International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 01
January 2017

Evaluation of Tcsc Power Flow Control Capability

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ABSTRACT

In an A.C Transmission system power flow can be controlled by injecting a compensating voltage in series with the line. Thyristor Controlled series compensators (TCSC) are utilized as a conventional means for the purpose. This paper utilizes the steady state model of Thyristor controlled series capacitor and a unified power flow controller for series voltage compensation, and evaluating their range of power flow control for simple network. The models are incorporated into the existing Newton Raphson load flow algorithm. The iterative equations of the Newton Raphson load flow algorithm are modified by the device parameters and the combined set of power flow equations and the TCSC control equations are solved for convergence of the formula. Matlab codes are utilized for the implementation of the devices in the Newton-Raphson algorithm. Power flow control ranges are evaluated for standard 5 bus system. Results are reported and studies are presented to illustrate the power flow capabilities of TCSC.

Keywords: Converters, Control Strategy, MATLAB, Newton Raphson algorithm, Power flow, TCSC

I. Introduction

OWING to the higher industrial demands and deregulation of the power supply industry the transmission facilities are being overused. This provides the momentum for exploring new ways of maximizing the power transfers of existing transmission facilities while, at the same time, maintaining acceptable levels of network reliability and stability. This scenario makes necessary the development of high performance control of the power network. Recent advancement in power electronics has proven to satisfy this need by introducing the concept of flexible AC transmission system (FACTS). The FACTS controllers are used in regulating the power flows, transmission voltages and mitigate

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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the dynamic disturbance. Since its inception the FACTS devices has developed in steps, the first generation being mechanically controlled capacitors and inductors. The second generation of FACTS devices replaced the mechanical switches by the

thyristor valve control. This gave a marked improvement in the speed and the enhancement in concept to mitigate the disturbances. Power flow in a transmission line can be controlled by regulating the voltage at the two ends of the line, the phase angle or the reactance of the line. Thyristor controlled series compensators works on the principal of regulating the voltage of the transmission line by injecting voltage employing capacitor or inductor. In order to fully investigate the impact of this device on power system effectively, it is essential to formulate their correct and appropriate model. Generally there are three types of model of FACTS devices available in the literature.

(i) Steady state model for system study state evaluation.

(ii)Electromagnetic model for detailed equipment level investigation.

(iii) Dynamic models for stability studies.

This paper deals with the steady state models of TCSC [6] which can be incorporated in Newton Raphson load flow algorithm.

II. Power Flow control

In its most basic form the power transmission line can be represented by a two bus system k, m. The active power transmitted betweens bus nodes k and m is given by

$$P = \frac{|V_k||V_m|}{X_l} sin(\delta_k - \delta_m)$$

where Vk and Vm are the voltages at the nodes, (δk-δm) the angle between the voltages and XL the line impedance. The power flow can be controlled by altering the voltages at a node, the impedance between the nodes and the angle between the end voltages. The reactive power is given by.

$$Q = \frac{|V_k|^2}{X_l} - \frac{|V_k|}{X_l}\frac{|V_m|}{} cos(\delta_k - \delta_m)$$

THYRISTOR-CONTROLLED SERIES COMPENSATION

Thyristor-Controlled Series Compensation (TCSC) is used in power systems to dynamically control the reactance of a transmission line in order to provide

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 01
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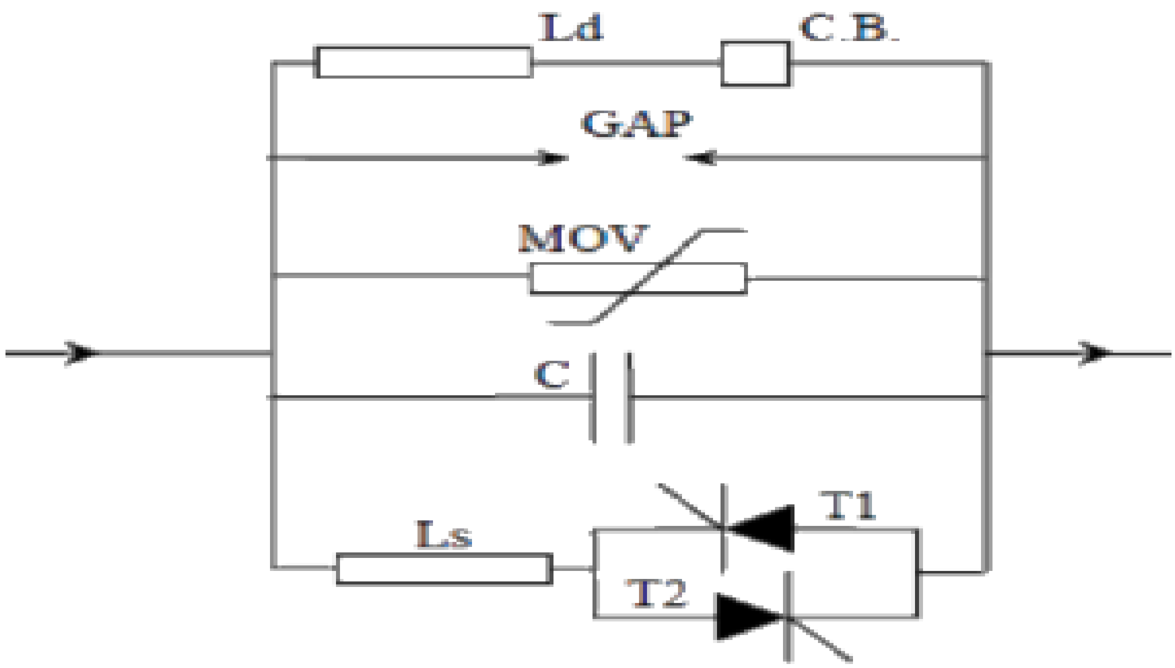
sufficient load compensation. The benefits of TCSC are seen in its ability to control the amount of compensation of a transmission line, and in its ability to operate in different modes. These traits are very desirable since loads are constantly changing and cannot always be predicted.

TCSC designs operate in the same way as Fixed Series Compensation, but provide variable control of the reactance absorbed by the capacitor device. The basic structure of a TCSC can be seen below:



A thyristor-controlled series compensator is composed of a series capacitance which has a parallel branch including a thyristor-controlled reactor. TCSC operates in different modes depending on when the thyristors for the inductive branch are triggered. The modes of operation are as listed:

- Blocking mode: Thyristor valve is always off, opening inductive branch, and effectively causing the TCSC to operate as FSC
- Bypass mode: Thyristor valve is always on, causing TCSC to operate as capacitor and inductor in parallel, reducing current through TCSC
- Capacitive boost mode: Forward voltage thyristor valve is triggered slightly before capacitor voltage crosses zero to allow current to flow through inductive branch, adding to capacitive current. This effectively increases the observed capacitance of the TCSC without requiring a larger capacitor within the TCSC.

Because of TCSC allowing different operating modes depending on system requirements, TCSC is desired for several

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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reasons. In addition to all of the benefits of FSC, TCSC allows for increased compensation simply by using a different mode of operation, as well as limitation of line current in the event of a fault. A benefit of using TCSC is the damping of sub synchronous resonance caused by torsional oscillations and inter-area oscillations. The ability to dampen these oscillations is due to the control system controlling the compensator. This results in the ability to transfer more power, and the possibility of connecting the power systems of several areas over long distances.

Implementation Of TCSC Models In Newton Raphson Power Flow Algorithm.

The TCSC power equations are combined with the network equations and linearised with respect to the state variables. The linearized power flow equations can be represented as [F(X)] = [J] [ΔX] where [F(X)] is power flow mismatch vector, [J] is the Jacobian matrix; [ΔX] is the state variable correction vector [1]. The device parameters are used as state variable. For the TCSC the variable reactance is taken as state variable. The inclusion of these variables increases the dimension of the jacobian.

B. Control Strategy

For the TCSC variable series reactance is taken as the state variables. This reactance is adjusted in the Newton Raphson algorithm at each iteration automatically along with the network state variables to achieve the specified power and voltage. The variable reactance XT represents the equivalent reactance of all the series connected modules making up the TCSC, when operating in either the inductive or the capacitive regions

Test Case and Simulation

Standard 5 bus test network is tested without TCSC and with TCSC, to investigate the behavior of the two devices in the network. In the analysis bus 1 is taken as slack bus, 2 and 3 are voltage control buses and 4, 5 are load buses. To include the TCSC in the network an additional bus (bus no 6) is introduced as shown. For TCSC the inductive reactance is taken 0.015 pu. The TCSC is implemented as variable series reactance model for power flow control. The series reactance is taken as state variable and its value is adjusted automatically to obtain specified power which was taken as 0.19 pu. For the TCSC the convergence was obtained at 9 iterations. The simulation yields the power flow for lines and bus active and reactive powers which are tabulated below.

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 01
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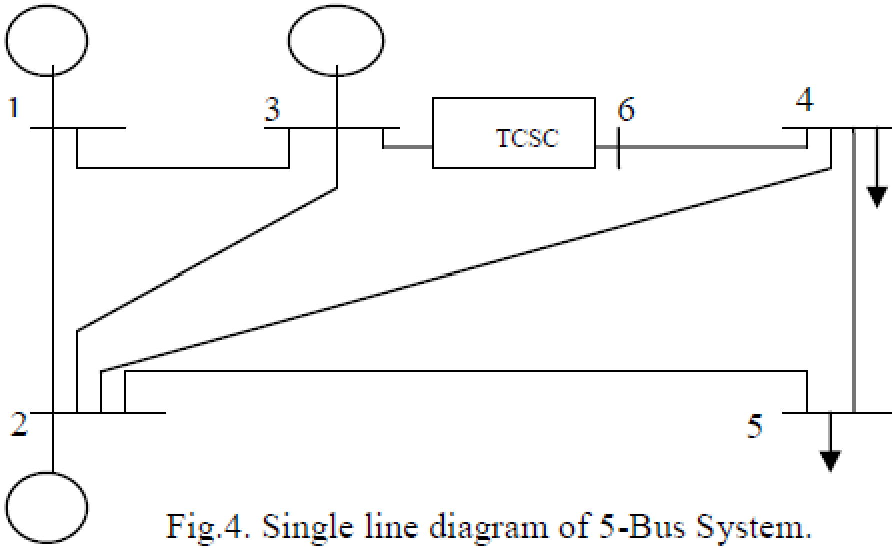

Fig.4. Single line diagram of 5-Bus System.

CONCLUSION

The steady state models of TCSC are evaluated in Newton Raphson algorithm and the results obtained showed the possible power flow control range with TCSC.

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