Study of Transient Stability Improvement of IEEE 9-Bus System by using SVC

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Abstract— *the objective of this paper is to determine the improvement in transient stability of IEEE 9Bus system using STATIC VAR compensator. SVC is one of the FACTS devices which can make the power supply more efficient and reliable. Power systems are continuously subjected to various types of disturbances which in turn cause the problem of losing stability. Transient stability is one of the most important stability of the power system. The loss of Transient stability is due to varies disturbances like faults, sudden change in loads and tripping off the lines after fault or heavy loss of loads. Power systems are Operating nearer to their stability limits due to economic and environment reasons. In under damped Power systems disturbances lead power system into unstable state. So, the tools for mitigating such a sensitive problem have an important significance. Static VAR Compensator (SVC) can control reactive power and therefore it is used to improve transient stability as well as the voltage profile. The proposed work includes IEEE 9-Bus Test system incorporated with SVC controller using Mipower Software. The simulation shows how the oscillations are damped out with SVC controller.*

Keywords- *Power system modeling; Mipower software techniques; Simulations; Transient stability; SVC*

I. INTRODUCTION

Transmission networks of present power systems are becoming progressively more stressed because of increasing demand and limitations on building new lines. One of the consequences of such a stressed system is the risk of losing stability following a disturbance. Flexible ac transmission system (FACTS) devices are found to be very efficient in a stressing transmission network for better utilization of its existing facilities without sacrificing the desired stability margin. Flexible AC Transmission System (FACTS) controllers, such as Static VAR Compensator (SVC) and Static Synchronous Compensator uses the latest technology of power electronic switching devices in electric power transmission systems to control voltage and power flow, and play an important role as a stability aid for and transient disturbances in an interconnected power systems.

The electric power industry has experienced a huge increment in power consumption. The growth in demand for electricity supply such as growth of loads and generation, lack of new transmission lines and competitive electricity market pressure has made power systems nowadays operating closer to their static and dynamic limit. Despite of the fact that bulk power transfers are increasing, the growth of electric power transmission facilities is restricted. In addition with the aging of power transmission network, the control of power transmission is required to be fast and reliable. Power systems are also often subject to low frequency electro-mechanical oscillations resulting from electrical disturbances and consequence of the development of interconnection of large power system. The oscillation of the generators rotors cause the oscillation of other power system variables (bus voltage, transmission lines active and reactive power, etc) which constraints the capability of power transmission, threatens system security and damages the efficient operation of the power system .

Low frequency oscillation can be categorized to as local and inter-area mode. Local mode oscillation typically range between 1-2 Hz consists of the oscillation of a single generator or a group of generators against the rest of the system, while inter-area mode typically range between 0.1-1 Hz consists of the oscillation among groups of generators. Generally, power system stabilizers (PSS) are applied on selected generators to damp local oscillation modes effectively.

The fast progress in the field of power electronics has widened the option for power industry to improve power system stability via utilization of the controllable flexible alternating current transmission system (FACTS). Besides their capability to control transmission grid and increasing transmission capacity, FACTS devices also offer an alternative option to mitigate power system oscillation. According to IEEE, FACTS device is "a power-electronic based system and other static equipment that provide control of one or more ac-transmission system parameters to enhance controllability and increase power-transfer capability". Initially, FACTS device was developed to solve rising system problems due to the limit in

transmission line construction, to facilitate the increasing power export and/or import and wheeling transaction among utilities. FACTS devices have cover a number of technologies that enhance the security, capacity and flexibility of power transmission systems. By installing FACTS devices, the power systems will able to increase existing transmission network capacity while maintaining or improving the operating margins necessary for systems stability.

As PSS been applied to damp local oscillation modes, Static VAR Compensator (SVC) which is one of the FACTS devices, has been used as a supplementary controller to improve transient stability and power oscillation damping of the system. Most of these controllers are designed based on conventional method i.e designed based on the literalized model for the sake of simplicity. However, conventional controller cannot provide satisfactory performance over a wide range of operation points and under large disturbances since power system is a non-linear system.

The flexibility of present transmission systems needs to be dramatically increased under the thyristor-based transmission or FACTS Controllers, (the Static Var Compensator or SVC, the Thyristor- Controlled Series Capacitor or TCSC, and the Thyristor-Controlled Phase Angle Regulator or TCPAR) employ conventional thyristors (i.e., those having no intrinsic turn-off ability) to control one of the three parameters determining power transmission, voltage (SVC), transmission impedance (TCSC), and transmission angle (TCPAR).

Shunt compensation can be achieved through the use of static VAR compensators, which is currently a mature technology. When discussing the creation, movement, and utilization of electrical power, it can be separated into three areas, which traditionally determined the way in which electric utility companies had been organized. These are illustrated in Figure 1 and are:
➢ Generation
➢ Transmission
➢ Distribution

Fig.1. Illustration of the creation, movement, and utilization of electric power

The power electronic based equipment is prevalent in each of these three areas, such as with static excitation systems for generators and Custom Power equipment in distribution systems.

II. POWER SYSTEM STABILITY

Stability: The stability of a system refers to the ability of a system to return back to its steady state when subjected to a disturbance. As mentioned before, power is generated by synchronous generators that operate in synchronism with the rest of the system. A generator is synchronized with a bus when both of them have same frequency, voltage and phase sequence. We can thus define the power system stability as the ability of the power system to return to steady state without losing synchronism. Usually power system stability is categorized into **Steady State**, **Transient** and **Dynamic Stability** shown in Figure 2.
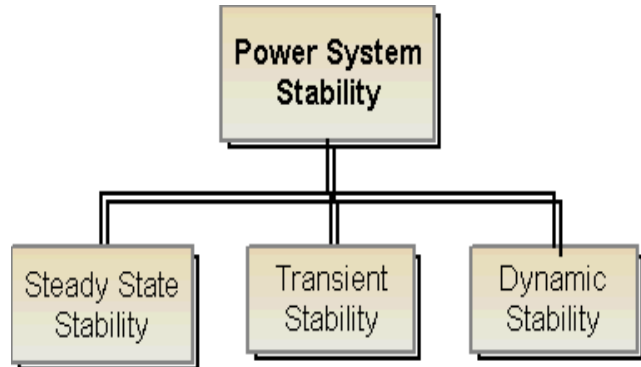

Fig.2. Classification of power system stability

A. Steady State Stability: Studies are restricted to small and gradual changes in the system operating conditions. In this we basically concentrate on restricting the bus voltages close to their nominal values. We also ensure that phase angles between two buses are not too large and check for the overloading of the power equipment and transmission lines. These checks are usually done using power flow studies.

B. Transient Stability: Involves the study of the power system following a major disturbance. Following a large disturbance the synchronous alternator the machine power (load) angle changes due to sudden acceleration of the rotor shaft. The objective of the transient stability study is to ascertain whether the load angle returns to a steady value following the clearance of the disturbance.

C. Dynamic stability: The ability of a power system to maintain stability under continuous small disturbances is investigated under the name of **Dynamic Stability** (also known as small-signal stability). These small disturbances occur due random fluctuations in loads and generation levels. In an interconnected power system, these random variations

can lead catastrophic failure as this may force the rotor angle to increase steadily.

III.   STATIC VAR COMPENSATER

Static Var systems are used in transmission applications for several purposes. The primary purpose is for rapid control of voltage at weak points in a net work. Installations may be at the midpoint of transmission interconnections or at the line ends. The Static Var Compensator is basically a shunt connected variable Var generator whose output is adjusted to exchange capacitive or inductive current to the system to control reactive Power and voltage of the electric power systems. One of the most widely used configurations of the SVC is the FC-TCR type in which a Fixed Capacitor (FC) is connected in parallel with Thyristor Controlled Reactor (TCR). In its simple form SVC is connected of FC-TCR configuration as shown in Figure.3. The SVC is connected to a coupling transformer that is connected directly to the ac bus whose voltage is to be regulated.
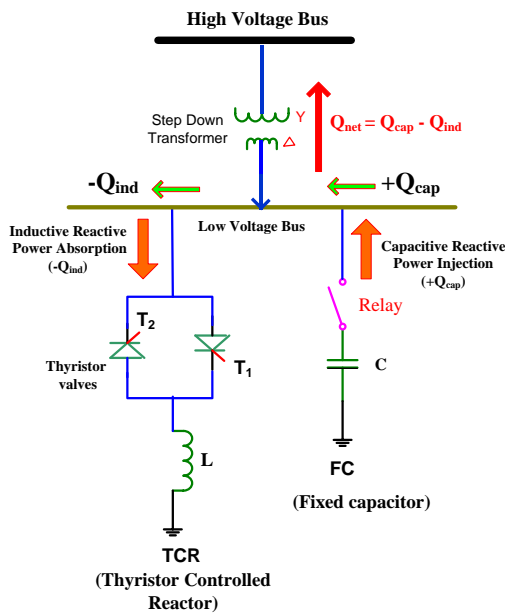

Fig.3 Typical SVC System

The effective reactance of the FC-TCR is varied by firing angle control of the anti parallel thyristors. The firing angle can be controlled through a controller in such a way that the voltage bus where the SVC is connected is maintained at the reference value. The model of SVC is shown in Figure. The magnitude of the SVC is inductive admittance BL (α) is a function of the firing angle α and is [5] given as

$$B_L(\alpha) = \frac{2\pi - 2\alpha + \sin 2\alpha}{\pi X_S}$$

$$\text{where } \frac{\pi}{2} < \alpha < \pi, \ X_S = \frac{V_S^2}{Q_L}, \ V_{S'}$$

Vs Is SVC bus bar voltage and QL is MVA rating of reactor. As the SVC uses a fixed capacitor and variable reactor combination (TCR- FC), the effective shunt admittance is

$$B_S = \frac{1}{X_C} - B_L(\alpha)$$

Where X_C is capacitive reactance.

IV.POWER OSCILLATION DAMPING

In case of an under damped power system, any minor disturbance can cause the machine angle to oscillate around its steady sate value at the natural frequency of the total electromechanical system. The angle oscillation, of course, results in a corresponding power oscillation around the steady state power transmitted. The lack of sufficient damping in some cases may become a limiting factor for the transmittable power.

Since the power oscillation damping is a sustained dynamic event, it is necessary to vary the applied shunt compensation. As the SVC can give variable VAR output, it can be controlled in such a way that it will give the capacitive or leading reactive power when the rotationally oscillating generator accelerates i.e. dδ/dt>0,so that the compensator increases the midpoint voltage hence the transmitted power.

As the SVC is controlled to give lagging reactive power, when the rotationally oscillating generator decelerates i.e. dδ/dt<0   so that the electric power transmitted will be decreased to balance the insufficient mechanical power input. In this way the we can reduce the oscillations generated in the power system. So, By employing the SVC in the system we can reduce the oscillations of power angel When there is an occurrence of fault , by Controlling the thyristor switches which were connected to Inductor and Capacitor banks respectively we can do this.

In the figure.4 shows the damping of Power Oscillations in two machine Power system. Power wave forms with respect to time without SVC and with SVC .The Power Oscillations are damped quickly by using SVC.
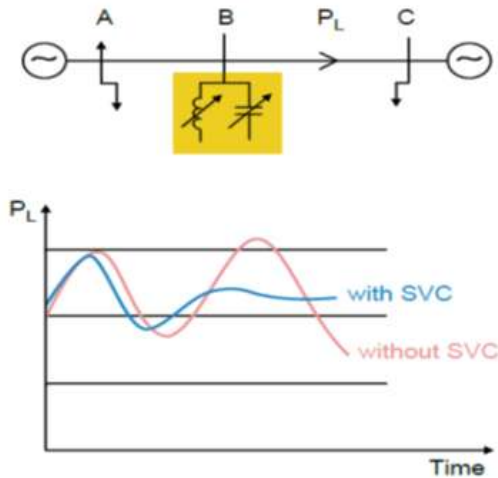
Fig.4. Damping of Power Oscillations

GENERATOR DATA TABLE						
FROM	POWER	Q-MIN	Q-MAX	V-SPEC	CAP.	MVA
NAME*	MW	MVAr	MVAr	p.u.	CURV	RATING
Bus1	71.6	-72	72	1.04	0	247.5
Bus2	163	-72	72	1.025	0	192
Bus3	85	-72	72	1.025	0	128
LOAD DATA TABLE						
FROM	REAL	REACTIVE				
NAME*	MW	MVAr				
Bus8	50	15	Change in load here			
Bus5	125	50				
Bus6	90	30				

V. SIMULATION RESULTS

Here IEEE 9Bus Test System is taken for the analysis of transient stability. MiPower simulation Software is used for performing the analysis. The single line diagram is shown in figure 5.The system analysis is carried with parameters on 100 MVA base. The SVC with Control block is modeled in Mipower with rating 22MVAR.

		V-MAG	ANGLE	MW	MVAr	MW	MVAr	MVAr
	FROM							
NO.	NAME	p.u.	DEGREE	GEN	GEN	LOAD	LOAD	COMP
1	Bus1	1.04	0	23.877	30.737	0	0	0
2	Bus2	1.025	14.27	163	-2.941	0	0	0
3	Bus3	1.025	9.47	85	-19.233	0	0	0
4	Bus4	1.0231	-0.74	0	0	0	0	0
5	Bus5	0.9926	-1.3	0	0	125	50	0
6	Bus6	1.0105	-1.04	0	0	90	30	0
7	Bus7	1.0316	8.74	0	0	0	0	0
8	Bus8	1.0328	6.79	0	0	50	15	0
9	Bus9	1.0321	6.78	0	0	0	0	0

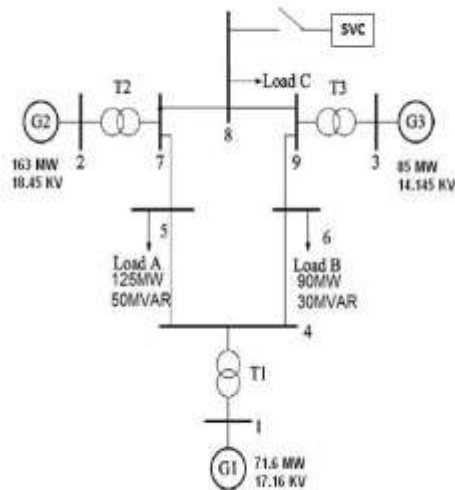**BUS VOLTAGES AND POWERS DATA TABLE**

Fig.5. IEEE 9 Bus Test System

Three Generators are connected at the Bus No. 1, 2, 3 and loads are connected at the Bus No 5, 6, 7 as shown in the figure. The network data is presented in the given tables.

a. **Test Case1:** For Transient stability analysis the disturbance is given to the system by changing load C form 100MW and 35MVAR to 150 MW and 50MVAR at 0.1Sec.Waves of Voltage (pu) with respect to time by with and without connecting SVC is Plotted.
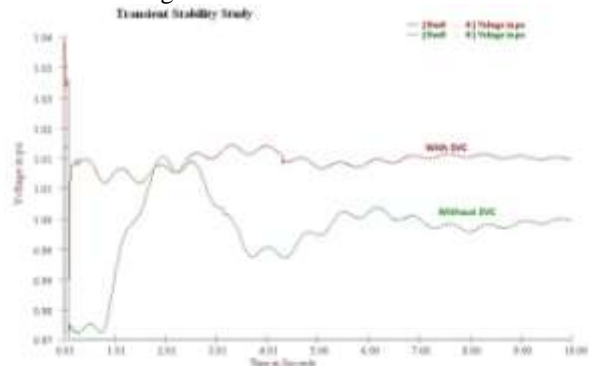

Fig.6. Voltage (pu) Wave forms at Bus 8 with and without SVC

b. **Test Case 2:** In this Case, the disturbance is given to the system by changing the load at

Bus 8 form 35MW and 15MVAR to 80MW and 50MVAR at 0.1Sec.Waveform of Voltage (pu) with respect to time by with and without connecting SVC is Plotted.
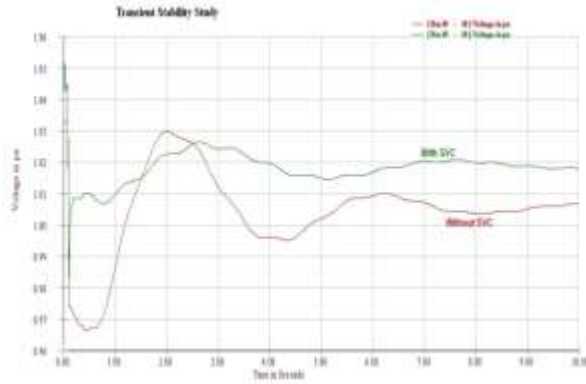

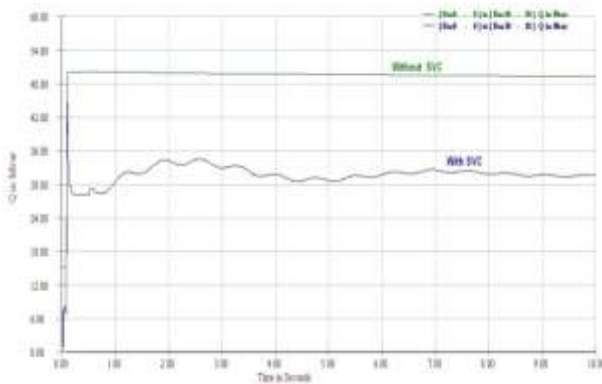Fig.7. Voltage (pu) Waveforms at Bus 8 with and without SVC

Fig.8 Reactive Power Waveforms at Bus 8 with and without

SVC

VI. OBSERVATIONS

From the simulation work it is clear that the transient stability of the system is highly affected by SVC. The damping time is reduced from 9sec to 7sec in both the cases. Voltage Profile is improved, the amplitude of oscillations reduced from 8.5 KV to 2.2KV in case1 and 14.3KV to 4.4KV. So, With SVC In transmission line, Voltage and Power Oscillations are damped quickly and transient period has decreased.

VII. CONCLUSION

Improvement of Transient Stability of IEEE 9Bus Test System with SVC is observed by making a simulation model in Mipower. The usefulness of SVC to damp power Oscillations in multi machine Power system is studied. It is found that the transient stability of the Power system is highly affected by SVC. In

transmission line Voltage and Power Oscillations are low when we connect SVC and transient period has decreased to a significant value for above parameters of transmission line. So, it can be concluded that the transient stability of IEEE 9bus test system with different loads is improved by using SVC.

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