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# Modeling and Simulation of Static Var Compensator for Improvement of Voltage Stability in Power System

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***Abstract* — This paper investigates the effects of Static Var Compensator (SVC) on voltage stability of a power system. This paper will discuss and demonstrate how SVC has successfully been applied to power system for effectively regulating system voltage. One of the major reasons for installing a SVC is to improve dynamic voltage control and thus increase system load ability. This paper presents modeling and simulation of SVC in MATLAB/Simulink. In this paper A SVC is used to regulate voltage in a power system. When system voltage is low the SVC generates reactive power (SVC capacitive). When system voltage is high it absorbs reactive power (SVC inductive). The SVC is rated +100 Mvar capacitive and 50 Mvar inductive. The SVC more effectively enhance the voltage stability and increase transmission capacity in a power system.**

***Keywords* — Dynamic Performance, FACTs, Matlab/Simulink, Transient Stability.**

## I. INTRODUCTION

Today’s changing electric power systems create a growing need for flexibility, reliability, fast response and accuracy in the fields of electric power generation, transmission, distribution and consumption. Flexible Alternating Current Transmission Systems (FACTS) are new devices emanating from recent innovative technologies that are capable of altering voltage, phase angle and/or impedance at particular points in power systems. Their fast response offers a high potential for power system stability enhancement apart from steadystate flow control. Among the FACTS controllers, Static Var Compensator (SVC) provides fast acting dynamic reactive compensation for voltage support during contingency events which would otherwise depress the voltage for a significant length of time. In emerging electric power systems, increased transactions often lead to the situations where the system no longer remains in secure operating region. The flexible AC transmission system (FACTS) controllers can play an important role in the power system security enhancement. However, due to high capital investment, it is necessary to locate these controllers optimally in the power system. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics. Placement of these devices in suitable location can lead to control in line flow and maintain bus voltages in desired level and so improve voltage stability margins. Voltage instability is one of the phenomena which have result in a major blackout. Moreover, with the fast development of restructuring, the problem of voltage stability has become a major concern in deregulated power systems. To maintain security of such systems, it is desirable to plan suitable measures to improve power system security and increase voltage stability margins. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage magnitude control simultaneously by their fast control characteristics and their continuous compensating capability and so reduce flow of heavily loaded lines and maintain voltages in desired level[2].

## II. SVC CONTROL SYSTEM

The control system consists of,

-A measurement system measuring the positive-sequence voltage to be controlled. A Fourier-based measurement system using a one-cycle running average is used.

-A voltage regulator that uses the voltage error (difference between the measured voltage Vm and the reference voltage $V_{ref}$) to determine the SVC susceptance B needed to keep the system voltage constant.

-A distribution unit that determines the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of TCRs.

-A synchronizing system using a phase-locked loop (PLL) synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the thyristors. This is shown in Fig. 3.

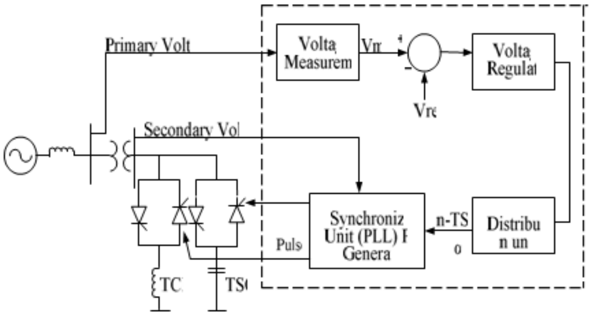

Fig. 1 The Control System of SVC

## III. SVC V-I CHARACTERISTICS

The SVC can be operated in two different modes:

- In voltage regulation mode
- In var control mode (the SVC susceptance is kept constant)

When the SVC is operated in voltage regulation mode, it implements the following V-I characteristic[1].

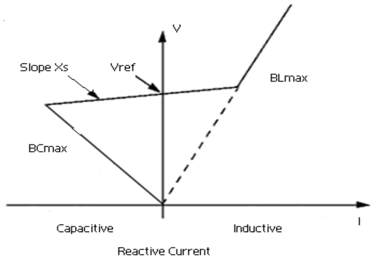

Fig 2. The V-I Characteristics Curve of SVC

As long as the SVC susceptance B stays within the maximum and minimum susceptance values imposed by the total reactive power of capacitor banks ($B_{cmax}$) and reactor banks

($B_{lmax}$), the voltage is regulated at the reference voltage Vref . However a voltage droop is normally used usually between 1% and 4% at maximum reactive power output). The V-I characteristic is described by the following three equations

$V = V_{ref} + X_s.I$ SVC is in regulation range ($-B_{max} < B < B_{Lmax}$) (1)
$V = -I / Bc_{max}$ SVC is fully capacitive ($B = B_{cmax}$) (2)
$V = I / Bl_{max}$ SVC is fully inductive ($B = B_{Lmax}$) (3)

Where,

V = Positive sequence voltage (p.u.)

I = Reactive current (p.u./$P_{base}$) ($I > 0$ indicates an inductive current)

$X_s$ = Slope or droop reactance (p.u./$P_{base}$)

$B_{Cmax}$ = Maximum capacitive susceptance (p.u./$P_{base}$) with all TSCs in service, no TSR or TCR

$B_{Lmax}$ = Maximum inductive susceptance (p.u./$P_{base}$) with all TSRs in service or TCRs at full conduction, no TSC

$P_{base}$ = Three-phase base power

## IV. MODELING OF SVC

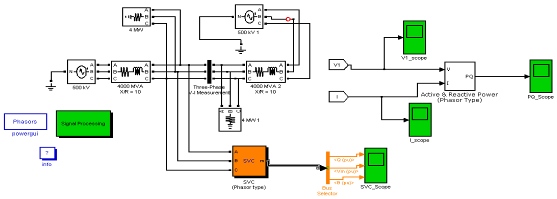

Fig 3. Simulation of Static Var Compensator in Simulink

A static var compensator (SVC) is used to regulate voltage on a sytem .When system voltage is low the SVC generates reactive power (SVC capacitive). When system voltage is high it absorbs reactive power (SVC inductive).The SVC is rated +100 Mvar capacitive and 50 Mvar inductive.The two 500kv Three-Phase Programmable Voltage Source is used to vary the system voltage to observe the SVC performance.

The SVC is set in voltage regulation mode with a reference voltage Vref=1.0 pu. The voltage droop is 0.03 pu/ 100MVA, so that the voltage varies from 0.97 pu to 1.015 pu when the SVC current goes from fully capacitive to fully inductive.

Initially the source is generating nominal voltage. Then, voltage is successively decreased (0.97 pu at t = 0.1 s), increased (1.03 pu at t = 0.4 s) and finally returned to nominal voltage (1 pu at t = 0.7 s).

A positive of Q(pu) value indicates inductive operation and a negative value of Q(pu) value indicates capacitive operation. A positive value of SVC susceptance indicates that the SVC is capacitive and a negative value indicates inductive operation.

The SVC response speed depends on the voltage regulator integral gain Ki (Proportional gain Kp is set to zero), system strength (reactance Xn) and droop (reactance Xs). If the voltage measurement time constant and average time delays Td due to valve firing are neglected, the system can be approximated by a first order system having a closed loop time constant.

$$T_c = 1/(K_i (X_n + X_s)) \qquad (4)$$

With system parameters

**Ki = 400**
**Xn = 0.0667 pu/100 MVA**
**Xs = 0.03 pu/100 MVA**

## V. SYSTEM MODEL WITHOUT SVC

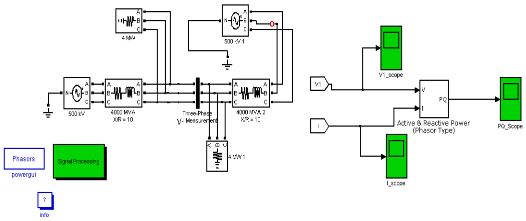

Fig 4. Simulation of System without SVC

In the present work system is simulated in simulink to observe the positive sequence voltage profile in the absence of SVC. As SVC provides dynamic response to voltage steps created through Three Phase Programmable Voltage Source, it will now be analysed from this model the changes that takes place in positive sequence voltage profile of the system.

## VI. SIMULATION RESULTS

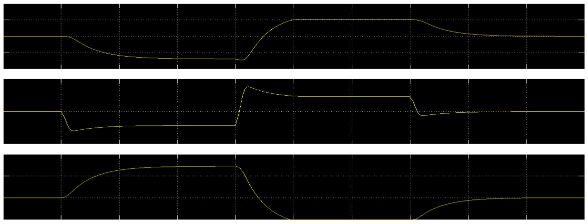

Fig. 5 Simulation Curves of Q(pu), Vm(pu) and B(pu)

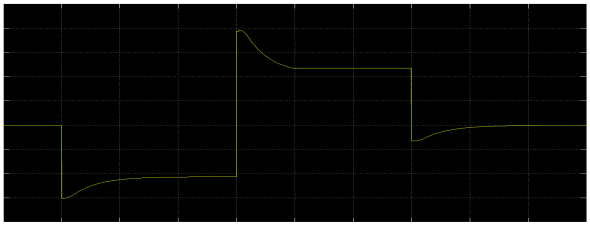

Fig 6. Simulation Curve of Actual Positive Sequence Voltage

These Simulation curves are result of this paper. Initially the source is generating nominal voltage. Then, voltage is successively decreased (0.97 pu at t = 0.1 s), increased (1.03 pu at t = 0.4 s) and finally returned to nominal voltage (1 pu at t = 0.7 s) through 500KV Three Phase Programmable Voltage Source. Waveforms of Q(pu), Vm(pu) and B(pu) are shown in fig. 4 . In fig. 5 waveform of actual positive sequence voltage V1 is also shown.

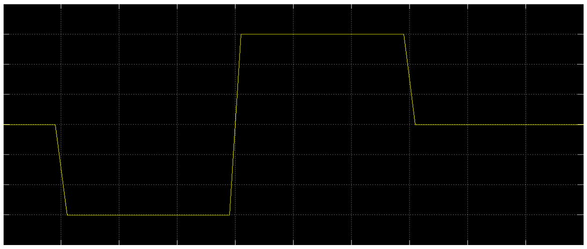

Fig 7. Waveform of Actual Positive Sequence Voltage V1 without SVC

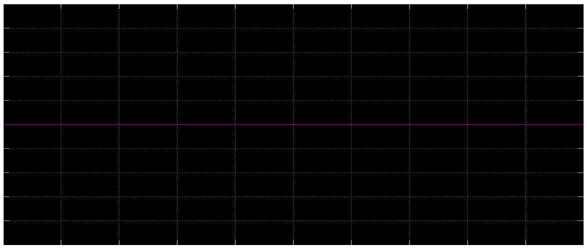

Fig 8. Reactive Power without SVC

Now as shown in fig. 4 the system is modelled again without SVC to check the voltage profile of the system. Initially the source is generating nominal voltage. Then, voltage is successively decreased (0.97 pu at t = 0.1 s), increased (1.03 pu at t = 0.4 s) and finally returned to nominal voltage (1 pu at t = 0.7 s) through Three Phase Programmable Voltage Source. It can be observed in fig. 7 positive sequence voltage is present in steps and dynamic response of SVC shown in fig. 5 is absent.

## VII. CONCLUSION

Hence it can be concluded that SVC will successfully control the dynamic performance of power system and will effectively regulate the system oscillatory disturbances and voltage regulation of the power system. Simulations carried out confirm that SVC could provide the fast acting voltage support necessary to prevent the possibility of voltage reduction and voltage collapse. This paper inspects actual positive sequence voltage in a system model with or without SVC. Analysis of SVC reactive power output (pu) in response to voltage steps is presented in this paper. However it is well known that these FACTS controllers have the additional advantage of being able to control "fast" system oscillations due to their quick response. Hence by properly modeling these controllers in transient stability programs, it would be interesting to determine any other possible advantages of these controllers in voltage stability studies.

The authors are currently working on developing appropriate models for other FACTS controllers, namely, STATCOM, SSSC, UPFC for transient and steady state stability analysis, to also analyze the advantages and disadvantages of these controllers in voltage stability studies.

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