ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 4, April 2017

Voltage Stability Improvement Using Static Var Compensators (SVC)

[1] Shanti Chaturvedi
Assistant Professor
Department Of Electrical Engineering
AC Patil College of Engineering , Kharghar Navi Mumbai

***Abstract*-— Flexible AC Transmission System (FACTS) controllers, such as the Static Var Compensator (SVC), employ the latest technology of power electronic switching devices in electric power transmission systems to control voltage and power flow, and improve voltage regulation. Given a profit-driven, deregulated electric power industry coupled with increased load growth, the power transmission infrastructure is being stressed to its upper operating limits to achieve maximum economic returns to both generator and transmission system owners. In such an environment, system stability problems such as inadequate voltage control and regulation must be resolved in the most cost-effective manner toimprove overall grid security and reliability. Static**

***Keywords*: FACTS, SVC, Var, voltage control**

I. INTRODUCTION

In recent years, thyristor controlled static var compensators are being used for fast reactive power control. Advances in high power semiconductors, microelectronics and digital controls which are already used in HVDC transmission systems have made this improvement possible. SVCs were originally developed for power factor compensation of fast changing loads (such as arc furnaces) in early 1970's but later (before the end of the decade) were adapted for dynamic shunt compensation of AC transmission lines. They are extremely fast in response (about 2- 3 cycles) and free from the problems of synchronous condensers (such as loss of synchronism and increased maintenance due to rotating parts). Electrical loads both generate and absorb reactive power. Since the transmitted load varies considerably from one hour to another, the reactive power balance in a grid varies as well. The result can be unacceptable voltage amplitude variations or even a voltage depression, at the extreme a voltage Var Compensators are being increasingly applied in electric transmission systems to economically improve voltage control and post-disturbance recovery voltages that can lead to system instability. An SVC provides such system improvements and benefits by controlling shunt reactive power sources, both capacitive and inductive, with state-of-the-art power electronic switching devices. This paper will discuss and demonstrate how SVC has successfully been applied to control transmission systems dynamic performance for system disturbances and effectively regulate system voltage. System and SVC modelling will also be discussed. collapse. A rapidly operating Static Var Compensator (SVC) can continuously provide the reactive power required to control dynamic voltage oscillations under various system conditions and thereby improve the power system transmission and distribution stability. Installing an SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions. In addition an SVC can mitigate active power oscillations through voltage amplitude modulation.

SVCs are used for:

1. Increasing power transfer in long lines

2. Stability improvement (both steady state and transient) with fast acting voltage regulation

3. Damping of low frequency oscillations (corresponding to electromechanical modes)

4. Damping of subsynchronous frequency oscillations (due to torsional modes)

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 4, April 2017

5. Control of dynamic overvoltages

An SVC is typically made up of the following major components:

- Coupling transformer
- Thyristor valves
- Reactors
- Capacitors (often tuned for harmonic filtering)

Basic branches of an SVC

The dynamic controllable branches of an SVC are the TCR (Thyristor-controlled-reactor) and the TSC (Thyristor switched- capacitor).

Figure 1 below shows the basic circuit of a TCR.

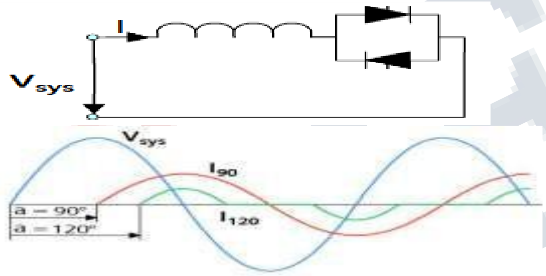


Figure.1 Basic circuit of a TCR

Antiparallel connected thyristors are series-connected with a reactor of high quality (very low losses). A sinusoidal voltage will result in a sinusoidal current when the thyristors are continuously conducting (α = 90°). By delaying the start of the current in each halve cycle by delaying the firing signal for the thyristors the current will start later and end earlier as seen in the lower part of figure 4.6 (example for α = 120°). Such a chopped current wave form contains fundamental and harmonic currents. The advantage of the TCR is the fine control of its installed reactive power from full load to zero and vice versa. The chopped current waves contain all harmonics of order 3, 5, 7, 9, 11, 13 etc within the single branch of a TCR. By connecting three TCR branches in delta all triplen harmonics will be suppressed. In reality the line current does not only contain the so-called characteristic six pulse harmonic currents but also non-characteristic currents which arise mainly due to negative sequence voltage content in the system voltage (all triplen harmonics) and even harmonics which result from tolerances on the firing pulses in positive and negative direction.

Figure 3 below shows the basic circuit of a TSC.

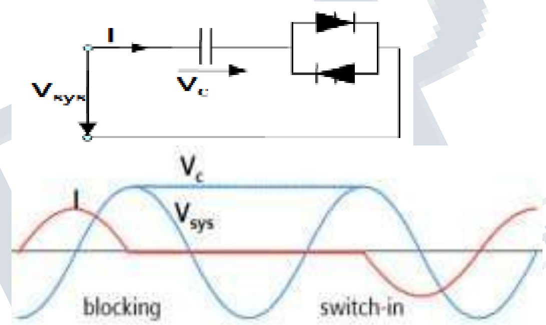


Figure3.Basic circuit of a TSC

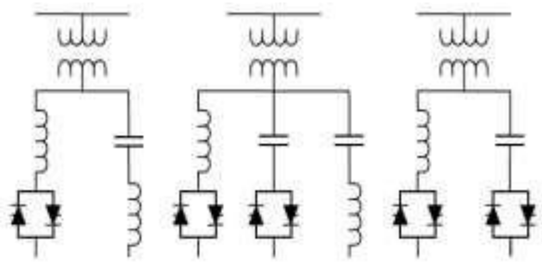
Here the reactor of the TCR is replaced by a capacitor. At full conduction of the valves the synusoidol voltage Vsys results in a 90° phase shifted capacitive current I. If the thyristors are no longer switched by firing pulses the current I through the capacitor stops and the voltage Vc of the capacitor does no longer follow the system voltage Vsys and remains at the voltage at the time of blocking. The best time to reconnect the capacitor is at the point of time where system voltage and the capacitor voltage are equal. At that point only minimum transients due to switching-on will occur. At all other times more or less strong transients will occur and therefore only step-wise control of the TSC is allowed.

1. Configurations of SVCs

Using TCR-, TSC- and Filter (or so-called fixed connected: FC) branches result in possible configurations as shown below in figure 4:

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 4, April 2017



TCR-FC TCR-TSC-FC TCR-TSC

Figure.4.Configurations of SVCs

This thesis gives details of an 300 Mvar, 735 kV/16 KV SVC installed in a transmission system. The SVC will effectively solve the voltage regulation problem in the study area and delay the costly construction of a new 40 mile, 230 kV transmission line. Budgetary cost of an 87 Mvar SVC is around $8 million, where a 40 mile 230 kV transmission line is approximately $19 million.

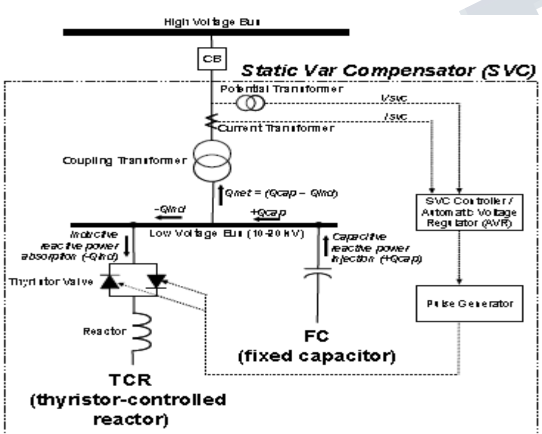


Figure 5. SVC with control concept briefly illustrated

2. SVC V-I Characteristic

The SVC can be operated in two different modes:

- In voltage regulation mode (the voltage is regulated within limits as explained below)
- In var control mode (the SVC susceptance is kept constant)

When the SVC is operated in voltage regulation mode, it implements the following V-I characteristic.

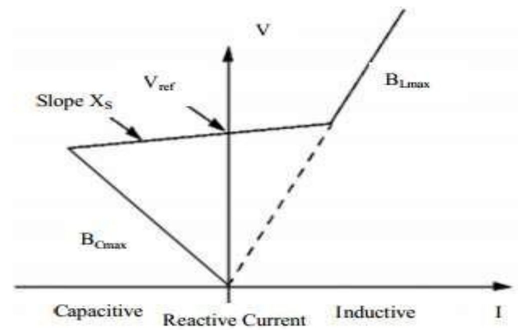


Figure 6. SVC V-I Characteristic.

As long as the SVC susceptance B stays within the maximum and minimum susceptance values imposed by the total reactive power of capacitor banks (Bc_{max}) and reactor banks (Bl_{max}), the voltage is regulated at the reference voltage Vref. However, a voltage droop is normally used (usually between 1% and 4% at maximum reactive power output), and the V-I characteristic has the slope indicated in the figure. The V-I characteristic is described by the following three equations:

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

Where

V = Positive sequence voltage (pu.)

I = Reactive current (pu/Pbase) (I > 0 indicates an inductive current)

Xs = Slope or droop reactance (pu/Pbase)

B_{Cmax} = Maximum capacitive susceptance (pu/Pbase) with all TSCs in service, no TSR or TCR

B_{Lmax} = Maximum inductive susceptance (pu/Pbase) with all TSRs in service or TCRs at full conduction, no TSC

IFERP
connecting engineers... developing research

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 4, April 2017

P_{base} = Three-phase base power

II. CONTROL SYSTEM FOR SVC

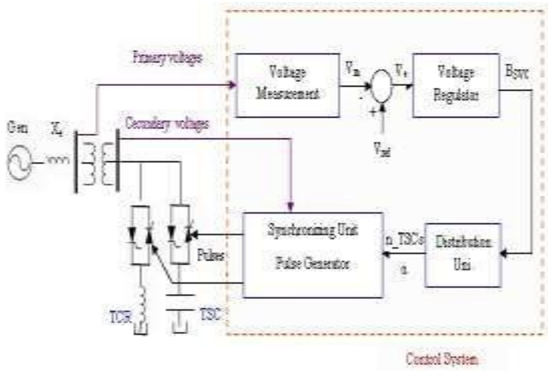


Figure 7. Control System for SVC

The control system consists of

A ***measurement system*** measuring the positive-sequence voltage to be controlled. A Fourier-based measurement system using a one-cycle running average is used.

Measuring module

In SVC model, the characteristics of the measuring and filter circuit can be approximated by transfer function as given below:

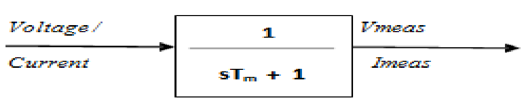


Figure 8The measuring circuit time constant is 0.001-0.005s

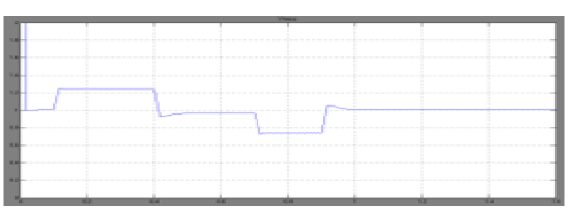


Figure 9 Vmeas/Vref (Pu)

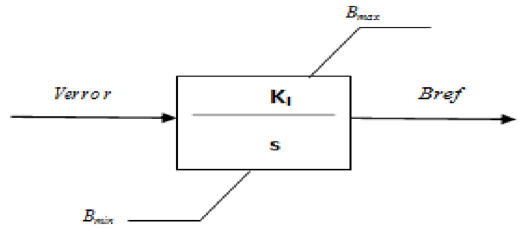


Figure 10 Voltage Regulator Model integral type.

For this example Ki = 800.

A distribution unit that determines the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of TCRs.

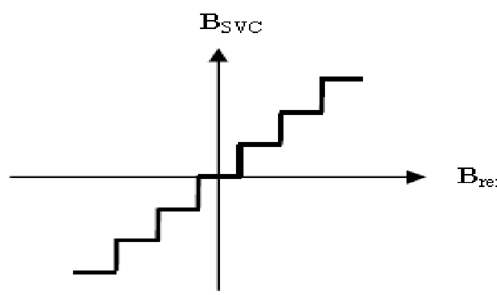


Fig.11. Distribution unit model for TSR-TSC type SVC

A synchronizing system using a phase-locked loop (PLL) synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the thyristors

III. MATHEMATICAL MODELLING OF SVC

A 300-Mvar Static Var Compensator (SVC) regulates voltage on a 6000-MVA 735-kV system. The SVC consists of a 735kV/16-Kv 333-MVA coupling transformer, one 109- Mvar thyristor-controlled reactor bank (TCR) and two 94-Mvar thyristor-switched capacitor banks (TSC1 TSC2) connected on the secondary side of the transformer. Switching the TSCs in and out allows a discrete variation of the secondary reactive power from zero to 188 Mvar capacitive (at 16 kV) by steps of 94 Mvar, whereas phase control of the TCRallows a continuous variation from zero to 109 Mvar inductive.

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 4, April 2017

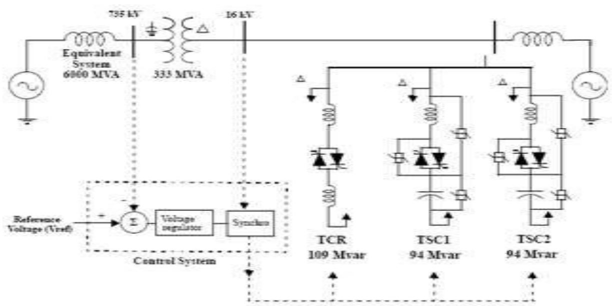


Figure.12. Detailed 735 kV Transmission System

Taking into account the leakage reactance of the transformer (15%), the SVC equivalent susceptance seen from the primary side can be varied continuously from -1.04 pu/100 MVA (fully inductive) to +3.23 pu/100 Mvar (fully capacitive). The SVC controller monitors the primary voltage and sends appropriate pulses to the 24 thyristors (6 thyristors per three-phase bank) in order to obtain the susceptance required by the voltage regulator. When the SVC operating point changes from fully capacitive to fully inductive, the SVC voltage varies between 1 - 0.02 = 0.98 p.u and 1+ 0.01 =
1.01 p.u.
The SVC rating is as follows:

QTSC=2 * 94Mvar = 188Mvar ,
QTGR=109Mvar

a) At rated line-to-line voltage Urated, the nominal inductive and capacitive currents of SVC referred to primary side are determined as follows:

(1) QLrated=√ Urated.ILrated = Urated^2.BLrated

ILrated=QLrated/√ Urated = (Q2.TSC-QTCR)/√ Urated
= (188-109)*1000/(√ *735) = 62.05A

(2) QCrated=√ Urated.ICrated = Urated^2.BCrated

ICrated=QCrated/√ Urated = (Q2.TSC)/√ Urated
=
(188)*1000/(√ *735)= 147.67A

(b) At the maximum line-to-line voltage

Umax= 742.35 KV

(3) QLmax=√ Umax.ILmax =
Umax^2.BLrated

ILmax=QLmax/√ Umax = ILrated Umax / Urated
=62.6705

(c) At the minimum line-to-line voltage

Umin= 712.95 kV
(4) QCmin=√ Umin.ICmin =
Umin^2.BCrated

ICmin = ICrated Umin / Urated = 143.2399A

The reactive of the TCR and TSC are calculated as
XLrated= U^{2}rateds /QLrated= 16^2/109=2.348
Xtransf = 0.15*U^{2}rated s /Ptransf =
16^2/333=0.115
(5) XLTCR(Δ) =XLrated - Xtransf=
2.233 XLTCR(1) = 3*2.233 =
6.67Ω LLTCR = 6.67/2* *60 =
17.7mH

(6) XCrated = U^{2}rated s /QCrated =
16^2/188=1.3617

C = 1/2* *60*188 = 1.947mH

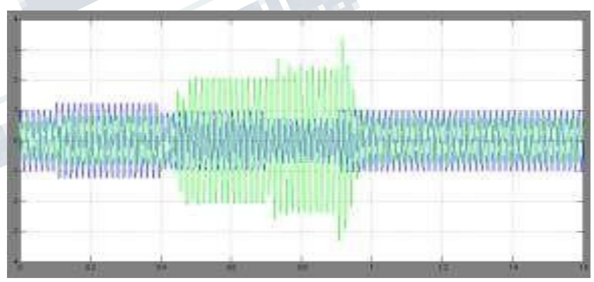


Figure 13. Positive Sequence of Voltage and Current

Initially the source voltage is set at 1.01 pu, resulting in a 1.0 pu voltage at SVC terminals when the SVC is out of service. As the reference voltage Vref is set to 1.0 pu, the SVC is initially floating (zero current). This operating point is obtained with TSC1 in service and TCR almost at full conduction (α = 90 degrees).
At t=0.1s voltage is suddenly increased to 1.255 pu. The SVC reacts by absorbing reactive power (Q=-76 Mvar) to bring the voltage back to 1.245 pu. At this point all TSCs are out of service and the TCR is almost at full conduction (α = 90 degrees).

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 4, April 2017

At t=0.4 s the source voltage is suddenly lowered to 0.932 pu. The SVC reacts by generating 189.4 Mvar of reactive power, thus increasing the voltage

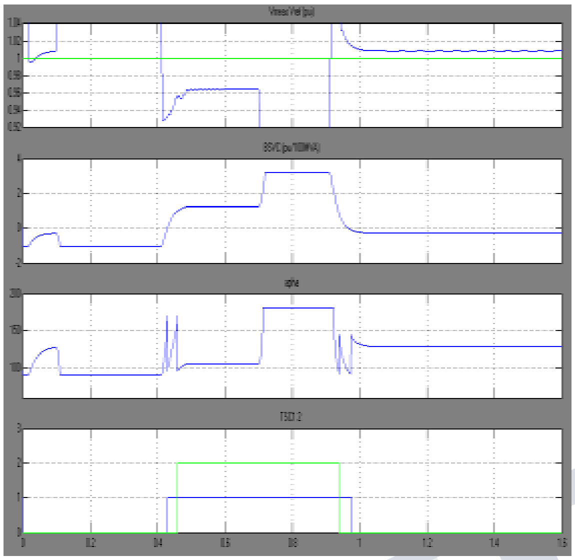


Figure14 Vmeas/Vref, Reactive Power, No. of TSC (on/off), Firing angle alpha and Bsvc

IV. CONCLUSIONS

In this paper, we have modeled the small disturbances including control action, resulting in the determination of the required rating of SVC for the given subject matter. Furthermore, it has also determined the appropriate control signal for adequate transient stability as well as control structures corridors to give most viable and composite perception of the SVC control system. Therefore, the power system stability describes the voltage control at the point of SVC connection to the system. This technique may be used to verify the adequacy of the control parameters. And finally, we connect an SVC on a power grid to control the voltage and the reactive power.

REFERENCES

1. Acha. E, Agelidis. V.G, Anaya-Lara. O, Miller. T.J.E (2002): Power Electronic Control in Electrical Systems" 451pp. Chap 6 & 9. Newnes Publisher.

2. Xiao-Ping. Z, Rehtanz. C, Bikash. P (2006): Flexible AC Transmission Systems: Modelling and Control. 395pp. Chap.2, Springer Berlin Heidelberg New York.

3. Chi. W.J, Wu. C.J (1992): Voltage profile correction of a load bus by static reactive power compensators with contization controllers. Electric Power System Research..

4. Gerin –Lajole.L, G.Scott, S. Breault, E. V Larsen, D. H. Baker and A. F. Imece (1990): Hydro - Quebec Multiple SVC Application Control Stability Study. IEEE Transactions on Power Delivery, pp .1543-1551.

5. Hubbi. W, Hiyama. T (1998): Placement of static var compensator to minimize power system losses. Electric Power Systems Research, PP 95-99.

6. Lin. C.E, Chen. T.C, Huang. C.L (1988): Optimal control of a static var compensator for minimization of line loss. Electric Power Systems Research, PP 51-61.

7. Noroozian. M (1996): Modelling of SVC power system studies. ABB Power Systems Division, information NR500-026E, Sweden.

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

9. Gyugyi, L., 1988. Power electronics in electric utilities: Static var compensators. Proc. IEEE, 76(4): 483-494. Stagg, G.W. and A.H. El- Abiad, 2002. Computer methods in power system analysis. 1st Edn., Mc Graw-Hill.

10. Saadat, H., 2002. Power System Analysis. Tata McGraw- Hill.

11. Hingorani, N.G. and L. Gyugyi, 2000. Understanding, FACTS concepts and Technology of flexible AC transmission systems. IEEE Press, New York.