

# STATCOM - STATic synchronous COMPensator: Theory, Modeling, and Applications

**Kalyan K. Sen, Member, IEEE**  
Westinghouse Electric Corporation  
1310 Beulah Road  
Pittsburgh, PA 15235, USA

**Abstract** - This paper describes the theory and the modeling technique of a *Flexible Alternating Current Transmission Systems* (FACTS) device, namely, *STATic synchronous COMPensator* (STATCOM) using an *Electromagnetic Transients Program* (EMTP) simulation package. The STATCOM, a solid-state voltage source inverter coupled with a transformer, is tied to a transmission line. A STATCOM injects an almost sinusoidal current, of variable magnitude, at the point of connection. This injected current is almost in quadrature with the line voltage, thereby emulating an inductive or a capacitive reactance at the point of connection with the transmission line. The functionality of the STATCOM model is verified by regulating the reactive current flow through it. This is useful for regulating the line voltage.

**Keywords** - AC transmission, FACTS, power flow controller, power converter, inverter, thyristor, GTO, etc.

## I. INTRODUCTION

*Flexible Alternating Current Transmission Systems* (FACTS) devices, namely *STATic synchronous COMPensator* (STATCOM), *Static Synchronous Series Compensator* (SSSC) and *Unified Power Flow Controller* (UPFC), are used to control the power flow through an electrical transmission line connecting various generators and loads at its sending and receiving ends. FACTS devices consist of a solid-state voltage source inverter with several Gate Turn Off (GTO) thyristor switch-based valves and a DC link capacitor, a magnetic circuit, and a controller [1]. The number of valves and the various configurations of the magnetic circuit depend on the desired quality of AC waveforms generated by the FACTS devices. The inverter configuration described in this paper is one of many different possible configurations that can be used to build a voltage source inverter.

In this paper, a STATCOM which is connected to a simple transmission line, shown in Fig. 1, has been modeled using an *Electromagnetic Transients Program* (EMTP) simulation package.

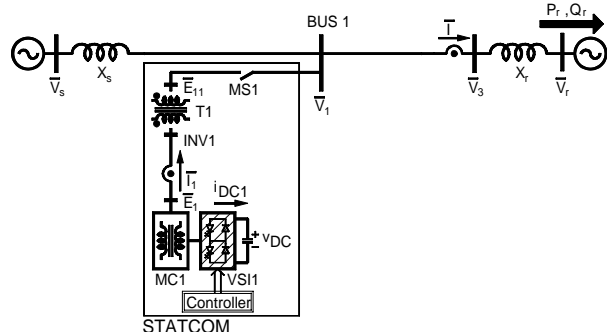


Fig. 1 A Static Synchronous Compensator Model in EMTP

The STATCOM is connected at BUS 1 of the transmission line which has an inductive reactance,  $X_s$ , and a voltage source,  $\bar{V}_s$ , at the sending end and an inductive reactance,  $X_r$ , and a voltage source,  $\bar{V}_r$ , at the receiving end, respectively. The STATCOM model in EMTP consists of a harmonic neutralized voltage source inverter, *VSII*, a magnetic circuit, *MCI*, a coupling transformer, *TI*, a mechanical switch, *MSI*, current and voltage sensors, and a controller. The primary control of the inverter is such that the reactive current flow through the STATCOM is regulated.

## II. DESCRIPTION OF THE INVERTER

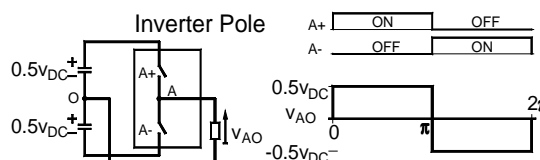


Fig. 2 An Inverter "Pole" and its Output Voltage

Fig. 2 shows a single phase inverter circuit, referred to as a "pole," which consists of a positive valve, A+, and a negative valve, A-. When a pole is connected across a series of capacitors which are charged with a total DC voltage of  $v_{DC}$  and the valves are closed and opened alternately, the pole output voltage,  $v_{AO}$ , at the midpoint of the pole A with respect to the midpoint, O, of the DC link capacitor is a square wave containing a positive sequence fundamental component and all the odd harmonic components, such as the zero sequence third, the negative sequence fifth, and the positive sequence seventh, etc. The amplitude of the fundamental component is  $(2/\pi)v_{DC}$  and the amplitude of any odd harmonic component ( $n$ ) normalized to the fundamental component is  $(1/n)$  where  $n = 2k + 1$  for  $k = 1, 2, 3$ , etc.

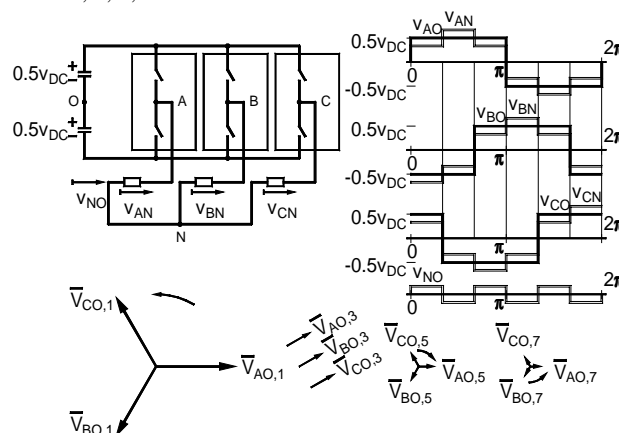


Fig. 3 A 6-Pulse Inverter and its Output Voltages

Fig. 3 shows three poles A, B, and C which are connected across the same DC link capacitor and the pole outputs are connected to a 3-phase load whose neutral point, N, is not connected to the midpoint of the capacitor. The poles A, B, and C which form a 6-pulse inverter are operated in such a way that the pole voltages,  $v_{AO}$ ,  $v_{BO}$ , and  $v_{CO}$ , are time shifted from one another by one third of the time period of the pole voltage. Therefore, the fundamental phasors,

99WM706 A paper recommended and approved by the IEEE Transmission and Distribution Committee of the IEEE Power Engineering Society for publication in the IEEE Power Engineering Society's 1999 Winter Meeting Conference Proceedings.