A Novel Improved Voltage Stabilizer using a Power System Stabilizer (PSS) and Static Var Compensator (SVC)

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***Abstract* — The SVC is an effective element for shunt reactive compensation devices in high voltage power systems. In this paper we: i) first outline the basic function of Power System Stabilizer (PSS) and Static Var Compensator (SVC), then ii) we set up a model for single machine infinite bus (SMIB) power system, to iii) propose a coordinated system of additional excitation stabilizer (PSS) and compensator (SVC) to iv) effectively enhance the voltage stability after the occurrence of a large disturbance. The obtained results of the proposed method is an important step in research for power system transient analysis.**

Keywords-Static Var compensator; Power system stabilizer; Single machine infinite bus power system; Voltage stability

I. INTRODUCTION

Voltage stability is concerned with the ability of a power system to maintain acceptable voltage at all buses in the system under normal conditions and after being subjected to a disturbance [1]. A system enters a state of voltage instability when a disturbance, increase in load demand, or change in system condition causes a progressive and uncontrollable decline in voltage. The main factor causing voltage instability is the inability of the power system to meet the demand for reactive power [2, 3].

Although there have been numerous studies for improving power system voltage stability, an effective approach to improving the stability of power systems uses generator excitation control in combination with Flexible AC Transmission Systems (FACTS) devices. Static Var Compensator (SVC) is of interest since it is used in power systems to regulate the system voltage and improve power system stability: in particular it is capable of rapidly injecting and absorbing active and reactive power in order to increase grid transfer capability through enhanced dynamic voltage stability, to provide smooth and rapid reactive power compensation for voltage support, and to improve both damping oscillations and transient stability [4, 5]. In this paper, we are interested in studying the system voltage stability enhancement of a power system including generator excitation controller and SVC.

II. PROBLEM FORMULATION

At present, the power system commonly uses the additional excitation control (i.e. power system stabilizer, PSS) attached in the excitation regulator. It can effectively enhance the damping of the generator excitation system, inhibition of low-frequency oscillations occur, thereby improve the transient and dynamic stability of power system [6].

This paper continues this line of investigation and improves further transient response performance for transient stability and voltage regulation enhancement of power systems with SVC. And simulation results are provided for a single machine infinite bus (SMIB) power system with excitation control of a synchronous generator and SVC control.

III. POWER SYSTEM MODELS

The power system models considered here consist of the dynamics of a synchronous generator and SVC. A dynamic model of the synchronous generator can be obtained by representing the M1 by a transient voltage source, E , behind a transient reactance, X'_d . In this paper, as depicted in Fig. 1, a thyristor-controlled-reactor (TCR) fixed-capacitor type of SVC is employed and the SVC can serve as a variable susceptance connected in shunt (parallel) with the power systems.

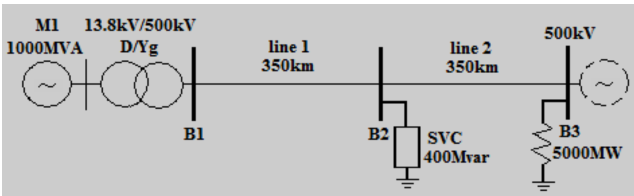

Fig.1 A Single Line Diagram of SMIB with SVC

For simplicity, the dynamic behavior of the SVC is often modeled as a first-order differential equation. As a result, the dynamics of synchronous generator with excitation control and the SVC regulator in SMIB power systems can be modeled as follows [7]:

$$\dot{\delta} = \omega - \omega_s$$

$$\dot{\omega} = \frac{1}{M}(P_m - P_E - D(\omega - \omega_s))$$

$$\dot{E} = \frac{X_{d\Sigma}}{X'_{d\Sigma}T'_0} E + \frac{X_d - X'_d}{X'_{d\Sigma}T'_0} V_\infty \cos\delta + \frac{u_f}{T'_0} \qquad (1)$$

$$\dot{B}_L = \frac{1}{T_r}(B_L - B_{L0} + u_r)$$

with

$$P_E = \frac{EV_\infty \sin\delta}{X'_{d\Sigma} - (X'_d + X_T)X_L(B_L - B_C)} \qquad (2)$$

where δ is the power angle of the generator, ω denotes the relative speed of the generator, $D \geq 0$ is a damping constant, P_E is the electrical power delivered by the generator to the voltage at the infinite bus V_∞, ω_s is the synchronous machine speed, $\omega_s = 2\pi f$, H represents the per unit inertial constant, f is the system frequency, and $M = 2H/\omega_s$. $X'_{d\Sigma} = X'_d + X_T + X_L$ is the reactance consisting of the direct axis transient reactance of M1, the reactance of the transformer, and the reactance of the transmission line X_L . Similarly, $X_{d\Sigma} = X_d + X_T + X_L$ is identical to $X'_{d\Sigma}$ except that X_d denotes the direct axis reactance of M1. T'_0 is the d-axis transient short-circuit time constant. $X_1 = X'_d + X_T$, $X_2 = X_L$, u_f is the field voltage control input. P_m is the mechanical input power to be assumed constant throughout this paper. B_L and B_C are the susceptance of the inductor in SVC (pu.) and the equivalent capacitor (pu.), B_{L0} is the initial value of the inductor in SVC (pu.), u_r is the SVC control input to be designed, and T_r is a SVC time constant.

In practice, the generator transient voltage (E) is often physically not measurable and $B_L - B_C$ may not be convenient to monitor as active electrical power; thus, the active power P_E can be divided into two new variables, namely, an active electrical power of generation excitation alone P_e and a real electrical power of the SVC device P_{svc} , as follows:

$$P_E = P_e + P_{svc}$$

$$P_e = \frac{EV_\infty \sin\delta}{X'_{d\Sigma}}$$

$$P_{svc} = \frac{(X'_d + X_T)X_L(B_L - B_C)}{X'_{d\Sigma} - (X'_d + X_T)X_L(B_L - B_C)} \frac{EV_\infty \sin\delta}{X'_{d\Sigma}}$$

$$= \frac{(X'_d + X_T)X_L(B_L - B_C)}{X'_{d\Sigma} - (X'_d + X_T)X_L(B_L - B_C)} P_e \qquad (3)$$

It is well known that a large interconnected system can be usually represented by an infinite bus once its voltage and frequency remain constant under all conditions. Even though in a large-scale power system there are several generators, it is often possible to reduce the system to a set of equivalent (one or two) machines that are of interest, connected to an equivalent network (Thevenin equivalent circuit) as shown in Fig.1.Roughly speaking, the SMIB power systems considered in this paper can be regarded as a subsystem of a multimachine power system. On the other hand, if the reduced order power system is not an adequate representation of the system for transient stability studies, then we can extend the control method proposed in this work to multimachine systems with SVC which will be reported in the future.

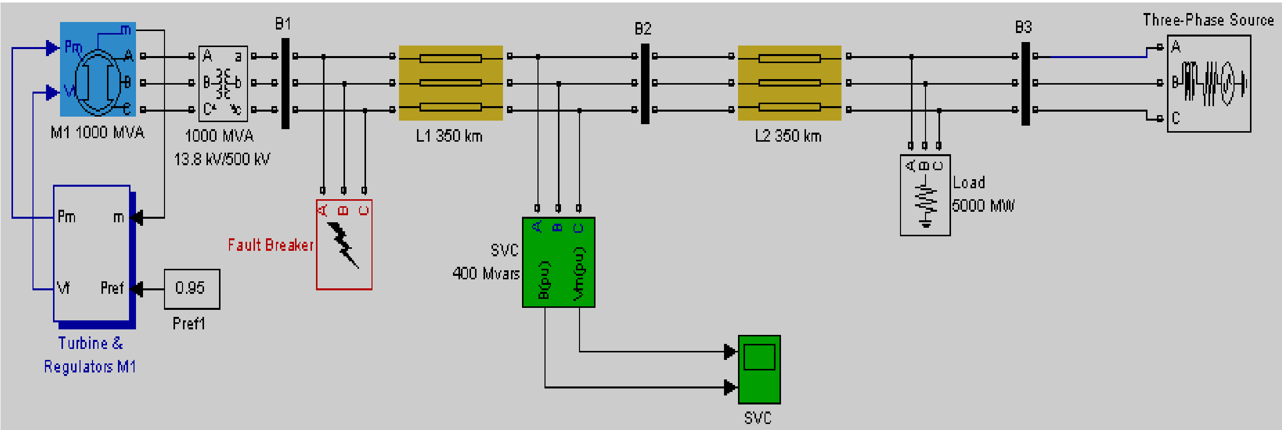

Fig.2 Simulation Model of SMIB with SVC

IV. Description of the Simulation Model

Consider the single line diagram as shown in Fig. 2 with the M1 connected through a high voltage transmission line to an infinite-bus. The hydraulic generator is equipped with a hydraulic turbine and governor (HTG), excitation system, and power system stabilizer (PSS). Two types of stabilizers can be connected on the excitation system: a generic model using the acceleration power (Pa=difference between mechanical power and output electrical power) and a Multiband stabilizer using the speed deviation (dw). Manual

Switch allow you to select the type of stabilizer used for the M1 or put the PSS out of service.

The load center is modeled by a 5000MW resistive load. To maintain system voltage stability after faults, the transmission line is shunt compensated at its center by a 400Mvar Static Var Compensator (SVC).

In this case we assume that the mechanical power input to the generator is constant. The M1 delivers 1.0pu.power while the terminal voltage, V_{ref} , is 0.9897pu. and the infinite-bus voltage is 1.0pu. A Fault Breaker block is connected at bus B1, we will use it to simulate different faults and observe the impact of the PSS and SVC on system voltage stability.

V. SIMULATION RESULTS

In this section, simulation results using a combination of generator excitation and SVC controllers in a SMIB system are shown using power angle stability, and voltage and frequency regulation to point out the system stability enhancement, in particular voltage stability.

First put the PSS in service. Suppose that there is a large disturbance (three-phase fault) occurring at bus B1, thereby resulting in rotor acceleration and voltage sag. Eventually, such a fault is cleared by opening and reclosing the circuit breaker at each end of the affected line. Verify that the SVC is in fixed susceptance mode with Bref=0. Start the simulation. By looking at the d_theta1_2 signal, you should observe that the M1 quickly fall out of synchronism after fault clearing, as shown in Fig.3.

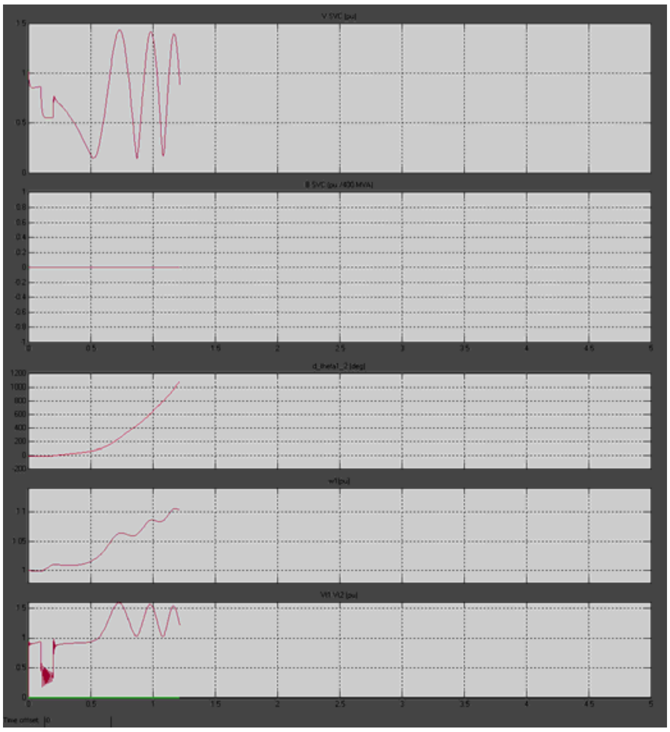

Fig.3 Impact without SVC for a Three-Phase Fault
(Fault applied at t=0.1 s and cleared at t=0.2 s)

Now change the SVC mode of operation to Voltage regulation. The SVC will now try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.009pu.). The chosen SVC reference voltage corresponds to the bus voltage with the SVC out of service. In steady state the SVC will therefore be floating and waiting for voltage compensation when voltage departs from its reference set point. Restart simulation and observe that the system is now stable with a three-phase fault, as shown in Fig.4.

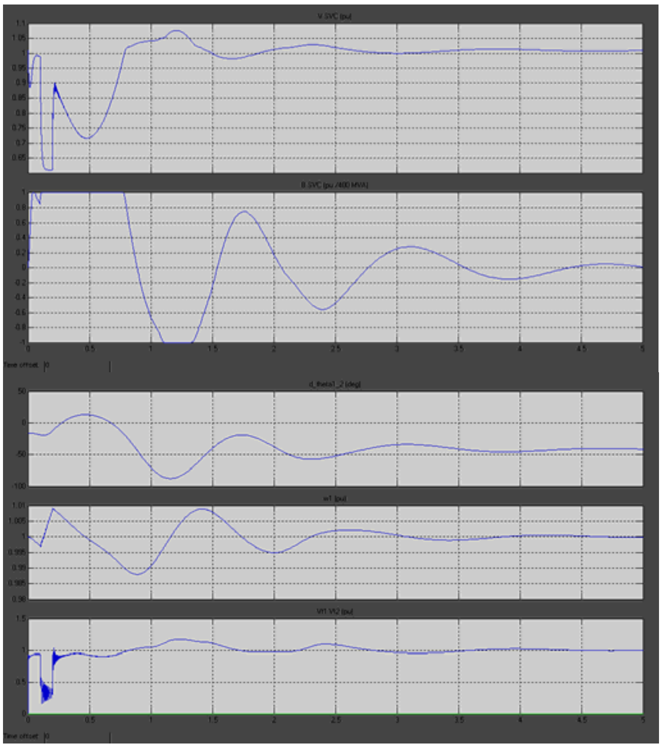

Fig.4 Impact of the SVC for a Three-Phase Fault
(Fault applied at t=0.1 s and cleared at t=0.2 s).

VI. CONCLUSION

The SVC is considered as an effective tool for shunt reactive compensation devices for the use on high voltage power systems. In this paper, we have shown that coordinated control of additional excitation control (PSS) and SVC in SMIB power systems can be effectively used to enhance the voltage stability of power systems after the occurrence of a large disturbance. From simulation results above, it can be overall concluded that, the real power loss minimization and voltage stability limit improvement is remarkable by reactive power compensation by SVC, and the coordinated control of PSS and SVC is capable of not only achieving the expected performance requirements but also accomplishing better dynamic performance. The obtained results of this work are of practical significance and applicable value.

ACKNOWLEDGMENT

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