Simulation of FACTS Reactive Power via Static VAR Compensator

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Abstract—This work presents a review of comparison of different FACTS controllers in the power system for stability enhancement. VAR compensation is defined as the management of reactive power to improve the performance of ac power systems. The focus of this research is simulation of single phase TCR/TSC Static Var Compensator to solve voltage regulation and system dynamic performance deficiencies. SVC is thyristor based controller that provides rapid voltage control to support electric power transmission voltages during immediately after major disturbances. Voltage stability, voltage regulation and power system stability, damping can be improved by using these devices and their proper control. Static Var Compensator (SVC) and capacitor bank improves the overall response of the system. The simulation results confirm the competitive dynamic response of the system using capacitor bank and SVC.

Keywords-- Capacitor Bank, Static VAR Compensator (SVC), Reactive Power compensation, TSC, TCR.

I. INTRODUCTION

SVC’s being dated from early 70’s, have the largest share among FACTS devices. They consist of conventional thyristors which have a faster control over the bus voltage and require more sophisticated controllers compared to the mechanical switched conventional devices. SVC’s are shunt connected devices capable of generating or absorbing reactive power. By having a controlled output of capacitive or inductive current, they can maintain voltage stability at the connected bus. Static VAR systems are applied by utilities in transmission applications for several purposes. The primary purpose is usually for rapid control of voltage at weak points in a network. Installations may be at the midpoint of transmission interconnections or at the line ends. Static Var Compensators are shunt connected static generators / absorbers whose outputs are varied so as to control voltage of the electric power systems. An SVC can improve power system transmission and distribution performance in a number of ways. Installing an SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions. The dynamic stability of the grid can also be improved, and active power oscillations mitigated.

II. SYSTEM MODELING

2.1 MAJOR COMPONENTS OF SVC

- Coupling transformer
- Thyristor valves
- Reactors
- Capacitors (often tuned for harmonic filtering)

In general, the two thyristor valve controlled/switched concepts used with SVCs are the thyristor-controlled reactor (TCR) and the thyristor-switched capacitor (TSC). The TSC provides a “stepped” response and the TCR provides a “smooth” or continuously variable susceptance. A TCR consists of a fixed reactor in series with a bi-directional thyristor valve. A TSC consists of a capacitor in series with a bi-directional thyristor valve and a damping reactor.
The thyristor switch acts to connect or disconnect the capacitor for an integral number of half cycles of the applied voltage. The capacitor is not phase controlled it is simply on or off. Because of this TSC does not produce harmonic distortion. The reactor in the TSC circuit serves to limit current under abnormal conditions, as well as to tune the TSC circuit to a desired frequency. Comprehensive power system study is required to develop appropriate model to emphasized particular problems to be solved by SVC applications. Normally following studies are required for an SVC application from early planning stage till operation.

1) Load flow studies
2) Small and large disturbance studies
3) Harmonics studies
4) Electromagnetic transient studies
5) Fault studies

The main objective of load flow analyses is to determine the node voltages reactive and active power flow in the network branches, generations and loss. The power flow studies related to SVC applications are:
1. To determine the location and preliminary rating of the SVC.
2. To render information on the effects of the SVC on the system voltages and power flows.
3. To provide the initial condition for system transient analysis.

2.2 THYRISTOR-CONTROLLED REACTORS AND THYRISTOR SWITCHED CAPACITORS (TCR/TSC)
Basically, this is the combination of TCR and TSC. In this configuration, the control of the static var compensator is based on measuring the reactive component of load current at the instant of voltage zero. Then, the measured current is used to determine the firing angle so that the SVC absorbs or injects the amount of reactive power required for compensation. However, there is a time interval between the instant of measuring the reactive component (in one half-cycle) and the firing instant (the next half-cycle). This inherent delay of its operation mode is one of its major limitations.

III. SIMULATIONS MODELS
The simulation is done using Matlab Simulink version 7.8. As the snubber circuit has already been specified with Th1, the snubber of Th2 must be eliminated. Thyristor blocks have an output identified by the letter m. This output returns a Simulink vectorized signal containing the thyristor current and voltage. These quantities are shown in scope Th1. At every cycle a pulse 28 has to be sent to each thyristor α degrees after the zero crossing of the thyristor commutation voltage. For Pulse 1 phase delay parameter is set as 1/60 and for pulse 2 it is set as 1/60 + 1/120.

Fig. 1. Simulink Model TCR
The simulation is also done using Matlab Simulink version 7.8. As the snubber circuit has already been specified with $\text{Th1}$, the snubber of $\text{Th2}$ must be eliminated. Thyristor blocks have an output identified by the letter m. This output returns a Simulink vectorized signal containing the thyristor current and voltage. These quantities are shown in scope$_{\text{Th1}}$. In this simulation a step block is used to provide continuous firing signal to two thyristors. The value of the initial voltage across the capacitor $C_1$ should be -0.3141 V. This voltage is not exactly zero because the snubber allows circulation of a small current when both thyristors are blocked.

**Fig. 2. Simulink model of TSC**

**Fig.4. Simulink Model of TCR/TSC SVC**

**Fig.5. Current through Primary Winding of Transformer**

**Fig.6. Switching Pulses for Thyristor T1**
IV. SIMULATION RESULTS OF TSC

**Fig. 7. Switching Pulses for Thyristor T2**

**Fig. 8. Current & Voltage across Thyristor T1**

**Fig. 9. Current & Voltage across Thyristor T2**

**Fig. 10. Current & Voltage across Thyristor T1**

**Fig. 11. Current & Voltage across Thyristor T2**
The Variation of Currents & Voltages Across the thyristors T1 and T2 is studied in the TSC. In TSC the Thyristor Switch acts to connect or disconnect the capacitor for an Integral number of half cycles of the applied voltage. The capacitor is not phase controlled as in TCR it is simply on or off.

V. SIMULATION RESULTS OF SVC
These Simulation curves are result of this paper. Initially the source is generating nominal voltage. Then, voltage is successively decreased (0.97 pu at t = 0.1 s), increased (1.03 pu at t = 0.4 s) and finally returned to nominal voltage (1 pu at t = 0.7 s) through 500 kV Three Phase Programmable Voltage Source. Waveforms of Q(pu), Vm(pu) and B(pu) are shown in Fig. 14. In Fig.15 waveform of actual positive sequence voltage V1 is also shown.

Now as shown in Fig. 16 the system is modeled again without SVC to check the voltage profile of the system. Initially the source is generating nominal voltage. Then, voltage is successively decreased (0.97 pu at t = 0.1 s), increased (1.03 pu at t = 0.4 s) and finally returned to nominal
voltage (1 pu at t = 0.7 s) through Three Phase Programmable Voltage Source. It can be observed in Fig. 16 positive sequence voltage is present in steps and dynamic response of SVC shown in Fig. 17 is absent.

VI. CONCLUSION

From the above simulation results we conclude that SVC not only considerably improves transient stability but also compensates the reactive power in steady state. The SVC is used to control power flow of power system by injecting appropriate reactive power during dynamic state. We also conclude that if the fault clearing time is less, more stability improvement. On the other hand less transient stability improvement occurs if fault clearing time is more. The variation of Currents & Voltages across the thyristors T1 and T2 in the TCR & TSC is studied in chapter 6. In TCR variation of Reactive Power can be made by varying firing angle of thristors. In TSC the Thyristor Switch acts to connect or disconnect the capacitor for an Integral number of half cycles of the applied voltage. The capacitor is not phase controlled it is simply on or off. In TSC as expected the transient component of capacitor voltage and current has disappeared. Static Var Compensators (SVCs) are used primarily in power system for voltage control as either an end in itself or a means of achieving other objectives, such as system stabilization. The main advantage of SVCs over simple mechanically-switched compensation schemes is their near-instantaneous response to changes in the system voltage. For this reason they are often operated at close to their zero-point in order to maximize the MVAr reserves they can rapidly provide when required. This work presents a detailed overview of the voltage-control characteristics of SVC and waveforms of voltage and current across anti parallel thyristors Th1 and Th2 for a given pulse is shown both for TCR and TSC. Switching pulses for TCR and TSC are also shown in chapter 5. After viewing the simulation results obtained in Fig 14 it can be easily concluded that SVC will successfully control the dynamic performance of power system and will effectively regulate the system oscillatory disturbances and voltage regulation of the power system. Simulations carried out confirm that SVC could provide the fast acting voltage support necessary to prevent the possibility of voltage reduction and voltage collapse. Fig. 16 inspects actual positive sequence voltage in a system model with or without SVC. However it is well known that these FACTS controllers have the additional advantage of being able to control “fast” system oscillations due to their quick response. Hence by properly modeling these controllers in transient stability programs, it would be interesting to determine any other possible advantages of these controllers in voltage stability studies. The presented simulation result shows that SVC is capable to power system oscillation damping successfully. Hence it is concluded that the maximum capacitive power generated by a SVC is proportional to the square of the system voltage (constant susceptance).

VII. FUTURE SCOPE

Some of the scopes to carry out further work in this area are mentioned below:

- Fuzzy logic based adaptive controllers for SVS can be developed.
- Appropriate models for other FACTS controllers, namely, STATCOM, SSSC, UPFC for transient and steady state stability analysis, to also analyze the advantages and disadvantages of these controllers in voltage stability studies.
- In addition to the detail designs implementation of SVS controller in Indian power system can be investigated in much more detail.
- Economic comparative study can be made for effective FACTS controllers for enhancement of power transfer capability enhancement and damping of sub synchronous resonance and to find out the most economic FACTS controller.
- Effect of coordinated applications of many FACTS controllers can be investigated for dynamic transient and voltage stability enhancement and damping of power system oscillations of further work.
REFERENCES


