

USING A TCSC FOR LINE POWER SCHEDULING AND SYSTEM OSCILLATION DAMPING – SMALL SIGNAL AND TRANSIENT STABILITY STUDIES

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Abstract – This paper describes, in a tutorial manner, TCSC control aspects illustrated through simulation results on a small power system model. The analysis and design of the TCSC controls, to schedule line power and damp system oscillations, are based on modal analysis, and time and frequency response techniques. Transient stability results are included, to validate and refine the TCSC controller design and protection logic under large disturbances.

Keywords – FACTS Controllers, Eigenanalysis, Controller Design, System Oscillations, Power Flow, Transient Stability

1. INTRODUCTION

The potential benefits of Flexible AC Transmission Systems (FACTS) are now widely recognized by the power system engineering community [1,2]. Two Thyristor Controlled Series Compensation devices (TCSC) [3,4], along with a Thyristor Switched Series Capacitor (TSSC), have been in operation for some time in North America [5]. Two other TCSCs were commissioned in early 1999 in South America [6]. The short-term need to assess the impact of FACTS technology has led to R&D efforts on modeling, methodologies and software for static and dynamic analyses, and control strategies. Dynamic studies must contemplate both low and high frequency phenomena, calling for the use of different computer tools.

This paper deals with TCSC control aspects under both small signal and large disturbance conditions. A tutorial exercise on TCSC oscillation damping control and line power scheduling strategies is presented using a small power system model. An alternative control structure is proposed for the practical implementation of the “constant angle” strategy [7]. This strategy allows the rerouting of incremental power transfers in interconnected power systems. Eigenvalue, frequency domain, step response and transient stability results are provided. The data on the example power system utilized are provided in the Appendix so the results may be reproduced or expanded upon by others.

2. TCSC CONTROLS AND POWER SYSTEM MODEL DESCRIPTION

The example system model (see Fig. 1 and Appendix) comprises a 5-unit hydro power plant connected to an infinite bus through a step-up transformer followed by two transmission circuits. The two operating points considered

correspond to generation levels of 1000 MW or 800 MW in the case of a line outage.

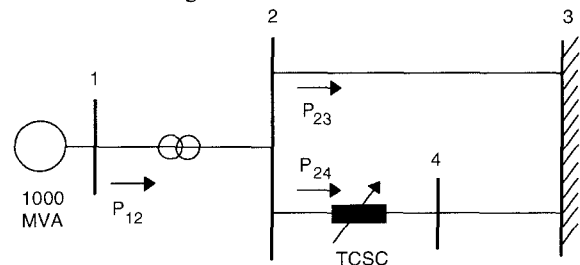


Fig. 1. Small Power System with TCSC.

The generator has a 5th order model with data described in the Appendix. The automatic voltage regulator is represented by a first-order transfer function, also given in the Appendix. The TCSC device is located in line 2-4.

2.1 TCSC Model and Control System Diagram

Fig. 2 shows the control system diagram of a TCSC connected to a transmission line, considering also the dynamics of the linearized power system model. The blocks $PI(s)$ and $POD(s)$ denote the transfer functions of the TCSC line power scheduling controller and Power Oscillation Damping (POD) controller, respectively. The blocks $F_1(s)$ and $F_2(s)$ relate the TCSC output (variable line series susceptance, $B_{2,4}$) to the controlled system variable (x_{cont}) and the input variable to the POD controller, (x_{inp}). Functions $F_1(s)$ and $F_2(s)$ have the same order as the number of system state variables. The symbol x_{ref} denotes the TCSC reference or setpoint, whose value in steady-state is equal to x_{cont} due to the PI controller action.

The TCSC model consists of current injections at buses 2 and 4, which are assumed to be the device terminals. The initial value for its susceptance ($B_{2,4}^0$) is the line 2-4 series susceptance, which is directly modeled into the power flow equations. The TCSC variable susceptance ($B_{2,4}$) is given, at any instant, by the summation of two susceptances: B_{PI} (the PI-controller output) and B_{POD} (the POD controller output). The TCSC thyristor firing and other delays are usually represented by a single lag of about 15ms, but were not modeled here for simplicity and because they do not significantly impact the electromechanical stability phenomena [3,8].