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How TCSC Controller Benefit AC Transmission Line for Voltage Stability

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Abstract--This paper provides a summary of one of the three planned presentations on the topic of “ASSESSMENT OF VOLTAGE STABILITY USING TCSC CONTROLLER”. This paper is on Part I of the session and focuses on a summary of the issues and benefits of applying TCSC controllers to AC power systems. The overall process for system studies and analysis associated with TCSC installation projects and the need for FACTS controller models is also discussed. Finally, an introduction to the basic circuits of TCSC controllers is provided with a focus on its system performance characteristics. This paper is designed to be accompanied by the presentation material.

Index Terms--Flexible AC Transmission Systems, FACTS, Power Electronic Equipment, Power System Stability, Power System Control

1 INTRODUCTION

FACTS or "flexible AC transmission systems" is a term that has been suggested for the use of solid state devices to control bulk power flow in transmission systems. The Electric Power Research Institute supported this idea, and many researchers have invested efforts on the value and potential of FACTS. At this time, it appears that the main value of FACTS lies in improving transmission capability; increasing the flexibility of power flow control (e.g., for wheeling or for economic dispatch); for controlling voltage (and var flow); and possibly additional advantages in lower voltage systems (e.g., distribution systems). FACTS controllers enhance the static performance viz. increased loading, congestion management, reduced system loss, economic operation, etc., and dynamic performance viz. increased stability limits, damping of power system oscillation, etc. In this paper, an overview of FACTS controllers is explained.

Flexible Alternating Current Transmission System (FACTS) is a static equipment used for the AC transmission of electrical energy. It is meant to enhance controllability and increase power the transfer capability of the network. It is generally a power electronics-based device. FACTS is defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability."

Series compensation has been utilized for many years with excellent results in AC power transmission in a number of countries all over the world. The usefulness of the concept can be demonstrated by well-known expressions Eq. (1) and Eq. (2) relating to active power transfer and voltage [1]:

$$P = V1V2\sin\delta / X \qquad (1)$$

$$V = f(P, Q) \qquad (2)$$

Here, $V1$ and $V2$ denote the voltages at either end of the interconnection, whereas δ denotes the angular difference of the said voltages. X is the reactance of the transmission circuit, while P and Q denote the active and reactive power flow. From Eq. (1) it is evident that the flow of active power can be increased by decreasing the effective series reactance of the line. Similarly it is demonstrated that by introducing a capacitive reactance in the denominator of Eq. (1), it is possible to achieve a decrease of the angular separation with power transmission capability unaffected, i.e. an increase of the angular stability of the link. The influencing of transmission reactance by means of series compensation also

opens up for optimizing of load sharing between parallel circuits, thereby bringing about an increase in overall power transmission capacity again. Likewise a valuable feature, active losses associated with power transmission can be decreased, as well. From Eq. (2) it is seen that the voltage of a transmission circuit depends of the flow of active as well as reactive power. The explicit relationship between the quantities in the formula is not simple. Closer analysis reveals, however, that the reactive power contribution from a capacitive element in series with the line acts to improve the reactive power balance of the circuit, and thereby to bring about a stabilization of the transmission voltage. It can further be shown that this reactive power contribution is instantaneous and of a self regulatory nature, i.e. it increases when the line load increases, and vice versa. It consequently contributes to voltage stability in a truly dynamic fashion. This makes series compensation a highly effective means for up keeping or even increasing voltage stability in a heavily loaded transmission circuit. And likewise, it allows additional power transmission over the circuit without upsetting voltage stability. With the reactance of the capacitive element, i.e. the series capacitor equal to XC and the inductive reactance of the line equal to XL, we can define the degree of series compensation,
k:

$$k = XC / XL \quad (3)$$

2. TCSC FOR POWER TRANSMISSION

2.1. *CIRCUIT*

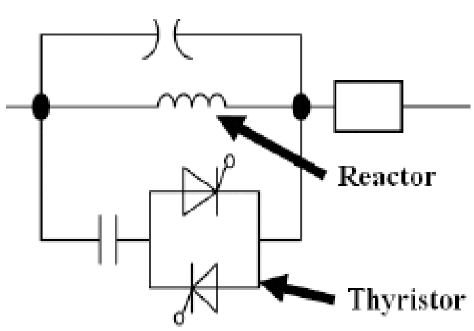

Fig. 1 Simple diagram of TCSC

Figure 1 shows the simple diagram of 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.

2.2. *CONTROL MECHANISM*

With TCSC, it is possible to vary the degree of compensation k at mains frequency (50 Hz) with rapidity limited only by the speed of response of the electronic scheme used in the TCSC. This opens up for applications previously not encountered in conjunction with series compensation, such as post-contingency power flow control and damping of active power oscillations. By referring to Eq. (1), it is readily seen that the introducing of a periodic modulation of the line reactance in the denominator of a suitably low frequency (usually less than 1Hz for inter-area power oscillations), it is possible to counter-act and subsequently damp out active power oscillations. Since it is not infrequent to encounter particularly active power oscillations as a limiting factor on power transmission capacity of radial interconnecting ties, the TCSC concept is very useful as a tool for extending the possibilities for AC power interconnection between regions, both as far as amounts of power and geographical distances are concerned.

2.3. *IMPACTS*

2.3.1. *Balancing of load flows*

This enables the load flow on parallel circuits and different voltage levels to be optimized, with a minimum of power wheeling, the best possible utilization of the lines, and a minimizing of overall system losses at the same time.

2.3.2. *Increasing of first swing stability, power oscillation damping, and voltage stability*

This enables a maximizing of system availability as well as of power transmission capability over existing as well as new lines. Thus, more power can be transmitted over fewer lines, with a saving of money as well as of environmental impact of the transmission link.

2.3.3. *Power system interconnection*

Interconnecting of power systems is becoming increasingly widespread as part of power exchange between countries as well as regions within countries in many parts of the world. Such are found in the Nordic countries, Argentina, and Brazil.

3. PRACTICAL APPLICATIONS OF TCSC

By the end of year 2004, seven TCSCs have been installed worldwide. In Asia, three TCSC came into operation; two in China and one in India, bringing Asia into the forefront of the advanced FACTS technology. Table 1 shows the complete list of TCSC installed worldwide as of December 2004 [2].

Table 1: Complete list of TCSC installation

Year	Country	KV	Purpose	Place
1992	USA	230	To increase power transfer capability	Kayenta substation, Arizona
1993	USA	500	Controlling line power flow and increased loading	C.J.Slatt substation, Northern Oregon
1998	Sweden	400	Sub Synchronous Resonance mitigation	Stöde
1999	Brazil	500	To damp inter-area low freq (0.2 Hz) oscillation	Imperatriz and Sarra de Mesa
2002	China	500	Stability improvement, low frequency oscillation mitigation	Pinguo substation, State power south company, Guangzhou
2004	India	400	Compensation, Damping interregional power oscillation	Raipur substation
2004	China	220	Increase Stability margin, suppress low frequency oscillation	North-West China Power System

4. Conclusion

With the history of more than three decades and widespread research and development, FACTS controllers are now considered a proven and mature technology. The recent introduction of TCSC has further widened the scope and added new valuable benefits. This paper reveals an overview of TCSC as one the best proposed devices in FACTS family, its applications and the prospects of TCSC as an effective power system improvement tool for Bangladesh.

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