OVERVIEW OF THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC) IN POWER TRANSMISSION SYSTEM

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1. Introduction

In early 90s, a general concept in term of operation and planning of power systems was proposed and widely discussed since then. The Flexible Alternating-Current Transmission Systems (FACTS), incorporating a wide range of possibilities for better utilization. Improvement of voltage and current limits on the power electronics devices leads to a fast development of FACTS in the last decade. FACTS are defined by the IEEE as “AC transmission systems incorporating power electronics-based and other static controllers to enhance controllability and increase power transfer capability. And among the proposed FACTS devices, possibly the Thyristor Controlled Series Capacitor (TCSC) has given the best results in terms of performance and flexibility. It can have various roles in the operation and control of power systems, such as scheduling power flow; decreasing unsymmetrical components; reducing net loss; providing voltage support; limiting short-circuit currents; mitigating sub-synchronous resonance (SSR); damping the power oscillation; and enhancing transient stability.

Research on control strategies for TCSC can be traced back to 1966 when Kimbark [3] analysed the improvement in transient stability of power systems by using switched series capacitors. This was a very simple control; the maximum amount of compensation was inserted at the same time that the faulted line was switched out. Ramarao et al.[4] proposed an optimal control of the capacitance. Pontryagin’s maximum principle was used to obtain bang-bang control. It was one of the earliest closed-loop control systems for series compensation.

2. TCSC in Power Transmission System

**Fig. 1 Simple Diagram of TCSC**

**I. Circuit and Function**

Figure 1 shows the simple diagram of TCSC. This structure is modeled as

\[ X = X_0 + \Delta X \]

where \( \Delta X = f(\Delta \varphi) \). \( \Delta X \) is the capacitive reactance.

TCSC comprised of a series capacitor bank, shunted by a Thyristor Controlled Reactor (TCR), to provide a smoothly variable series capacitive reactance. It is a one-port circuit in series with transmission line; it uses natural commutation; its switching frequency is low; it contains insignificant energy storage and has no DC-port. Insertion of a capacitive reactance in series with the line’s inherent inductive reactance lowers the total, effective impedance of the line and thus virtually reduces its length. As a result, both angular and voltage stability gets improved. Furthermore, in contrast to capacitors switched by circuit breakers, TCSC will be more effective because thyristors can offer flexible adjustment, and more advanced control theories can be easily applied.

**II. Characteristics and Problems**

In this chapter, we will be discussing about some characteristics of TCSC that have been discussed all over the region for about 20 years ago. These chapter have been summarized and we could see clearly some part of the characteristic and the problem occurs within it. Two major characteristic of TCSC that will be discussed below is sub-synchronous resonance that would appear in the generator oscillation and transient voltage stability controlling.

(i) Sub-synchronous Resonance (SSR)

SSR has gained its name from the fact that the frequency of interest happen to lie in a region below the synchronous frequency of the network. The main concern in SSR studies is a significant oscillatory electromagnetic torque developed on the generator rotor and the possibility of shaft damage from torsional stresses [5]. As in general, any device that controls or responds rapidly to power or speed variations in the sub-synchronous frequency range is a potential source for excitation of oscillations [5].

Simulations of the IEEE First Benchmark Model [6] show that even without a fault, sub-synchronous oscillations appear in that system. They just take more time to develop. In other words, the occurrence of a fault may speed up the process (Torque Amplification), while the possibility of SSR is mainly due to the nature of the combined mechanical-electrical system. The eigenvalue results for the first benchmark model show that the thyristor switching can have a significant effect on system stability and that the effect varies with the firing angle [7].

The papers on the inclusion of the TCSC in SSR studies are centered on two field installations, Western Area Power Administration’s Kayenta site [8,9], and Bonneville Power Administration’s Slatt substation [10,11]. The Kayenta system was analyzed with time-domain simulation of a detailed model of the AC system, a machine and TCSC with controls [8]. While for the Slatt system, the effect of the TCSC was evaluate by measuring the electrical damping torque as a function of machine rotor speed. Analog and digital simulators modeled the AC system, machine and TCSC controls.

(ii) Transient voltage stabilizing control

The inserted series capacitor will also affects the reactive power distribution in the interconnected power system. Thus, paper [12] suggests that TCSC be used to enhance voltage stability. In a transient voltage stability analysis, TCSC is operated in a big range for a long period, which is very different from small signal voltage stability. And this means that the
operation limits of a TCSC must be well considered. For other practical reasons, such as availability of the measurement and the burden of calculation, relatively simple controllers are used in the installed TCSC [13,14].

There are also other characteristics regarding TCSC and it’s such as power damping oscillation, fault current, non-linear control model, dynamic characteristic etc.

3. Discussions

For two major characteristic that have been discussed above, MATLAB, the friendly user of technical computing have been used as study-system case. In this case, we used 3-Machine and 9-Bus System as transient stability study model. The analysis is done first with the model and the result are simulated by MATLAB.

4. Conclusion

This paper has addresses a quick overview of thyristor controlled series capacitor as one the best proposed devices in FACTS family and its applications in power transmission system. There are also two major characteristic of TCSC and that are the existing of sub-synchronous resonance in generator oscillation controller and TCSC as transient voltage stabilizing controller. And for both characteristic, we proposed a 3-machine and 9-Bus System Transient Stability Study Model simulated by MATLAB friendly technical programming as study-case system.

It has considered the application of TCSC for closed-loop control of power flow in both constant power and constant angle modes of operation. The results indicate that the power flow controller (TCSC) operation has an important influence on both the small signal and transient stability characteristic of the system.

References