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Static VAR Compensator for Weak Grid Systems

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Abstract**—**In our daily routine life majority of electric loads usedare inductive in nature. Adequate supply of active power and reactive power must be supplied to these loads to ensure proper operation. If not provided with required active power and reactive power, these inductive loads burdens the system unnecessarily. Hence resulting in low power factor.In a local electrical distribution system it in uneconomical to upgrade existing network for improvement of power factor.In weak grid system residential consumers use voltage stabilizers to cope up with poor quality of voltage, while industrial consumers use switched capacitors. But voltage stabilizers regulate the voltage on cost of drawing more current from system. On the other hand switched capacitors technology is not robust enough to handle instant variations in power demand. Low power factor on local grid systems can be addressed using static var compensators. In this paper designing of SVC for local grid system is discussed.

Keywords**—** Static VarCompenstor (SVC), Thyristor switched capacitor (TSC), Thyristor controlled reactor (TCR), Gate turn off thyristor (GTO), Flexible alternating current transmission systems (FACTS)

I. Introduction

In this modern era stable supply of electricity is need of everyone. [1] Electric power system consists of generation, transmission and distribution. Electricitiy is generated at power station by means of different sources, that can be either hydal, wind, nuclear or thermal energy. Generated electricity is transmitted to grid stations through transmission system. End consumers are connected to electric power system via distribution system. Grid is unnecessarily loaded if consumers are supplied with poor power quality. As to compensate with poor power quality consumer employ different methods which aren't effective enough. Residential consumers uses voltage stabilizers. If voltage at consumer end is lower than nominal voltage then voltage stabilizer stepup the voltage on cost of drawing more current from system. As an accumulative result voltage stabilizers draws more reactive power from system. [2] [4] Industrial consumers uses switched capacitors. However control of switched capacitor is manual and can't be used under varying voltage. Therefore a compensating device is required which can compensate for reactive power support according to system requirement.[3] [5]Static var compensator (SVC) is used for power quality improvement under dynamic conditions. But flexibility of SVC is limited for local grid station. In this paper detailed design for SVC is discussed. Designed model is simulated in MATLAB for different loading conditions & results are obtained for different scenarios.

II. Static var Compensator (SVC)

First static var compensator (SVC) was installed in 1987. They are considered to be first generation of FACTs devices. SVC is a shunt compensating device. [6] SVC is used in electric power system for reactive power compensation and to provide voltage support. SVC has three basic configurations: Thyristor switched capacitor (TSC), Thyristor controlled reactor (TCR) and combination of both TSC & TCR.

A. Thyristor switched capacitor (TSC)

[7] Thyristor switched capacitor consists ofthyristor valves, current limiting reactor and power capacitor.Thyristor valve consists of two inverse parallel thyristors in parallel to eachother. As thyristor allows current in one direction, that's why this inverse parallel thyristor symmetry is needed. Thyristor valves are added in series to withstand line voltage. TSC is used to add leading reactive VARs to system. TSC can be switched on or switched off using thyristor valve. But TSC can't be operated in phase control fashion. Blocking / deblocking of TSC can only be varied in steps. However proper care must be taken while deblocking TSC. Optimum time to unblock a TSC is when line voltage is at minimum. Any sudden excitation or misfiring will damage thyristor valve.

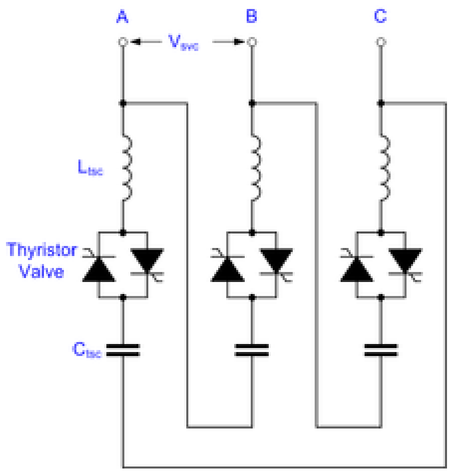

Figure-1: Thyristor Switched Capacitor (TSC)

B. Thyristor Controlled Reactor (TCR)

Thyristor controlled reactormainly consists of thyristor valves and inductor (reactor). TCR is used to limit the voltage and improve power factor on lightly loaded transmission lines. For capacitive power factor of system, TCR is used to add reactive (inductive) power to system. TCR can be operated in phase controlled fashion. Reactive power delivered to system can be adjusted by varying the firing angle for thyristor valve. Unlike TSC, TCR generates high harmonics. [8] TCR is usually connected in delta fashion to filterthese harmonics.

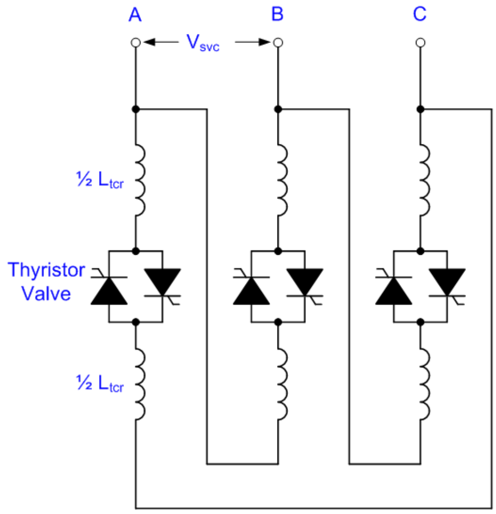

Figure-2: Thyristor Controlled Reactor (TCR)

C. *Combination of TSC and TCR*

TSC and TCR are oftenly used in combination to provide more flexibility to compensation of reactive power. Their combination is known as SVC. SVC can be used to provide lagging or leading VARs according to system demand. SVC isn't installed directly on main line, rather its connected through a stepdown transformer. This reduces number of components that are to be used in SVC designing.

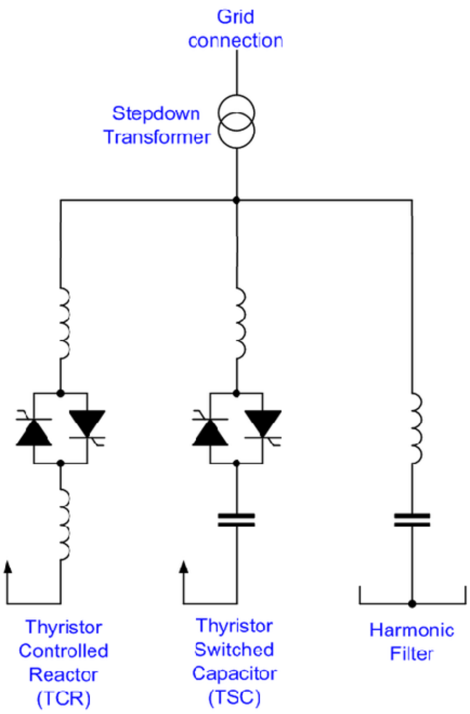

Figure-3: Static VAR Compensator (Combination of TSC & TCR)

III. Designing of Static VAR Compensator

Static VAR compensator consists of mainly two components, TSC and TCR. Figure 4 is showing thyristor switched capacitor which is designed in Simulink (MATLAB).

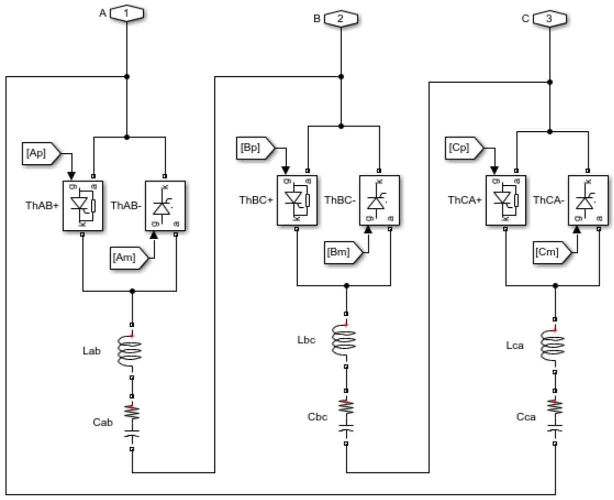

Figure-4: Three Phase Thyristor Switched Capacitor Block (Simulink)

Three branches of TSC are connected in delta fashion. TSC is consisting of capacitor, inductor and thyristor valves. [9] Thyristor valve control the injection of reactive power from TSC to system by means of firing angle. Firing angle is controlled by external circuitry. Firing angle is increase or decreased by control circuit depending on reactive power need. Value of capacitor to be used depends upon system reactive power need. [10] The equation which relates reactive power with capacitance is given by:$Q_C = V_{L-L}^2 \times 2 \times \pi \times f \times C$ In this model each capacitor has value of 0.2F to provide a reactive power support of 30MVAR (leading). Reactor (Inductor) is used to protect the capacitor from incoming surges of currents. [11] Inductor must have a value of$L_R = (0.67 * C) \times (V_{max}/ I_{max})^2$. Value of current limiting reactor in this case is set to be 0.3uH. Figure 5 is showing thyristor switched reactor block.

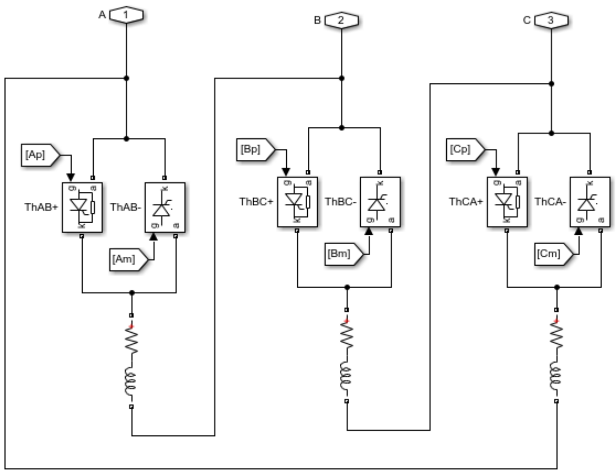

Figure-5: Three PhaseThyristor Controlled Reactor Block (Simulink)

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In SVC thyristor controlled reactor (TCR) is used alongside thyristor switched capacitor (TSC). TCR is used to limit the voltage. Also during transient period TCR provides lagging VARs to system whenever needed. Injection of reactive power from TSC and TCR is controlled by switching of thyristor valves with application of gating pulses. These gating pulses control blocking and deblocking of SVC. Control circuit generates these measurements by instant measurements of system reactive power consumption. Figure 6 is showing control blocks for SVC.

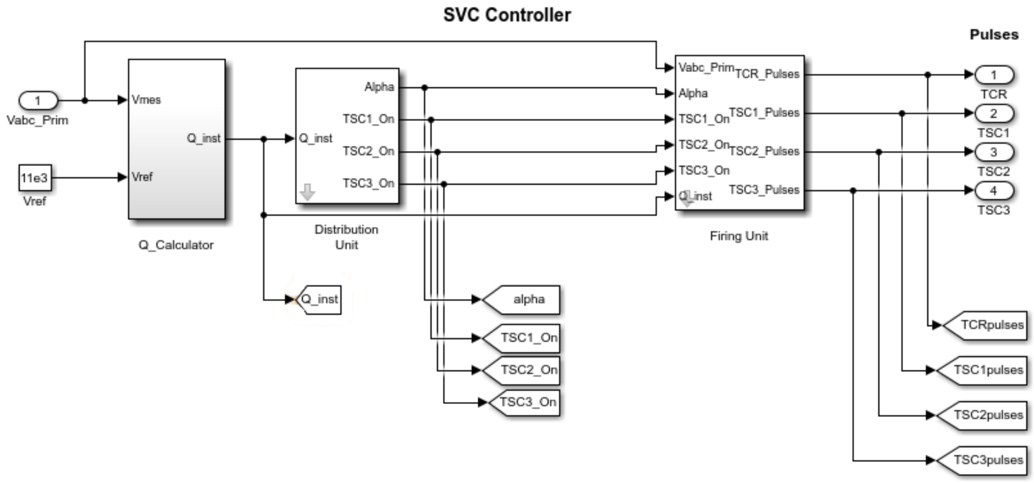

Figure 6: SVC Controller

SVC controller measures Q of the system. Depending on value of Q, distribution unit turns on or turns off TSC units. Each TSC unit can provide upto 30MVAR (ld) support. If required reactive power is within range of 30MVAR then only first TSC is switched on. For 31-60 MVAR range both TSC 1 and TSC 2 are switched on. And they both provide equal reactive support. For example, required reactive support is 40 MVAR, then both TSC 1 and TSC 2 will provide 20MVAR each. If required compensation is above 60MVAR then TSC 3 is also switched on. Firing unit generates gating signals for thyristor controlled rectifier and thyristor switched capacitor. In this simulation gate turn off thyristor was used. Advantage of using gate turn off thyristor is that it can be turned on or turned off at any instant using gate signals. While a simple thyristor can only be turned on using gate signal. It turns off only when the polarity reverses. But in case of gate turn off thyristor it can be brought into conduction state by applying gate signals also it can be switched off by using gate signal of opposite polarity. That's why switching of gate turn off thyristor can be fully controlled by external gating signals.Figure 7 is showing gating signals for thyristor valves.

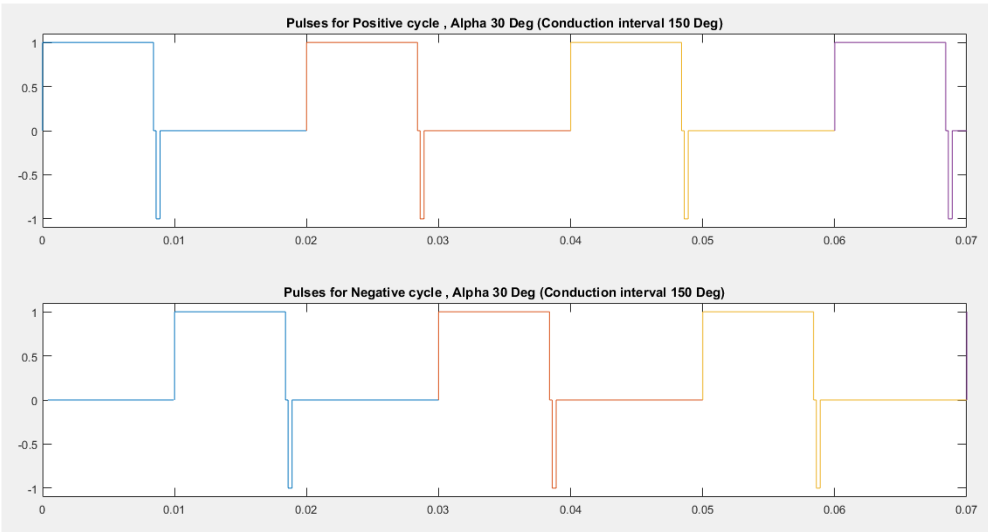

Figure 7: Gating signals for conduction interval of 150 degree

IV. SIMULATION & RESULTS

Designed model is simulated for different loading conditions. Voltage and current graphs are plotted for simulated scenarios. For each loading condition system is first simulated without SVC. Power factor of each loading condition is noticed initially. Then system is simulated for same loading condition with SVC. Effect of SVC on power factor improvement is then observed under each loading conditions.It is observed that SVC compensates for cosumed reactive power and power factor of system is improved. Following figure is showing results for different loading scenarios.

Active Load (MW)	Reactive Load before Simulation (MVAR Lg)	Power Factor before Simulation (Lg)	Power Factor After Simulation (Lg)	Compensated (MVAR)
25	12	0.9	0.94	3
25	15.5	0.85	0.96	8.5
50	24.2	0.9	1	24.2
50	37.5	0.8	0.98	28.8
50	45	0.75	0.96	31.2
100	62	0.85	0.96	34
100	75	0.8	0.94	39.5

Figure 8: Results Table

In above figure column 1 and 2 are specifying the loading conditions. Column 3 is showing power factor of system before compensation by SVC. Column 4 is showing power factor of system after compensation by SVC. In each scenario power factor is greatly improved. Following figures shows voltage and current waveforms for loading condition for 50MW active load and 24MVAR lagging reactive load.

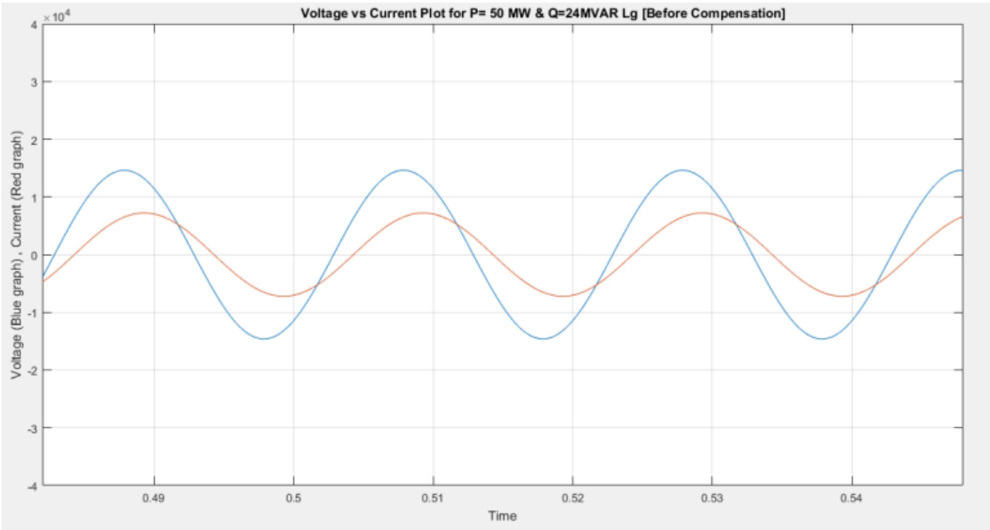

Figure 9: Voltage vs Current Graph (Before Compensation)

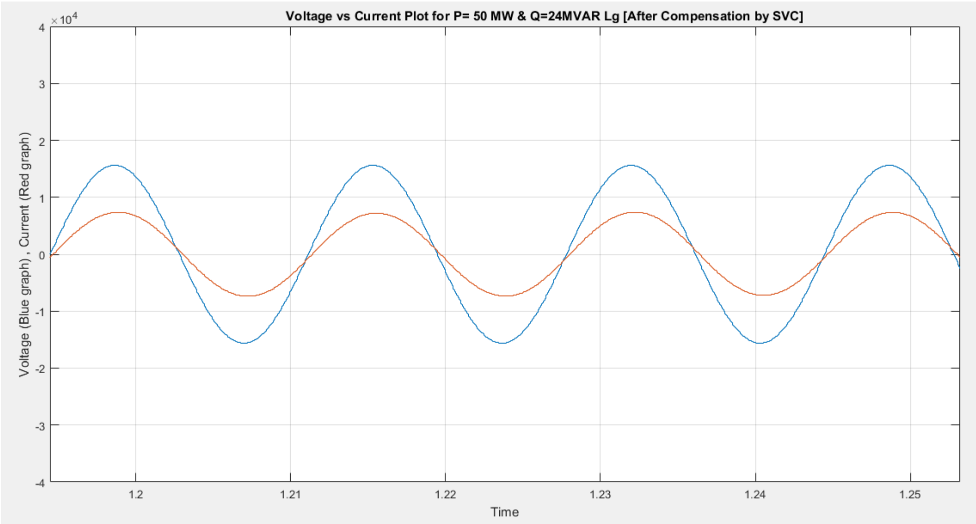

Figure 10: Voltage vs Current Graph (After Compensation)

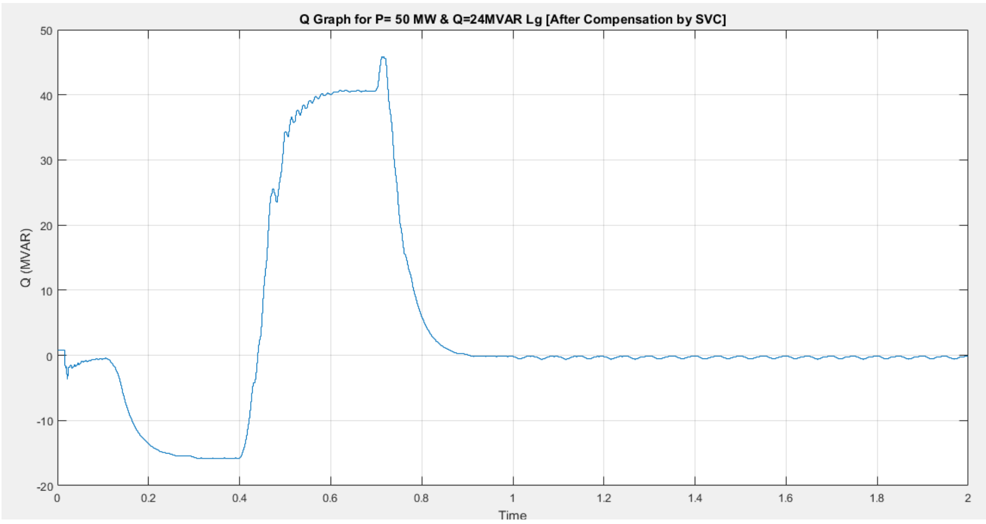

Figure 11: System Q Graph

Results of simulation shows that SVC has compensated for system reactive power within 0.8 secs. After 0.8 sec system response becomes stable, & power factor is improved to unity.

CONCLUSION

The work presented in this paper is about use of SVC on weak grid lines for voltage support, compensation of reactive power and improvement of power factor. The model presented in this paper was simulated in MATLAB. From results it can be concluded that with help of phase controlled SVC real time power factor improvement can be done in comparatively short time. Harmonics generated by switching of SVC are nullified if gating signals are provided to SVC at appropriate time. With improvement in power factor, demand of reactive power will decrease and hence burden from local grid stations will decrease.

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