Comparative Study of TCSC and SVC for Power System

Mr. Siddalinga Nuchhi¹, Dr.G.D.Kamalapur², Pradeep Hunoor³

¹,³ Assistant Professor, Department of Electrical &Electronics Engineering, B.L.D.E.A’s V.P.
Dr.P.G.Halakatti College of Engineering & Technology, Vijayapur, Karnataka-India
² Professor & Head, Department of E&E, S.D.M.CET, Dharwad, Karnataka-India

Abstract—The electric energy consumption is continuously increasing due to rapid growth of the technology in the world. The performance of the power system is affected due to increasing complexity and size of the transmission system. Hence to remove identified bottlenecks and to seek good power grid delivery capability in the system now a day’s FACTS devices has been considered as one of the best planning alternative in present scenario. TCSC and SVC have the important role in controlling the active power as well as reactive flow to the power network as well as voltage regulation and transient stability. So the analysis and Simulation of TCSC and SVC controllers using SIMULINK is carried out in this paper. A case study of standard IEEE five-bus system is modeled in the SIMULINK for the comparisons of the results obtained using TCSC and SVC models. Finally the best suited FACTS device is suggested for the application in the transmission lines.

Keywords—Flexible AC Transmission Systems (FACTS), TCSC, SVC, Voltage Stability, THD, Transient analysis, Five bus System.

I. INTRODUCTION

To operate the power system successfully, the engineer’s must be capable of providing the reliable and uninterrupted service to the loads for the system to be reliable, one has to keep the synchronous generators operating in parallel. In electrical transmission and distribution the inherent characteristics is that real power is essentially required with the reactive power. The lines are dominantly reactive network and the transmission losses are increased by reactive power. Ability of the system to regain its normal operating condition even after a small disturbance is know as stability of the system. For analysis of the transint stability of power system parameters like sudden changes in the load, generation or transmission system parameters due to the switching or faults are considerd [2]. To increase the stability of the system dynamic voltage support in lines and reactive power compensation identified as the significant measure.

II. OVERVIEW OF FACTS

FACTS controllers in power system are widely used in the development of power electronics [3]. The concept of Flexible AC Transmission Systems (FACTS) is proposed by Hingorani. Here the power electronic controllers in AC transmission systems are employed, which can assure fast and reliable control of power flows and voltages. The thyristor or high-power transistor is the basic element for a variety of high-power electronic Controllers. FACTS technology provides the opportunity to [2] [3]

A. FACTS deal with:
1) Regulation of power flow in prescribed transmission routes
2) Secure loading of lines near the thermal limits
3) Prevention of cascading outages by contributing to emergency control
4) Damping oscillations which can threaten the security or limit the usable line capacity.

The conventional control devices like synchronous condenser, thyristor controlled reactor, thyristor switched capacitor having less system stability limit, less voltage flicker control when...
compared to emerging facts devices like TCSC, SVC and IPFC and UPFC [4][5]. This work checks the improvement of steady state stability and transient stability with different types of FACTS devices and their similarities with standard five bus system for result verification.

The main purpose of this paper is to analyze the steady state and transient stability of the power system network considering the design of TCSC and SVC controller for enhancement in the stability of the power system network. Pi-section model is developed using the SIMULINK model by considering the actual parameters of the line and the steady state analysis for the voltage regulation, Reactive power compensation and THD for both the system is carried out by varying the line length of transmission network from 400-1500 Km and the results are tabulated. Then the percentage voltage regulation, reactive power compensation and THD for the system with and without TCSC and SVC controllers are tabulated and analyzed. After this a standard Five Bus system is developed and the load flow analysis is carried out without any controllers, and then TCSC and SVC controllers are applied for the five bus system taking the buses where voltage drop is more, and the analysis is carried out. The best suited FACTS controller is suggested for the better compensation of line. Finally the transient analysis of the system with and without controllers is analyzed.

III. FACTS CONTROLLERS

a. Basics of TCSC:
This is well known as the technique of "rapid adjustment of network impedance". The basic TCSC module comprises a fixed series capacitor, in parallel with a thyristor-controlled reactor (TCR) as shown in Figure 1. The TCR is formed by a reactor in series with a bi-directional thyristor valve that is fired at a phase angle ranging between 90º and 180º with respect to the capacitor voltage [6]. A TCSC is a series-controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range. The principle of series compensation is to increase the fundamental-frequency voltage across an capacitor in series compensated line through appropriate variation of the firing angle. This enhanced voltage changes the effective value of the series-capacitive reactance and control the reactive power.

![Figure 1 Basic conceptual TCSC module](image)

C. Basics of SVC: The Static Var Compensator is a parallel connected device of the Flexible AC Transmission Systems (FACTS) which uses power electronics to control power flow and improve transient stability on power grids [7]. By controlling the total quantity of reactive power injected or absorbed from the power system SVC can regulate voltage at its terminals. SVC generates reactive power (Capacitive) when system voltage is less. If voltage is more, it will absorbs reactive power (Inductive). By switching three-phase capacitor and inductor banks connected on the secondary side of a coupling transformer the variation of reactive power can be performed. Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR).
IV. SIMULATION

The work is simulated by using MATLAB/SIMULINK modeling. The Transmission line is modeled using the SIMULINK modeling and here Pi-section transmission line is preferred for the analysis. After modeling, the voltage regulation, Real and Reactive Power, Total Harmonic Distortion (THD), Efficiency is plotted by taking the normal condition of the line for the different line lengths varied from 400-1500 Km. Then modeling of TCSC and SVC controllers is done as shown in Figure 4 and 5, after this the above said parameters of the line with TCSC and SVC controllers is tabulated. after this stability in the Voltage, Real and Reactive Power, THD with and without TCSC and SVC controllers are analyzed and the changes in the system are observed. After this a standard five bus system is developed using SIMULINK and the load flow analysis is done and the weak buses are pointed out(bus number 1 and 5) and then the designed TCSC and SVC controllers are applied to weak buses and load flow is carried out and the best suited controller is suggested for compensation in line. Finally the transient analysis is carried out with the different types of faults considered and the behavior of system with and without controllers is observed.

TABLE 1: Parameters of Transmission line, Source and the Load

<table>
<thead>
<tr>
<th>Source</th>
<th>Load</th>
<th>Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage of line 440KV, 50Hz</td>
<td>Star-grounded</td>
<td>Pi – model (π)</td>
</tr>
<tr>
<td>Star-grounded</td>
<td>V=440KV</td>
<td>Resistance=R=0.14Ω/km</td>
</tr>
<tr>
<td>3-Φ SC base=MVA 5000</td>
<td>Active power=P=200MW</td>
<td>Inductance=L=0.1046mH/km</td>
</tr>
<tr>
<td>Base Voltage=440KV</td>
<td>Reactive Power=Q=150MVAr</td>
<td>Capacitance=C=4.8μF/km</td>
</tr>
<tr>
<td>X/R ratio= 7.0</td>
<td></td>
<td>Line length=Varied from 400-1500km</td>
</tr>
</tbody>
</table>
IV. SIMULINK MODELS OF TCSC AND SVC CONTROLLERS

Figure 3 Simulink model of TCSC controller
D. Five Bus System

**Figure 4** Simulink model of SVC

**Figure 5.** Five Bus system representation

<table>
<thead>
<tr>
<th>Line</th>
<th>Length</th>
<th>Resistance</th>
<th>Reactance</th>
<th>Changing MVAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>64.4</td>
<td>0.042</td>
<td>0.168</td>
<td>4.1</td>
</tr>
<tr>
<td>1-5</td>
<td>48.3</td>
<td>0.031</td>
<td>0.126</td>
<td>3.1</td>
</tr>
<tr>
<td>2-3</td>
<td>84.8</td>
<td>0.031</td>
<td>0.126</td>
<td>3.1</td>
</tr>
<tr>
<td>3-4</td>
<td>128.7</td>
<td>0.084</td>
<td>0.336</td>
<td>8.2</td>
</tr>
<tr>
<td>3-5</td>
<td>80.5</td>
<td>0.053</td>
<td>0.210</td>
<td>5.1</td>
</tr>
<tr>
<td>4-5</td>
<td>96.5</td>
<td>0.063</td>
<td>0.252</td>
<td>6.1</td>
</tr>
</tbody>
</table>

**TABLE 2:** Standard Parameters of Transmission Line
V. RESULTS OF COMPARISON

Here a combined analysis of TCSC and SVC controllers carried out. The results of TCSC and SVC are combined together and plotted in the graphs and the observations are made for the performance evaluation of the SVC and TCSC for the voltage regulation, reactive power compensation, and total harmonic distortion for varying line length. From the below results obtained the best suited FACTS device is suggested for compensation in the lines.

![Graph showing Voltage Regulation vs Varying Line Length](image)

**Figure 7. Voltage Regulation V/s Varying Line Length**

From the above graph shown in figure 7 it can be inferred that as the line length is varied without compensating device voltage regulation is more and by the introduction of compensating device voltage regulation can be reduced and TCSC gives better result than SVC.
From the above graph shown in figure 8 it can be observed that as the line length is varied without compensating device reactive power compensation is less and by insertion of device reactive power compensation can achieved. Upto 800km of line length SVC gives better result and after 800km to 1500km TCSC yields best results.

From the above graph shown in figure 9 it can be observed that as the line length is varied with compensating devices and the reactive power compensation is achieved by SVC upto 900KM and after 900 km TCSC plays an important role.
From figure 10 it can be observed that as the line length is varied the total harmonic distortion is less by using the TCSC as compensating device and THD is more in SVC. Hence TCSC gives reduced THD for this system.

\[ \text{Figure. 10. THD V/s Varying Line Length} \]

From figure 11 it can observe the variation of fault current with respect to different types of fault in consideration and for normal condition the fault current is more upto 3500Amps and if we are using compensating devices then fault current can be reduced at maximum extent and SVC gives better result than TCSC as it is a shunt compensation in practice.

\[ \text{Figure. 11. Transient analysis of system under different Fault conditions} \]

E. Waveforms of Transient stability analysis:

\[ \text{Figure. 12. Transient waveform without Controllers} \]
F. Results of Five bus system:

![Fig.13. Transient Waveform after adding Controllers](image)

![Figure.14 Voltage regulation for different cases](image)

![Figure.15 Reactive Power for different cases](image)

VI. CONCLUSION

Finally from this work conclusion can be given as TCSC and SVC helps in better voltage regulation in the transmission line and higher reactive power compensation in the line reactance. Power quality in the system is improved due to voltage stability achieved in the line. Hence there is reduction in the circulating reactive power and these controllers improves the system stability limits, also controls the power flows so that it can flow through designated routes. By comparing the above results obtained we can conclude that for shorter distance of transmission that is below 900Km TCSC controller is more useful and for longer transmission lines above 900Km to 1500Km SVC controllers can give better reactive power compensation and voltage regulation as well as the THD. Here the three phase faults and three-phase to ground faults are more severe as given in the results. Hence by adding both
of these controllers we can reduce the transients that are occurring in the power system network to some extent as shown.

REFERENCES


