage recovery time is also reduced. Thus it is clearly demonstrated here how SVC or STATCOM can aid voltage recovery and increase voltage stability in contingent conditions.

3.4.3 Comparisons of Device Performance

It is clearly observed that with the generic device models used in simulation, there is no significant difference between the performance of the two devices in the presented analysis. The STATCOM does marginally outperform the SVC as it does provide slightly more voltage support during the fault and recovery time. It also has a minutely faster response time (almost negligible for this case). This suggests that there will not be significant difference between the performance of SVC and STATCOM for voltage recovery and regulation application for this particular network model. It may also suggest that perhaps further investigation may need to be done with detailed models

4.0 Conclusion

4.1 Summary of results and findings

Through the previous analyses we have briefly demonstrated that:

- Variable reactive compensation can improve steady state voltage profile and improve the active power transfer limit.
- SVC and STATCOM provide fast acting voltage support in transient conditions.
- SVC and STATCOM aid in voltage recovery during fault and contingent conditions.
- Using generic models in simulation, there is no significant difference between the performance of SVC and STATCOM for voltage recovery and regulation applications in this particular network model.

4.2 Further Work

- Artificially increasing the stress on the system to observe any possible difference between the performance of the generic device models in extreme worst case scenarios.
- Implementing and simulating more detailed device models.
- Examine the effectiveness of these devices in flicker mitigation.
- Examine harmonic levels introduced by the devices.

5.0 References

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