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Voltage Control of Transmission Line Using Fixed Capacitor & Thyristor-Controlled-Reactor

KEYWORDS
Flexible AC Transmission System (FACTS); Fixed Capacitor (FC); Thyristor-Controlled Reactor (TCR); Static VAR Compensator (SVC)

Ashok B. Darji

Lecturer in Electrical Engineering, R. C. Technical Institute, Ahmedabad

ABSTRACT *Fixed Capacitor and Thyristor Controlled Reactor (FC-TCR) is variable shunt impedance type controller. It can be best suited for maintaining voltage profile at varying load. This paper presents voltage and reactive power flow control through a transmission line by placing the FC-TCR at receiving end.*

1. INTRODUCTION

Power system is a large transmission network because of location of generating station and loads at different and distant geographical locations. Electrical power systems are complexly interconnected. Reactive power changes produced by load variations and line switching can cause adverse effects on system voltage stability and the interconnected system security. Static VAR compensators (SVCs) are utilized to enhance the integrated AC system voltage stability. Fixed Capacitor and Thyristor-Controlled-Reactor (FC-TCR) is static VAR compensator, which can provide inductive and capacitive VAR compensation. The capacitor is fixed and the inductor current is varied which results in maintaining receiving end voltage profile.

2. TRANSMISSION LINE

The active power flow through the transmission line is given by $P = (VS * VR / X) \sin \delta$, Where X is the line reactance which depends on physical properties of the line and that cannot be decreased. So the network is often not optimally utilized. For long transmission network, because of stability consideration, the normal power flow is kept below the peak value, i.e. line is operated at power level much below than their thermal limits. The AC transmission network requires dynamic reactive power control to maintain satisfactory voltage profile under varying load condition and transient disturbance. The steady state transmittable power can be increased and the voltage profile along the line can be controlled by appropriate Reactive Shunt Compensation. The purpose of reactive shunt compensation is to change the natural electrical characteristics of the transmission line to make it more compatible with load demand.

3. FACTS DEVICES

In the late 1980s, the Electric Power Research Institute (EPRI) introduced a new approach to solve the problem of designing and operating power systems; the proposed concept is known as Flexible AC Transmission systems (FACTS). The improvements in the field of power electronics have major impact on the development of the concept. The development of Thyristor-valves capable of handling large currents, as well as technique of using them to switch capacitor in and out and control the current through a reactor have provide the power system with a new tool to meet reactive power generation and absorption demands. FACTS has arisen as a technology to offer new opportunities for controlling power and enhance the capacity of present and new transmission lines. FACTS Controller can control parameters and variables related with transmission line in power system like series impedance, shunt impedance, current and voltage in the system. FACTS devices have the principle role to enhance controllability and power transfer capability in ac systems. FACTS involve conversion and/or switching power electronics devices in the range of few tens to hundred megawatts. There are various types of FACTS devices like series, shunt and combined FACTS devices. Shunt devices include variable reactance type or switching convertor type devices.

4. COMPENSATION

A simple radial feeder with line reactance X and load impedance Z_L is shown in figure 1. Shunt FACTS device is installed in the parallel of load at the receiving end. It compensates the reactive power flow in the line and hence receiving end voltage is maintained. If load is inductive, the shunt FACTS device generate capacitive VAR. When long transmission line is at no load or very lightly loaded, the receiving end voltage increases due to capacitive VAR generation of charging current. This effect of higher voltage at receiving end is known as Ferranti effect. In such type of situation the shunt FACTS device generate inductive VAR. So in both the cases voltage profile at receiving end is maintained.

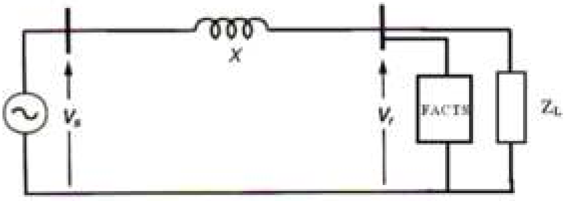

Figure 1 Transmission line with Compensation

5. FC-TCR

The basic structures of a Static VAR Compensator (SVC) consists of a Fixed shunt Capacitor (FC) and a Thyristor Controlled Reactor (TCR). A simple SVC that works both in the capacitive and inductive range can be obtained by a FC in parallel with a TCR. The FC-TCR is the most commonly used SVC device in practice. SVC is based on Thyristors without gate turn off capability. It includes separate equipment for leading and lagging vars. The TCR is used for absorbing reactive power and FC or Thyristor-Switched Capacitor (TSC) for supplying the reactive power. SVC is considered as a lower cost alternative to Static Synchronous Compensator (STATCOM). TCR is a subset of SVC in which conduction time and hence, current in a shunt reactor is controlled by a Thyristor based ac switch with firing angle control. A TCR is one of the most important building blocks of thyristor-based SVCs. Although it can be used alone, it is more often employed in conjunction with fixed or thyristor switched capacitors to provide rapid, continuous control of reactive power over the entire selected lagging-to-leading range. TCR and FC-TCR come under the category of variable shunt type FACTS controller. Shunt controller is like a current source which draws current from the line (TCR) or injects current in to the line (FC or TSC) and hence it can achieve effective voltage control. TCR can be used to minimize the line over voltage under no load or light load conditions (Ferranti effect). FC or TSC can be used to increase voltage level under heavy load condition. Combination of both (FC-TCR and TSC-TCR) can be used to maintain voltage profile at any load. The basic arrangement of TCR is shown in fig. 2. The current in the reactor is varied by change in the Thyristor delay angle α.

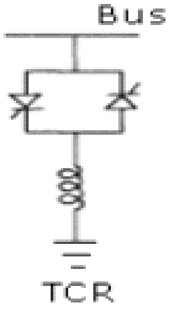

Figure 2 TCR Basic Schemes

Fig. 3 illustrates the voltage and current waveforms of TCR [1]. The current in the reactor iL(t) can be expressed with

$$i_L(t) = \frac{1}{L}\int_{\alpha}^{\omega t} v(t)\,dt$$

$$= \frac{1}{\omega L}\left(\sin \omega t - \sin \alpha\right) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The amplitude I_{Lf} of the fundamental reactor current as a function of angle α can be expressed as: B_L

$$i_{LF}(\alpha) = \frac{v}{\omega L}\left(1 - \frac{2}{\alpha} - \frac{1}{\pi}\sin 2\alpha\right) \ldots\ldots\ldots\ldots\ldots (2)$$

And admittance B_L, as a function of angle α can be written directly from (2) as,

$$B_L(\alpha) = \frac{1}{\omega L}\left(1 - \frac{2}{\pi}\alpha - \frac{1}{\pi}\sin 2\alpha\right) \ldots\ldots\ldots\ldots\ldots (3)$$

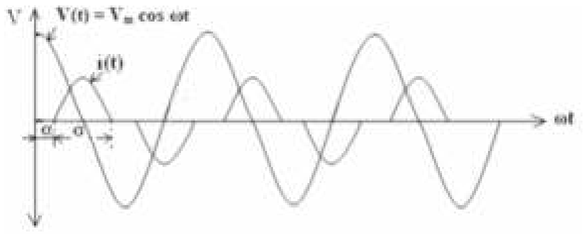

Figure 3 waveforms of TCR

In the basic arrangement of FC-TCR the current in the reactor is varied by change in thyristor delay angle α.The constant capacitive var generation (Q_C) of the FC is opposed by the variable var absorption (Q_L) of the TCR to get the required output (Q). At the maximum capacitive var output, the TCR is off (α=180). To decrease the capacitive output, the current in the reactor is increased by decreasing the delay angle α. At zero var output, the capacitive and inductive var becomes equal. With further increase in TCR current, the inductive current becomes larger than the capacitive current resulting in a net inductive var output. Thus Fixed Capacitor and Thyristor Controlled Reactor can compensate receiving end voltage and reactive power flow from the line. This maintains receiving end voltage profile of the transmission line at any load and hence line can be loaded at its optimum level.

REFERENCE

[1] Hingorani N. G. & Gyugyi Laszlo "Understanding FACTS Concept and Technology of Flexible AC Transmission System", IEEE Press, (Book). | [2] Sharaf, A.M.; Snider, L.A.; "An intelligent voltage controller for static VAr compensators" System Theory, 1994., Proceedings of the 26th Southeastern Symposium on 20-22 March 1994 Page(s):239 - 243 | [3] Chaghi, A.; Louchene, A.; Bensaadi, R.; "A micro-controller-based voltage balancer in a electrical distribution system" Power System Technology, 2002. Proceedings. PowerCon 2002. International Conference on Volume 2, 13-17 Oct. 2002 Page(s):666 - 670 vol.2 | [4] Gelen, A.; Yalcinoz, T.;"The behaviour of TSR-based SVC and TCR-based SVC installed in an infinite bus system" Electrical and Electronics Engineers in Israel, 2008. IEEEI 2008. IEEE 25th Convention of 3-5 Dec. 2008 Page(s):120 – 124 | [5] Peiyuan Chen; Zhe Chen; Bak-Jensen, B.; "Comparison of steadystate SVC models in load flow calculations" Universities Power Engineering Conference, 2008. UPEC 2008. 43rd International 1-4 Sept. 2008 Page(s):1 - 5 | [6] Paserba John J "How FACTS Controllers Benefit AC Transmission Systems", Power Engineering Society General meeting, 2004 10-10 June 2004, page(s): 1257-1262, vol.2 | [7] M. Moghavvemi and M. 0. Faruque, "Effects of Facts Devices on Static Voltage Stability", TENCON 2000. Proceedings. 24-27 Sept. 2000, page(s): 357-362, vol.2.