Modelling and Analysis of Thyristor Controlled Series Capacitor using Matlab/Simulink

Satvinder Singh
Assistant Professor, Department of Electrical Engg.
YMCA University of Science & Technology, Faridabad, India

Pawan Kumar
Instructor, Department of Electrical Engg.
YMCA University of Science & Technology, Faridabad, India

Atma Ram
Assistant Professor, Department of Electrical Engg,
Govt. Engineering College, Paniwala mota, Sirsa, India

Abstract: The need for more efficient electricity systems management has given rise to innovative Technologies in power generation and transmission. Flexible AC Transmission Systems (FACTS) is one of such technologies that respond to these needs. It significantly alters the way transmission systems are developed and controlled together with improvement in asset utilization, system flexibility and system performance. Different types of FACTS devices are being used now-a-days. Thyristor Controlled Series Compensator is one of the series compensating FACTS devices. Thyristor Controlled Series Compensator (TCSC) consists of a series compensating capacitor shunted by a Thyristor Controlled Reactor (TCR). The basic idea behind the TCSC scheme is to provide continuously variable impedance by means of partially cancelling the effective compensating capacitance by the TCR. Transmission lines compensation by means of TCSC can be used to increase the power transfer capability, improve transient stability, reduce transmission losses and dampen power system oscillations. In this work device modelling of TCSC have to be carry out along using MATLAB7.5/Simulink. The thyristor of TCR branch are fired at firing angle $\alpha = 60^0$ degree. The Response of capacitor voltage, the response of TCR currents and response of capacitor currents at the given firing angle is studied.

Keywords : Matlab , Thyristor Controlled Series Compensator, Transmission system

I. INTRODUCTION

The objective of this work is to model a Thyristor Controlled Series Compensator and Modelling and Simulation of Thyristor Controlled Series Compensator is carried out using MATLAB/ Simulink Power System Bockset.

The simulation responses of TCR currents, capacitor currents and capacitor voltages presented for firing angle $\alpha=60^o$. In this simulation, it is advantageous to have small inductive reactance (XL) in providing well defined charge reversal and control of the time period of the compensating voltage which is important for handling sub-synchronous resonance. Small XL increases the magnitude of current harmonics generated by the TCR and circulated through the series capacitor and thus also increases the magnitude of capacitor voltage harmonics injected into the line. The impedance of the TCR reactor does not significantly alter the physical operation of the TCSC; provided that it is sufficiently small in relation to the impedance of the capacitor to facilitate the desired control of the series compensation.

Since system oscillations are greatly influenced by line impedance, TCSC is effective in providing additional power oscillation damping. The harmonics in the system are also damped out in early cycles and there are no disturbances after that.

The major benefits of TCSC are the abilities to schedule power flows along desired lines and to rapidly modulate the effective impedance in response to power system dynamics. It has been seen that with the increase in degree of compensation the power flow across the transmission line increases.

II. THYRISTOR CONTROLLED SERIES CAPACITOR

TCSC is a capacitive reactance compensator which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance. The TCSC is based on thyristor without the gate turn-off capability. A variable reactor such as Thyristor Controlled Reactor (TCR) is connected across a series capacitor. Depending on the TCR firing angle, the capacitive impedance is varied. The TCSC may be single large unit or may consist of several equal or different-sized smaller capacitors in order to achieve a superior performance.

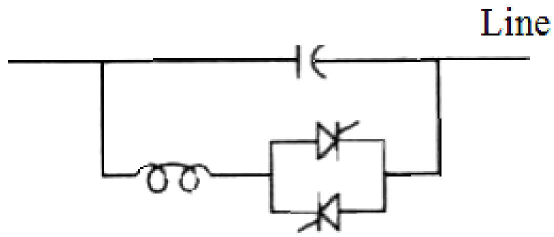

Fig.1 Schematic diagram of TCSC

A capacitive reactance compensator, which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance . A variable reactor such as a Thyristor-controlled Reactor (TCR) is connected across a series capacitor. Considering an ideal case, when the TCR firing angle is 180 degrees, the reactor becomes non conducting and the series capacitor has its normal impedance. As the firing angle is advanced from 180 degrees to less than 180 degrees, the capacitive impedance increases. At the other end, when the TCR firing angle is 90 degrees, the reactor becomes fully conducting, and the total impedance becomes inductive, because the reactor impedance is designed to be much lower than the series capacitor impedance. With 90 degree firing angle, the TCSC helps in limiting fault current. The TCSC may be single, large unit, or may consist of several equal or different sized smaller capacitors in order to achieve a superior performance.

TCSC Application

Series capacitors have been successfully utilized for many years in electric power Networks. With series compensation, it is possible to increase the power transfer Capability of power transmission systems at a favourable investment cost and with a short installation time compared to the building of additional lines. This is due to the inherent ability of series capacitors to achieve:

(i) Increased dynamic stability of power transmission systems
(ii) Improved voltage regulation and reactive power balance
(iii) Improved load between parallel lines

With the advent of Thyristor Control, the concept of series compensation has been broadened and its usefulness has been increased further.

III. RESULTS AND DISCUSSIONS

Simulation and Analysis

In the simulation the Thyristor Controlled Series Capacitor (TCSC), the following system Parameters are considered.

Capacitive reactance (XC) = 15 Ω
Inductive reactance (XL) = 2.56 Ω
System frequency (ω) = 2*pi*60^0
Angle of advance (β) = (pi/2)-(Alpha*pi/180)
Alpha (α) = Firing angle

In the beginning only the fixed series compensating capacitor is in the circuit since thyristor in TCR branch have not been fired thus the line current iL passes through the capacitor and charging of the capacitor takes place. Therefore the TCR branch is open and prevailing line current iL produces voltage across the fixed series compensating capacitor. The thyristor of TCR branch are fired at firing angle $\alpha = 60^0$

(a) Response of Capacitor Voltages at Firing Angle (α =60^0)

The simulation response of capacitor voltages for phases a, b and c at firing angle α =60^0 have been presented from time t=0 sec. to t=1 sec. in Fig.2 to Fig4. Thyristor Controlled Series Capacitor (TCSC) consists of a fixed series compensating capacitor in parallel with the TCR. The capacitor voltage waveform at α=60^0, for phase a, is shown in Fig. 2 from time t=0 to t=1.0 sec. It has been observed that voltage amplitude remains almost same from t=0.2 sec. to t=0.5 sec. After t=0.5 sec. transients have been observed as shown in Fig. 2. The capacitor voltage amplitude before t=0.5 is 0.25 as shown in Fig. 3, but after t=0.5 sec. transients are observed and the voltage amplitude is increased to a value of 0.35. This sudden rise in the capacitor voltage is observed due to the reason that, at the instant of turn on of thyristor in TCR branch; two substantially independent events occur; one is that (for first half cycle) line current iL, being a constant source of current continues to discharge the capacitor; other is that, the charge of the capacitor will be reversed during the resonant half cycle of the LC circuit formed by the conduction of TCR branch. The resonant charge reversal produces a d.c. offset for the next half cycle of the capacitor voltage as shown in Fig. 4. This is the reason for the sudden rise in the capacitor voltage after the firing of thyristor of TCR branch. Similarly the simulation response of capacitor voltages for phase b and c can be explained as shown in Fig. 5 to Fig. 10.

(b) Response of TCR currents at Firing Angle (α =60^0)

The simulation response of TCR currents for phases a, b and c at firing angle α =60^0 have been presented from time t=0 sec. to t=1 sec. in Fig.5 to Fig.7. The TCR current at α =60^0 for phase 'a' is as shown in Fig. 5 and it is observed that from t=0 to t=0.5 sec. value of current is zero since thyristor are not conducting. At t=0.5 sec. thyristor in TCR branch are fired at α =60^0 and hence after t=0.5 sec. In TCR current, spikes are observed, this is due to the sudden rise in the capacitor voltage; observed earlier in capacitor voltage waveform for phase 'a'. Similarly the simulation response of TCR currents for phase b and c can be explained as shown in Fig. 6 and Fig. 7.

(c) Response of Capacitor currents at Firing Angle (α =600)

The simulation response of capacitor currents at firing angle α =60^0 have been presented in Fig.8. The current ic in the series fixed capacitor is equal to the sum of line current (iL) and TCR current. The simulation response of TCR currents and capacitor voltages for phases a, b and c with respect to time, have been shown for a firing angle of 60^0. The line currents and capacitor currents have also been shown.

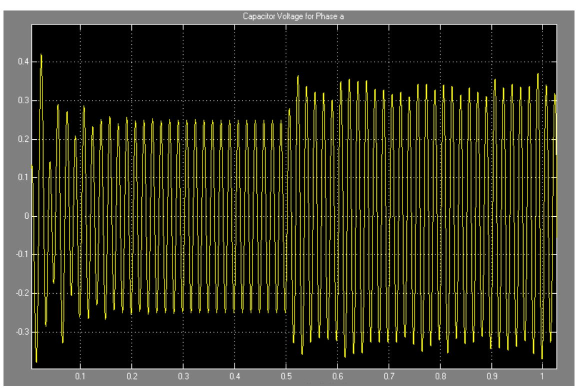

Fig.2 Capacitor Voltage for Phase a (α=60°)

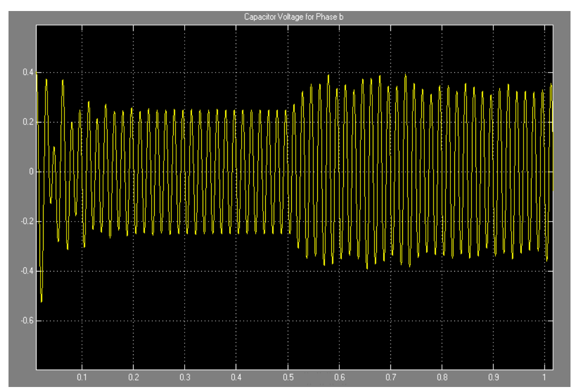

Fig.3 Capacitor Voltage for Phase b (α=60°)

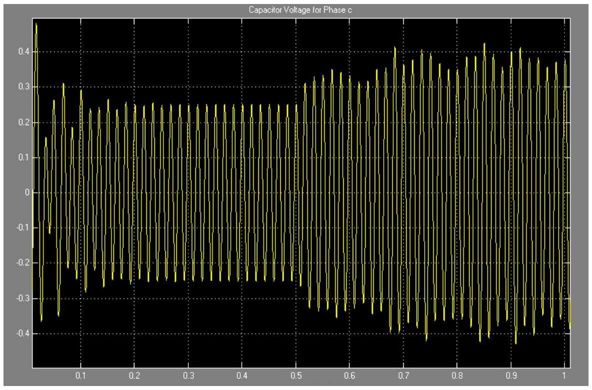

Fig.4 Capacitor Voltage for Phase c (α=60°)

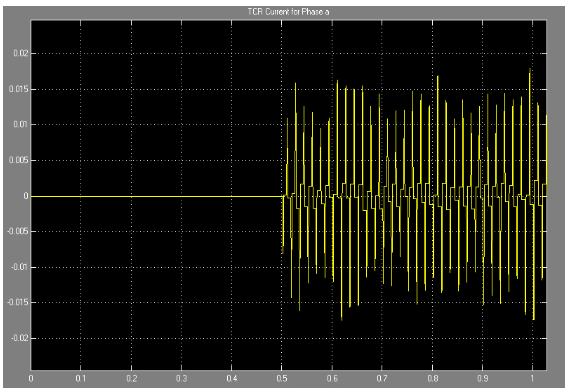

Fig.5 TCR Current for Phase a (α=60°)

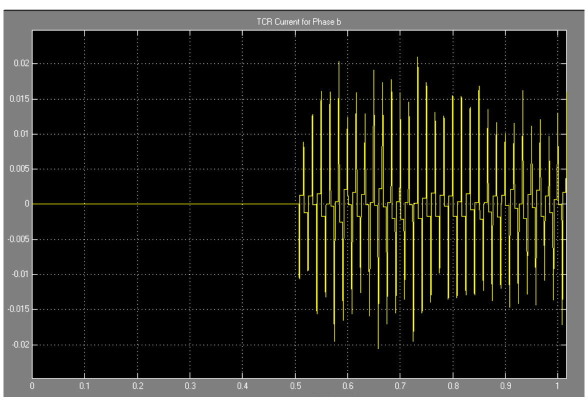

Fig.6 TCR Current for Phase b (α=60°)

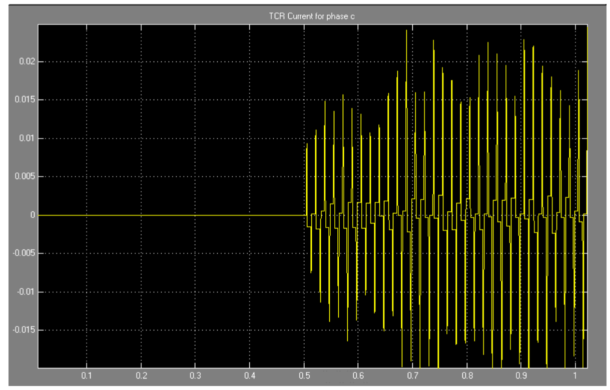

Fig.7 TCR Current for Phase c (α=60°)

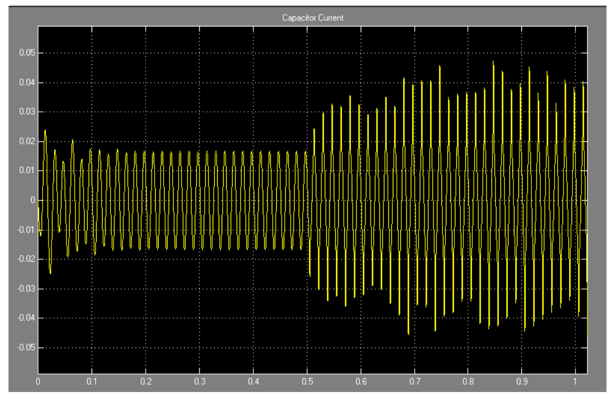

Fig.8 Capacitor Current for Phase c (α=60°)

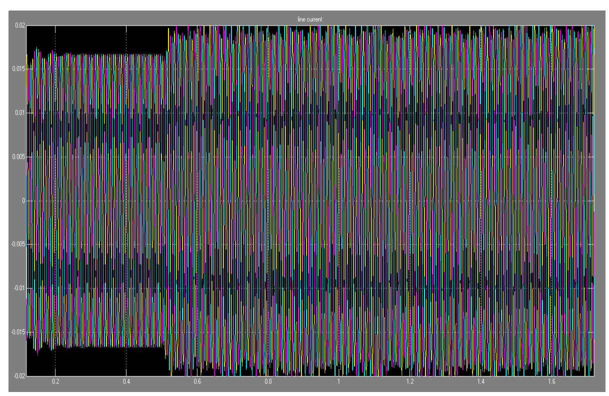

Fig.9 Line current

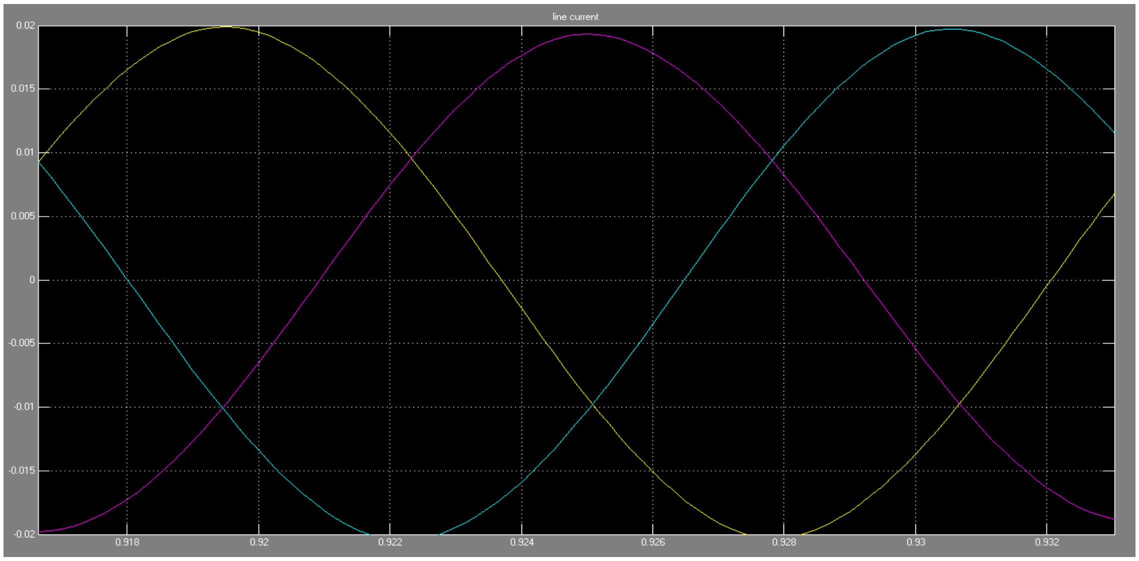

Fig.10 Expanded view of line current

CONCLUSION

Modelling of Thyristor Controlled Series Capacitor carried out using MATLAB7.5/Simulink Power system Blockset. The simulation responses of TCR currents, capacitor currents and capacitor voltages have been presented for firing angle $\alpha=60^0$.

FUTURE SCOPE

The work done can be extended by installing TCSC at multiple sites in the system. Here single module of TCSC is to be used at the site, more number of modules can be installed. Further it can be coordinated with other FACTS controllers.

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