Voltage Stability Enhancement Using Static Synchronous Series Compensator (SSSC)

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Abstract— At the recent years, power system becomes a large complex interconnected network that contains of hundreds of buses and generating stations. In addition, to provide the required power, new installation of power generators and transmission lines are required. Due to the environmental and economic constraints of installation of new generators and increasing demands, transmission line flows has been increased on the existing transmission lines which may increase the risk of losing voltage stability and blackouts in the system collapse. Flexible AC transmission systems (FACTS) controllers have been mainly used for solving various power system stability control problems. The main objective of this paper is an investigate in enhancement of voltage stability via static synchronous series compensator (SSSC). This work is presented to present the transmission line voltage stability & machine oscillation damping stability by using SSSC controller to enhance the stability of a power system. Simulation results shows that SSSC controller is more effective to enhance the voltage stability and increase transmission capacity in a power system. The dynamic performance of SSSC is presented by real time voltage and current waveforms using MATLAB software for IEEE 4 bus system.

Key words: FACTS, Power system, SSSC (static synchronous series compensator), Voltage Stability, Power oscillation damping, MATLAB Simulink.

I. INTRODUCTION

In recent years, greater demands have been placed on the transmission network and the increase in demands will rise because of the increasing number of non utility generators and Heightened competition among utilities themselves. Increasing demands, lack of long-term planning, and the need to provide open access electricity market for Generating Companies and utility customers, all of them have created tendencies toward less security and reduced quality of supply [1]. The power systems of today, by and large, are mechanically controlled.

There is a widespread use of microelectronics, computers and high-speed communications for control and protection of present transmission systems; however, when operating signals are sent to the power circuits, where the final power control action is taken, the switching devices are mechanical and there is little high-speed control. Another problem with mechanical devices is that control cannot be initiated frequently, because these mechanical devices tend to wear out very quickly compared to static devices. In effect, from the point of view of both dynamic and steady-state operation, the system is really uncontrolled. Power system planners, operators, and engineers have learned to live with this limitation by using a variety of ingenious techniques to make the system work effectively, but at a price of providing greater operating margins and redundancies.[3]

These represent an asset that can be effectively utilized with prudent use of FACTS technology on a selective, as needed basis. The FACTS devices (Flexible AC Transmission Systems) could be a means to carry out this function without the drawbacks of the electromechanical devices such as slowness and wear. FACTS can improve the stability of network, such as the transient and the small signal stability, and can reduce the flow of heavily loaded lines and support voltages by controlling their parameters including series impedance, shunt impedance, current, voltage and phase angle. Controlling the power flows in the network leads to reduce the flow of heavily loaded lines, increased system load ability, less system loss and improved security of the system [7].

The static synchronous series compensator (SSSC) FACTS controller is used to prove its performance in terms of stability improvement. A Static Synchronous Series Compensator (SSSC) is a member of FACTS family which is connected in series with a power system. It consists of a solid state voltage source converter (VSC) which generates a controllable alternating current voltage at fundamental frequency[8]. When the injected voltage is kept in quadrature with the line current, it can emulate as inductive or capacitive reactance so as to influence the power flow through the transmission line. While the primary purpose of a SSSC is to control power flow in steady state, it can also improve transient stability of a power system. Here PI controller is used to control the parameters of the power system [2].

II. BASIC OPERATION PRINCIPLE OF SSSC

![Functional Model of SSSC](image)

The Fig.1 Shows a functional model of the SSSC where the dc capacitor has been replaced by an energy storage device such as a high energy battery installation to allow active as well as reactive power exchanges with the ac system. The SSSC’s output voltage magnitude and phase angle can be varied in a controlled manner to influence power flows in a transmission line. The phase displacement of the inserted voltage Vpq, with respect to the transmission...
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line current line I, determines the exchange of real and reactive power with the ac system [5][6].

III. CONTROL STRATEGY OF SSSC

A phase-locked loop (PLL) which synchronizes on the positive-sequence component of the current I. The output of the PLL (angle $T=\omega t$) is used to compute the direct-axis and quadrature-axis components of the AC three-phase voltages and currents (labeled as $V_d$, $V_q$ or $I_d$, $I_q$ on the diagram). Measurement systems measuring the $q$ components of AC positive-sequence of voltages $V_1$ and $V_2$ ($V_{1q}$ and $V_{2q}$) as well as the DC voltage $V_d$. AC and DC voltage regulators which compute the two components of the converter voltage ($V_{d\_conv}$ and $V_{q\_conv}$) required to obtain the desired DC voltage ($V_{d\_ref}$) and the injected voltage ($V_{q\_ref}$). Fig. 2 represents that control concept[6]. The $V_q$ voltage regulator is assisted by a lead forward type regulator which predicts the $V_{conv}$ voltage from the $I_d$ current measurement[7].

IV. TWO MACHINE POWER SYSTEM MODELLING

The dynamic performance of SSSC is presented by real time voltage and current waveforms. Using MATLAB software the system shown in Fig. 3, has been obtained. In the simulation one SSSC has been utilized to control the power flow in the 500 KV transmission systems.

![Fig. 3: Single Line Diagram of Test System](image)

This system which has been made in ring mode consisting of 4 buses (B1 to B4) connected to each other through three phase transmission lines L1, L2-1, L2-2 and L3 with the length of 280, 150, 150 and 5 kln respectively. System has been supplied by two power plants with the phase-to-phase voltage equal to 13.8 Kv. Active and reactive powers injected by power plants 1 and 2 to the power system are presented in per unit by using base parameters $S_b=100$MVA and $V_b=500$KV, which active and reactive powers of power plants 1 and 2 are $(24-j3.8)$ and $(15.6-j0.5)$ in per unit, respectively[2].

V. MATLAB/SIMULINK RESULTS WITHOUT SSSC

First, power system with two machines and four buses has been simulated in MATLAB environment, and then powers and voltages in all buses have been obtained. The results have been given in Table 1. Using obtained results bus-2 has been selected as a candidate bus to which the SSSC be installed. Therefore, the simulation results have been focused on bus-2.

![Fig. 4: Voltage rating of bus-2 without SSSC](image)

![Fig. 5: Current at bus-2 without SSSC](image)

![Fig. 6: Active Power of bus-2 without SSSC](image)
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Fig. 7: Reactive Power of bus-2 without

A. Bus-2 parameter with sssc

Fig. 8: Simulink model of system with SSSC

Table II: Simulation results with SSSC

<table>
<thead>
<tr>
<th>BUS NO.</th>
<th>VOLTAGE (PU)</th>
<th>CURRENT (PU)</th>
<th>P (PU)</th>
<th>Q (PU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1.04</td>
<td>13.65</td>
<td>12.9</td>
<td>-2.6</td>
</tr>
<tr>
<td>B2</td>
<td>1.05</td>
<td>7.3</td>
<td>7.1</td>
<td>-1.15</td>
</tr>
<tr>
<td>B3</td>
<td>1.005</td>
<td>10</td>
<td>9.85</td>
<td>-0.15</td>
</tr>
<tr>
<td>B4</td>
<td>1.02</td>
<td>5.6</td>
<td>5.65</td>
<td>-0.35</td>
</tr>
</tbody>
</table>

After the installation of SSSC, besides controlling the power flow in bus-2 we want to keep constant the voltage value in 1 per unit, hence the power flow is done in the presence of SSSC and the simulation results are as follows. According to the Fig. 11, by installing the SSSC, active power damping time will be less than the mode without SSSC and it will be damped faster. Also as shown in Fig. 12, reactive power damping time will be decreased and system will follow the references value with acceptable error.

VI. MATLAB/SIMULINK RESULTS WITH SSSC

Power system with two machines and four buses after incorporating SSSC has been simulated in MATLAB environment, and then powers and voltages in all buses have been obtained. The results have been given in Table 2

![Fig. 9: voltage at bus-2 with SSSC](image)

![Fig. 10: current at bus-2 with SSSC](image)

![Fig. 11: Active Power of bus-2 with SSSC](image)

![Fig. 12: Reactive Power of bus-2 with SSSC](image)

After the installation of SSSC, besides controlling the power flow in bus-2 we want to keep constant the voltage value in 1 per unit, hence the power flow is done in the presence of SSSC and the simulation results are as follows. According to the Fig. 11, by installing the SSSC, active power damping time will be less than the mode without SSSC and it will be damped faster. Also as shown in Fig. 12, reactive power damping time will be decreased and system will follow the references value with acceptable error.

The power system stability improvement i.e. voltage level, machine oscillation damping, real & reactive power in a power system model of SSSC with proposed Power System Controller for faulted conditions. The simulation of a two-machine power system model with Static synchronous series compensator (SSSC) based damping controllers in the presence of a three-phase short circuit fault is considered. The results show that the power system oscillations are damped out very quickly with the help of SSSC based damping controllers in few seconds.
VII. CONCLUSION

It has been found that the SSSC is capable of controlling the flow of power at a desired point on the transmission line. It is also observed that the SSSC injects a fast changing voltage in series with the line irrespective of the magnitude and phase of the line current. The results show that the use of SSSC is having improved dynamic response and at the same time faster than other conventional controllers.

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REFERENCES


