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# Modelling and Simulation of SVC for Enhancing Voltage & Reactive Power Compensation

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*Abstract*— This paper deals with modelling and simulation of SVC (TSC-TCR) in power System with variable load for Efficient Voltage regulation. The effect of reactive power compensation has been analysed with and without SVC. Simulations of the SVC were carried out for A.C. transmission lines in MATLAB Simulink platform. Simulation results prove that the SVC is capable for Efficient Voltage regulation with proper reactive Power support.

***Key words:*** Static VAR compensator (SVC), TSC-TCR, Voltage Regulation, FACTS

## I. INTRODUCTION

Transmission systems are becoming increasingly stressed because of growing demand and because of restrictions on building new lines. However, most high voltage transmission systems are operating below their thermal rating due to such constraints as stability limits [1]. 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 [2] 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.

FACTS mainly find applications in the following areas:

- Enhanced power transfer capability
- Improved system stability and power quality
- Reduced environmental impact
- Reduced transmission losses

Following types of FACTS devices are used to enhance the performance of transmission system:

(1) Shunt Devices

- Static Var Compensator (SVC)
- Static Synchronous Compensator (STATCOM)

(2) Series Devices

- Thyristor Controlled Series Capacitor (TCSC)
- Static Synchronous Series Compensator (SSSC)

Two types of SVCs are used frequently.

- Fixed Capacitor-Thyristor Controlled Reactor (FC-TCR)
- Thyristor Switched Capacitor-Thyristor Controlled Reactor (TSC-TCR)

## II. 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. 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. When system voltage is high, it absorbs reactive power. The variation of reactive power is performed by switching capacitor banks and firing of inductor at different angle connected on the secondary side of a coupling transformer.

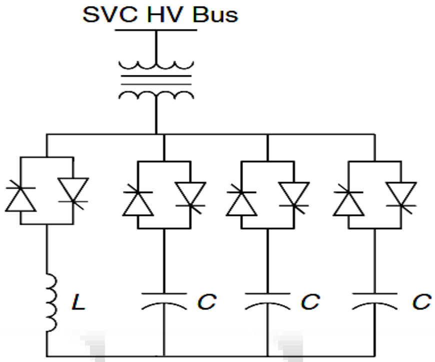

Fig. 1: Circuit Diagram of the TCR-TSC

The TSC–TCR compensator shown in Figure1 usually comprises n TSC banks and a single TCR that are connected in parallel. The rating of the TCR is chosen to be 1/ n of the total SVC rating. The TSCs of an SVC can only be switched in or switched out. Because of this, the amount of reactive power supplied by the TSCs can only be adjusted by steps by changing the number of TSCs that are switched in at the same time. The higher the number of TSCs that are switched in, the higher the amount of reactive power supplied by the TSCs. The TCR, on the other hand, can be adjusted as needed from a full-conducting state (TCR firing angle = 90°) to a non-conducting state (TCR firing angle = 180°), thereby allowing precise and continuous adjustment of the amount of reactive power which the SVC exchanges with the ac power system to which it is connected.

As the size of TCR is small, the harmonic generation is also substantially reduced. The main motivation in developing TSC–TCRs was for enhancing the operational flexibility of the compensator during large disturbances and for reducing the steady-state losses.

## III. MODEL SYSTEM OF SVC

In order to investigate the impact of SVC on power systems, appropriate SVC model is very important. In this section, SVC and its mathematical model will be introduced. SVC is built up with reactors and capacitors, controlled by thyristor valves which are in parallel with a fixed capacitor bank. It is connected in shunt with the transmission line through a shunt transformer and thus, represented in Figure 1. Figure 2 shows the equivalent circuit at which SVC is modeled.

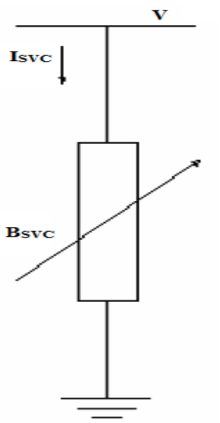

Fig. 2: Equivalent Circuit of SVC

The model considers SVC as shunt-connected variable susceptance, BSVC which is adapted automatically to achieve the voltage control. The equivalent susceptance, Beq is determined by the firing angle α 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

$$Beq = B_L(\alpha) + Bc$$

$$B_L(\alpha) = -\frac{1}{\omega L}\left(1 - \frac{2\alpha}{\pi} - \frac{\sin(2\alpha)}{\pi}\right)$$

$$Bc = \omega C \text{ and } 0^0 \leq \alpha \geq 90^0$$

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

$$P_{SVC}=0$$

$$Q_{SVC} = -V^2 B_{SVC}$$

Where V is the bus voltage magnitude

As the reactive power demand at the bus varies, the susceptance is varied subject to the limits. However, the reactive power is a function of the square of the bus voltage. Hence the reactive power generated decreases as the voltage decreases.

## IV. SIMULATION AND RESULT DISCUSSION

The aim of the simulation is to determine the relationship between loading and voltage on receiving side. With the increase in loading, the voltage at the receiving end side dips. Voltage sags are more pronounced when the inductive loading is present. The Test system parameters with their values and units are shown in table I.

| Sr. No. | System Quantities | Parameters Value |
|---|---|---|
| 1. | Source | 1-phase,<br>11 kV (L-L), 50 HZ. |
| 2. | Transmission line | R=1 Ω , L= 5 mh |
| 3. | Load (L1) | RL load:<br>Active power = 400 kW<br>Reactive Power=200kVAR<br>(Inductive) |
| 4. | TSC-TCR parameters | TSC : C1 = C2 =C3 = 9μF,<br>TCR : L = 57 mH |

Table 1: Test System Parameters

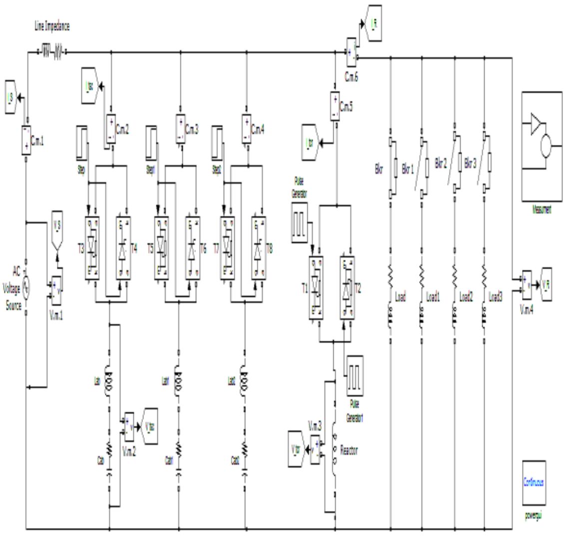

Fig. 4: Simulink Model Of Test System-1

(1) Without TSC-TCR

| Vs (kV) | Qs (MVAR) | Load | Vr (kV) | Qr (MVAR) |
|---|---|---|---|---|
| 11.00 | 0.2 | L1 | 10.93 | 0.197 |
| 11.00 | 0.4 | 2L1 | 10.87 | 0.390 |
| 11.00 | 0.60 | 3L1 | 10.80 | 0.578 |
| 11.00 | 0.80 | 4L1 | 10.74 | 0.763 |

Table 5.11: System Parameters without TSC-TCR

(2) With TSC-TCR

| C | α° | Vs (kV) | Qs (K VAR) | LOAD | Vr (kV) | Qr (M VAR) |
|---|---|---|---|---|---|---|
| 1 | 157° | 11 | 6.5 | L1 | 10.96 | 0.19 |
| 2 | 152° | 11 | 12.6 | L2 | 10.92 | 0.39 |
| 2 | 162° | 11 | 15.1 | L3 | 10.89 | 0.58 |
| 3 | 155° | 11 | 20.9 | L4 | 10.85 | 0.77 |

Table 5.12: System Parameters with TSC-TCR

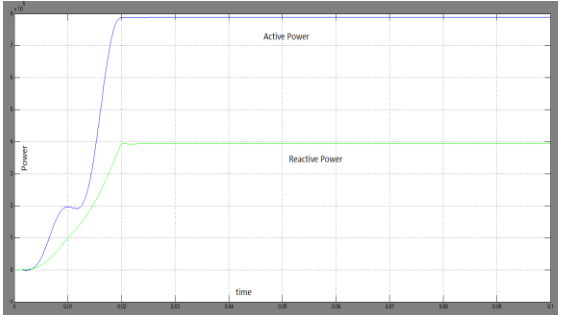

Fig. 5 (a)

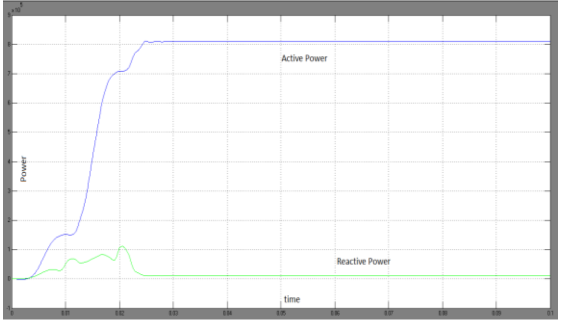

Fig. 5 (b)

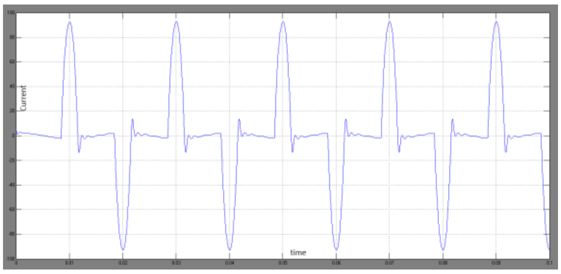

Fig. 5 (c)

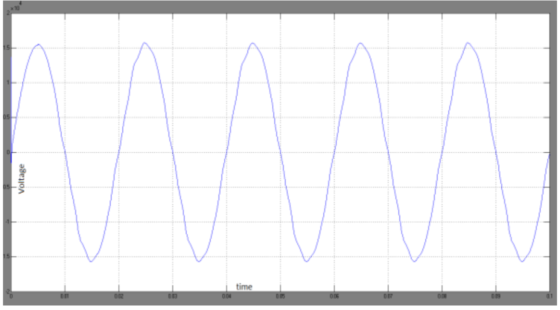

Fig. 5 (d)

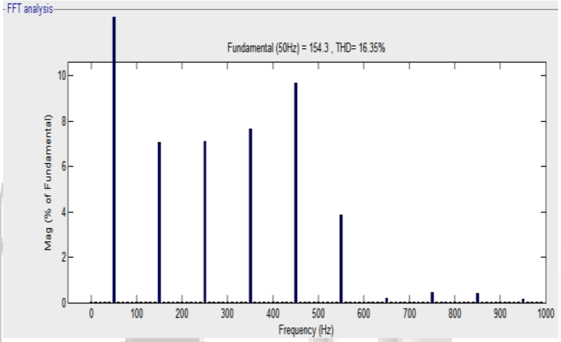

Fig. 5 (e)

Fig. 5: (A) Active & Reactive Power Without TSC-TCR (B) Active & Reactive Power With TSC-TCR, (C) $I_{tcr}$ For A° = 152,(D) Voltage At Load Side, (E) FFT Analysis of TSC-TCR

In Table no. I & II show the results for before and after compensation. The table shows that Voltage before compensation of SVC is 10.74 kV and after compensation it increased up to 10.85 kV.

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## VI. CONCLUSION

From the simulation results for TSC-TCR using MATLAB Simulink it is found that suggested scheme can effectively use to control voltage and reactive power profile. Simulation results also show that TSC-TCR is effective compensation technique compare to mechanical operated or other dynamic power flow controllers. Different load conditions have been checked on simulation to investigate the importance of coordination between Thyristor Switched Capacitor - Thyristor Controlled Reactor (TSC -TCR).

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