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PERFORMANCE INVESTIGATION OF TCSC SYSTEM FOR 400 KV RAIPUR-ROURKELA LINE, THROUGH SIMULATION

Ashish Singh[1], Satyadharma Bharti[2]
[1]*ME Scholar*
Department of Electrical Engineering
Rungta College of Engineering and Technology Bhilai CG (India),
[2]*Associate Professor*
Department of Electrical Engineering
Rungta College of Engineering and Technology Bhilai CG (India),
[1] aks.bit@gmail.com
[2] s.bharti@rungta.ac.in

Abstract

Thyristor-Controlled Series Capacitor (TCSC)is one of the members of FACTS device family which is used to enhance power transfer capability of the transmission line, Sub synchronous resonance (SSR) Mitigation, Power oscillation damping and improvement in Transient stability of the power system. Present paper is an attempt to investigate system performance of TCSC for closed loop control of TCSC systems installed in India on Raipur-Rourkela, 400kV, double circuit line. PSCAD software based Simulation tests are carried out and the effectiveness of the Raipur located TCSC system is investigated under fault condition.

Keywords— **Thyristor-Controlled Series Capacitor (TCSC), FACTS, Sub-Synchronous Resonance (SSR).**

INTRODUCTION

A few numbers of TCSCs have been installed in different parts of the world and performing well the primary purpose of their installation. A fast and efficient control of transmission line can be ensured through continuous monitoring of the line having TCSC, leading to dynamic control of power flow in some of the selected lines. TCSC provides damping of the power swings caused due to local and inter-area oscillations both. It helps to suppress sub-synchronous oscillations as well. In the event of development of a large overvoltage across capacitors, an immediate fast bypass of these series connected capacitors can ensure through firing control of thyristors. At the time of high short-circuit current flow, the operating mode of TCSC gets converted from controllable-capacitance to the controllable-inductance mode, which results in the reduction of short circuit current [1].

Anand Mohan *et al.*(2002) described a TCSC model considered in the studies comprised of damping loop for damping of low-frequency inter-area oscillations during dynamic conditions. The study briefly describes the behavior of the combined system under different network conditions. Fixed series capacitor (40%) along with 5-15% variable compensation (TCSC) mechanism has been proposed for installation on Rourkela-Raipur line to damp the low frequency inter-area oscillations while meeting the prescribed contingency criteria like single circuit outage, HVDC one pole tripping and so forth. [2].R.N. Nayak *et al.*(2004) described in their paper that the Series compensation is a tool for utilization of existing transmission infrastructure optimally. Both thyristor controlled reactor (TCR) and Power Oscillation Damper (POD) required for control purpose. Series Compensation on 400 kV lines offers techno-economically attractive option to optimal utilization of infrastructure. The study presents network, deign aspect as well as studies considered for the installation of series compensation on 400 kV lines [3]. S.C. Misra *et al.* (2000) described application of TCSC and various aspects and results of system studies carried out to design the first synchronous inter –regional link between Eastern and Northern Regions [4].

Power Grid Corporation of India Ltd (PGCIL) has purchased two TCSC from ABB for Raipur Rourkela line. This substation is located at Kumhari, Raipur. Apparent reactance is changed by boosting the capacitor voltage. The valve located on the platform level which is water-cooled and equipped with two vertically mounted, anti-parallel stacks of thyristors. The thyristor valve is rated for a continuous current of 1850 A and a voltage of 12.7 kVrms., with rated withstand short-circuit currents up to 55 kA peak.[5]. Table I describes main technical data of TCSC components [5].

TABLE I: MAIN TECHNICAL DATA OF TCSC RAIPUR

Parameter	Fixed Segment	TCSC Segment
Nominal system voltage	400 kV	400 kV
Rated line current	1550 A	1550 A
Line current overload, 30 minutes	2093 A	2093 A
Line current overload, 10 minutes	2325 A	2325 A
Physical capacitor reactance	54.7 Ω	6.83 Ω
Nominal capacitive boost factor	1.0	1.2
Boost factor range	–	1.0–3.0
Rated capacitor reactive power	394 Mvar	71 Mvar
Rated capacitor bank voltage	84.8 kV	12.7 kV
Degree of compensation	40%	5% *
ZnO rating (incl. redundancy)	56 MJ	15 MJ

** (@ 1.0 boost factor)*

Dragan Jovcic *et al.* (2005) have presented an analytical, linear, state-space model of a thyristor –controlled series capacitor (TCSC), the model is sufficiently accurate for most control design applications and practical stability issue in the subsynchronous range. The model is implemented in MATLAB and verified against PSCAD/EMTDC in the time and frequency domains for a range of operating conditions [6].S. Meikandasivam *et al.* (2008) have explained about Behavioural Study of TCSC Device. Simulink model of TCSC device is given, and corresponding waveforms are analyzed [7].

R. Grunbaum *et al.* (2006) described the dynamic studies were carried out by POWERGRID, and finally based on the studies, 40% Fixed Series Compensation along with 5-15% variable through TCSC was proposed at the Raipur end on each of the two inter-connectors. Dynamic simulations performed during the design stage, and subsequently confirmed at the commissioning and testing stage, have proved the effectiveness of the TCSC as power oscillation dampers [8]. Stig Nilsson *et al.* (2013) have described Performance Evaluation and Applications Review of Existing Thyristor Control Series Capacitor Devices – TCSC [9].Sonora Dixit and Raj Kumar Jhapte have described in their paper about Optimization Location of TCSC to control Power Swing on the same line [10]

K. Balamurugan *et al.* (2013) have described in their paper about Improving Power System Dynamics by Series Connected FACTS Controllers (TCSC). An efficient PSCAD based simulation using TCSC has solved the power oscillation damping problem [11].Yashar Emami *et al.* (2017) have presented the Constant Angle (CA) control approach of TCSC controller on the IEEE first benchmark SSR model for damping of SSR torques and powers. Also, a close-loop control as constant-angle control mode of TCSC is studied that can work in inductive mode aid to the alleviation of sub-synchronous resonance and damping of Torque and power oscillations. This control strategy supersedes the constant-current control in its ability to suppress the SSR [12].

Rakesh A. Dafde and M Chetan Bobade (2015) have presented a model control circuit by using a microcontroller to generate trigger pulses to fire the gate of the thyristors according to the set firing angle for required output. The different waveforms in the capacitive as well as their inductive region of TCSC, optimal setting of TCSC is determined through the software code written in MATLAB [13]. J. V. Kadia and J. G. Jamnani (2012) have described in their paper about Constant Angle Control of TCSC for Mitigation of SSR. They have presented the use of a constant angle (CA) control of the TCSC to study of subsynchronous resonance (SSR) [14].

S. Meikandasivam and Rajesh Kumar Nema (2011) have presented in their paper about the Performance of Installed TCSC Projects world-wide. The paper intends to discuss some important TCSC projects installed the world around and highlights the benefits derived regarding enhancing power networks. They have also investigated the maximum power transfers on a lossless symmetrical transmission line with Fixed Series Capacitors (FSC) and TCSC device installed with possible power improvement at these locations are calculated and tabulated [15].

The objective of present paper is to investigate the performance of TCSC system whose components are designed as per data and specifications available as per literature review for Raipur Rourkela line.

METHODOLOGY

The TCSC unit basically consists of a series capacitor, C, in parallel with a thyristor-controlled reactor, Ls, as shown in Fig. 1 (a). However, a practical TCSC unit also includes protective equipment normally connected with series capacitors, as shown in Fig.1(b).

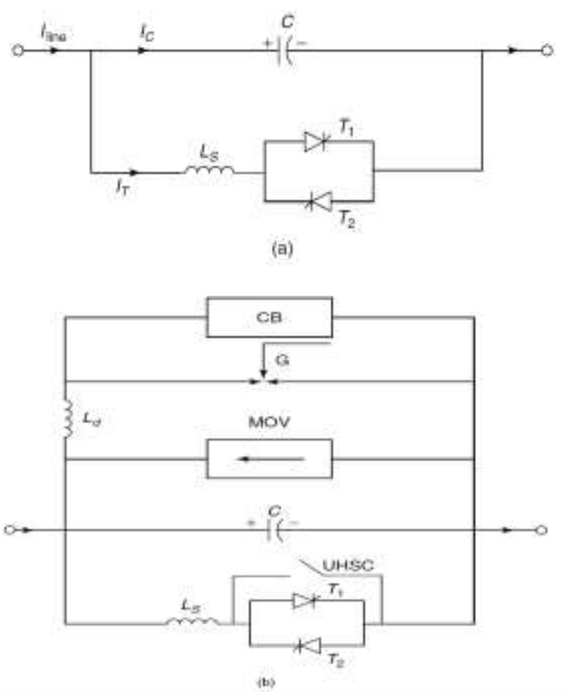


Fig.1: A TCSC Module: (a) basic (b) practical [1]

A metal-oxide varistor (MOV), basically a nonlinear resistor, is connected across the series capacitor to prevent the occurrence of high-capacitor over voltages. Not only does the MOV limit the voltage across the capacitor, but it allows the capacitor to remain in circuit even during fault conditions and helps to improve the transient stability. Also a circuit breaker, CB is installed across the capacitor, for controlling its insertion in the line. In addition, the CB bypasses the capacitor if equipment-malfunction or severe fault events occur. A current-limiting inductor, Ld, is included in the circuit to confine both the magnitude and the frequency of the capacitor current during the capacitor-bypass operation. If the TCSC valves are required to operate in the fully "on" mode for long durations, the conduction losses are minimized by installing an ultra–high-speed contact (UHSC) across the valve [1]

In present paper, a simulation model of Raipur Rourkela transmission line is modelled in PSCAD software. The parameters of transmission line are taken as per guidelines given on Manual on Transmission Planning Criteria, Central Electricity Authority, New Delhi, January 2013 [16]. For 400 kV double circuit quad conductor line R,B,X values are taken (Line parameters (per unit / km / circuit, at 100 MVA) base:

Positive sequence R = 9.177×10^{-6}
Positive sequence X = 1.582×10^{-4}
Positive sequence B = 7.33×10^{-3}
Zero Sequence R_0 = 1.557×10^{-4}
Zero Sequence X_0 = 6.246×10^{-4}
Zero Sequence B_0 = 4.237×10^{-3}

A TCSC module is designed as per data given in Table 1. Figure 2 gives a screenshot of the model of used in simulation study and Figure 3 represents a part of control circuit for one of the phase however the other phases are also having same control technique.

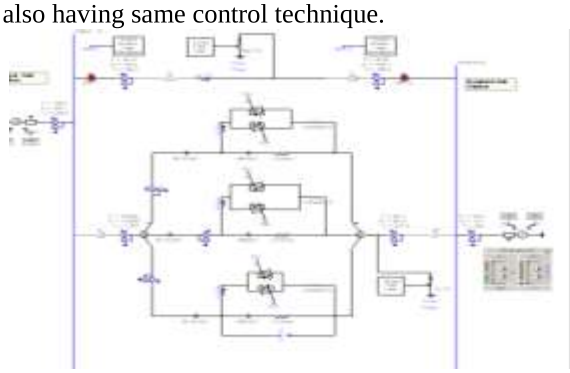


Fig.2: Screenshot of the Model

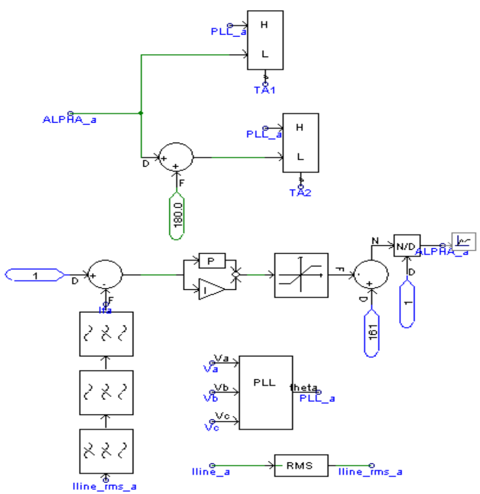


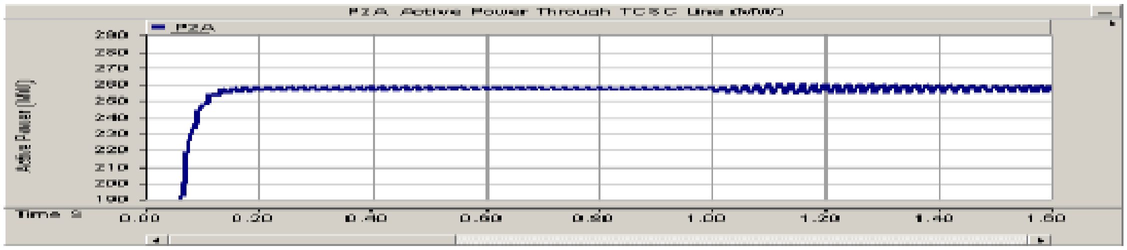
Fig.3: Closed loop Control for TCSC

A double circuit line is demonstrated in the model. In both the circuits, the transmission line is divided in two circuits having a length of 206 km, hence total length of line is taken as 412 km. In upper line a fault is provided at the mid-point of the line. In lower line, TCSC device is modelled in which fixed compensation is achieved through 58.19 μF capacitor and TCSC capacitor is rated for 133.16 μF; Reactor inductance (TCR) is taken as 3480 μH. TCSC firing is controlled form a closed loop control strategy. Gate pulses are given to T_1, T_2, T_3, T_4, T_5 and T_6 thyristors, connected in pair, in anti-parallel in each phase.

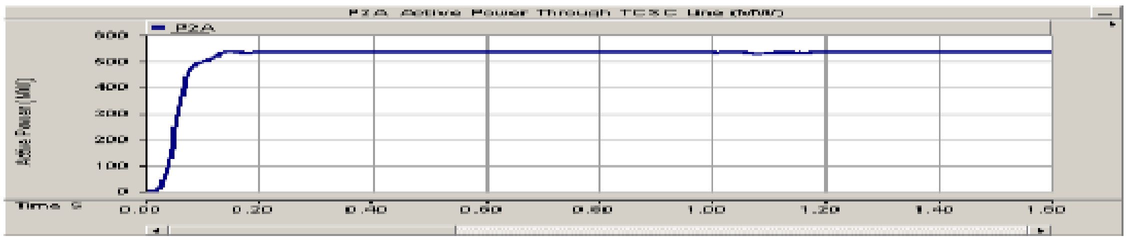
RESULTS AND DISCUSSIONS

With the application of TCSC, The power Transfer capability of the line is increased from 256 MW to 532 MW (maintaining same value of δ between Raipur –Rourkela bus) The system is found to be working effectively for Damping of Power Oscillation, which is evident from the output measured at Raipur Bus. Power out graph without TCSC and with TCSC are presented in Figure 4.

Without TCSC



With TCSC



FUTURE SCOPE

1. The present work can be extended for damping of torsional oscillations.
2. Stability issues for a distribution network with different types of distributed generation sources and FACTS devices could be examined and FACTS-based controllers could be designed for improving the stability.
3. Increase in active power transfer capacity indicates that the use of TCSC is a one of the good solution rather than building new transmission line.

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