CHAPTER-1

INTRODUCTION AND LITERATURE REVIEW

Industrialization has changed the world, which can be observed from the increased use of Electrical energy in all aspects of life. This not only led to increased generation but also has opened doors to explore new ways of power generation (be it conventional or non-conventional). Power transmission of grids can always be improved by upgrading or adding of new transmission Lines but this limited by economic and environmental considerations including the right of way (ROW) concern. This led to FACTS (Flexible AC Transmission Systems) by EPRI in late 1980's which include use of Power electronics in Power system for more reliable, controllable and more efficient power supply [1, 2]. A power line can function nearer its top thermal rating if regulated by flexible ac transmission system controllers. The power electronic revolution began in early 1980's which opened a path for ac/dc converters for HVDC transmission of bulk power and to large distances, UPS systems, Drives for sensitive loads and now to integrate PV and Wind generating systems into the main grid[4-8].

FACTS controllers can be broadly divided into four categories[1,8], which include 1.series controllers- Examples of such controllers are Static Synchronous Series Compensator (SSSC), Thyristor-Switched Series Capacitor (TSSC), Thyristor-Controlled Series Reactor (TCSR), 2.shunt controllers-. Examples of such systems are Static Synchronous Generator (SSG), Static VAr Compensator (SVC), 3.combined series-series controllers-example is the Interline Power Flow Controller (IPFC), and 4.combined series-shunt controllers- Examples of such controllers are Unified Power Flow Controller (UPFC) and Thyristor- Controlled Phase-Shifting Transformer (TCPST).

Series FACTS Controllers have been found to be more effective in improving the power transmission capability of existing transmission corridors [9]. Among the series FACTS Controllers, TCSCs have been the earliest ones to be designed and installed over numerous practical installations worldwide [10-14]. They are also used for improvement in system stability, voltage regulation, reactive power balance and load sharing between parallel lines [15-20]. A TCSC module consists of a series capacitor and a parallel path including a thyristor switch and a series inductor. Also in parallel, same as in conventional series capacitor application is a metal-oxide varistor (MOV) for overvoltage protection and a bypass breaker. A complete TCSC system may consist of several such modules and conventional series capacitor part in series to improve the overall power system performance. The complete circuit analysis is discussed in [21].

Now, assessment of key issues like voltage, frequency, and reliability in power system operation may be done quite effectively by resorting to power flow and derived studies. The main objective of a power flow study is to determine the steady-state operating condition of the electrical power network. The steady-state may be determined by finding out, for a given set of loading conditions, the flow of active and reactive powers throughout the network and the voltage magnitudes and phase angles at all buses of the network these are explained [22, 23]. Expansion, planning and daily operation of power systems relies on extensive power flow studies. The information conveyed by such studies indicates whether or not the nodal voltage magnitudes and active and reactive power flows in transmission lines and transformers are within prescribed operating limits [24]. If voltage magnitudes are outside bounds in one or more points of the network, then appropriate action is taken in order to regulate such voltage magnitudes. Similarly, if the study predicts that the power flow in a given transmission line is beyond the power carrying capacity of the line, and then control action is taken.

For determining the steady state operating point of any power system network installed with TCSC, power flow model of TCSC is required. Since the Newton-Raphson algorithm was adopted as the de-facto industry standard for power flow vis-à-vis its quadratic convergence characteristics, this work concerns with the development of a Newton-Raphson power flow model of the TCSC. This has provided the main motivation for adopting a full Newton-Raphson technique in our FACTS load flow program [25].

A Newton power flow model of the TCSC can be developed in two ways. Firstly, it is done by assuming it as a variable susceptance called (1).variable impedance model. The susceptance of the TCSC is chosen as the state variable. The relation between reactance and firing angle is non-linear [26] and the graph can be observed in [25]. For evaluation of the reactance only fundamental frequency is considered as the higher harmonic currents are eliminated by the filters. This technique uses a Newton Raphson loop to find out the firing angle alpha from the Susceptance obtained as the result of the load flow [27].The drawback of this model is that the firing angle corresponding to such a compensation level has to be determined by resorting to an iterative process, in addition to the load flow solution. Moreover, it is not possible to assess within the load flow solution whether or not the solution is taking place in the vicinity of a resonant point. The only indication would be a divergent iterative process, the above two points are highlighted in [25, 27, 28]. The second method of modeling is called (2).Firing angle model, in this model the firing angle is chosen as the state variable, this method eliminates the additional iterative process required in the former. The firing angle itself is obtained as the result of the load flow conducted on the system. Moreover the availability of the reactance graph helps us to choose good initial approximations which help in achieving good convergence. The resonance region of operation can be avoided by proper selection of alpha operating values. Elimination of multiple resonance points can be dealt with selection of 'k' value which is generally less than 3 as discussed by Guowen [29].

The Newton power flow model of the TCSC developed was tested on a small six bus system [3] and the IEEE 30 bus test system [30]. At first, the base case power flow was carried out. Subsequently, a TCSC was installed in one of the lines. The line power flow was set to a value slightly more than the base case value and the power flow solution was obtained. This was repeated for different lines and different values of corresponding line power flows. Power flow solutions were obtained for both the susceptance and the firing angle models. Solution values displayed a close match for both the models.

In all the case studies, very good convergence characteristics were obtained, which validates the model.