Placement of TCSC for Improvement of Power Flow

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Abstract— In these modern days due to the ever increasing demand of power in expansion to transmission network, the transmission line are to be operated under loaded condition and there is a risk of power flow control and voltage instability. Flexible AC Transmission Systems (FACTS) is one of the most technologies that respond to these needs. Thyristor Controlled Series Compensator (TCSC) is the series compensating FACTS devices. Thyristor Controlled Series Compensator (TCSC) consists of a series compensating capacitor shunted by a Thyristor Controlled Reactor (TCR). In this paper work device modeling of TCSC has been carried out along with development of transmission system. The Load flow analysis is one of the most important solutions in power system studies. The TCSC series device has been applied to 11 bus power transmission system using MATLAB/SIMULATION.

Keywords-- FACTS, Power flow, Two Area network, TCSC Model.

I. INTRODUCTION

Today's modern interconnected power system is highly complex in nature. FACTS (Flexible Alternating Current Transmission System) are generally based on power electronics. These are generally used for increasing transmission capacity in the power system and have capacity to control several parameters in transmission network. The main purpose of series compensation in power systems is to vary the impedance of transmission line. The use of these controllers gives grid planners and operators a greater flexibility regarding the type of control actions that can be taken at any given time.

In a three phase ac power system active and reactive power flows from the generating plant to the load through a different transmission networks buses and branches. The flow of active and reactive power is known as power flow or load flow. Power flow analysis is used in the steady-state operating condition of a power system to determine the different parameters of line. Power flow analysis is widely used by power distribution during the planning and operation of power distribution system.

A rapid development of TCSC research work started in last decade of 20th century and flourished in the beginning of first decade of 21st Century with the development of new method of controlling TCSC. The entire collection of research work of TCSC device is revealed and classified as per applications. The applications of TCSC device not only have accrued benefits in terms of increased transmission line capacity, but also enhance the power oscillation damping (POD), sub synchronous resonance mitigation (SSR) and transient stability.

II. TCSC (THYRISTOR CONTROLLED SERIES CAPACITOR)

IEEE Definition: 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.

Thyristor-controlled series capacitors (TCSC) is a type of series compensator, can provide many benefits for a power system which include controlling power flow in the line, damping power oscillations, and mitigating sub synchronous resonance. The TCSC concept is that it uses an extremely simple main circuit. The capacitor is inserted directly in series with the transmission line and the thyristor-controlled inductor is mounted directly in parallel with the capacitor.

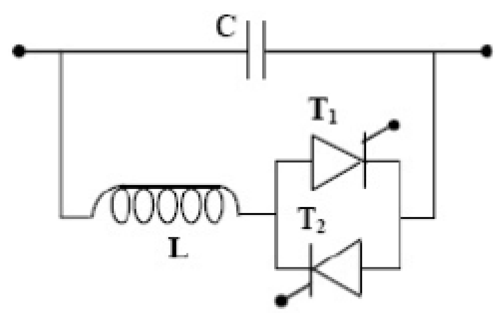


Fig. 1 A simple diagram of TCSC device

Transmission lines compensation by means of TCSC can be used to enhance the power transfer capability improve transient stability and reduce transmission losses and damping power system oscillations. In this paper work device modeling of TCSC will be carried out along with development of transmission system using MATLAB.

The primary uses of TCSC are to enhance the power system angle stability and to mitigating the sub- synchronous resonance risk by regulating reactive power and maximizing transient synchronizing torque between the interconnected power systems. However, the inserted series capacitor also affects the reactive power distribution in the interconnected power systems. Thus suggests that TCSC be used to enhance the voltage stability.

III. OPERATION OF TCSC

The TCSC consists of three main components: capacitor bank C, bypass inductor L and bidirectional thyristors SCR 1 and SCR 2. The firing angles 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. When the thyristors are fired, the TCSC can be mathematically described as follows:

The impedance of TCSC (ZTCSC)

$$ZTCSC = (-jXc)\,(jXTCR) / j(XTCR-XC)$$

$$ZTCSC= (-JXc) / (1-Xc/ XTCR)$$

The current through the TCR (ITCSC) is given by

$$ITCSC = (-jXc)\ IL / j(XTCR - Xc)$$

$$ITCSC = IL / (1 – XTCR / Xc)$$

Since the losses are neglected, the impedance of TCSC is purely reactive. The capacitive reactance of TCSC is obtained.

$$XTCSC = Xc / (1 – Xc / XTCR)$$

The basic operation of TCSC device can be easily explained from circuit analysis.Fig.2 shows a TCSC which consists of a series compensating capacitor (C) shunted by a Thyristor Controlled Reactor (TCR). TCR is a variable inductive reactor (XL(α)) tuned at firing angle α, as shown in Fig.2.

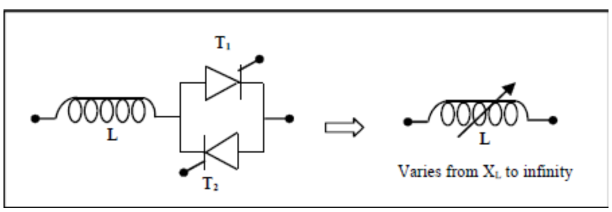


Fig. 2 Equivalent circuit of TCR

For the variation of α from 0 to 90°, TCR reactance XL (α) varies from actual inductive reactance (XL) to infinity. This controlled reactor is connected across the series capacitor, so that the variable capacitive reactance, as shown in Fig. 3 is possible across the TCSC which modify the transmission line reactance. Effective TCSC reactance XTCSC with respect to alpha (α)

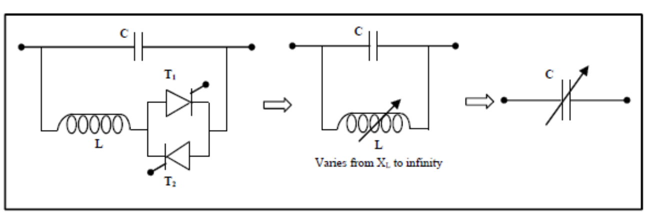


Fig. 3 Equivalent circuit of TCSC

IV. OPERATING CHARACTERISTIC

Figure 4 shows the operating characteristics curve of a TCSC device. It is drawn between effective reactance of TCSC and firing angle α.

In capacitive mode the range for impedance values is approximately 120Ω -136Ω.

a) Firing angle α for Inductive mode: 0°-49°.
b) Firing angle α for Resonance Region: 49°-69°.
c) Firing angle α for capacitive mode: 69°-90°.

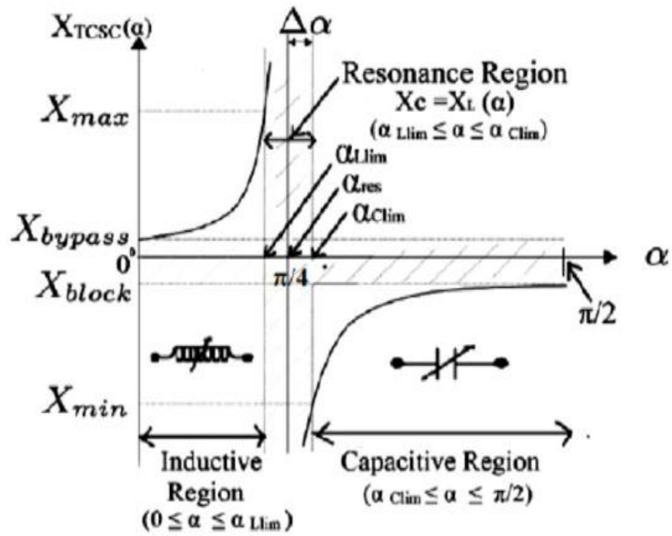


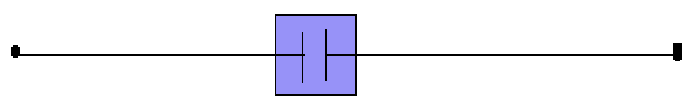
Fig. 4 operating characteristics of TCSC

V. LOCATION OF TCSC

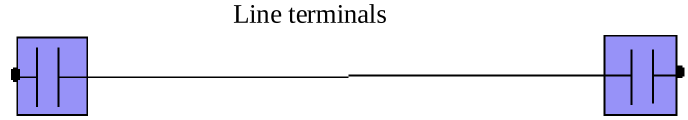
A series capacitor bank can theoretically be located anywhere along the line. Factors influencing choice of location include cost, accessibility, and fault level, maintainability of series capacitor, protective relaying consideration, voltage profile and effectiveness in improving power transfer capability. When a series capacitor is to be installed in a transmission line mainly following locations are considered.

1. Midpoint of the line.
2. Line terminals
3. 1/3 or 1/4 points of the line

Midpoint location:



Line terminals



1/3 or 1/4 points of the line

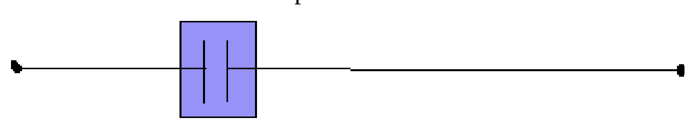


Fig 5 The location of series capacitor banks is important for several reasons:

• The compensation “effectiveness” of the series capacitor varies as a function of the series capacitor location along the line.

• The series capacitor location affects the voltage profile along the line.
• The transmission line protection and the series capacitor main circuit equipment are affected by the series capacitor location.
• The series capacitor location affects the maintainability of the series capacitor.

VI. POWER FLOW ANALYSIS

The power flow analysis (also known as load flow study) is an important tool involving numerical analysis of phenomenon and operation of power system. In a three phase ac power system active and reactive power flow from the generating station to the load through different networks buses and branches. Power flow studies provide a systematic mathematical approach for determining various bus voltages magnitude and their phase angle, active and reactive power flows through different branches, and buses. Power flow analysis is used to determine the steady state operating condition of a power transmission system.

1. BUS CLASSIFICATION

Depending on the quantities that have been specified, the buses are classified into 3 categories.

a. Load bus (Type 1):- In a load bus, the real power (P) and the reactive power (Q) are known. The variables V and δ are not specified. So this bus is also called as PQ bus.
b. Generator bus/Voltage Controlled bus (Type 2):- In a generator bus, the voltage (V) is kept constant and the output power (P) is fixed. These two items are controlled by the excitation system and the governor. The unknown variables are Q and δ. So this bus is also called as PV bus.
c. Swing bus/Slack bus (Type 3):- At the reference generator or swing bus, the voltage (V) and the load angle (δ) are known. The unknown variables are P and Q.

2. POWER FLOW STUDIES

There are three methods used for load flow studies mainly:-

I) Gauss seidel method
2) Newton raphson method
3) Fast decoupled method

A faster solution is obtained using the Newton Raphson method and is suitable for large-scale problems. In this approach, the partial derivatives are used to construct the Jacobian matrix.

VII. MODELLING AND SIMULATION

The simple two bus system as shown in fig 6. The system with three phase fault without TCSC as shown in fig 7 and with TCSC in fig 9. The corresponding waveform of reactive power without TCSC is shown in fig 8 and with TCSC is shown in fig 10.

In this simulation process the three phase fault (LLLG) is occurred at 0.2sec with the duration of 0.1sec. The fault clearing time for the circuit breaker is 0.4sec.The purpose of this simulation is to increase the power transfer capability by using TCSC.

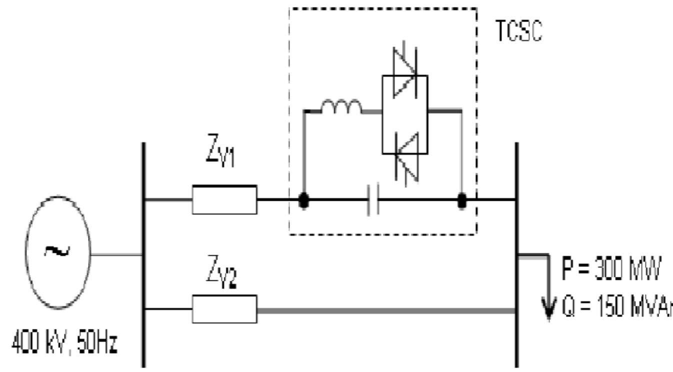


Fig. 6.Simple two bus system.

VIII. SIMULATION & RESULTS

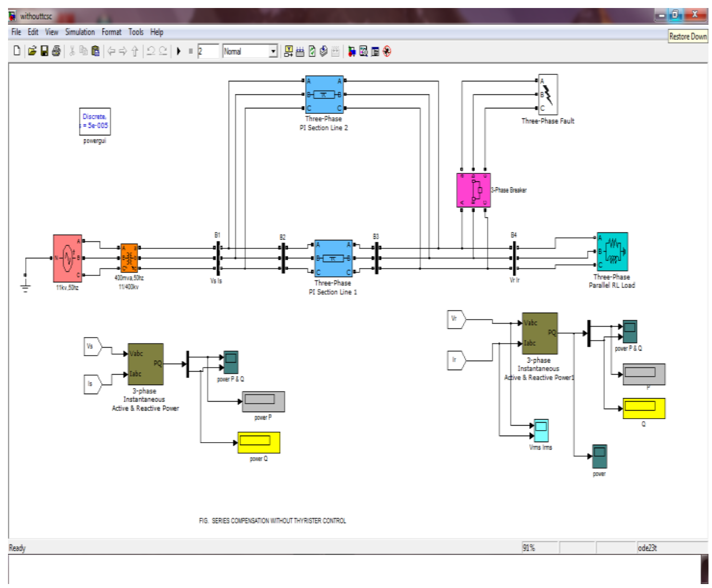


FIG. 7- SIMULINK model without TCSC controller

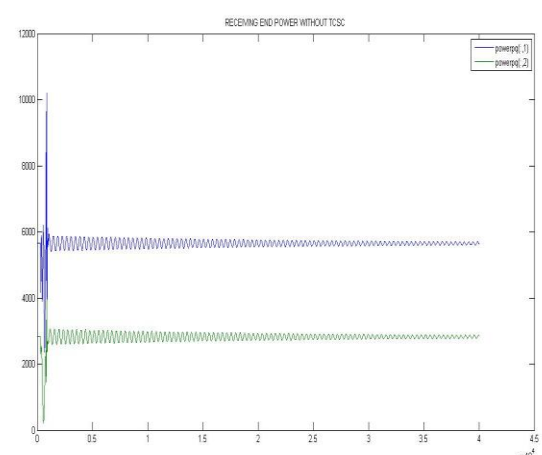


Fig. 8 Receiving end power without TCSC

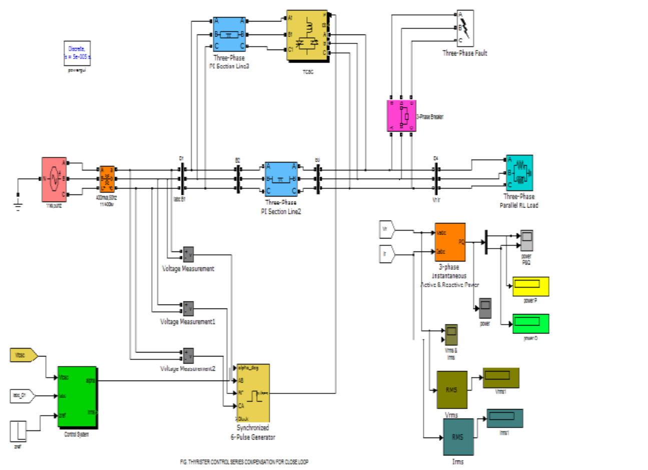


FIG. 9- SIMULINK model with TCSC controller

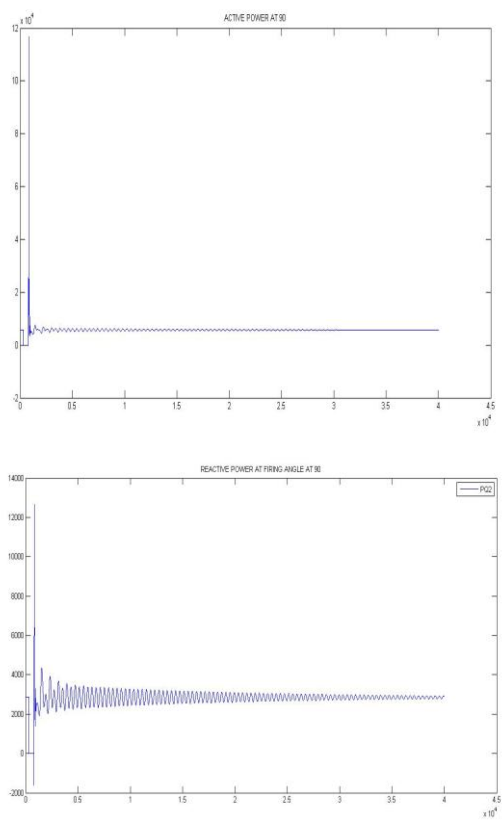


Fig. 10 Receiving end power with TCSC

TABLE 1:- THE POWER FLOW IN THE LINE AT THE LOAD P=300MW AND Q=150MVAR

		Firing angle α			
Power	Without TCSC	90°	130°	140°	180°
P(MW)	296	285	284.3	298.4	295.4
Q(MVAR)	148.5	142.3	141.3	148.3	148.3

TABLE 2:- POWER FLOW IN THE LINE AT THE LOAD P=300MW AND Q=200MVAR

		Firing angle α			
Power	With TCSC	90°	130°	140°	180°
P(MW)	294	277.4	274.2	295.3	292.9
Q(MVAR)	196.8	188.3	187.3	198.7	197.2

The result is shows at firing angle α=140° and 180°, the power flow in line increasing as compare to the conventional method (without TCSC). The table shows the result for different load and firing angle.

IX. CONCLUSION

In this paper, optimal placement and sizing of TCSC device has been proposed for improving and controlling the power flows. The performance of TCSC is also studied. A simulation result of MATLAB/SIMULINK model of a TCSC controller shows the effect of TCSC in controlling of active and reactive power in the transmission line. By controlling the firing angle of a thyristor from 180 degree to lower values the effective impedance of the TCSC can be varied from capacitor impedance to 3 times the capacitor impedance. This work is also extended for automatically controller by the set of mode of operation when there will be a sudden change in load or sudden disturbance or any faults in the power system. the location of TCSC is based on load flow analysis. After selecting the location the level of compensation varies from 30% to 70% maximum power transfer occurs in the system.

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