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Transient Stability Enhancement of a Series Compensated Line using TCSC

Neelu Sharma[1] and Dharam Niwas[2]

[1]M.Tech. Scholar, Indus Institute of Engineering and Technology, Kinana, Jind, Haryana (India)
neelusharma465@gmail.com

[2]Asstt. Prof., Indus Institute of Engineering and Technology, Kinana, Jind, Haryana (India)

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Abstract

The paper describes the effect of TCSC (Thyristor Controlled Series Capacitor), a series FACTS (Flexible AC Transmission System) device, in a series compensated line. The paper investigates the reduction of first sub transient swing after contingency, when a TSCS is connected in series compensated line. TCSC also enhance the transient stability and leads to the mitigation of ssr oscillations. The system used in this study is taken as the first IEEE benchmark model. Simulations are carried out in MATLAB/Simulink environment with TCSC to analyze the effects of TCSC on transient stability performance of the system. The simulation results demonstrate the effectiveness and robustness of the TCSC on transient stability improvement of the system.

Keywords: *FACTS, TCSC, Transient Stability, Series Compensation.*

I. Introduction

Modern power system is a complex network comprising of numerous generators, transmission lines, variety of loads and transformers. Today's changing electric power systems create a growing need for flexibility ,reliability ,fast response and accuracy in the field of electric power systems .FACTS are new devices introduced by the recent innovative technologies that are capable of altering voltage, phase angle and/or impedance at particular points in power system. They are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the voltage stability, steady state and transient stability of a complex power system. This allows increased utilization of existing network closer to thermal loading capacity, and thus avoiding the need to construct a new transmission lines.

TCSC is one of the important members of FACTS family that is increasingly applied with long transmission lines by the utilities in modern power systems .It can have various roles in the operation and control of power systems, such as scheduling the power flow, decreasing unsymmetrical component, reducing net loss, providing voltage support, limiting short circuit currents, mitigating sub synchronous resonance, damping the power oscillation and enhancing transient stability.

Simulations results have been demonstrated. The paper is organized as follows. Section II gives a brief introduction of TCSC, a series FACTS device used. A system MODEL with a TCSC is described in Section III. The computer simulation results for system under study are presented and discussed in Section IV and in Section V conclusions are given. The various parameters of the system are listed in Appendix.

II. TCSC in Power System

TCSC is a series FACTS device which allows rapid and continuous changes of the transmission line impedance. TCSC leads to rapid, continuous control of the transmission-line series-compensation level. It allows dynamic control of power flow in selected transmission lines within the network to enable optimal power-flow conditions and prevent the loop flow of power. Damping of the power swings from local and inter-area oscillations and suppression of sub synchronous oscillations are others advantages of TCSC. At sub synchronous frequencies, The TCSC presents an inherently resistive–inductive reactance. The sub synchronous oscillations cannot be sustained in this situation and consequently get damped.

The basic conceptual TCSC module comprises of series capacitor C in parallel with a thyristor controlled reactor L_S.

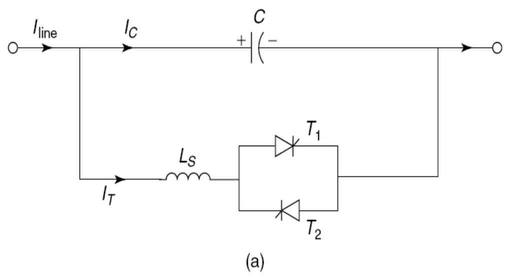

Figure I: Conceptual Model of TCSC

The firing angle of the thyristors is controlled to adjust the TCSC reactance in accordance with the system control algorithm, normally in response to some system parameter variations. According to the variation of the thyristor firing angle or conduction angle, this process can be modeled as a fast switch between corresponding reactance's offered to the power system.

When the thyristors are fired, the TCSC can be mathematically described as :
I_{c}=Cdv/dt

v=L di_L/dt

where 'v' is the instantaneous voltage across the TCSC. The instantaneous current of the controlled transmission line is the sum of the instantaneous values of the currents in the capacitor banks and inductor respectively. Assuming that the total current passing through the TCSC is sinusoidal; the equivalent reactance at the fundamental frequency can be represented as a variable reactance $X_{TCSC.}$ The TCSC can be controlled to work either in the capacitive or in the inductive zones avoiding steady state resonance. There exists a steady-state relationships between the firing angle α and the reactance X_{TCSC}. This relationship can be described by the following equation:

$$Xtcsc = Xc - \frac{Xc^2}{(Xc - Xp)}\frac{(\sigma + \sin\sigma)}{\pi} + \frac{4Xc^2}{(Xc - Xp)}\frac{\cos(\frac{\sigma}{2})^2}{(k^2 - 1)}\frac{(k\tan\left(\frac{k\sigma}{2}\right) - \tan(\frac{\sigma}{2})}{\pi}$$

Where X_C=Nominal reactance of the fixed capacitor C
$X_{P=}$Inductive reactance of inductor L connected in parallel with C
σ=2(π-α) =Conduction angle of TCSC controller
k= $(X_C/ X_P)^{1/2}$

III. System Model with TCSC

The study system consists of a hydraulic turbine driven synchronous generator (a four mass model) supplying bulk power to an infinite bus over a long transmission line. A TCSC is located in series with the series compensated transmission line which provide transient stability enhancement and reduce the first sub transient swing.

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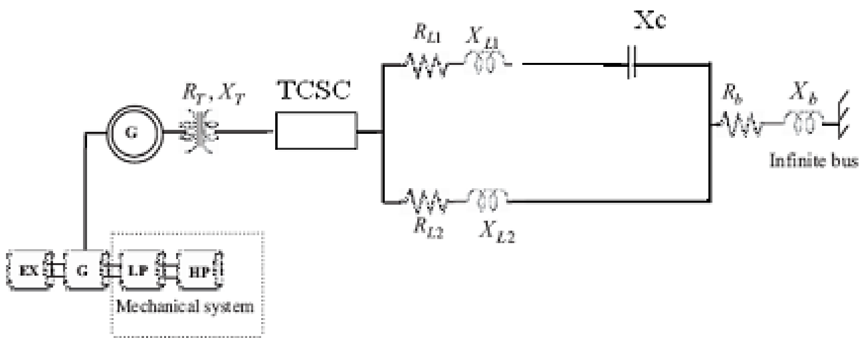

Figure II (a): Single Line Diagram of System Model

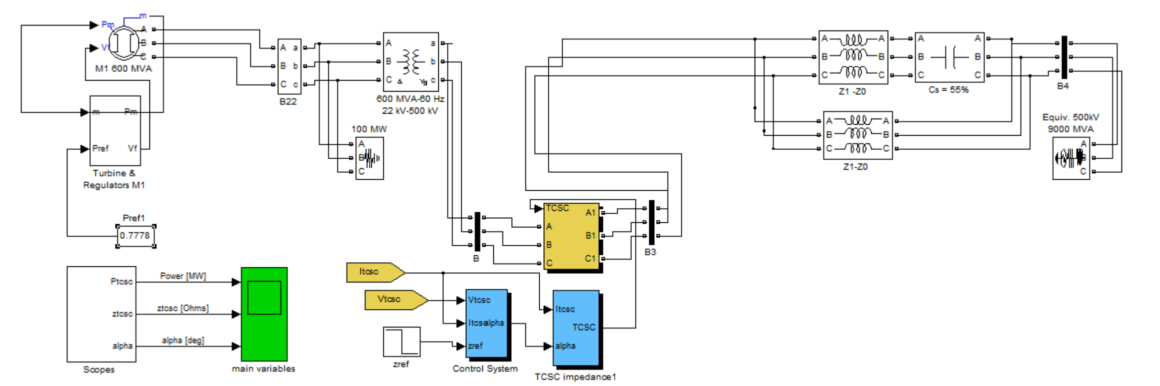

Figure II (b): MATLAB Simulation Model of Power System for Transient Stability Study with TCSC

IV. Computer Simulation

The power system as proposed in Section 3 is modeled with one hydraulic generating units of 600 MVA and connected via transmission line as shown in Fig. II (b) for our study [4]. The synchronous machines are equipped with a hydraulic turbine, governor (HTG) and excitation system. Initial power output of the generator is P = 0.7778 pu. A three phase fault occurs at time t = 0.02 s. The original system is restored upon the clearance of the fault. Figure III (a) & (b) shows the variation of output active power and electromagnetic torque without and with TCSC with respect to time, for a fault clearing time (FCT) of 0.03 s. It is clear from the figure that TCSC is effective in improving stability.

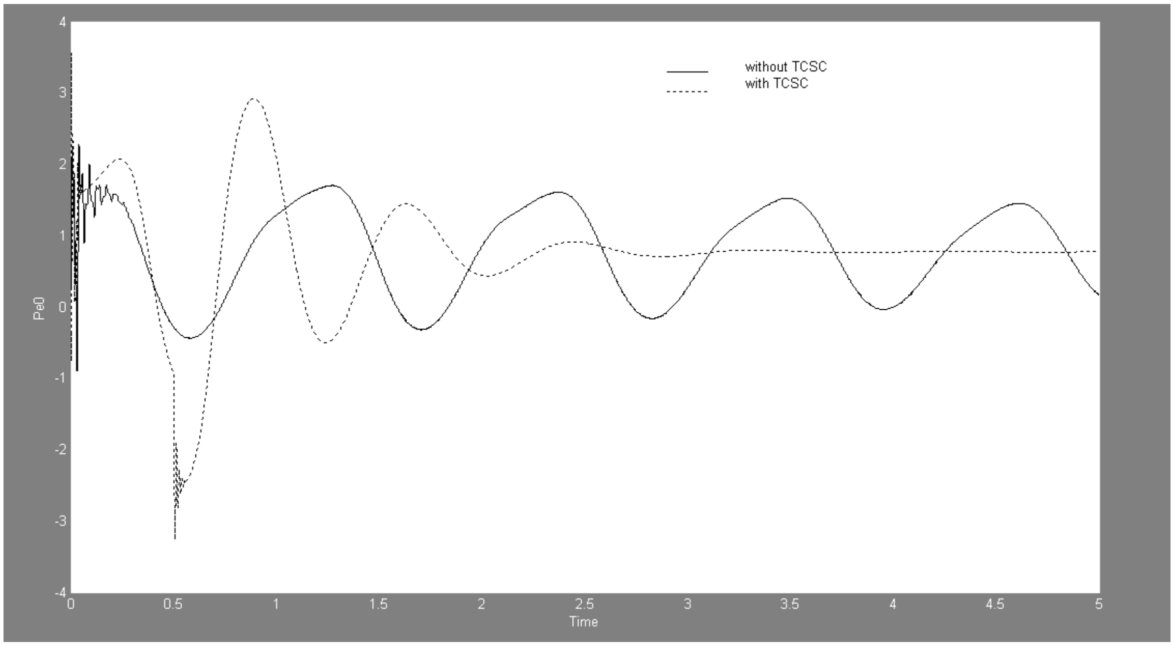

Figure III (a): Output active power of the series compensated line with and without TCSC

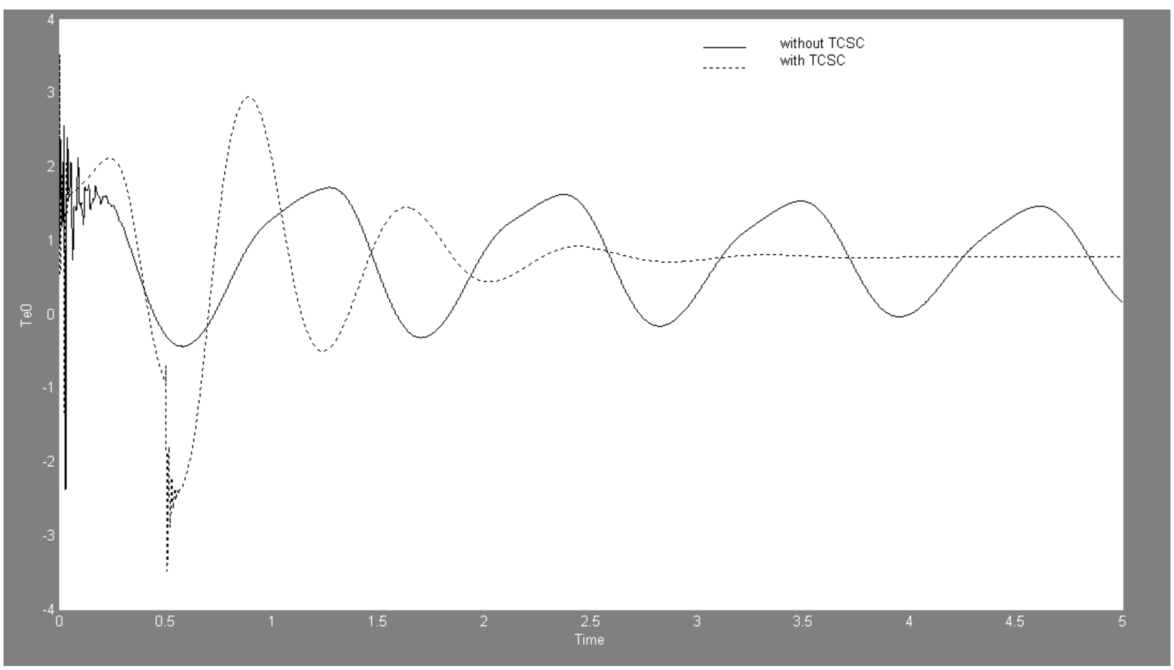

Figure III (b): Electromagnetic Torque of the Series Compensated Line with and without TCSC

V. Conclusion

In this paper it has been noticed that TCSC improves the transient stability of the power system in a series compensated line. In series compensated line TCSC damp the oscillations & system becomes stable at t=2.7sec.

APPENDIX

Generator parameters:
P=600MVA,
V=20KV,f=60,X_d=1.305,X_d'=0.246,X_d''=0.252,X_q=0.474,X_q'= 0.474,X_q''=0.243

Excitor Parameters:
K_a=200, T_a=0.02, K_e=1

Turbine Parameters:
K_a=10/3,T_a=0.07,R_p=0.005,K_p=1.163,K_i=0.105,K_d=0

Transformer Parameter:
P=600MVA,f=60,V_1=22e3,R_1=0.06/100,L_1=0,V_2=500e-3,R_2=0.06/100,L_2=0.12

TCSC Parameters:
TCSC capacitance= 21.977e-6, TCSC reactance= 0.043, Manual alpha=78

Three Phase Source Parameter:
V=500e3*0.98, phase angle=9.2-40 , Base voltage(VA)=9000MVA,Base voltage(Vrms)=500kv,X/R=10

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