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QUALITY IMPROVEMENT OF THE VOLTAGE LEVEL IN THE TRANSMISSION LINES USING STATIC VAR COMPENSATOR CONTROLLERS

Raghad Hameed Ahmed
Department of Electronic Technology, Central Technical University Baghdad, Iraq
E-Mail: raghadhameed90@gmail.com

ABSTRACT

In these aspects Flexible AC Transmission Systems (FACTS) technology with relatively low investment, compared to new transmission or generation facilities allows the industries to enhance power system performance, improve quality of supply and also provide an optimal utilization of the existing resources. FACTS devices are divided as Shunt controller and Series controller. Shunt controller called Static VAR Compensator (SVC) are used for power factor correction and to improve voltage profile. The modeling and simulation results obtained in MATLAB software too.

Keywords: static VAR compensator, thyristor switched capacitor, thyristor controlled reactor.

INTRODUCTION

The need for more power generation is increasing around the globe. The main cause is excessive growth witnessed in the industrial sector. This growth necessitates the expansion in transmission interconnection. This transmission interconnection reduces the production cost and increases the effectiveness in power system operation. Updated control services are provided by the Flexible Alternating Current (FACTS) devices which can support both steady state power flows along with the dynamic stability control. By controlling the power-flow without rearranging the generation, system may greatly improve the results.

To enhance the power transfer process, FACTS may be used which is capable of controlling more than one AC transmission systems. FCATS controller may be dividing into three categories:

- Series Compensation
- Shunt Compensation
- Combined Shunt-Series Compensation

Static VAR Compensator (SVC), which are connected as shunt FACTS may be useful for improving voltage profile other usage may include recovering of a transient stability and power oscillation damping.

BACK GROUND

Static VAR Compensator (SVC) is the first generation of (FACTS) device is based on thyristor switch which offers dynamic shunt compensation and controls shunt capacitor reactor. To keep the voltage at certain level, reactive power output is repeatedly being adjusted by the dynamic shunt compensation. The technological basis for the Advanced FACTS Controllers devices are silicon controlled rectifiers and conventional thyristor.

SVC is usually used in electric arc furnace worldwide in order to provide effectiveness in industries. From the day SVC is developed, it is being utilized by developing countries for different services.

Way to generate reactive power

Reactive power is generated through several ways:

- Static VAR compensators (SVC)
- Synchronous alternators
- Synchronous compensators (SC)
- Banks of static capacitors

Static VAR compensators

As the field of power electronics is progressing day by day, the static devise to regulate the reactive power which is Thyristor switched Capacitors (TSC) and Thyristor Controlled Reactors (TCR). These compensation systems keep electromechanical mechanism in which switching is done by the use of ant parallel thyristor as shown in Figure-1.

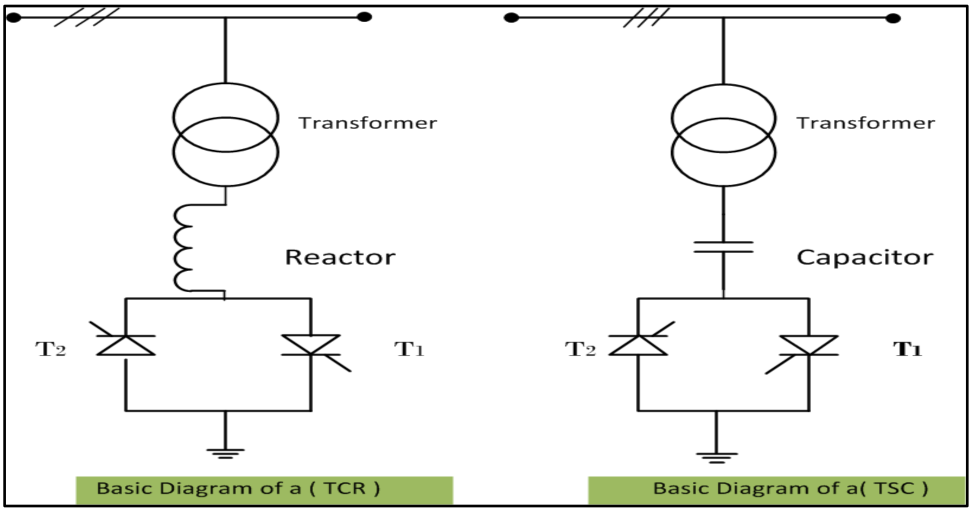

Figure-1. Basic diagram of a TCR and TSC.

Transferred reactive power is regulated on every point by collection of capacitors by TSC. However, TCR are utilized for the continuous monitoring of reactive power from inductors. By combine both TSC and TCR, continuous control of produced reactive power can be obtained. Applications of such devices are in power systems with high voltages.

MATERIALS AND METHODS

Static VAR compensator (SVC)

In Static VAR compensators, voltage, at the connection point with power system is controlled by the adjustment of susceptance in order to balance the reactive power deficiencies. In case of emergency events, speedy dynamic reactive voltage compensation is being provided by the SVC. Power swings are also reduced by SVC and its optimized reactive power control helps in minimizing the system losses.

This compensator consists of either thyristor controlled reactor (TCR) or thyristor switched capacitors (TSCs) with such power factor correcting capacitors which are permanently connected and offer harmonic filtering in combination with suitable tuning reactors. In order to compensate power systems dynamically for providing voltage support, increasing transient stability and achieving improved damping.

Such SVC schemes were devised and applied that use TCRs combined with TSCs and capacitive filters fixed on the secondary side of coupling transformer.

The thyristor controlled SVCs function as reactive impedances which can be controlled. Basically, the current drawn by the reactor banks and capacitors is managed by the valves of thyristor and in that way they generate the reactive power or take it in from the AC system.

Therefore, an SVC along with the required coupling transformers needs reactors and capacitors having full rating for the generation or absorption of reactive power, moreover, for large systems an electronic switching circuit i.e. thyristor valves is also needed. The circuit diagram of Static VAR Compensator is shown in Figure-2.

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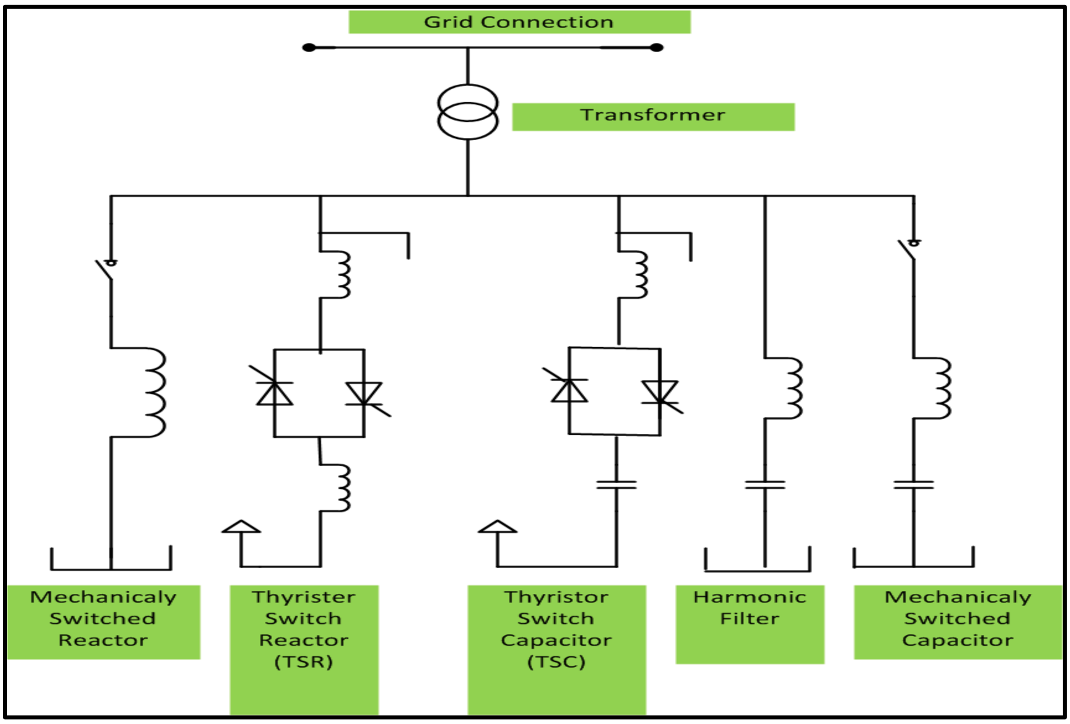

Figure-2. Compensator of Static var.

Implementation of three-phase static VAR compensator model

The Static VAR Compensator (SVC) is basically a shunt component belonging to the family of Flexible AC Transmission Systems (FACTS). It uses power electronics for controlling flow of power and improving transient stability on the power grids.

Terminal voltages are regulated by SVC by managing the reactive power that is instilled into the power system or absorbed from it. Reactive power is generated by SVC at low values of system voltage, while the reactive power is absorbed by it when the voltage of system gets high. The reactive power is varied by switching 3-phase capacitor and inductor banks that have connection with a coupling transformer's secondary side.

Three thyristor switches are used for switching each of the capacitor bank on or off. Reactors are either phase-controlled i.e. Thyristor Controlled Reactor, or switched on-off i.e. Thyristor Switched Reactor. Static VAR compensator's single-line diagram and a basic block diagram depicting its control unit is shown in Figure-3.

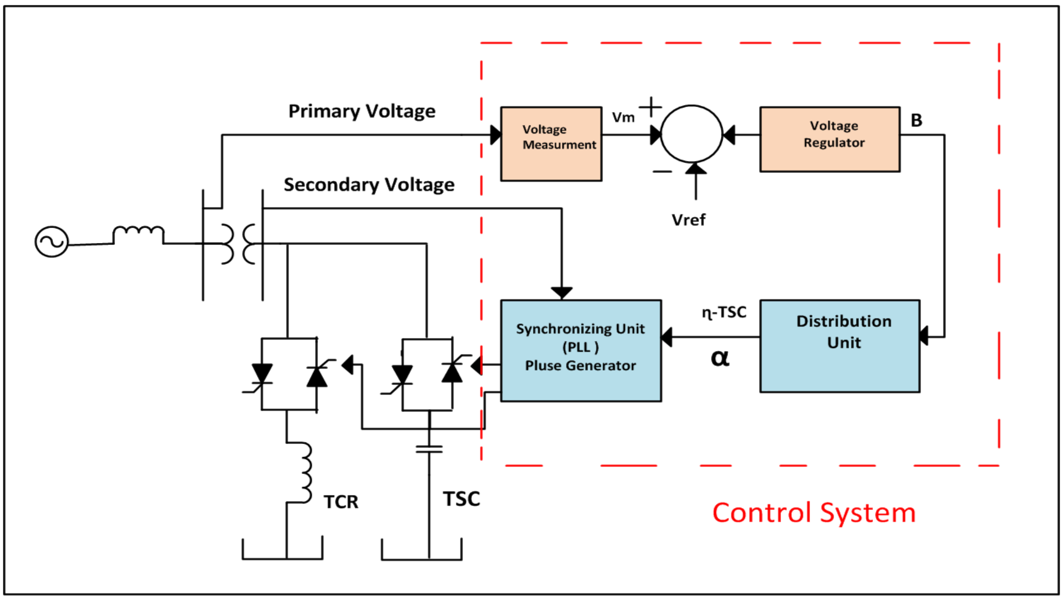

Figure-3. Single- line diagram of static VAR compensator and a simplified block diagram of its control system.

The control system includes:

- A voltage measurement system to compute the positive-sequence voltage that is to be managed. For this, Fourier analysis having running average of one cycle is employed

- A voltage regulator to find out the SVC susceptance (B) for keeping the voltage of system at constant level. To get this, the regulator makes use of the voltage error which is the difference of measured voltage (Vm) with respect to reference voltage (Vref)

- A distribution unit for determining the Thyristor Switched Capacitors and ultimately TSRs that have to be switched on and off for computing the firing angle (α) of TCRs

- A synchronizing unit employing a phase-locked loop (PLL) that has synchronization with the secondary voltages plus a pulse generator for sending suitable pulses to the thyristor

- The Phasor Type block is a model that must be used with the simulations, turned on with Powergui block. This can be utilized in 3- phase power systems along with the synchronous generators and dynamic loads for performing studies on transient stability and observing SVC impact on electromechanical oscillations and transmission capability. The in depth demonstration of power electronics, measurement and synchronization systems are not included in this model. These systems are rather estimated by basic transfer functions which give in an accurate illustration at the fundamental frequency of the system.

V-I Characteristic of SVC

The SVC can function in two modes:

- Voltage regulation mode

- VAR control mode

In voltage regulation mode, the Voltage-Current characteristic implemented by SVC is shown in the Figure-4.

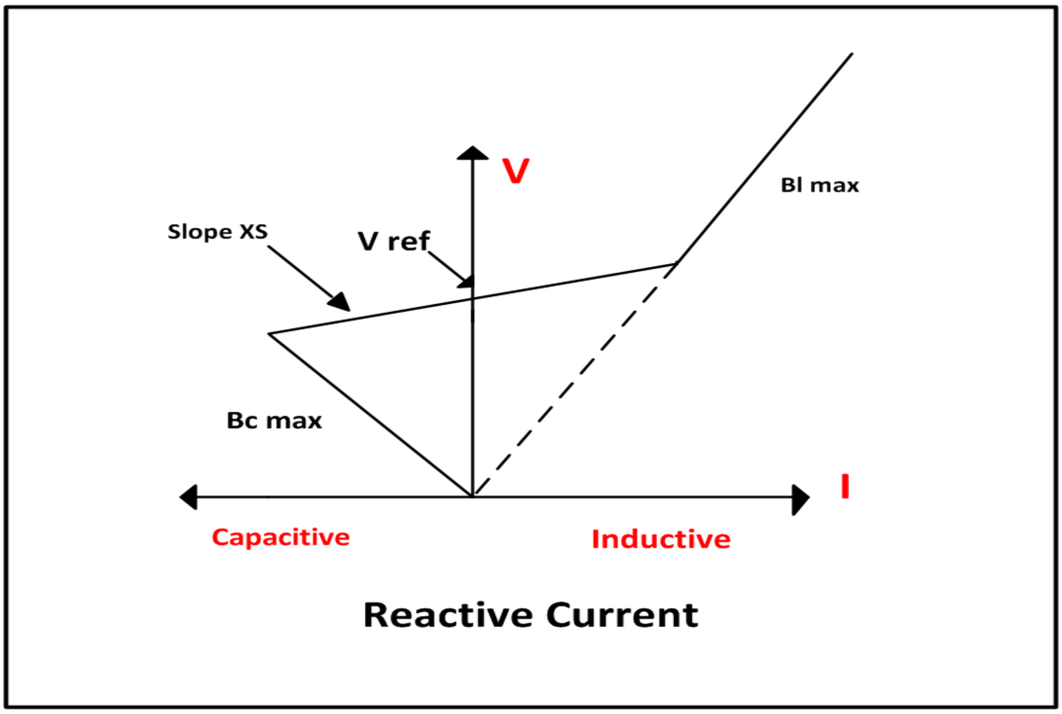

Figure-4. SVC V-I Characteristic.

The voltage is kept at its reference value (Vref) provided that the SVC susceptance (B) lies between the max and min values forced by the sum reactive power of reactor banks (BI_{max}) and capacitor banks (BC_{max}). Though, a droop in voltage is usually used typically between (1% - 4%) of max reactive output power and the slope of V-I characteristic is shown in the Figure-4 The following three equations are used to describe the V-I characteristic.

$$V = \begin{cases} V_{ref} + Xs \cdot I & \text{if SVC is in regulation range } (-Bc_{max} < B < Bl_{max}) \\ -\dfrac{I}{Bc_{max}} & \text{if SVC is fully capacitive } (B = Bc_{max}) \\ \dfrac{I}{Bl_{max}} & \text{if SVC is fully inductive } (B = Bl_{max}), \end{cases}$$

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Dynamic response of SVc

In voltage regulation mode, the speed of SVC reaction to system voltage variation is dependent on the gains of voltage regulator i.e. integral gain (K_i) and proportional gain (K_p), the system strength and the droop reactance (X_s).

In case of voltage regulator of integral-type i.e. when Kp =0, if average time delay (T_d) and voltage measurement time constant (T_m) resulting because of valve firing are ignored, approximation of the closed-loop system having power system and SVC can be done by a 1st order system which has the subsequent closed-loop time constant.

$T_c = 1 / (Ki(Xs + Xn))$

Where

T_c Closed loop time constant

Ki Proportional gain of the voltage regulator (pu_B/pu_V/s)

Xs Slope reactance pu/Pbase

Xn Equivalent power system reactance (pu/Pbase)

RESULTS AND DISCUSSIONS

After designing a model, its dynamic behaviour can be simulated using any of the available mathematical integration options by either writing commands in MATLAB Command Window or directly in Simulink. In order to run a set of simulations, commands are more helpful practically. For instance, while performing Monte Carlo simulations, MATLAB scripts can be used to apply a certain factor on a set of values.

Simulation results can be viewed via scope or other available display blocks. The parameters can also be changed to observe the effects on outcome. MATLAB allows saving these simulation results for getting an idea or post processing.

Analysis tools

Trimming and linearization tools are included under this category. Besides it also includes various other tools in MATLAB and its application toolboxes. Since Simulink is being integrated with MATLAB; simulation, analysis and revision of models can be done inany of these environments.

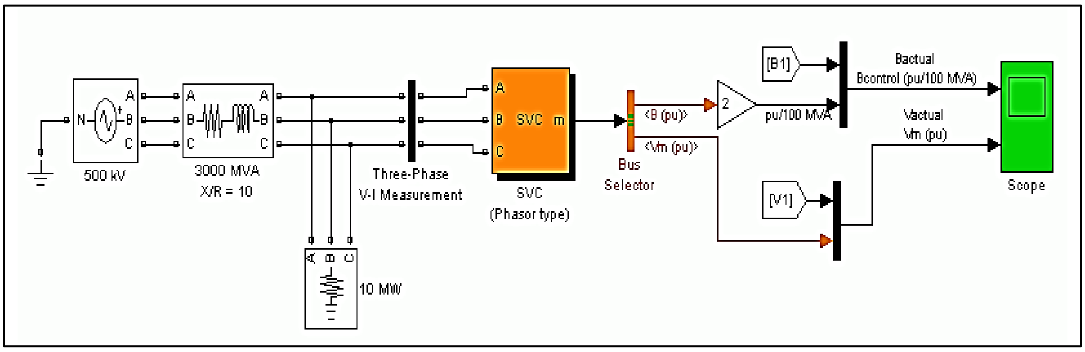

Figure-5. Steady State and Dynamic Operation of SVC Regulation Voltage (+200Mvar / -100 Mvar).

In block menu of SVC, the voltage regulation mode is selected having Vref equal to 1.0pu. The droop reactance is set to be 0.03pu/200 MVA which gives a voltage variation from (0.97pu–1.015pu) when fully capacitive SVC current goes to fully inductive. To get the (V-I characteristic) of SVC, the blue block should be double clicked. As shown in Figure-5.

The Programmable 3-Phase voltage source is employed for varying the voltage of system and observing the performance of SVC. At the start, nominal voltage i.e. 500kV is generated by the ource. Afterwards, there is a sequential decrease in voltage (0.97pu @ t = 0.1sec), followed by an increase (1.03pu @ t = 0.4sec) and lastly the nominal value is attained (1pu @ t = 0.7sec).

The simulation is run and the dynamic response of SVC with respect to voltage is observed on scope.

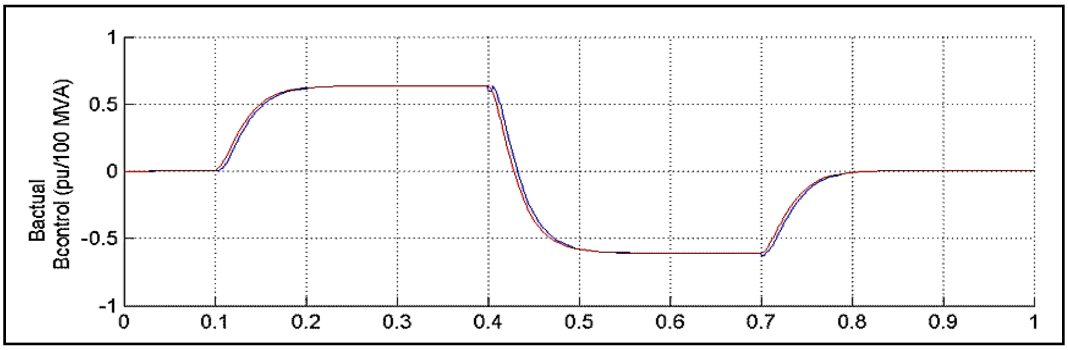

Figure-6. Bactual voltage regulator control signal output B.

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The real positive-sequence of susceptance B1the voltage regulator control signal output B is shown in above Figure-6.

Figure-7 illustrates the positive-sequence voltage of real system and output voltage of SVC measurement system.

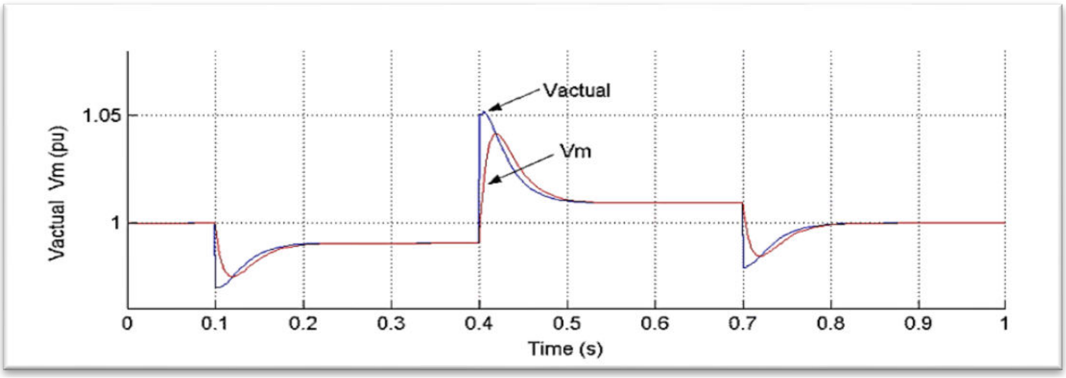

Figure-7. Vactual and Vm.

The speed of SVC response is dependent on the integral gain of voltage regulator i.e. Ki (While proportional gain, Kp=0), droop reactance i.e. Xs and strength of system i.e. Xn.

Since the approximation of system can be done as 1st order system with a closed-loop time constant equal to 1/ (Ki(Xs + Xn)), if average delay in time (Td) and time constant for measuring voltage Tm are being neglected.

The system can be approximated by a first-order system having a closed-loop time constant:

Tc = 1 / (Ki(Xs + Xn))
Ki 300
Xn = 0.0667pu/200 MVA
Xs = 0.03pu/200MVA

Using these values, the closed-loop time constant comes out to be 0.0354 sec.

By increasing the gain of regulator and decreasing strength of system, Tm and Td become significant and an oscillatory response is being observed which eventually leads to instability.

The Figure-8 gives a comparison of SVC susceptance (B output of the voltage regulator) at two different short-circuit levels: 600MVA and 3000MVA.

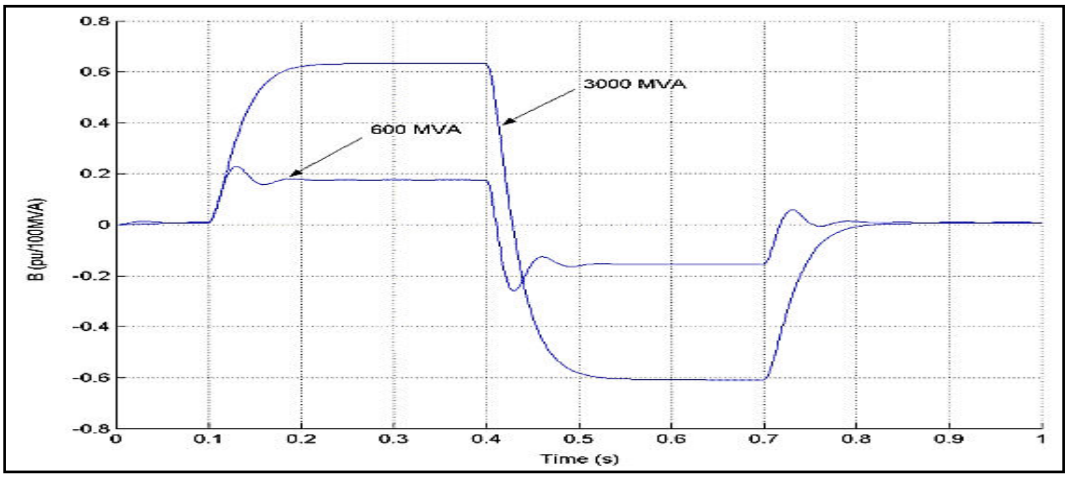

Figure-8. Comparison of SVC Susceptance.

CONCLUSIONS

Static VAR compensators are utilized for solving issues of reactive power systems. Implementation of static VAR compensator can be helpful in enhancing the quality performance of the power systems. Moreover, system allows the regular monitoring of inductive to capacitive system with faster response time. By using system, voltage and phase are also controlled in a better way. Network losses may also be reduced by implementing static var systems. Other advantages include grid voltage stabilization, improved power delivery, reduced damp oscillations, and better monitoring of harmonic in power systems. In future, it is intended to consider simulation of metal oxide in the thyristor. Such device may be utilized in power grid systems in future.

In past years, generation of power is affected by man environmental conditions and cost of the power system and lines installation. This became the reason for making necessary developments in the existing power systems

There are many advantages of installing FACTS systems such as dynamic reactive power compensation with stability mechanism in steady-state and transient systems, voltage regulation with enhancement in power delivery mechanism, reduced transmission line losses etc. All of the applications lead towards the design and implementation of FACTS y factors such as energy crisis, environmental conditions, and cost of the power system and lines installation. This became the reason for making necessary developments in the existing power systems

There are many advantages of installing (SVC) systems such as dynamic reactive power compensation with stability mechanism in steady-state and transient systems, voltage regulation with enhancement in power delivery mechanism, reduced transmission line
Advantages of (SVC) controller

Monitoring and control of steady state voltage

- Regulating steady state power flow on transmission line
- Improvement in transient stability

LIST OF ABBREVIATION

FACTS Flexible Alternating Current Transmission System:

SVC	Static Var Compensator
TSC	Thyristor Switched Capacitor
TCR	Thyristor Controlled Reactor
KP	Proportional Gain
KI	Integral Gain
Tc	Closed Loop Time Constant
Xs	Slope Reactance (pu / pbase)
Xn	Equivlent Power System Reactore (pu/ pbase)

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