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TCSC Series Power Electronic Controller for Power Flow Control: A Review

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***Abstract*— There several FACTS devices are existing, the use of the device is completely depending upon the applications. To manage or mitigate the harmonics, improve stability, improve voltage and current profile and several power qualities issues. The load and demand can also be managed by using the FACTS controller. Among this power electronic controller's thyristor-controlled series capacitor (TCSC) have power to control the power flow with the injection of reactance with the line. It manages the power flow between the busses and maintain the voltage and current profile. TCSC behaves as a variable reactance device in which this can be operated in two modes blocking mode and bypass or conduction mode.**

Keywords—TCSC, FACTS controllers, power flow etc.

I. INTRODUCTION

Modern power systems are designed to operate efficiently to supply power on demand to various load centres with high reliability. The generating stations are often located at distant locations for economic, environmental and safety reasons [1, 2]. For example, it may be cheaper to locate a thermal power station at pithead instead of transporting coal to load centres. Hydropower is generally available in remote areas. A nuclear plant may be located at a place away from urban areas. Thus, a grid of transmission lines operating at high or extra high voltages is required to transmit power from the generating stations to the load centres [3, 4]. In addition to transmission lines that carry power from the sources to loads, modern power systems are also highly interconnected for economic reasons. The interconnected systems benefit by-

(a) Exploiting load diversity (b) Sharing of generation reserves and (c) Economy gained from the use of large efficient units without sacrificing reliability.

However, there is also a downside to ac system interconnection the security can be adversely affected as the disturbances initiated in a particular area can spread and propagate over the entire system resulting in major blackouts caused by cascading outages [3, 4, 5].

A major disturbance can also result in the swinging of generator rotors which contribute to power swings in transmission line It is possible that the system is subjected to transient instability and cascading outages as individual components (lines and generators) trip due to the action of protective relays. If the system is operating close to the boundary of the small signal stability region, even a small disturbance can lead to large power swings and blackouts [6]. The increase in the loading of the transmission lines sometimes can lead to voltage collapse due to the shortage of reactive power delivered at the load centres. This is due to the increased consumption of the reactive power in the transmission network and the characteristics of the load (such as induction motors supplying constant torque) [7, 8]. The factors mentioned in the previous paragraphs point to the problems faced in maintaining economic and secure operation of large interconnected systems. The problems are eased if sufficient margins (in power transfer) can be maintained [9,10]. This is not feasible due to the difficulties in the expansion of the transmission network caused by economic and environmental reasons. The required safe operating margin can be substantially reduced by the introduction of Fast dynamic control over reactive and active power by high power electronic controllers [11] This can make the AC transmission network flexible' to adapt to the changing conditions caused by contingencies and load variations. Flexible AC Transmission System (FACTS) is defined as `Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability' [12]. The FACTS controller is defined as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters".

The FACTS controllers can be classified as

1. Shunt connected controllers
2. Series connected controllers
3. Combined series-series controllers
4. Combined shunt-series controllers

The variable impedance type controllers include (i) Static Var Compensator (SVC), (shunt connected) (ii) Thyristor Controlled Series Capacitor or compensator (TCSC), (series connected) (iii) Thyristor Controlled Phase Shifting Transformer (TCPST) of Static PST (combined shunt and series).

II. POWER FLOW CONTROL IN AC TRANSMISSION LINE

We may like to control the power flow in a AC transmission line to (a) enhance power transfer capacity and or (b) to change power flow under dynamic conditions (subjected to disturbances such as sudden increase in load, line trip or generator outage) to ensure system stability and security [11, 12, 13, 14]. The stability can be affected by growing low frequency, power oscillations (due to generator rotor swings), loss of synchronism and voltage collapse caused by major disturbances.

$$Pmax = \frac{V1V2}{X} \sin \delta max \quad (1)$$

Where δmax is selected depending on the stability margins and the stiffness of the terminal buses to which the line is connected. For line lengths exceeding a limit, Pmax is less than the thermal limit on the power transfer determined by the current carrying capacity of the conductors [14, 15]. The series compensation using series connected TCSC increases Pmax as the compensated value of the series reactance (XTCSC) is given by

$$X_{TCSC} = \frac{X_C . X_{Lmax}\left[\frac{\pi}{\pi-2\alpha-\sin(2\alpha)}\right]}{X_C + X_{Lmax}\left[\frac{\pi}{\pi-2\alpha-\sin(2\alpha)}\right]} \quad (2)$$

III. TCSC Modelling

In The proposed TCSC model is based on the power injection approach. The total number of buses for the system is increased according to the TCSC number, where, one reference bus should be added for each TCSC [1]. the TCSC implementation between sending bus S and receiving bus R, where bus A is the auxiliary bus (reference bus). This device is used to adjust the active power between sending and receiving buses to equal the specified value, P. However, this device can be modelled simply as two loads injected at sending and auxiliary buses. TCSC have the capacitor C, bypass inductor L and antiparallel thyristors T1 and T2. The triggering pulses of the thyristors are controlled to adjust the TCSC reactance in accordance with a system control algorithm, normally in response to some system parameter variations. According to the operating principle of the TCSC, it can control the active power flow for the line l (between bus- i and bus- j where the TCSC is installed).

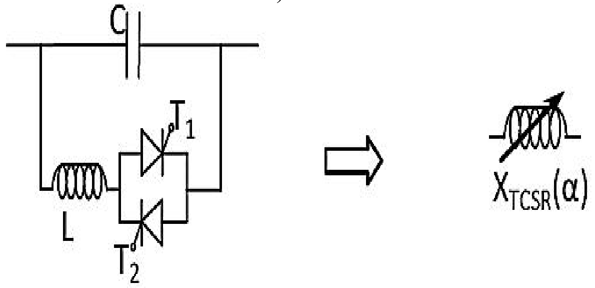

Fig. 1 TCSC model adjusted between two buses [6]

The real power P_{iinj}^{TCSC} and reactive power Q_{iinj}^{TCSC} injected at bus I can be expressed as:

$$P_{iinj}^{TCSC} = G_{ii}V_i^2 + (G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij})V_iV_j \quad (3)$$

$$Q_{iinj}^{TCSC} = - B_{ii}V_i^2 + (G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij})V_iV_j \quad (4)$$

Where,

$$G_{ij} = r_{ij}/(r_{ij}^2 + (X_{ij} - X_c)^2)$$

and

$$B_{ij} = (X_{ij} - X_c)/(r_{ij}^2 + (X_{ij} - X_c)^2)$$

TCSC works to performs like a fixed series capacitor, specified as Blocking mode and TCSC behaves like a parallel connection of the series capacitor and the inductor specified as Bypass mode.

$$X_{TCSC} = \frac{X_C . X_{Lmax}\left[\frac{\pi}{\pi-2\alpha-\sin(2\alpha)}\right]}{X_C + X_{Lmax}\left[\frac{\pi}{\pi-2\alpha-\sin(2\alpha)}\right]} \quad (5)$$

The rating of TCSC depends on the reactance of the transmission line where the TCSC is located.

$$X_{ij} = x_{line} + x_{tcsc} \quad (6)$$

$$x_{tcsc} = r_{tcsc} . x_{line} \quad (7)$$

Where, x_{line} is the reactance of the transmission line and r_{tcsc} is the coefficient which represents the degree of compensation by TCSC.

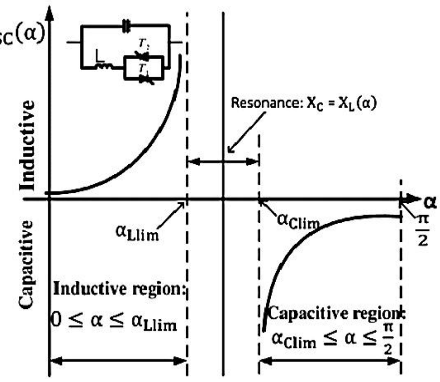

Fig. 2. Relationship Between Firing Angle (α) and X_{TCSC} [1]

IV.Controlling of TCSC

The power system stabilizer generates appropriate supplementary control signal to an excitation system of synchronous generator to damp the frequency oscillations and improves the performance of the power system dynamic. The performance of power system affected due to the system configuration and load variation. In order to achieve the appreciable damping, the series capacitor is suggested in addition to the power system stabilizer. Nonlinear simulations of single machine infinite bus system are carried out using the individual application of power system stabilizer and simultaneous application of power system stabilizer and thyristor-controlled series capacitor. There are different controlling techniques exist such as: numerical computing, logical computing, but among that Newton Raphson (NR) is most usable due to easy implementation of it.

V.CONCLUSION

Here in this study, we have studied the power flow and why this is important. In interconnected power systems, the actual transfer of power from one region to another might take unintended routes depending on impedances of transmission lines connecting the areas. TCSC is a useful means for optimizing power flow between regions for varying loading and network configurations.

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