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# Simulation and Analysis of Static Var Compensator with Matlab

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**ABSTRACT**
*The static var compensator (SVC) is one of the FACTS (flexible AC transmission system) controllers which is widely used to improve power systems transient stability because of its inherent role in controlling the active and reactive power flows in electrical transmission lines. This paper presents an application of (SVC) in electrical transmission lines by simulating a single-machine infinite-bus power system to study the dynamic response and observing the impact of the SVC for stabilizing the network during a voltage variation using Matlab/Simulink® environment.*

***Keywords*** *– FACTS devices, Rective power, simulink, static var compensator, Thyristor controlled reactor.*

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## I. INTRODUCTION

Power system engineering forms a vast and major portion of electrical engineering studies. It is mainly concerned with the production of electrical power and its transmission from the sending end to the receiving end as per consumer requirements, incurring minimum amount of losses. The power at the consumer end is often subjected to changes due to the variation of load or due to disturbances induced within the length of transmission line. For this reason the term power system stability is of utmost importance in this field, and is used to define the ability of the of the system to bring back its operation to steady state condition within minimum possible time after having undergone some sort of transience or disturbance in the line [1].

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 [1].Their fast response offers a high potential for power system stability enhancement apart from steady-state flow control.

To provide stable, secure, controlled, high quality electric power on today's environment and to do better utilization of available power system capacities Flexible AC transmission systems (FACTS) controllers are employed to enhance power system stability[1] in addition to their main function of power flow control. The Power electronic based FACTS devices are added to power transmission and distribution systems at strategic locations to improve system performance. FACTS are a family of devices which can be inserted into power grids in series, in shunt, and in some cases, both in shunt and series. During the last decade, a number of control devices under the term FACTS technology have been proposed and implemented. Application of FACTS devices in power systems, leads to better performance of system in many aspects. Voltage stability, voltage regulation and power system stability, damping can be improved by using these devices and their proper control [2].

## II. CONTROL OF REACTIVE POWER AND VOLTAGE

In steady state operation both active power balance and reactive power balance must be maintained. The reactive power generated by synchronous machines and capacitances must be equal to the reactive power of the loads plus the reactive transmission losses [3]. If the active power balance is not kept, the frequency in the system will be influenced, while an imbalance in reactive power will result in that the voltages in the system differ from the desired ones. If the power system is operated in the correct way, the voltage drops on the lines are usually small. The voltages in the nodes of the system will then almost be the same (flat voltage profile). In this case the transmission system is effectively used, i.e. primarily for transmission of active power, and not for transmission of reactive power.

As known from the Static Analysis the voltage in a system is strongly affected by the reactive power flow. Consequently the voltage can be controlled to desired values, by control of the reactive power. Increased production of reactive power gives higher voltage nearby the production source, while an increased consumption of reactive power gives lower voltage. Therefore it is of great interest to study which components and devices which can be used to regulate the reactive power in a power system. While the active power is entirely produced in the generators of the system, there are several sources of reactive power.
For some of these the reactive power is easy to control, while for others it is practically impossible. The reactive power of the synchronous machines is easily controlled by means of the excitation. Switching of shunt capacitors and reactors can also control the reactive power. If thyristors are used to switch capacitors and/or thyristors are used to control the current through shunt reactors, a fast and step-less control of the reactive power can be obtained. Such a device is called SVC (Static Var Compensator) [3].

## III. THE STATIC VAR COMPENSATOR (SVC)

The static var compensator (SVC) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids. [4]. It is a power quality device, which employs power electronics to control the reactive power flow of the system where it is connected. Proper placement of SVC reduces transmission losses, increases the available capacity, and improves the voltage profile as suggested by Biansoongnern et al [5].
The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). [6] When system voltage is high, it absorbs reactive power (SVC inductive). The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase controlled (Thyristor Controlled Reactor or TCR). [7, 11]
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 [8]. SVC also dampens power swings and reduces system losses by optimized reactive power control. In previous works the effective methods of control have been implemented to control of SVC in order to damp power swings [9].

In its simplest form, SVC is connected as Thyristor- controlled Reactor fixed capacitor (TCR-FC) configuration as shown in figure 2. Its major components include a coupling transformer, thyristor valves, rectors and capacitors (for harmonic filtering through tuning).

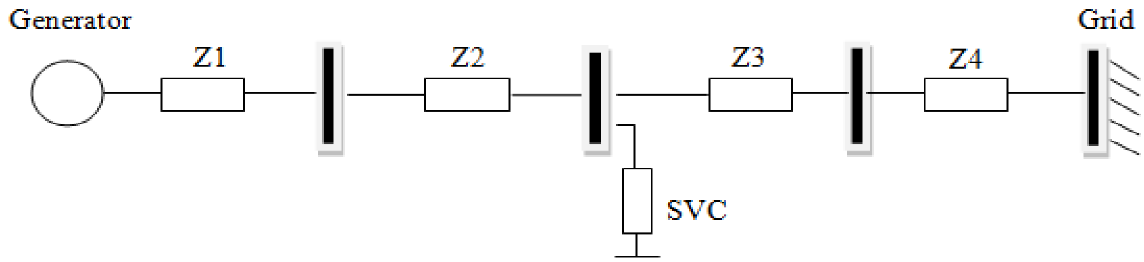


Fig. 1: Structure of SVC

Studies have been performed on a single machine connected to a constant voltage bus through two transformers Z1 and Z4 and a A transmission line divided equally into two sections Z2 and Z3 as shown in Fig. 1. An SVC device is connected at the middle bus. The SVC is a combination of reactors and capacitors. It can be controlled quickly by thyristor switching. The SVC acts as a variable susceptance.
The SVC uses conventional thyristors to achieve fast control of shunt-connected capacitors and reactors. The configuration of the SVC is shown in Fig. 2, which basically consists of a constant capacitor (C) and a thyris-tor controlled reactor (L).The delay angle control of the thyristor banks determines the equivalent shunt admittance presented to the power system.

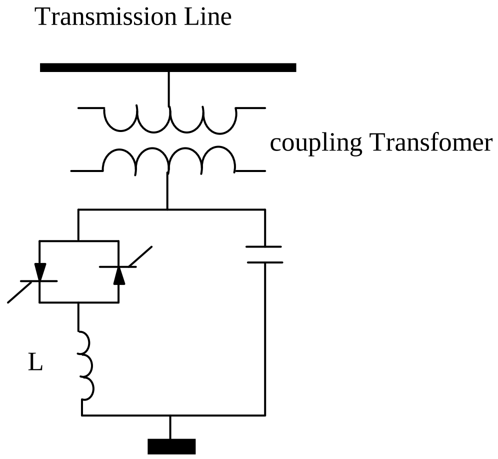


Fig. 2: SVC connected to a Transmission line

The model considers SVC as shunt-connected variable susceptance, $B_{SVC}$ which is adapted automatically to achieve the voltage control. The equivalent susceptance, $B_{eq}$ is determined by the firing angle of the thyristors that is defined as the delay angle measured from the peak of the capacitor voltage to the firing instant. The fundamental frequency equivalent neglecting harmonics of the current results in [10].

$$B_{eq} = B_L(\alpha) + B_c \tag{1}$$

$$B_L(\alpha) = \frac{1}{\omega c}\left(1 - \frac{2\alpha}{\pi} - \frac{\sin(2\alpha)}{\pi}\right), B_c = \omega c \text{ and } 0^0 \le \alpha \le 90^0 \tag{2}$$

$$P_{svc} = 0$$

$$Q_{svc} = -B_{svc}.V^2 \tag{3}$$

If the real power consumed by the SVC is assumed to be zero, then:

where $V^2$ is the bus voltage magnitude

## IV. EXPERIMENTAL SET UP

A simulink model for the simulation of the SVC is shown in figure 3. A static var compensator (SVC) is used to regulate voltage on 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 500 kV 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 (figure 4).

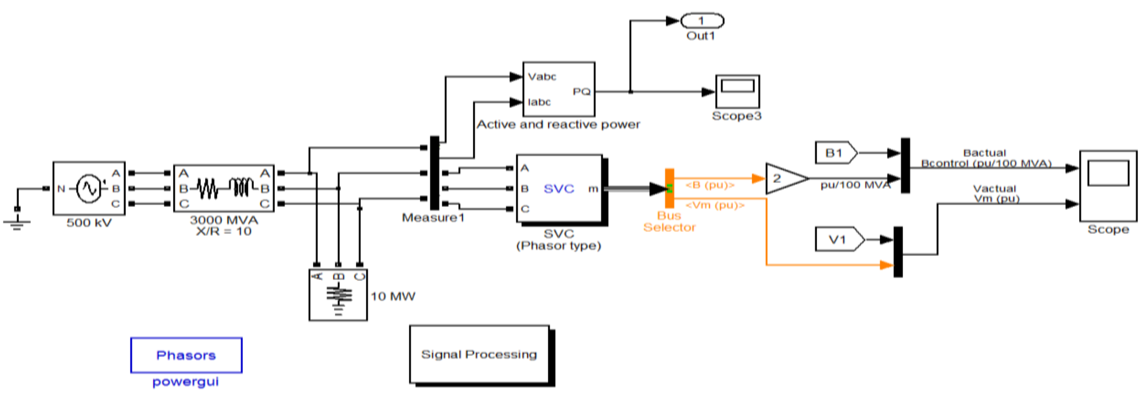


Fig. 3: Simulink model of the SVC connected to a power system

## V. RESULTS AND DISCUSSION

Initially the 500KV Three-phase Programmable voltage 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. Figure 4 and 5 show the dynamic response of the SVC to voltage steps. Figure 4 shows the actual positive sequence susceptance B1 (blue) and control signal output B (green) of the voltage regulator. Figure 5 shows the actual system positive-sequence voltage V1 and output Vm of the SVC.

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 [11].

$$T_c = \frac{1}{(k_i(X_n + X_s))} \quad (4)$$

Figure 6 shows a graphical representation of the active and reactive power of the 3-phase bus under study. The peak of the graph represents the instantaneous power value while the slope represents the average active power in Mvar.

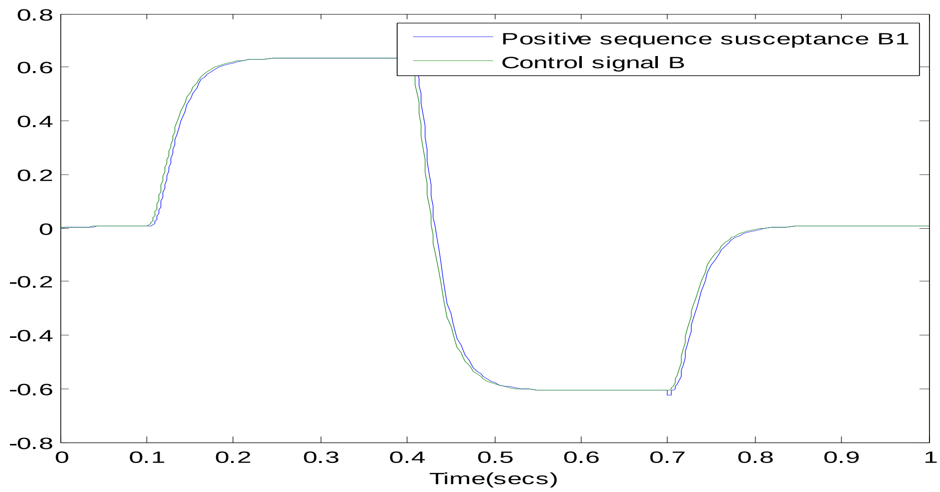


Fig. 4: Positive sequence susceptance and Control signal output voltage

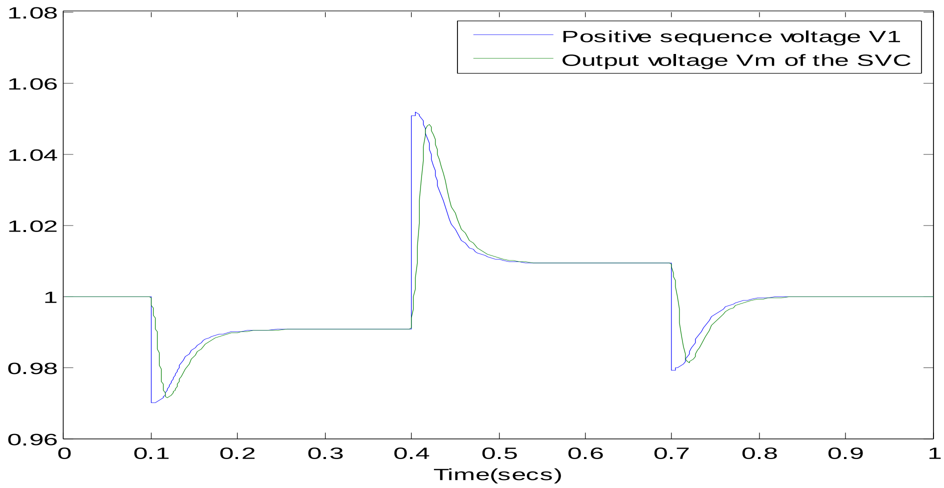


Fig. 5: Positive sequence voltage and SVC output voltage

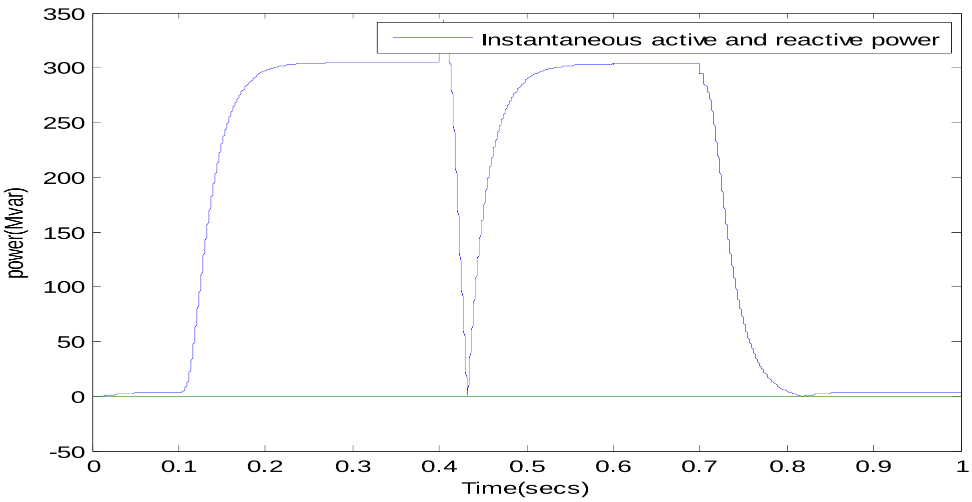


Fig. 6: Instantaneous active and reactive power

## VI. CONCLUSION

This paper proposed a model for power system using static var compensator (SVC) to improve transient stability. The basic structure of (SVC) is operating under typical bus voltage control and its model was described. The model represents the controller as variable impedance that changes with the firing angle of the thyristor reactor (TCR), simulations carried out confirmed that SVC could provide the fast acting voltage support necessary to prevent the possibility of voltage instability at the bus to which the SVC is proposed.
Matlab/simulink environment was used to carry out the simulation work and detailed results are shown to assess the dynamic performance of the SVC on the bus voltage stability.

## REFERENCES


[1] E. Acha, V.G. Agelidis, O. Anaya-Lara and T.J.E. Miller, Power Electronic Control in Electrical Systems, Newnes Power. Engineering Series, 2002.

[2] Nang Sabai ,Hnin Nandar Maung,and Thida Win"Voltage Control and Dynamic Performance of Power Transmission System Using SVC" ,World Academy of Science, Engineering and Technology, 2012, Vol:2 200806-23.

[3] Biannsoongnern, S.Chusanapiputt, and S.Phoomvuthisarn, "Optimal SVC and TCSC Placement for minimization of transmission losses", in proceedings of 2006 IEEE Conference on Power System Technology, pp.1-5, 2006.

[4] Biswas M. M and Kamol K. D. Voltage Level Improving by Using Static VAR Compensator, Global Journal of researches in engineering, Volume 11,pp.12-18, 2011.

[5] J. J. Paserba, "How FACTS controllers benefit AC transmission systems," IEEE Power Engineering Society General Meeting, Denver, Colorado, 6-10 June 2004.

[6] Minguez, R.Milano, Zarate Miano and R.Conejo, "Optimal Network Placement of SVC Devices", IEEE Transaction on Power System ,vol.22 ,no.-4 ,pp.1851-1860 ,2007.

[7] Yanzhou Sun,Linlin Wei"Simulation Analysis of Static var Compensator Based on The Matlab/Simulink",Journal of Theoretical Information Technology,20th May 2013.Vol.51 no.2

[8] Cai, L., Robust co-ordinated control of FACTS devices in large power systems. Ph.D. Thesis, University of Duisburg, Germany, Published by Logos Verlag Berlin. 2004.

[9] Kazerani, M., R. Marceau and Z. Wolanski,. Midpoint sitting of FACTS devices in transmission lines. IEEE Trans. Power Delv., 12(4): 1717-1722. 1997.

[10] Carsten, L., Security constrained optimal power flow for an economical operation of FACTS-devices in liberalized energy markets. IEEE Trans. Power Delivery, 17: 603-608. 2002.

[11] Sona, P. and M. Rajaram, Fuzzy logic controller for static synchronous series compensator with energy storage system for transient stability analysis. J. Comput. Sci., 7: 859-864. DOI:10.3844/jcssp.2011.859.864, 2011.