Investigation of Control Strategies of Svc to Improve Voltage Profile in Grid System

Gaurav Srivastava¹, Praveen kumar², Prof. Sunil kumar Goel³

¹Assistant Professor, ²Associate Professor, ³Professor, Electrical Engineering, Meerut Institute of Engineering & Technology, Meerut, India

Abstract—In this paper the control strategies of svc are described. Svc is used to stabilize the voltage profile in a grid system. In the designing of svc there is a combination of three TSC’s and one TCR. The svc consists of a group of shunt connected capacitor banks and inductors with fast speed of response afforded by thyristor switching. The svc provides the required amount of reactive power compensation at its point of connection by adjusting the fundamental frequency components of the current drawn by the TCR. Depending on the equivalent reactance, i.e. capacitive or inductive, the svc is capable of either drawing or supplying reactive power. In this paper the control strategies of svc is described at different conditions of system voltage that how it controls the grid voltage at different conditions.

Keywords—{Flexible a.c. transmission system (FACTS), Static var compensator (SVC), Thyristor controlled reactor (TCR), SVC Controller, Thyristor switched capacitor (TSC), Power electronics, Thyristors etc.}

I. INTRODUCTION

The modern power systems are very much unsecure because of voltage instability. This is due to large transmission networks, load model of different types, many generating stations, buses and deregulation of electric industries. The power systems has mainly the problem of voltage collapse because of less reactive power support. So to maintain the system voltage within desired limit, reactive power support is very much necessary. This task is accomplished by FACTS Controllers[1] that improves the overall performance of the power system.

The primary objectives of shunt compensator in both a transmission and distribution system is to increase the transmitted power in the transmission lines are as follows:

- To compensate poor load power factor to make the current drawn from source having nearly unity power factor.
- Suppression of harmonics in loads to make the current drawn from source nearly sinusoidal.
- Proper voltage regulation of the system voltage fluctuations due to the loads that cause it.

- To prevent the voltage instability of loads having poor power factor by supporting the end of line voltage. This increases the maximum power transmission capability of the transmission line while improving the voltage instability limits.
- Improvement of transient stability margin by increasing the maximum transmittable power in the transmission line.
- Damping out oscillations in the machine angle by exchanging active (real) power with the power system.

II. STATIC VAR COMPENSATOR

Static var compensators, regarded as the first FACTS controllers, have been used in North American transmission systems since late 1977 in western Nebraska [6].

According to definition of IEEE PES Task Force of FACTS Working Group: [3]

Static Var Generator or Absorber: A shunt-connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage) [1].

In this paper, the svc consists of three Thyristor switched capacitors (TSC’s) connected in parallel and one thyristor controlled reactor (TCR) for continuous control of reactive power. The term, “SVC” has been used for shunt connected compensators based on thyristors without gate turn-off capability. It includes separate equipment for leading and lagging vars; the TCR for absorbing reactive power and TSC for supplying the reactive power[3],[7].

The main element of SVC is an a.c. power semiconductor switch called “thyristor valve” which is used for rapid, continuous control of the effective shunt susceptance at a specific location in a transmission system by a set of inductors and capacitors [1].
TCR is composed of a fixed reactor and a bidirectional thyristor valve (Fig. 1). With the firing angle \( \alpha \), i.e. the angle between the peak of the voltage and the instance of firing the thyristor valve, the effective susceptance of the device is varied. In case of the TCR, the control of the firing angle is continuous.

\[
I_{1}(\alpha) = \frac{V}{\omega L} \left( 1 - \frac{2}{\pi} \alpha - \frac{1}{\pi} \sin 2\alpha \right)
\]

The equation (1) can be written as [1],

\[
I_{1}(\alpha) = V B_{TCR}(\alpha)
\]

\[
B_{TCR}(\alpha) = B_{\text{max}} \left( 1 - \frac{2}{\pi} \alpha - \frac{1}{\pi} \sin 2\alpha \right)
\]

Where, \( B_{\text{max}} = \frac{1}{\omega L} \), \( \left\{ -\frac{1}{\omega L} \leq B_{TCR}(\alpha) \leq 0 \right\} \)

The variation in \( \alpha \) varies the susceptance due to which fundamental component of current changes and it controls the reactive power absorbed by the TCR.

The capacitor banks are continuously on/off by TSC. The distribution unit of SVC controller determines the number of TSC’s required for reactive power control. So SVC operates in inductive and in capacitive mode by the combination of TCR and TSC’s [1].

III. SVC CONTROL SYSTEM

The Working of different units of control system is as given below:

a) Measurement system measures the positive sequence voltage which is to be controlled. The positive sequence voltage which is to be controlled is measured by measuring unit. A fourier based measurement system that uses a one-cycle running average is used.

b) Voltage regulator unit determines SVC susceptance \( B \) to maintain the system voltage constant. It is the main unit of SVC controller and uses voltage error which is the difference between the measured voltage (\( V_{\text{meas.}} \)) and reference voltage (\( V_{\text{ref.}} \)).

c) Distribution unit computes the firing angle alpha for TCR and number TSC’s are determined by this unit. TSC automatically switches on/off the capacitor banks.

d) Synchronizing unit has a Phase locked loop. The PLL is synchronized at the secondary voltage level. The pulse generator sends pulses to the thyristors.

The main tasks to meet the reactive power requirement of a grid system, the SVC controller has to determine the number of TSCs required for proper control of reactive power and firing angle alpha for TCR to switch TSCs in and out so as to match the required number of TSC’s determined above. It has to control the TCR firing angle so that the amount of reactive power which the TCR absorbs meets the desired value. It has to properly control the switching of TSCs for transient free operation (minimizing voltage transients in grid system).
IV. TEST SYSTEM MODEL

For the test model an SVC is designed to regulate the grid voltage of a 200-KV, 100-MVA system having frequency 50 hz. It has a coupling transformer of 220KV/11KV, 2000 MVA is connected to supply system and on the secondary side of transformer, one TCR (109-MVAR) and three TSC’s (94-MVAR each) are connected [9]. The main reason of using the transformer is to reduce the size and no.of components required in the SVC system due to low voltage at the secondary side of transformer. The simulink model of the test system is as shown in fig. The TCR absorbs the reactive power from the supply system to maintain system voltage within limit by the variation in firing angle while TSC supplies reactive power to the supply system to maintain system voltage constant.

The proper working of SVC controller is explained with the proper simulation of test model at different system voltages. The reference voltage is set at 1.0 pu and the analysis is done at different system voltages that how SVC controller maintains the grid voltage constant by the proper operation of TCR and TSC’s. The simulation results also explain the proper operating principle of TCR and TSC’s in order to obtain the susceptance required by the voltage regulator.

V. SIMULATION RESULTS

Results at different instants of system voltage:-

The reference voltage is set at 1.0pu. The results obtained by the simulation of test model describes the control strategies of SVC when system voltage is different at different instants. The SVC is set in voltage control mode.

Figure 6 shows the resulting waveforms of the test system at different instants. It includes the resulting waveforms of grid voltage and current, reactive power required to improve voltage profile, measured voltage with respect to the reference voltage (1.0 pu), firing angle alpha required for TCR, number of TSCs determine by the distribution unit and the secondary voltage. The test system is set at voltage regulation mode with the parameters of system voltage in pu [1.0 1.025 0.96 1.0] at instants [0 0.1 0.4 0.7] seconds.
Figure 7 shows the voltage across the load. The voltage waveform is almost sinusoidal in nature. The voltage across load is at the desired limit. The waveform shows that the SVC perfectly compensates the voltage fluctuations at the receiver end of the ac transmission line in less than about 7-8 cycles, no matter whether load decreases or increases.

Results When system voltage is 1.025 pu:-

Now the analysis of control strategies of SVC is done when the system voltage is taken at 1.025 pu.

Figure 8 shows the waveforms of grid voltage and current when the system voltage goes to 1.025 pu. The grid voltage is constant at 1.0 pu. During the interval 0.1 to 0.3, the system voltage is 1.0 pu so the grid current is almost in phase with the ac system voltage. At instant 0.3 second, the system voltage goes high to 1.025 pu so the system delivers reactive power or the TCR absorbs reactive power. So the grid current is lagging in nature.

Figure 9: Results across Load

Figure 9 shows the waveform of current across the load when the system voltage is high as 1.025 pu. The current across load is sinusoidal in nature and at the desired limit. The waveform shows the voltage across load when the system voltage is high as 1.025 pu. After the reactive power compensation by SVC, the voltage waveform is almost sinusoidal in nature. The voltage across load is at desired limit. The waveform shows that the SVC perfectly compensates the voltage fluctuations at the receiver end of the ac transmission line in less than about 7-8 cycles. It shows the flow of active power from the ac supply system to the load. For the maximum flow of active power, the reactive power management is automatically done by SVC. At 0.3 second, the system voltage is high as 1.025 pu so TCR absorbs (40-Mvar) reactive power, the graph goes on positive. The TCR is in full conduction mode and all TSCs are out of service.

Results When system voltage is 0.96 pu :-

Figure 10 shows the results across SVC when system voltage is taken as 0.96 pu.

It shows the waveforms of grid voltage and current. The grid voltage is constant at 1.0 pu. During the interval 0.1 to 0.3, the system voltage is 1.0 pu so the grid current is almost in phase with the ac supply voltage. At instant 0.3 second, the system voltage goes low to 0.96 pu so the ac supply system absorbs reactive power or the TSCs deliver reactive power. So the grid current is leading in nature.

At the starting time, the TSCs are out of service and TCR absorbs 40-Mvar of the reactive power to maintain system voltage in desirable limit. On the other hand, the ac supply system provides reactive power to the TCR so the graph of reactive power ac of supply system is negative after 0.3 second. The TCR is in full conduction state (alpha = 90 deg.) shows the number of TSCs required for reactive power supply to the ac supply system. After 0.3 second only the TCR absorbs reactive power so all the TSCs are out of service. The secondary voltage is sinusoidal in nature and almost is equal to the reference voltage.
The graph of reactive power when the system voltage decreases to 0.96 pu. At 0.3 second when the system voltage decreases to 0.96 pu, TSCs are in working state and provide reactive power to the supply system or on the other hand, the ac supply system absorbs rective power to maintain the voltage at desirable limit. So the graph of system reactive power is positive due to absorbing the reactive power by ac supply system. It shows the number of TSCs to supply reactive power to ac supply system. After 0.3 second TCR is in non-conduction state that is alpha is 180 degree. Now all the three TSCs are one by one and supplies reactive power to the supply system to maintain the system voltage at desirable limit.

The waveform of alphashows that when the system voltage reaches to 0.96 pu at 0.3 second, TCR is in non-conducting state so the alpha is 180 degree. After the reactive power compensation, the alpha remains at 110 degree. Alpha decreases when TCR absorbs reactive power from the supply system. The results in the above figure indicate, the SVC maintains the voltage across the ac power system to which it is connected (i.e., the receiver voltage) virtually equal to the ac power network voltage (i.e., the sender voltage). Therefore, it is possible to conclude that an SVC perfectly compensates the voltage across the ac power system to which it is connected.

Results When system voltage is 1.0 pu:

Now the analysis of control strategies of SVC is done when the system voltage is taken at 1.025 pu.
Figure 12: Results across SVC

Figure 12 shows the graph of grid voltage and current. The grid voltage is constant as 1.0 pu. when the system voltage is 1.0 pu, the grid current is almost in phase with the grid voltage. It shows the waveforms of reactive power required to maintain the system voltage at desired limit. When the system voltage is 1.0 pu then the SVC is out of service and the reactive power is almost constant. When the amount of reactive power required to compensate the voltage in the ac power system connected to an SVC of the TCR-TSC type is null, all TSCs are switched out and the TCR is set to the non-conducting state (TCR firing angle 180°). But in practical case for a small error between measured voltage and supply voltage, only one TSC will work and will supply reactive power to the system. So the ac supply system absorbs a small amount of reactive power hence the graph of supply system reactive power goes on positive. The waveform shows the firing angle alpha required for TCR. For a small error only one TSC is working and the TCR is set to almost non-conducting state. After some time, it remains constant to 114 degree. For a small error signal, only one TSC will work for a certain period to supply reactive power to supply system. The secondary voltage is sinusoidal in nature and almost is equal to the reference voltage.

Figure 13: Results across Load

Figure 13 shows current across the load when the system voltage is 1.0 pu. The current across load is sinusoidal in nature and at the desired limit. It shows the voltage across load when the system voltage is 1.0 pu. After the reactive power compensation by SVC, the voltage waveform is almost sinusoidal in nature. The voltage across the load is at the desired limit. It shows that the reactive power require by the ac supply system is very low because the system voltage is nearly about to 1.0 pu. Hence active power that flows from ac supply system to the load is almost constant. The system voltage is at desirable limit so very low amount of reactive power compensation is required.

The parameters taken for simulation are as follows:-

- TCR branch Inductance=18.7 mH, TSC branch Capacitance =308.4μF, TSC branch Inductance =1.13mH, Hysteresis-distribution unit=0.1(pu/100MVA), Transformer nominal power=2000MVA, 50HZ, Transformer total leakage=0.15(PU/Pnominal.), Nominal secondary voltage =11KV(rms, ph-ph), Kp =60, Ki =1400 [9].

VI. CONCLUSION

The results obtained by simulation of the test system indicate that the SVC precisely compensates the voltage across the ac power system to which it is connected. On the other hand, a battery of shunt capacitors rarely achieves precise voltage compensation of the ac power system to which it is connected. This is because the selection of shunt capacitors available for voltage compensation is limited. Therefore, an SVC generally achieves a much more precise voltage compensation of an ac power system than a battery of shunt capacitors. Due to much smaller size of TCR in SVCs of the TCR-TSC type, it is less costly and more efficient (i.e., it has less power losses) than the larger TCR in SVCs of the TCR-FC type.

So this paper fully investigates the control strategies of Static Var Compensator (SVC) at different values of grid voltage to improve the voltage profile of grid system.

REFERENCES


BIOGRAPHIES

Mr. Gaurav Srivastava: is working as an assistant professor at Meerut Institute of Engineering & Technology Meerut in Electrical Engg. Department. He has more over 5 years of experience in teaching. His area of interest is Power electronics, FACTS and Control system.

('gauravsri007@gmail.com')

Mr. Praveen Kumar: is Working as an Associate Professor in the Department of Electrical Engineering, Meerut Institute of Engineering and Technology, Meerut. He has more than 12 years of experience in Industry and Teaching. His area of interest is power system, Facts, Power electronics and drives

('onlypraveen1@gmail.com')

Prof. S. K. Goel: is Working as a Professor and Head Electrical Engineering department at Meerut Institute of Engineering & Technology, Meerut since 1999. He has more than 25 years of experience in Industry and Teaching. He has worked in several industries, in both public and private sector. His area of interest include Electrical machines, Power system, FACTS.

('skgoel_miet@rediffmail.com').