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Modelling and Simulation of 6-pulse Static Synchronous Compensator for Voltage Stabilty in Power System

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Abstract

This paper presents the use of a 6-pulse Gate Turn Off (GTO) model of voltage source converter Static Synchronous Compensator (STATCOM) for reactive power compensation and voltage stabilization on electric network. The device is connected in shunt with the power system bus and is controlled by a controller. The complete simulation of the STATCOM within a power system is performed in the MATLAB/Simulink environment using the Power System Blockset (PSB). The STATCOM Scheme and the electric grid network are modeled by specific electric blocks from the power system blockset The control system is based on Synchronous Reference Frame theory The performance of the selected ±100 Mvar STATCOM scheme connected to the 500-kV grid is evaluated. The operation of the STATCOM is validated in both the capacitive and inductive modes of operation. Reactive power compensation and voltage regulation is validated for load and system excursions.

Keywords- 6-pulse STATCOM, voltage stabilization,reactive compensation, Synchronous Referece Frame (SRF).

Introduction

The advent of FACT [1] devices e.g. STATCOM[2] ,SSSC, UPFC etc is giving rise to a new family of power electronic equipment for controlling and optimizing the dynamic performance of power system. In the last two decades the commercial availability of GTO [3] devices with higher power handling capability, have led to development of new controllable reactive power sources utilizing electronic switching of voltage source converter(VSC)[4]. The GTO switching devices enable the design of power electronic converters that can either be connected in parallel e.g. STATCOM (Static Synchronous Compensator) or in series e.g. SSSC with the power grids. STATCOM is one such power electronic converter which has characteristics similar to synchronous machine but without sluggish mechanical inertia and is used for compensation in both distribution and transmission lines.

Statcom Principle

STATCOM is a controlled reactive power source. It provides the desired reactive power generation and absorption entirely by means of electronic processing of voltage and current waveforms in a voltage source converter. A single line STATCOM is shown in Fig 1, where a voltage source converter is connected to bus through a reactance. Here STATCOM is seen as an adjustable voltage source behind a reactance. The exchange of reactive power between the converter and AC system can be controlled by varying amplitude of 3-phase output voltage 'Es' of the converter Fig 2.

If the amplitude of the output voltage of converter is increased above utility bus voltage 'Et', then a current flow through reactance from converter to AC system and voltage source converter generates capacitive reactive power for the AC system. If output voltage of converter is decreased below the utility bus voltage then current flows from AC system to the converter and converter absorbs inductive reactive power from AC system. If the converter output voltage equals the AC system voltage the reactive power exchange becomes zero, in that case STATCOM is said to be in floating state. In steady state operation and due to converter voltage losses the bus voltage always leads the converter voltage by a very small angle to supply the small active power losses.

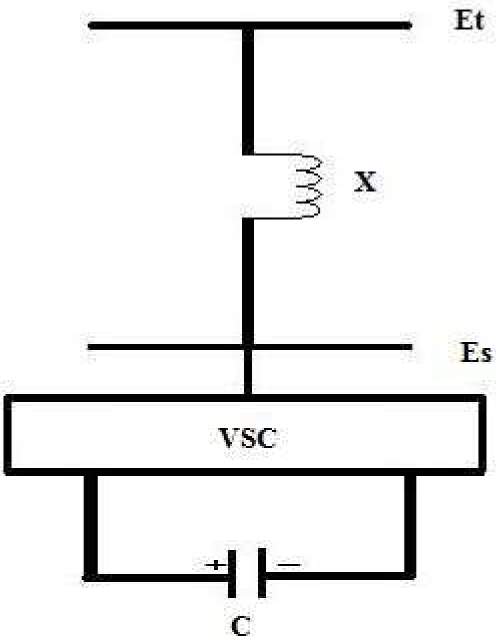

Fig 1: STATCOM Power Circuit

The reactive power supplied by STATCOM is given by

$$Q = \frac{(Es - Et)}{X}.Et$$

where,
Q is the reactive power in VAR's.
Es is the magnitude of STATCOM side voltage.
Et is magnitude of utility side voltage.
X is equivalent impedance between STATCOM and AC system.

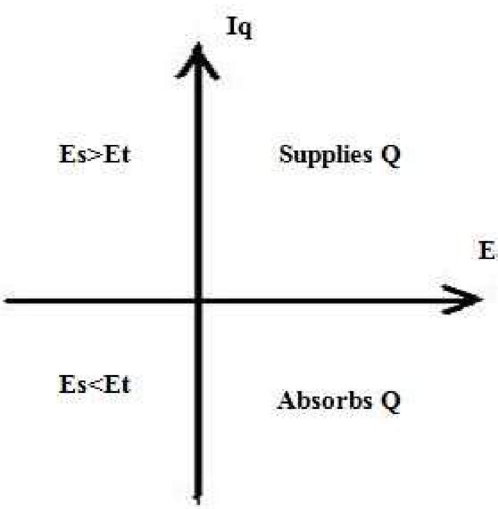

Fig 2: Power Exchange between STATCOM and AC System

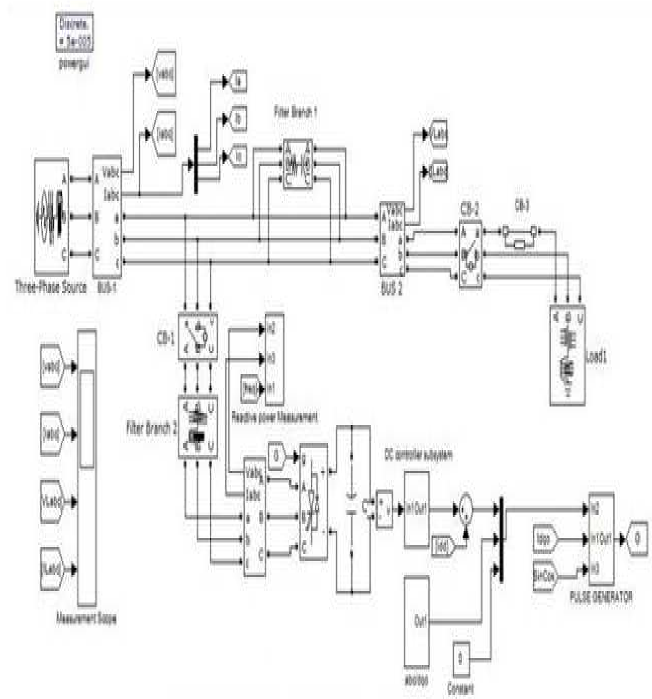

Fig 3: Simulink Model Of Proposed System

Simulink Model

A 6-pulse digital simulation full model of the STATCOM within a power system is presented in this paper. The digital simulation is performed using the MATLAB/Simulink software environment and the Power System Blockset (PSB). The basic building block of the STATCOM is the 6-pulse converter cascade implemented by using Matlab/Simulink. The control process is based on Split Synchronous Rotating Frame strategy. The operation of the STATCOM model is studied in both capacitive and inductive modes in a power transmission system and with one line open circuited.

A . Model Description

Modeling the STATCOM including the power network and its controller is done using Matlab/Simulink. It requires electric blocks from the power system and control blocks from the Simulink power blockset library. A ±100 Mvar STATCOM [5] device is connected to the 500-kV (L-L) transmission network. Figure 3 shows the MATLAB model of the studied system. The voltage source is represented by a 500 kV with 10000 MVA short circuit capacity and X/R = 11 followed by a bus B1 connected to bus b2 through transmission line.STATCOM is connected at the midpoint between bus B1 and B2 The system parameters used are given in Appendix. The STATCOM device consists mainly of the 6-pulse voltage source converter connected to the host grid network through a reactance. The dc link voltage is provided by the capacitor C which is charged from the AC host network. The proposed control scheme ensures the dynamic regulation of the bus voltage and the dc link voltage.

B. Proposed Control Strategy

A control scheme based on SRF[6] is implemented using the DC capacitor voltage. The dc side capacitor Voltage is chosen based on the change in the capacitor voltage. A PI controller with gains Kp= 0.001 and Ki = 0.0001 is used for generating reference current Id_{ref} which along with Iq_{ref} from PLL is used to generate the gating pulses for the VSC bridge as shown in figure 4.

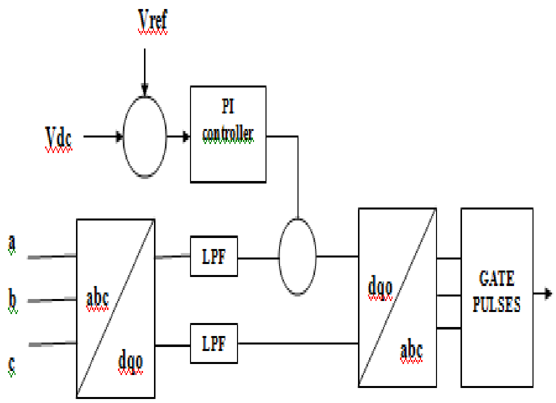

Fig 4: Proposed Current Control System

Simulation Results

The sample study radial power system is subjected to load switching at bus B2. At starting, the source voltage is such that the STATCOM is inactive. It doesn't absorb nor provide reactive power to the network. The network voltage, Et, is 1 pu and only inductive load with P=1 pu and Q=0.8 pu at rated voltage is connected at load bus B2 and the transmitted real and reactive power are PL=1.25 pu and QL=1 pu. The simulation is carried out by using the MATLAB/Simulink and power system blockset and the digital simulation results is given as shown in Figure 5. The following excursion sequence is tested:

STEP 1: Due to load switching at bus B2 at 0.1 the bus B2 voltage falls from 1 pu to 0.92 pu.At t = 0.1 sec, the static synchronous compensator STATCOM is switched and connected to the power system network by switching on the circuit breaker CB1. as shown in Figure (6). The STATCOM voltage Es lags the transmission line voltage Et by a small angle and therefore the dc capacitor voltage increases. The STATCOM is now operating in the capacitive mode and injects about 0.012 pu of reactive power into the AC power system, as shown in Figure (5). The B2 bus voltage is increased to 0.98 pu as shown in Figure (7).

STEP 2: Now at time t = 0.1 Sec, a capacitive load 2 with P=1 pu , Qc=0.8 pu at rated voltage is now added to the power system.At bus B2.due to addition of a capacitive load the voltage at bus B2 increases to 1.07 pu and also it causes unbalance is the source voltage and current waveforms due to increased harmonics as shown in figure (8). At time t=0.1 sec STATCOM is switched ON. Since the capacitive load has a compensative effect so the STATCOM absorbs reactive power of 0.02 pu from the AC system and also balances the three phase voltages and currents as shown in figure (10).The regulated bus voltage is 1.05 pu as shown in figure (9).

STEP 3: At time t=0.05 sec system is subjected to an unbalanced inductive load with P=1 pu and Q= 0.8 pu by switching off one of the lines on the load side using circuit breaker CB3. Without STATCOM the source is not able to deliver balanced currents as shown in figure (11). After switching STATCOM at t=0.05 sec the STATCOM is able to force the source to deliver the balanced currents by compensating reactive power as shown in figure (12) and reducing the harmonics by a large margin.

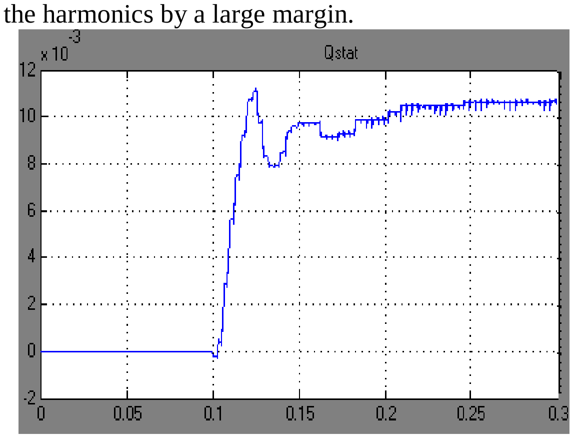

Fig 5: Reactive power supply from STATCOM for inductive load.

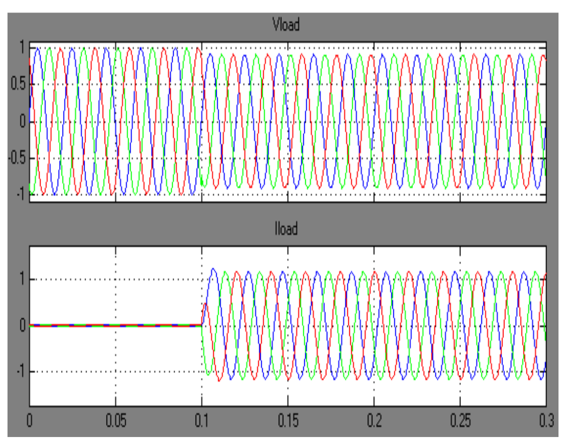

Fig 6: Load voltage and current for inductive without STATCOM

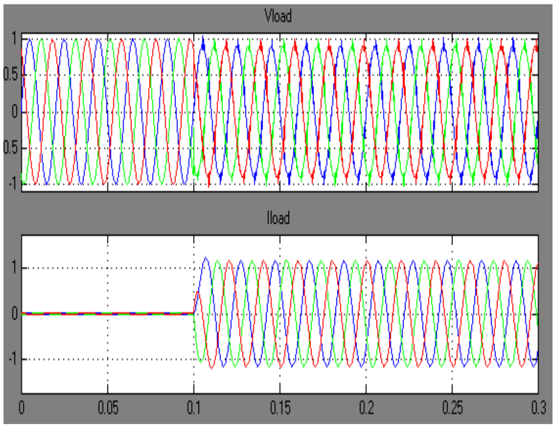

Fig 7: Load voltage and current for inductive load with STATCOM

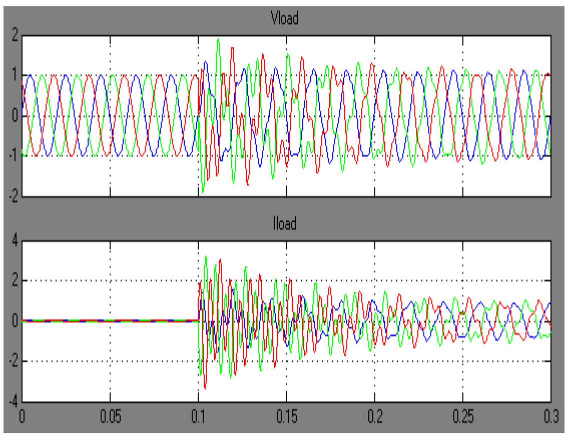

Fig 8: Load voltage and current without STATCOM for capacitive load

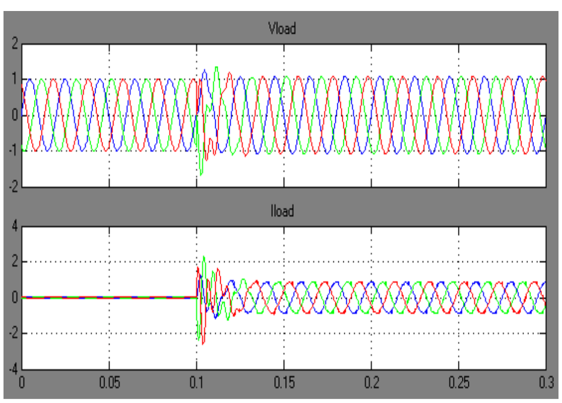

Fig 9: Load voltage and current with STATCOM for capacitive load.

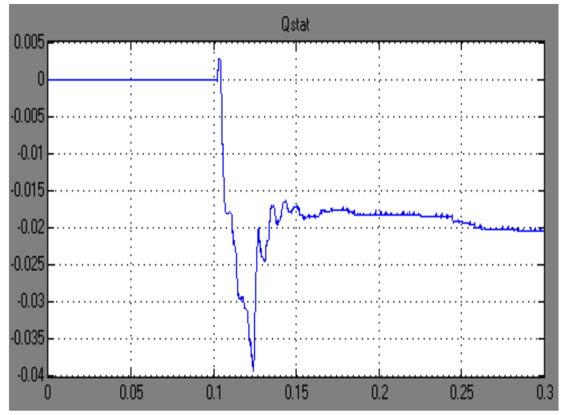

Fig 10: Reactive power Absorbed by STATCOM for Capacitive load.

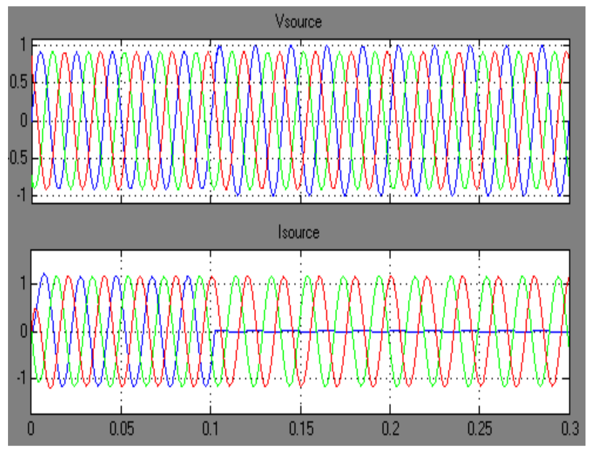

Fig 11: Source voltage and current with unbalanced load.

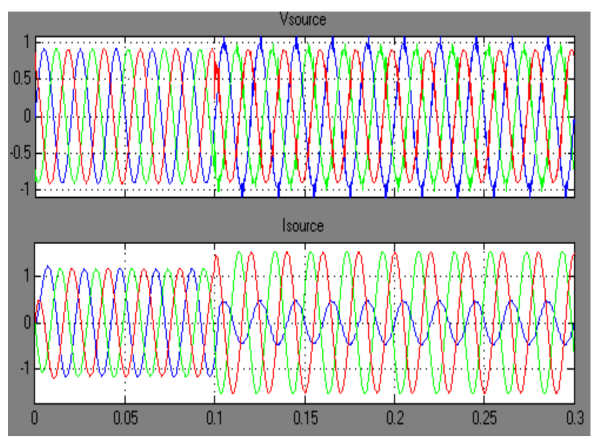

Fig 12: Source voltage and current with unbalanced load with STATCOM

Conclusion

This paper presented 6-pulse STATCOM and its use for reactive power compensation and voltage regulation. A MATLAB/Simulink based ±100 MVAR STATCOM has been developed and connected to the 500 kV AC grid network in order to provide the required reactive power compensation. The control process has been developed based on Synchronous Rotating Frame Theory. The operation of STATCOM is simulated for both inductive and capacitive loads in the sample power transmission system. The simulation results have demonstrated the effective reactive power compensation of 6-pulse STATCOM when subjected to different loads.

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APPENDIX

TABLE-1	
Three Phase AC Source	
Rated voltage	500 [KV]
Frequerncy	50 [Hz]
SC Level	10000 [MVA]
Base Voltage	500 [KV]
X/R	11
Three Phase Loads	
Load 1	
Active Power (P)	1000 [MW]
Reactive Power (QL)	800 [MVAR]
Load 2	
Active Power (P)	1000 [MW]
Reactive Power (Qc)	800 [MVAR]
STATCOM	
Nominal power	100 [MVAR]
Frequency	50 [Hz]
Equivalent Capacitance	7500 [µF]
GTO Switches	
Snubber resistance	1e5 [ohms]
Snubber Capacitance	inf
No. of bridge arms	3