Dynamic study and Stability Analyze of Damping Cohefision and Reactance in TCSC Controller Connected on Optimization SMIB System

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Abstract— **Thyristor controlled series compensator (TCSC) controller, can control the line impedance through the introduction of a thyristor-controlled capacitor in series with the transmission line. The TCSC controller is useful for stability improvement. Model is different from other paper because synchronous generator with just field circuit and one damper on q axis is used. While in other studies Phillips-Heffron has been uses .At the first step, the transition from a capacitive mode to bypass mode the TCSC controller is modelled with detailed dynamics. The TCSC controller is modelled in stability improvement. Then simulated TCSC shows that the oscillations are changed with escalate the damping coefficient. Change in value of reactance of the TCSC also affects the stability of the system. The analysis shows that if compensation is provided through TCSC controller then the system attains stability at a faster rate that has come in another paper from these writers.**

Keywords- Power System Stability; Transient Stability Limit; FACTS; Voltage Stability.

I. INTRODUCTION

FACTs controllers can balance the power flow and thereby using the existing power system network most efficiently. By fast response of FACTs controllers, facts can improve the stability of electrical power systems by helping critically disturbed generators to give away the excess energy got through the acceleration during fault. TCSC is an important device in FACTS family and is widely used as an effective and economical means to solve the power system stability problem. TCSC is an effective and economical means of solving problems of transient stability in long transmission lines. By flexibly quickly and adjusting the reactance of the TCSC, many relevant benefits can be achieved such as the better utilization of transmission capability, efficient power flow control, and transient stability improvement, power oscillation damping, control over sub synchronous resonance (SSR), and fault current limitation. In new past decades, 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 escalate in load demand make these kinds of problems more imminent in modern power systems. The problem of transient stability after a major fault can become a transmission power limiting factor. The power system should adjust to system conditions, in other words, power system should be flexible.

II. FACTS CONTROLLER IN POWER SYSTEM

A lot of studies and reports have been published on theses subjects. These Books cover the basic idea about the FACTs devices. A detailed explanation has been given for all the FACTs devices. FACTs technology clears new opportunities for controlling and enhancing the useable capacity of present, as well as new upgraded lines. The possibility that current through a line can be controlled at a reasonable cost enables a large potential of escalating the capacity of existing lines with longer conductors and use one of the FACTs controller to enable corresponding power to flow through such lines under normal and contingency conditions. These opportunities goes up through the capability of FACTs controllers to control the interrelated parameters that conducts the operation of transmission system including shunt impedance, series impedance, voltage, current, phase angle and the damping of oscillations at various frequencies below the rated frequency. By providing added flexibility, FACTs controllers can enable a line to get power closer to its thermal rating. FACTs technology points to devices that enable flexible electrical power system operation, i.e. controlled active & reactive Power flow redirection in transmission paths. Using power electronics with turn off capability cause FACTs device offers continuous control of power flow or voltage, against daily load changes or change in network topologies. The second generation FACTs results with much smaller reactive elements by. Because of their fast response FACTs can also improve the stability of an electrical power system by helping critically disturbed generators to give away the extra energy got through the acceleration during fault. A TCSC is a series controlled capacitive reactance that can provide continuous control of power on the AC line over a spread range. A simple understanding of TCSC functioning can be obtained by analyzing the behavior of a variable inductor connected in series with a fixed capacitor, as shown in figure 1. The equivalent impedance Z_{eq} of this LC combination can be expressed as:

$$Z_{eq} = \left(j\frac{1}{\omega C} \right) \| \left(j\omega L \right) = -j\frac{1}{\omega C - \dfrac{1}{\omega L}} \qquad (1)$$

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If $LC\omega^2>1$, the reactance of the FC is less than that of the parallel connected variable reactor and this combination provides a variable capacitive reactance. If $LC\omega^2=1$, a resonance develops that result in infinite capacitive impedance, this is an unacceptable condition. If $LC\omega^2<1$, then the combination provides inductance above the value of fixed inductor. This situation corresponds to the inductive venire mode of the TCSC operation, discussed in further section.

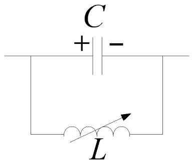

Figure 1. A variable inductor connected in shunt with a fixed capacitor.

The behavior of TCSC is same 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; where as in TCSC because of the voltage and current in the FC and thyristor controlled reactor (TCR) is not sinusoidal because of thyristor switching. The detail of TCSC working is discussed in further sections. TCSC circuit for the analysis can be shown in figure 2.

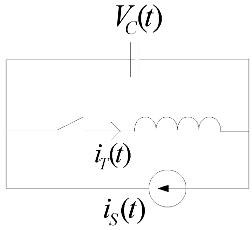

Figure 2. Simplified TCSC circuit.

The steady state thyristor current i_T can be given as

$$i_T(t) = \frac{K^2}{K^2-2} I_m \left(\cos\omega t - \frac{\cos\beta}{\cos k\beta}\cos\omega_r t\right) \qquad (2)$$
$$-\beta \le \omega t \le \beta$$

where

$$\omega_r = 1\big/\sqrt{LC} \qquad (3)$$

$$k = \frac{\omega_r}{\omega} = \sqrt{\frac{X_c}{X_p}} \qquad (4)$$

The steady state capacitor voltage at the instant $\omega t = -\beta$ is given as:

$$V_{c1}(t) = \frac{I_m X_c}{K^2-1}(\sin\beta t - k\cos\beta\tan k\beta) \qquad (5)$$

At $\omega_t = \beta, i_T = 0$ capacitor voltage is

$$v_c(t) = v_{c2} = -v_{c1} \qquad (6)$$

The final expression for the capacitor voltage is given as

$$V_c(t) = \frac{I_m X_c}{K^2-1}\left(-\sin wt + k\frac{\cos\beta}{\cos k\beta}\sin\omega_r t\right)$$
$$-\beta \le \omega t \le \beta \qquad (7)$$

$$v_c(t) = v_{C2} + \mathrm{Im}\, X_C(\sin\omega t - \sin\beta)$$
$$\beta \le \omega t \le \pi - \beta \qquad (8)$$

The fundamental component, V_{CF}, is obtained as:

$$V_{CF} = 4\big/Pi \int_0^{pi/2} vc(t)\sin\omega t\, d(\omega t) \qquad (9)$$

The equivalent TCSC reactance is given by:

$$X_{TCSC} = \frac{V_{CF}}{I_m} = X_C \frac{X_C^2}{(X_C - X_P)}\frac{2\beta + \sin 2\beta}{\pi} + \frac{4X_C^2\cos^2\beta(K\tan k\beta - \tan K\beta)}{(X_C - X_P)(K^2-1)\pi} \qquad (10)$$

where V_{CF} is fundamental component of the capacitor voltage, X_C is nominal reactance of the fixed capacitor only, X_P is inductive reactance of inductor connected in parallel with fixed capacitor. The resonant zone is avoided by installing limits on the firing angle. TCSC is mainly used in capacitive zone. The complete system has been represented in terms of SIMULINK blocks in a single integral model. SIMULINK is a software tool associated with MATLAB, used for modeling, simulating and analyzing dynamical systems. Single Machine Infinite Bus (SMIB) system with all the required components is modeled and is described. Simulink model of SMIB system with TCSC has been illustrated in Figure 3.

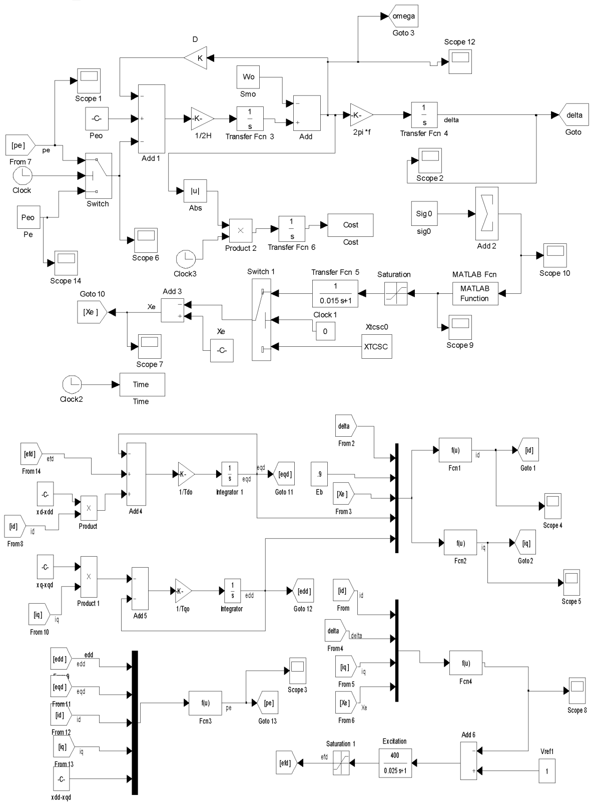

Figure3. Model of SMIB system using TCSC

III. SIMULATION RESULTS

This is useful for transient stability study as the power system configuration differ before fault and after fault. The SIMULINK model of SMIB with TCSC controller is analyzed for divers' conditions of damping constant. Figure 8 shows the rotor angle variation for SMIB with TCSC controller for diver's cohefision damping

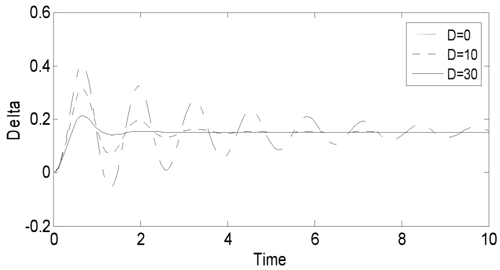

Figure 4 .Rotor angle variations $\Delta\delta$

Figure 4 indicates that the rotor angle (delta) at t = 0, increases to its maximum peak and oscillates to attain its steady state within 15-20 sec. Also divers variation with D=10 and D=30 is shown that shows stability time has reduced to 4 and 2 respectively. The effect of varying the damping constant on the power system stability and the value of firing angle (alpha) of142^{0}for diver's element of machine has shown in figure 5till 11. The analysis shows that if compensation is provided through TCSC controller then the system attains stability at a faster rate.

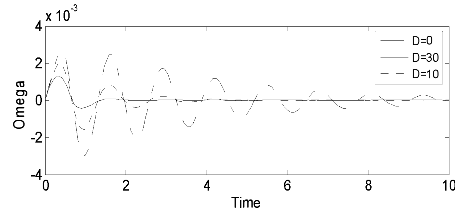

Figure 5 .speed variation $\Delta\omega$

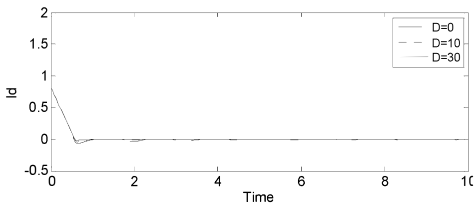

Figure 6 .current variation I_d

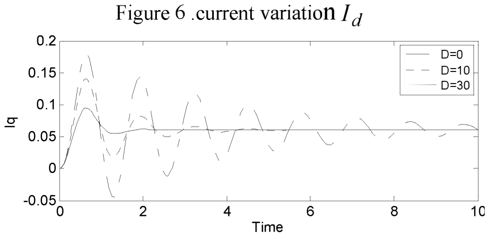

Figure 7 .current variation I_q

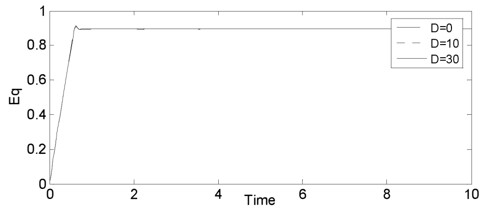

Figure 8 .voltage variation E_q'

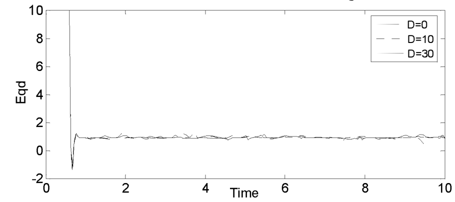

Figure 9 .voltage variation E_{fd}

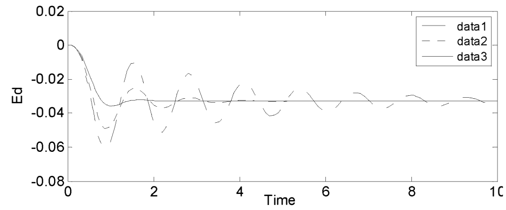

Figure 10 .voltage variation E_d'

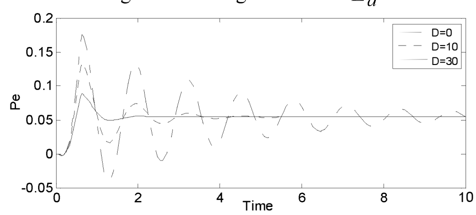

Figure 11.variation of P_e

Now change of damping variation for test of stability by choosing ω_{mo}=1. Divers variation of D=10, D=20 and D=30 has shown that shows stability time has reduced too in this case. The effect of varying the damping constant on the power system stability and the value of firing angle (alpha) of142^{0}for diver's element of machine has shown in figures 12 till 20. The analysis shows that if compensation is provided through TCSC controller then the system attains stability at a faster rate.

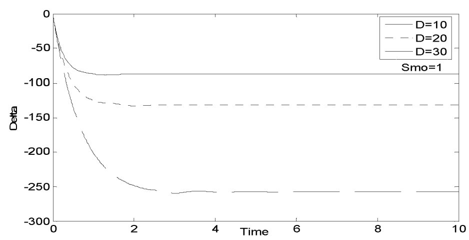

Figure 12 .Rotor angle variations $\Delta\delta$

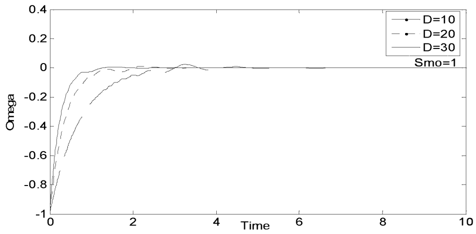

Figure 13.speed variation $\Delta\omega$

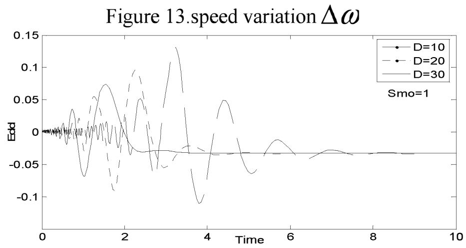

Figure 14 .voltage variation E'_d

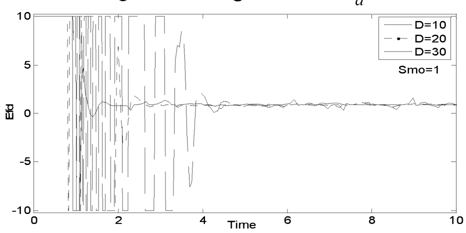

Figure 15 .voltage variation E_{fd}

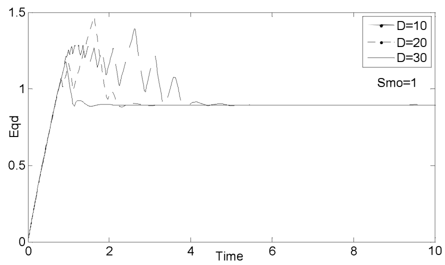

Figure 16 .voltage variation E'_q

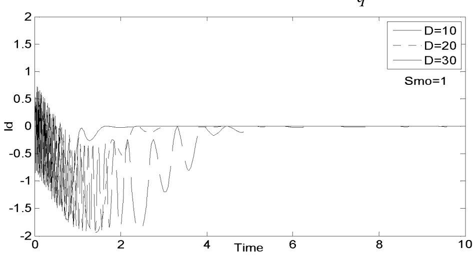

Figure 17 .current variation I_d

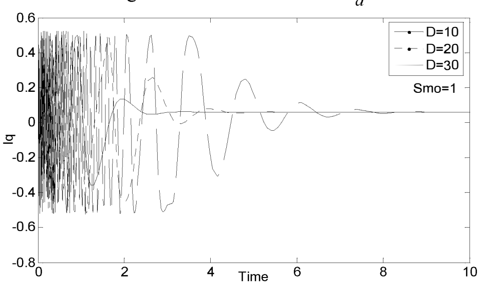

Figure 18 .current variation I_q

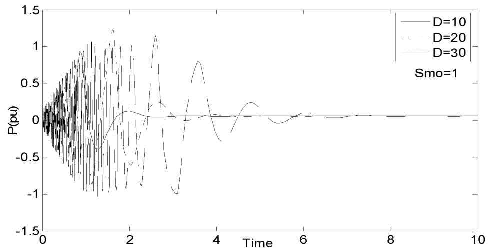

Figure 19.variation of P_e

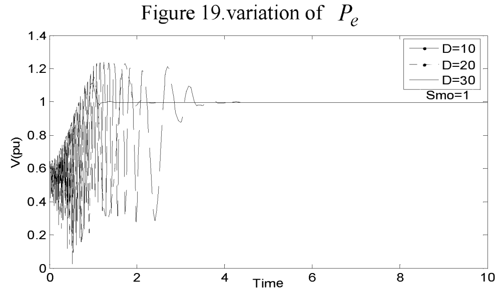

Figure 20.variation of v

Now the behavior of the system is again analyzed by boosting the value of TCSC capacitor. Figure22.shows the variation of rotor angle when the value of the capacitor of the TCSC (X_C) is varied .These changing is coming by increasing of X_C that clearly shows that system finally loses its stability.

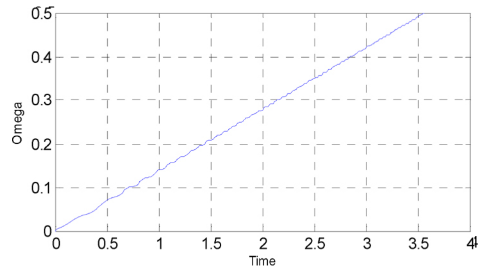

Figure 21 .speed variations $\Delta\omega$ by increasing of X_C

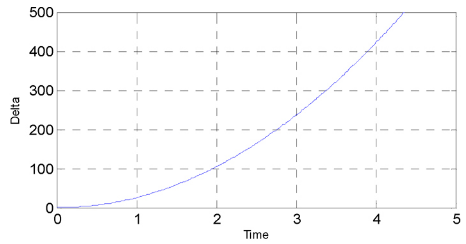

Figure 22.variation $\Delta\delta$ by increasing of X_C

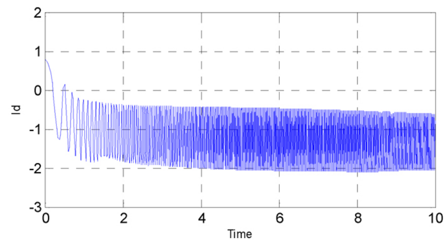

Figure 23.variation I_d by increasing of X_C

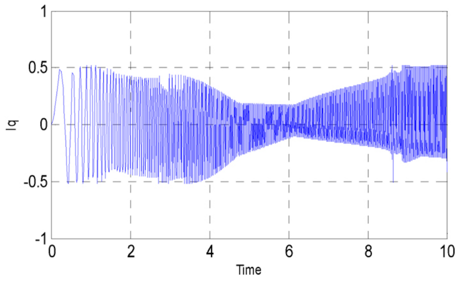

Figure24. Variation I_q by increasing of X_C

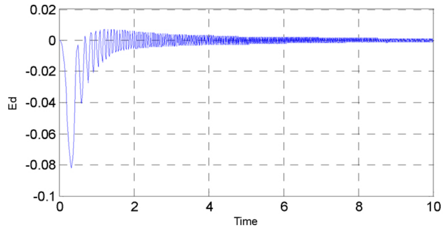

Figure25. Variation E_d' by increasing of X_C

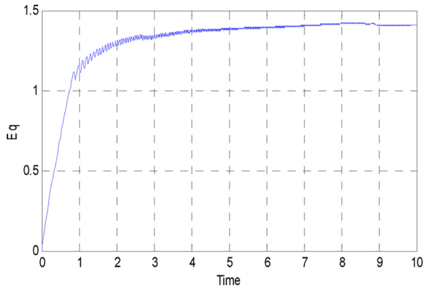

Figure 26.Variation E_q' by increasing of X_C

IV. CONCLUSION

The TCSC controller mathematical model and transfer function model is obtained. The transfer function model can be used in power system stability improvement. The compensation can be decided by changing the value of firing angle. TCSC characteristic is explained mathematically hence it can be implemented in MATLAB OR SIMULINK and further can be extended for different applications. The modeling can be done for single machine infinite bus system the analysis shows that the state of the system indicating whether the system is stable or unstable depends upon the reactance of the TCSC controller whose value changes with the change in conduction angle of thyristor in TCSC controller which in turn is governed by the rotor angle. If the value of damping constant (k=D in this paper) is increased keeping the controller gain, it is observed that the time taken for the system to get into a stable state reduces significantly.

And the relation between stability and Initial operating slip in pu (S_{mo}) has studied. The analysis also shows that if the value of reactance of the fixed capacitor of the TCSC is decreased, the time taken for the suppression of the first highest swing in rotor angle is also increased.

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