PARALLEL FACTS DEVICES FOR IMPROVING POWER SYSTEM STABILITY

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ABSTRACT

The performance of two parallel FACTS devices – the SVC and STATCOM has been examined in terms of their ability to provide damping to a power system. The outputs of PID controllers have been used to modulate the thyristor firing angle signal. The gains of the PID controllers were determined through a pole placement technique. Simulation results indicate that both the devices are capable of providing additional damping, but STATCOM is superior in terms of speed of response.

1. INTRODUCTION

Flexible AC Transmission System (FACTS) is one aspect of power electronics revolution that is taking place in all areas of electric energy. FACTS controllers use various power electronic circuit topologies or equipment that perform certain function such as current control, power control, etc., and has the potential use in generation, transmission and distribution of electric energy [1]. FACTS controllers can be divided into four categories – series controllers, shunt controllers, combined series – series controllers, and combined series-shunt controllers. Shunt controller is like a current source, which draws from or injects current into the line. Shunt controller, therefore, is a good way to control and damp voltage oscillations by injection of leading or lagging reactive current at and around the point of connection. There are various shunt-connected FACTS devices – the major ones in terms of applications are the static VAR compensator (SVC) and static synchronous compensator (STATCOM).

SVCs are well known to improve power system properties such as steady state stability limits, voltage regulation and var compensation, dynamic over voltage and under voltage control, counteracting sub-synchronous resonance, and damp power oscillations [2, 3]. Voltage controlled SVC, as such, does not provide any damping to the power system [4, 5]. However, it can be used to increase power system damping by introducing supplemental signals to the voltage set point [6].

The static compensator (STATCOM) provides shunt compensation in a similar way as SVC but utilizes a voltage source converter rather shunt capacitors and reactors [7]. The basic principle of operation of a STATCOM is the generation of a controllable AC voltage source behind a transformer leakage reactance by a voltage source converter connected to a DC capacitor. The voltage difference across the reactance produces active and reactive power exchanges between the STATCOM and the power system [8]. The effect of stabilizing controls on STATCOM controllers have been investigated also in several recent reporting [9, 10].This article compares the damping properties of these two parallel FACTS devices as achieved through PID controllers.

2. POWER SYSTEM MODEL WITH SVC AND STATCOM

SVC and STATCOM are both employed for reactive power control in a network and to provide voltage support. They are normally located at the mid-section of the transmission line (Fig.1). The SVC is a mature technology dating back its application since the 70's. SVCs are thyristor controlled/switched reactors and capacitors. There are various SVC configurations; the most popular one is the fixed-capacitor thyristor controlled reactor (FC-TCR). The STATCOM, on the other hand, is a relatively recent second generation FACT controllers. This normally comprises of a synchronous voltage source generating controllable AC behind a transformer leakage reactance. The voltage source converter is connected to an energy storage unit, usually a DC capacitor. The voltage difference across the reactance produces the reactive power exchange between the STATCOM and the power system. The block diagrams of the SVC and STATCOM controllers are given in Fig.2.

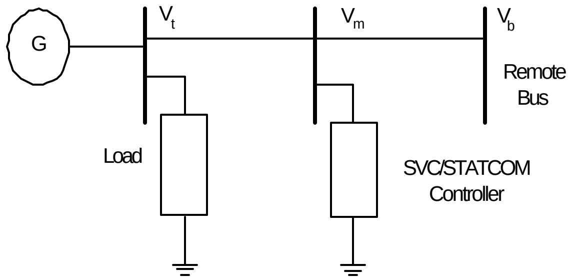

Fig.1 A single machine system with SVC/STATCOM at the mid bus

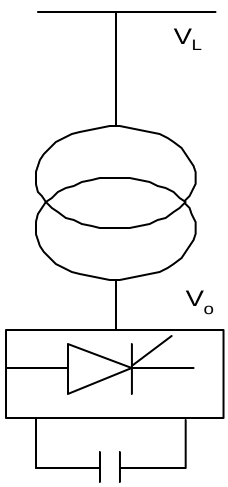

Fig. 2a. The STATCOM connected to mid-bus

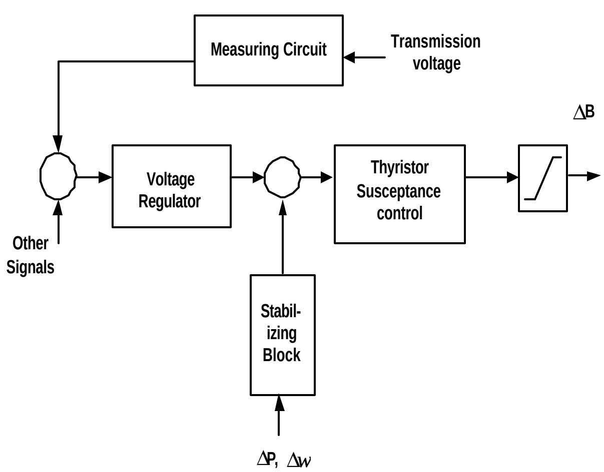

Fig. 2b. SVC Block representation

The V-I characteristics (Fig.3) show that the STATCOM can be operated over its full output current range at very low, typically about 0.2 pu system voltage levels. In contrast, the SVC, being composed of capacitors and reactors, becomes a fixed capacitive admittance and thus maximum attainable compensating current decreases linearly with AC system voltage. The STATCOM also has increased transient rating.

3. FACTS AND STABILITY ENHANCEMENT

The SVC voltage control loop, as such, (Fig.2) cannot provide extra damping to the power system. However, additional controls added to the voltage regulator output can provide damping. The STATCOM can interface suitable energy storage with the AC system for real power exchange through momentary or long term energy storage. For simplicity, the impact of a simple PID controller, as shown in Fig.4, is investigated here. The input to the controller is normally the variation of power flow at the point of connection or the variation of generator angular frequency which can be synthesized from the power flow.

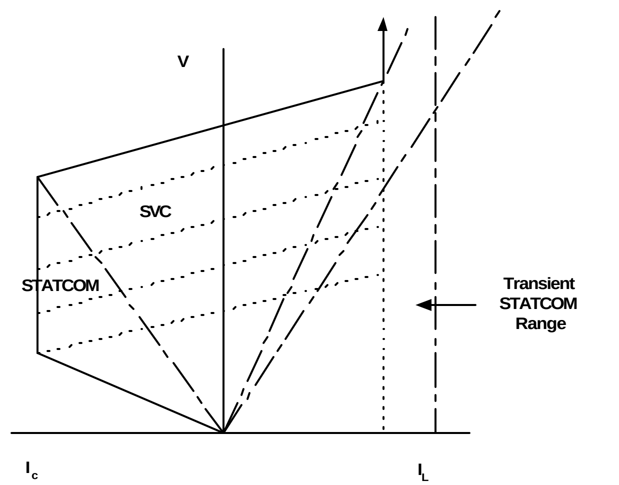

Fig. 3 V-I characteristic of STATCOM and SVC

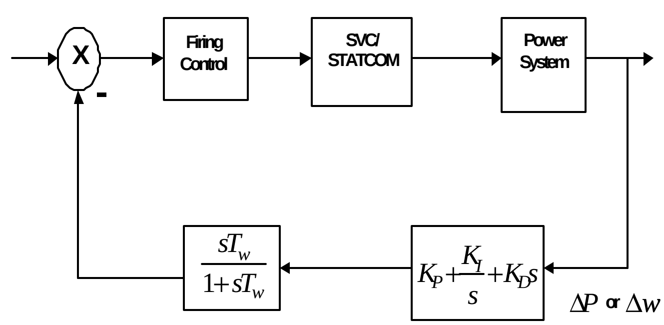

Fig. 4 PID control of an SVC/ STATCMO firing control circuit

The gains of the PID controller are obtained through a pole-placement technique. The steps involved in the design process are as follows.

1. Derive the nonlinear power system model including the SVC and STACOM.
2. Linearize the system of equations as,

$$\dot{x} = Ax + Bu \qquad (1)$$
$$y = Cx$$

x and y represent the state and control vectors. Consider output y to be the deviation of angular speed.

3. Taking Laplace transform of (1) and expressing

$$U(s) = H(s)Y(s)$$

or, $$U(s) = \frac{sT_w}{1+sT_w}[K_p + \frac{K_I}{s} + K_D s]Y(s) \qquad (2)$$

it can be shown that for a specified eigenvalue ? [11],

$$H(?(= \frac{?T_w}{1+?T_w}[K_P + \frac{K_I}{?} + K_D ?] \qquad (3)$$
$$= \frac{1}{C(?(-A)^{-1}B}$$

4. Specify location of three eigenvalues of the closed-loop system. Equation (3) will yield three simultaneous equations in terms of three parameters K_P. K_I and K_D.

4. RESULTS

The single machine power system given in Fig. 1 is modeled with SVC and STATCOM separately along with the PID feedback controllers. The dominant eigenvalues of the closed loop system are placed so as to give a damping ratio of approximately 0.29 for closed loop operation of the power system. The ideal zero of the PID controller is realized through a lead compensator with its pole located very far in the left half s-plane. A nominal power output of 0.9 pu at .95 pf lagging is considered for the controller design. The PID parameters for SVC controller are, K_p= -218.6897, K_I = - 3225, and K_D= -8.8949, while for the STATCOM the corresponding values are 32.767, 808.88, and -0.368, respectively. For a 100% torque pulse for 0.05 sec duration, the transient angular speed and rotor angle variations of the generator for no control, SVC control and STATCOM controls cases are shown by curves a, b, c, respectively in Figs.5 and 6.

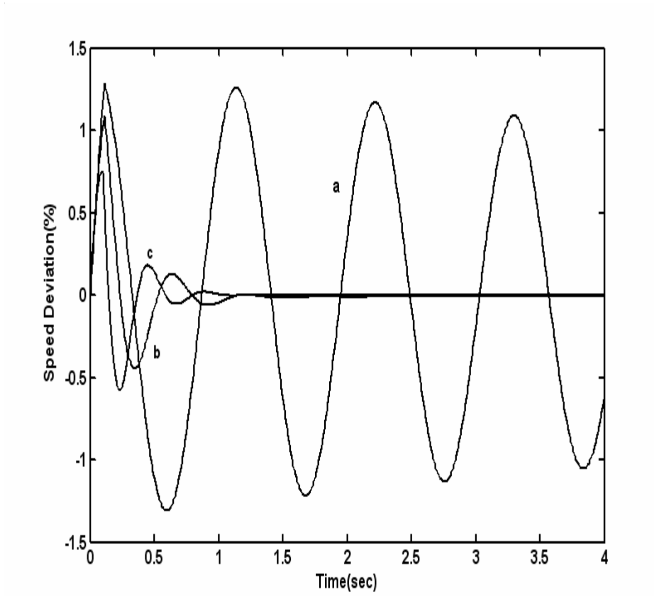

Fig. 5 Generator angular speed variation for a 100% input torque pulse for 0.5sec with, a) no stabilizing control, b) PID control in SVC, and c) PID control in STATCOM.

The PID controllers were tested with severe three-phase fault disturbances of 0.1sec duration on the remote bus. The nonlinear systems equations were simulated for this condition. Comparison of SVC and STATCOM performances in terms of generator angular speed and terminal voltage variations are shown in Figs. 7 and 8, respectively.

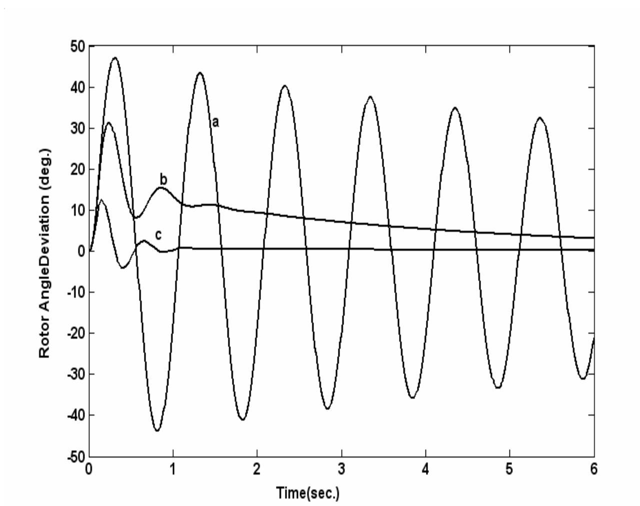

Fig.6 Generator rotor angle variation corresponding to Fig.5

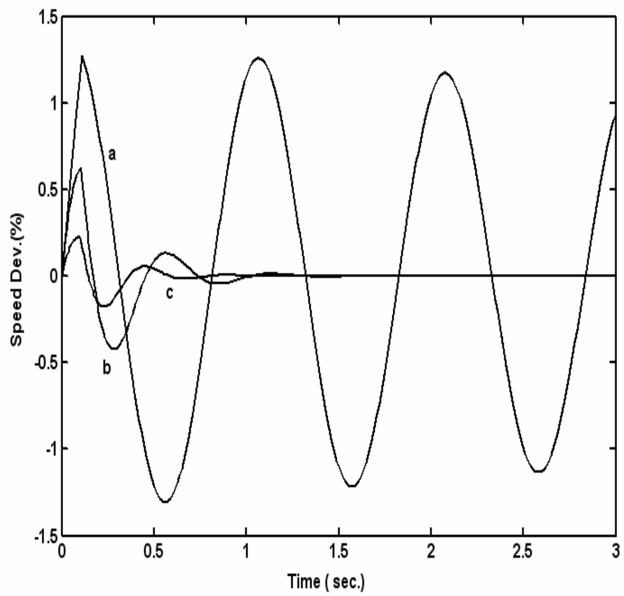

Fig. 7 Speed deviation of the generator following a three phase fault of 0.1 sec on the remote bus, with (a) no extra control, (b) SVC control, and (c) STATCOM control.

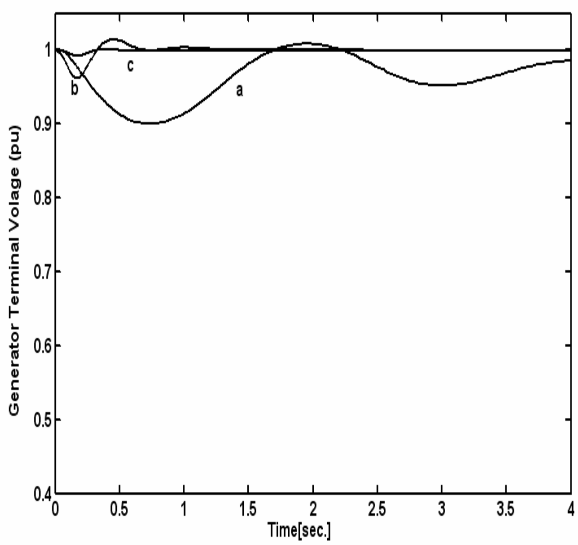

Fig.8 Terminal voltage variation of the generator corresponding to Fig.7

It can be observed that if properly controlled, both SVC and STATCOM can provide extra damping to the system. But since STATCOM is a completely electronic device, its speed of response is faster. The real advantage with STATCOM is its ability to respond at depressed voltage conditions, as may be experienced in a faulted system (Fig.8). The voltage recovery as well as stability properties are significantly improved with the STATCOM control.

5. CONCLUSIONS

The effect of SVC and STATCOM controllers in enhancing power system stability has been exa mined. Though both the devices can provide extra damping to the system, it has been demonstrated that STATCOM is very effective in enhancing system performance in situations where system voltages are very much depressed. Also, because of its fast response time, STATCOM control is superior to that of SVC

6. ACKNOWLEDGEMENT

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