International Journal of Electrical and
Electronics Engineering (IJEEE)
Vol.1, Issue 1 Aug 2012 9-18

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

ENHANCEMENT OF POWER FLOW USING TCSC CONTROLLER

[1]P PAUL CLEE & [2]SVL NARASIMHAM

[1]Department of EEE, Padmasri Dr.B.V.Raju Institute of Technology, A.P., India-502313

[2] Department of CSE, School of IT, JNTUH, Hyderabad, India -500085

ABSTRACT

Flexible AC Transmission systems (FACTS) technology plays a vital role as Power system engineers are currently facing challenges to increase the power transfer capabilities of existing transmission system. Instead of erecting a new transmission or generation facilities, the FACTS technology allows the industries to better utilize the existing transmission and generation reserves, while enhancing the power system performance. With FACTS technology the FACTS controllers are evolved; a group of power electronics controllers expected to revolutionize the power transmission and distribution system in many ways. The FACTS controllers clearly enhance power system performance, improve quality of supply and also provide an optimal utilization of the existing resources. Thyristor Controlled Series Compensator (TCSC) is a key FACTS controller and is widely recognized as an effective and economical means to enhance power system stability. In this paper TCSC-FACTS general type controller using MATLAB-SIMULINK simulation is given which can be used for practical network and the effect of the TCSC parameter variations over the system performance is studied.

KEYWORDS: Index Terms-- Facts, Facts Controller, Thermal Rating, Transient Stability Limit, Voltage Stability.

INTRODUCTION

The Modern electric power utilities are facing many challenges due to ever-increasing complexity in their operation and structure. In the recent past, one of the problems that got wide attention is the power system instabilities. With the lack of new generation and transmission facilities and over exploitation of the existing facilities geared by increase in load demand make these types of problems more imminent in modern power systems.

Demand of electrical power is continuously rising at a very high rate due to rapid industrial development. To meet this demand, it is essential to raise the transmitted power along with the existing transmission facilities. The need for the power flow control in electrical power systems is thus evident. With the increased loading of transmission lines, the problem of transient stability after a major fault can become a transmission power limiting factor. The power system should adapt to momentary system conditions, in other words, power system should be flexible. The idea of the so-called Flexible AC Transmission System (FACTS) has been introduced in 1980s.

TCSC- FACTS CONTROLLERS

Flexible alternating-current transmission systems (FACTS) are defined by the IEEE as "AC Transmission systems incorporating power electronics-based and other static controllers to enhance controllability and increase power transfer capability"[8]. Similarly, a FACTS controller is defined as "A power electronics- based system or other static equipment that provides control of one or more ac transmission parameters". In recent years, many different FACTS controllers have been proposed for performing a wide variety of functions. FACTS controllers modify the series and parallel impedances of transmission lines. The way a FACTS controller is connected to the ac power system has a direct effect on the transfer of active and reactive power within the system. Series connected controllers are usually employed in active power control and to improve the transient stability of power systems. Shunt connected controllers govern reactive power and improve the dynamic stability. The IEEE groups FACTS controllers into three main categories based on how they are connected to the ac power system: series, shunt, and combined series-and-shunt[4].

In principle all the series controllers inject voltage in series with the line, while all shunt controllers inject current into the system at the point of connection. Series connected controller impacts the driving voltage and hence the current and power flow directly. The shunt controller is like a current source, which draws from or injects current into the line. The shunt controller therefore provides an effective means to control voltage at and around the point of connection through injection of reactive current (leading or lagging) alone or a combination of active and reactive current for a more effective voltage control and damping of oscillations. Thyristor controlled series compensator, the first generation of FACTS, can control the line impedance through the introduction of a thyristor controlled capacitor in series with the transmission line[5]. TCSC is an effective and economical means of solving problems of transient stability, dynamic stability, steady state stability and voltage stability in long transmission lines. By flexibly and quickly adjusting the reactance of the TCSC, many relevant benefits can be achieved such as the better utilization of transmission capability, efficient power flow control, transient stability improvement, power oscillation damping, control over sub synchronous resonance (SSR), and fault current limitation[6].

Basic TCSC Module

The basic module of a TCSC has a series capacitor C, in parallel with a thyristor- controlled reactor, Ls as shown in Fig. 1[7-10]. An actual TCSC system usually comprises a cascaded combination of many such TCSC modules, together with a fixed series capacitor; CF. This fixed series capacitor is provided primarily to minimize costs[11].

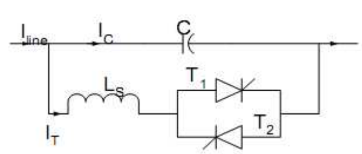

Figure 1: TCSC Basic Module

The capacitors C1, C2,.., Cn; in different TCSC modules may have different values to provide a wider range of reactance control. The inductor in series with the anti-parallel thyristor is split into two parts to protect the thyristor valves in case of inductor short circuit. The behavior of TCSC is similar to that of the LC parallel combination. The difference is that the LC combination analysis is based on pure sinusoidal voltage and current in the circuit, whereas in TCSC the voltage and current in the fixed capacitor (FC) and thyristor controlled reactor (TCR) are not sinusoidal because of thyristor switching. The details of TCSC operating principles are discussed in subsequent sections along with its mathematical modeling.

Analysis of TCSC

A Simplified TCSC circuit is shown in Fig. 2 for the purpose of mathematical analysis. Transmission line current is assumed to be the independent input variable and is represented as variable current source, $i_S(t)$. Here for the analysis the line current is assumed to be sinusoidal[8, 12]. The equivalent TCSC reactance (X_{TCSC}) is the ratio of V_{CF} to I_m .

The equivalent TCSC reactance is given by:

$$X_{TCSC} = \frac{V_{CF}}{I_m} = X_C - \frac{X_C^2}{(X_C - X_P)} \frac{2\beta + \sin 2\beta}{\pi} + \frac{4X_C^2}{(X_C - X_P)} \frac{\cos^2 \beta}{(k^2 - 1)} \frac{(k \tan k\beta - \tan \beta)}{\pi}$$

$$X_{TCSC} = \frac{V_{CF}}{I_m} = X_C - \frac{X_C^2}{(X_C - X_P)} \frac{\sigma + \sin \sigma}{\pi} + \frac{4X_C^2}{(X_C - X_P)} \frac{\cos^2(\sigma/2)}{(k^2 - 1)} \frac{(k \tan(k\sigma/2) - \tan(\sigma/2))}{\pi}$$

where V_{CF} = Fundamental component of the capacitor voltage.

X_C = Nominal reactance of the fixed capacitor only.

X_P = Inductive reactance of inductor connected in parallel with fixed capacitor.

β= Angle of advance.

The variation of per unit TCSC reactance as a function of firing angle α for different values of the compensation ratio $k=\sqrt{\frac{X_C}{X_P}}$ is described in Fig.3 (a). If value of X_C is changed then the maximum value of X_{TCSC} also changes and hence initial value of compensation can be changed[8]. Fig.3 (b) shows X_{TCSC} variation for different value of X_C for constant k.

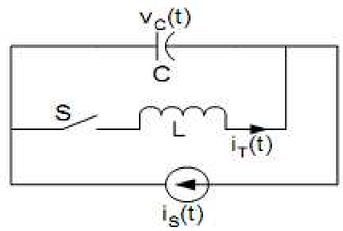

Figure 2: A Simplified TCSC Equivalent Circuit

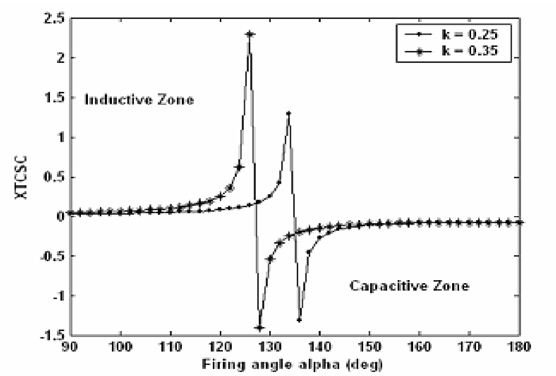

Figure 3(a) Change of X_{TCSC} with change of k for X_C = 0.08

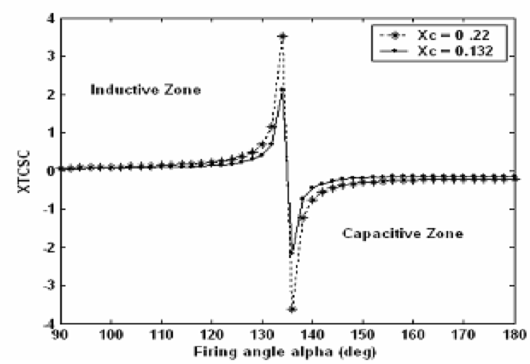

Figure 3(b) Change of X_{TCSC} with change of X_C for k = 0.25.

It is to be noted that a parallel resonance is created between X_P and X_C at the fundamental frequency. At the resonant point, the TCSC exhibits very large impedance and results in a significant voltage drop. The resonant region is avoided by installing limits on the firing angle. TCSC is mainly used in capacitive zone.

Tcsc Modeling Using Simulink

The complete system has been represented in terms of SIMULINK blocks in a single integral model.

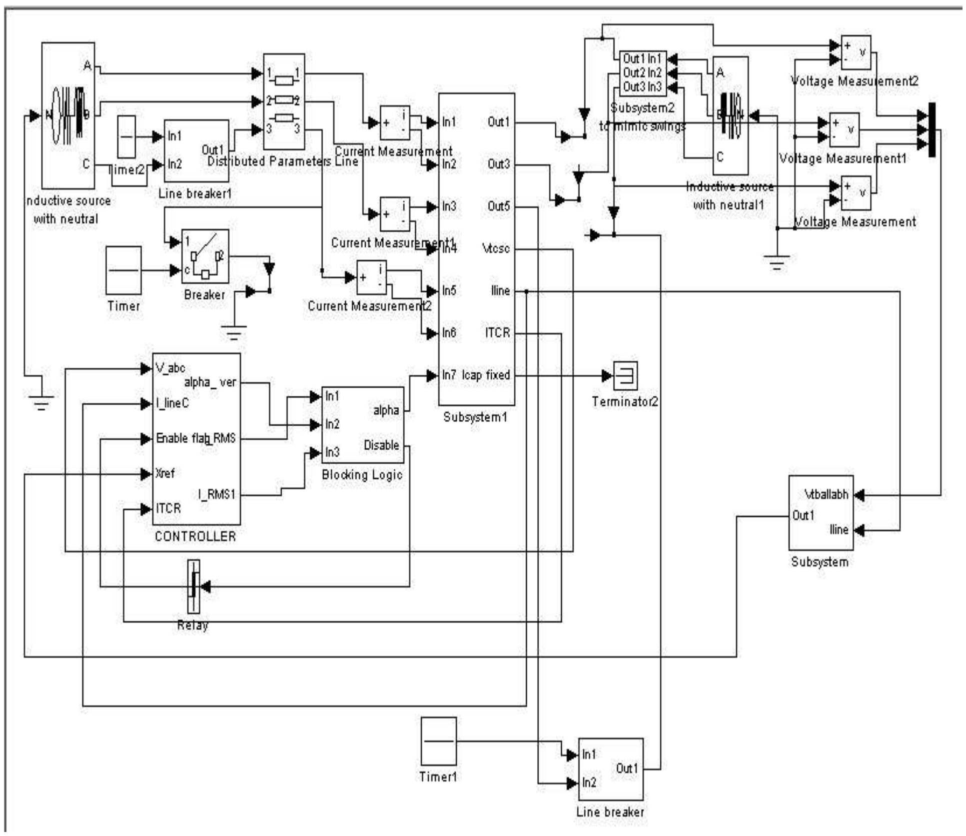

Figure 4: 3-phase transmission line with TCSC

For the above TCSC and 3-phase transmission line model one of the source is of Phase to ground voltage is 163.3KV with a phase angle of 35^{O} with the internal resistance of 0.1 ohm and inductance of 0.043H. Similarly the other end voltage Phase to ground voltage is 163.3KV with a phase angle of 0^{O} with the internal resistance of 0.1 ohm and inductance of 0.026H.

The transmission lime is model as distributed parameters line with positive sequence resistance of 0.0296 and inductance 1.044e-3 and capacitance of 16e-9. The length of the line is considered as 400KM.

SIMULATION RESULTS

In the figure 5 the waveforms are obtained for the gate pulse, the TCR current and the voltage across the TCSC or the Voltage across the capacitor and the line current. Gain blocks are used to view the waveforms for the required scale.

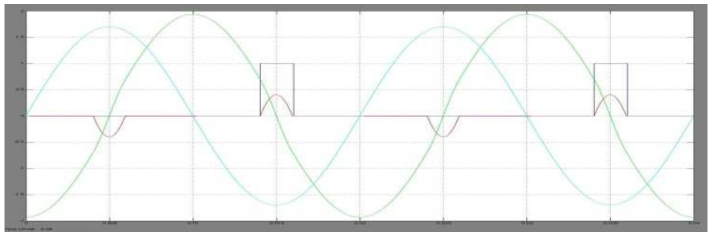

Figure 5: TCR wave forms

With the 3-phase transmission line model show previously the MATLAB-SIMULINK program is run for 2.2 seconds. At the beginning of the simulation the TCSC is shorted circuited with MOV switch and connected to the 3-phase transmission line at 1.525 sec and kept in the circuit upto 1.7 sec. The corresponding waveform of the V_{TCSC}, I_{TCR} and the Line current I_{line} are shown in the figures 6 and 7.

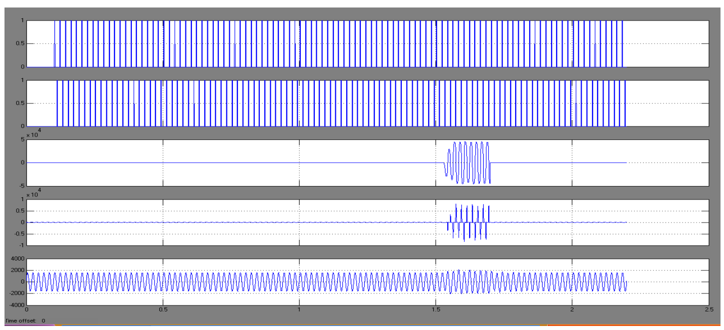

Figure 6: (a) gate-pulse 1 (b) gate-pulse 2 (c) Voltage across the TCSC or the Capacitor (d) I_{TCR} (e) I_{line}

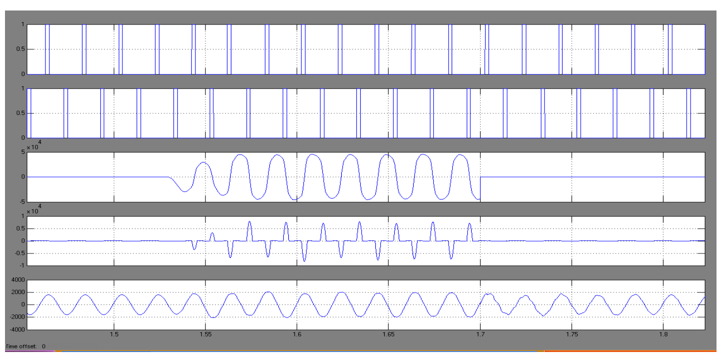

Figure 7: Effect of TCSC in the 3-phase line

In the below figures.8 and 9, during the time of TCSC connected to the 3-phase circuit the line current increases to almost of 40% that of the current flowing without TCSC. The figure also shows the 3-phase voltage at one of the end, and the X reference value which in-turn controls the gating signal to the thyristors of TCSC.

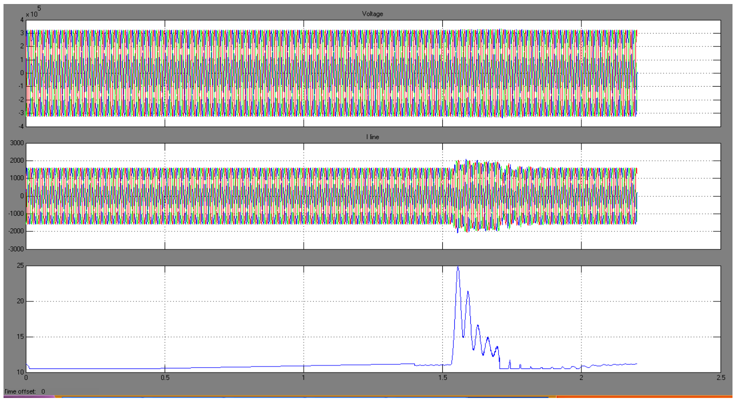

Figure 8: (a) Voltage at the other end of the transmission line (b) Line Current I line(c) X reference for the control circuit

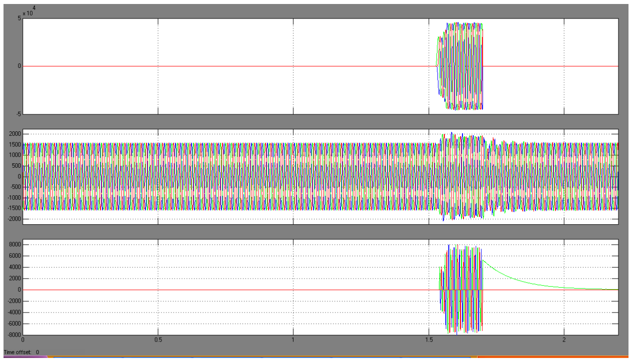

Figure 9: 3-phase voltage across the TCSC (a) 3-phase Line current (c) 3-phase current through the TCR

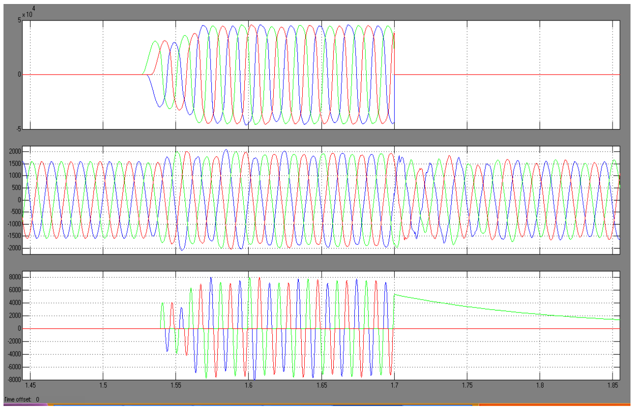

Figure 10: 3-phase voltage across the TCSC (a) 3-phase Line current (c) 3-phase current through the TCR

In the above figure 10 shows the simulated results of the TCSC incorporating in the 3-phase transmission line. The waveforms given are the 3-phase voltages across the TCSC. The voltage across the TCSC is zero up to 1.525 sec and is maximum of 4.5e4 V up to 1.7 sec. During this time the current flowing through the TCR increases as show above. The figure 11 gives the detail waveform during the period mentioned above.

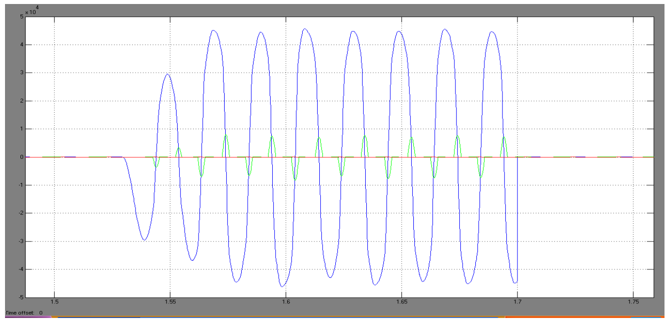

Figure 11: Current flow through TCR

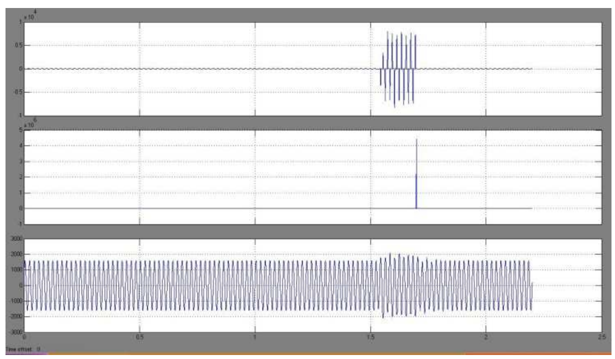

Figure12: (a) 1-phase Current through TCR (b) 1-phase Current through the Capacitor (c) Line current

Figure13: (a)1-phase Current through TCR (b) 1-phase Current through the Capacitor (c) Line current

CONCLUSIONS

The analysis shows that incorporation of FACTS – TCSC device in a 3-phase transmission network enhances the power flow. TCSC performance analysis for different cases is being carried out such as for short circuit fault, open circuit fault, or for any swing/oscillations, etc for a practical network and to compare the same with the IEEE 14 bus as well as 30 bus system.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the management of SVES, Hyderabad for extending their support in providing the resources at BVRIT, Narsapur, for continuing the work.

REFERENCES

1. J. Urbanek et al., “Thyristor controlled series compensation — prototype installation at Slatt 500 kV substation”, IEEE Trans. on Power Delivery, pp. 1460–1469, July 1993
2. N.G.Hingorani and L.Gyugyi, Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems, IEEE Press, New York, 2000
3. B.T.Ooi, “Assessment and Control of the Impact of FACTS Devices on Power System Performance”, IEEE Transactions on Power Systems, Vol. 11, No. 4, Nov. 1996.
4. Mohammad T. B., Hamill C. D., A classification scheme for FACTS controllers, www.hamill.co.uk/pdfs/acsffc__.pdf.
5. Zhang B. M., Ding Q. F., The development of FACTS and its control, APSCOM – 97, Hong Kong, Nov. 1997, pp. 48 – 53.
6. Lei X., Li X., Povh D., A nonlinear control for coordinating TCSC and generator excitation to enhance the transient stability of long transmission systems, Electric Power Research, 2001, Vol. 59, pp. 103 – 109.
7. Song Y. H., Johns T. A., Flexible AC transmission systems (FACTS), 1999 (IEE Pbs.).
8. Mathur R. M., Verma R. K., Thyristor-based FACTS controllers for electrical transmission systems, 2002 (IEEE press, Wiley & Sons Pbs.).
9. Xiaolu L., Xianzhong D., Jiang Y., Hongfa D., Yangzan H., Fundamental frequency model of thyristor controlled series capacitor for transient stability studies, Proc. POWERCON 1998, 1998, Vol. 1, pp. 333 – 337.
10. Han H. G., Park J. K., Lee B. H., Analysis of thyristor controlled series compensator dynamics using the state variable approach of a periodic system model, IEEE Trans. on Power Delivery, 1997, Vol. 12(4), pp. 1744 – 1750.

11. John J. P., Nicholas W. M., Einar V. L., Richard J. P., A thyristor controlled series compensation model for power system stability analysis, IEEE Trans. on Power Delivery, 1995, Vol. 10(3), pp. 1471 – 1478.

BIOGRAPHsIES

1. **Paul Clee P** is with Padmasri Dr BV Raju Institute of Technology, Narsapur, AP, India. His areas of interest include Power Systems, FACTS, Power Electronics, and High Voltage Engineering.

2. **SVL Narasimham** is with School of Information of Technology, JNTUH, Hyderabad. His areas of interest include Computer Graphics and pattern recognition, Power Systems, FACTS, High Voltage Engineering, Microprocessor and Microcontroller in simulation and modeling.