© 2014 IJEDR | Volume 2, Issue 1 | ISSN: 2321-9939

Improving Stability of the power system by using self-tuning STATCOM

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***Abstract* - The performance of power systems decreases with the size, the loading and the complexity of the networks. This is related to problems with load flow, power oscillations and voltage quality. Such problems are even deepened by the changing situations resulting from deregulation of the electrical power markets, where contractual power flows do no more follow the initial design criteria of the existing network configuration. Additional problems can arise in case of large system interconnections, especially when the connecting AC links are weak. FACTS devices, however, provide the necessary features to avoid technical problems in the power systems and they increase the transmission efficiency. This paper presents a study on the design of a shunt connected FACTS device (STATCOM) and investigates the application of this device to control voltage dynamics and to damp out the oscillation in electric power system. STATCOM is one of the key shunt controllers in flexible alternating current transmission system (FACTS) to control the transmission line voltage and can be used to enhance the load ability of transmission line and extend the voltage stability margin. In this paper, the proposed shunt controller based on the voltage source converter topology as it is conventionally realized by VSC that can generate controllable current directly at its output terminal. The performance and behavior of this shunt controller is tested in 3-machine 9-bus system as well as the performance is compared in the test system with and without STATCOM at three cases in MATLAB/Simulink. Simulation results prove that the modeled shunt controller is capable to improve the Power quality significantly.**

***Keywords* - FACTS, STATCOM, VSC, CSC, PLL, PWM, PID**

1 INTRODUCTION

The traditional steady state stability studies and Transient stability studies take into account the active power flow P and power angle ∂ and generally assume constant receiving and sending end bus voltage. The reactive power flow Q and voltage fall during heavy current flow is neglected. This approach could not explain the several black-outs in USA, Europe, Japan etc. during the last quarter of the twentieth century. The blackouts were due to voltage collapse. During voltage collapse, the bus voltage starts falling and as a result power transfer P through the transmission line starts reducing resulting in ultimate voltage collapse and loss of system stability of entire network. That’s why voltage stability studies have received more attention and have acquired a vital place in power system Studies. Voltage collapse phenomena take place where reactive Power management is inadequate. The application of power electronics in the electric power transmission plays an important role to make the system more reliable, controllable and efficient.

Due to deregulation, environmental legislations and cost of construction, it is becoming increasingly difficult to build new transmission lines. Thus it is essential to fully utilize the capacities of the existing transmission system. The flexible AC Transmission system (FACTS) has become a popular solution to our large/over extended power transmission & distribution system. FACTS devices are proving to be very effective in using the full transmission capacity while increasing power system stability, transmission efficiency and maintaining power quality and reliability of Power system. These devices are mainly based on either voltage source converter (VSC) or Current Source Converter (CSC)and have fast response time. As an important member of FACTS devices family, STATCOM has been at the centre of attention and the subject of active research for many years. STATCOM is a shunt connected device that is used to provide reactive power compensation to a transmission line. This controller can either absorb or inject reactive power whose capacitive or inductive current can be controlled independent of the AC line voltage. Thus, STATCOM can enhance the transmission line load ability by extending the MW margin and improves the oscillation of voltage transients through efficient regulation of the transmission line voltage at the point of connection.

This paper deals with the modeling of a SPWM based STATCOM with a PID controller implemented on a 3- machine 9-bus test system. The device is connected to a load bus with a converter transformer. The modeling of shunt controller and testing is simulated in the MATLAB/ Simulink environment. The controller is represented as block diagram that presents practical electronic model of shunt controller. PID controller is used to control the current injection at the connection point by varying the desired parameters, one is Modulation index (AM) and another is power angle.

2 MODELING OF SHUNT CONVERTER

Figure shows a construction of STATCOM utilizing one interconnection transformer and three GTO/Diode based double arm H-bridges. Each H-bridge is connected to the each phase of the secondary of interconnection transformer. Transformer primary is connected to the transmission line. Conventionally, shunt controllers are constructed of three phase converters or inverters. But it is possible to replace the three phase converter with three single phase converter. The three phase converter constructed with three single phase converter produces less switching ripples than the conventional three phase converter. So, three phase converter constructed with three single phase converters is used. T1, T2 and T3 represent the transformer coils of phase A, B and C respectively that form a three phase transformer secondary connected to shunt converter. A capacitor (C) which acts as a voltage source is used. The original circuit diagram of each GTO/Diode bridge (B1,B2 and B3) is shown in figure . Each H-bridge consists of four GTO and four diodes where the GTO and diode are connected in anti-parallel. So, four different control pulses are required to control each of bridges. Therefore to apply firing pulses to three different bridges properly, total twelve different pulses are required for controlling the shunt converter.

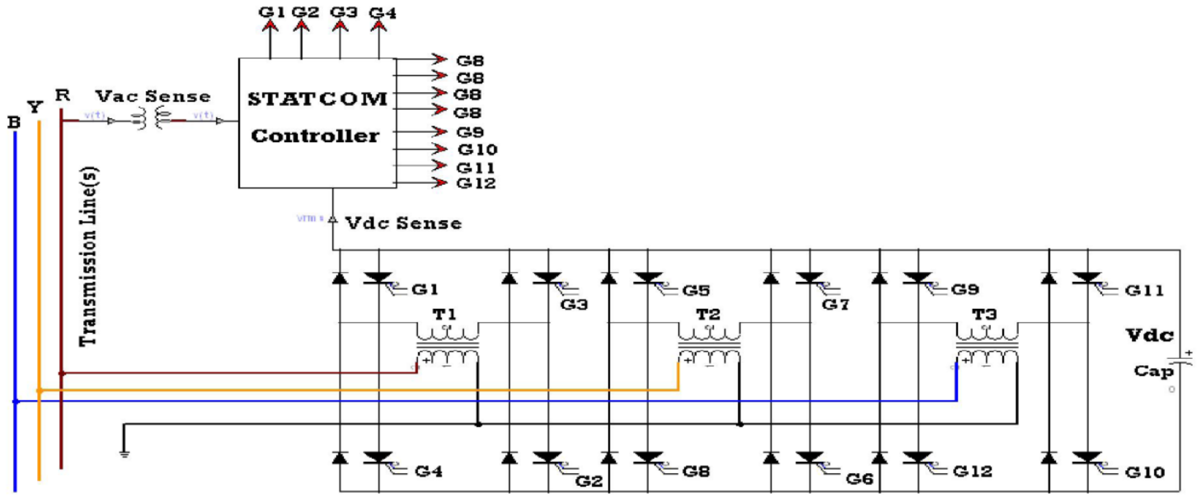

Fig 1

3 CONTROL STRATEGIES

STATCOM can be controlled in voltage control mode and Var control mode. The control used in this simulation is AC voltage control mode. Mainly, the control is divided into two parts. One is for angle order and another is for the order of modulation index. The shunt converter is operated in such a way as to demand this DC terminal power from the line keeping the voltage across the storage capacitor Vdc constant. So, according to equation-1, the angle is ordered in such a way that the net real power absorbed from the line by this shunt FACTS device is equal to the losses of the converters and the transformer only. The remaining capacity of this shunt converter can be used to exchange reactive power with the line so to provide VAR compensation at the connection point. The reactive power according to equation-2 is electronically provided by the shunt converter and the active power is transmitted to the DC terminals. The shunt converter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value.

The line voltage and Dc link voltage across capacitor are measured to calculate the amount of reactive power to regulate the line voltage and consequently the modulation index is varied in such a way as to calculate reactive power can be injected at the point of connection and thus the shunt FACTS device acts as a voltage regulator. The SPWM firing pulses to the GTOs are obtained by comparing the PWM carrier signal and the reference sine wave. The amplitude of reference sine wave is 1Volt and frequency is 50 Hz which is similar to system operating frequency. The carrier frequency is set at 1.5 KHz which is 30times the system operating frequency. The phase lock loop (PLL) plays an important role in synchronizing the switching to the system voltage and lock to the phase at fundamental frequency. The converter is consisted of 12 GTO with additional components. The controller controls the firing pulses from G1 to G12 which are sinusoidal pulse width modulated signals.

The following figure shows the block diagram of control strategy to generate only one pulse width modulated signal and 11signals can be generated similarly.

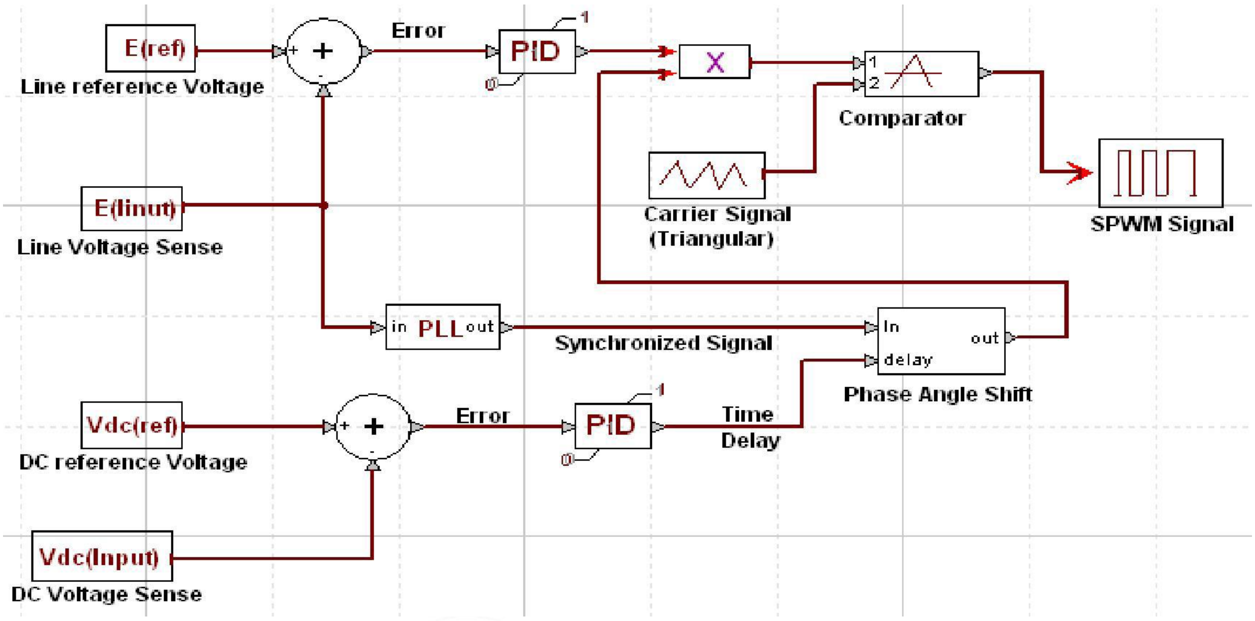

Fig 2

4 SIMULATION SETUP AND RESULTS

Figure 4 shows the 3 machine 9 bus test system for simulation. The test system includes machines, transmission lines and loads at different buses. The modeled FACTS device (STATCOM, 300 MVA) is installed at Bus-9. Two types of large loads (Load-1 & Load-2) are also connected at bus-9. Power is flowing to Bus-9 by TL1 and TL2.

At starting, Load-1(50 MW & 30 MVAR) and Load-2 (100 MW & 50 MVAR) is not connected to the Bus-9. A fault takes place at t=0.3 second at TL1 and instantaneously Bk-1 and BK -2 is tipped to isolate the transmission line TL1 from the system. At the same time (t=0.3s) Load-1 is connected to the system and Load-2 is connected at t=0.7 second. The start time of simulation at t=0 s and the end time is t=1 second. Waveforms Scales are zoomed so that the voltage oscillations can be seen clearly.

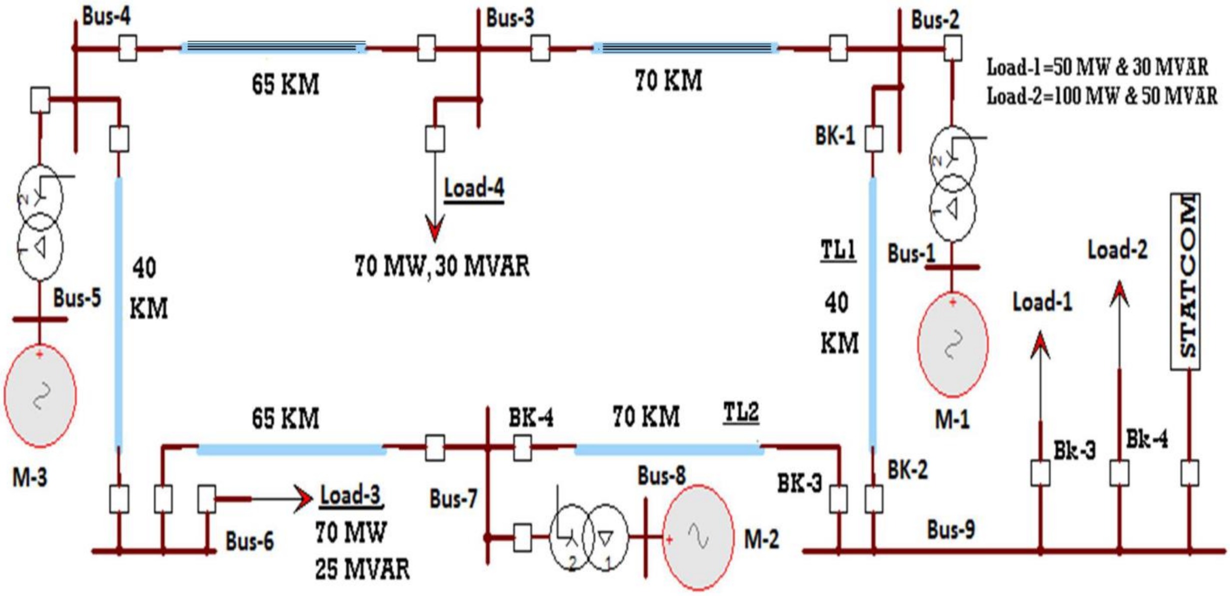

Fig 3

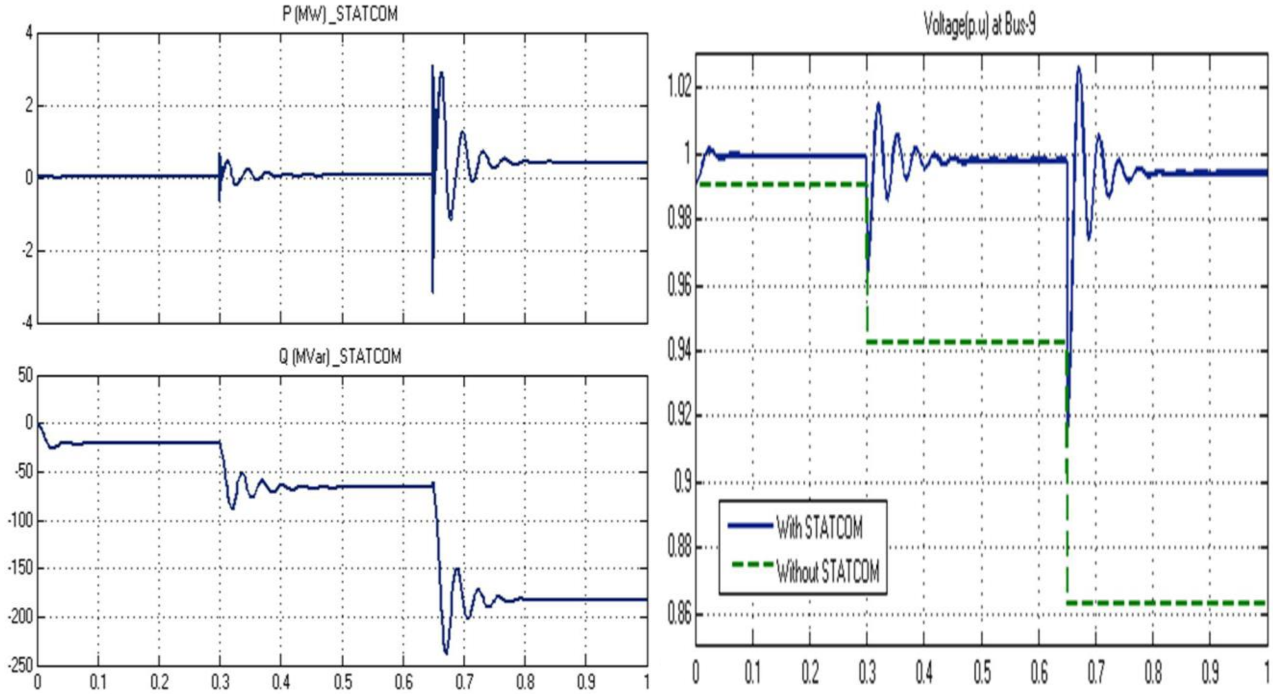

Fig 5

5 CONCLUSION

In simulation, worst events are considered to examine the performance of modeled shunt connected FACTS device. The simulation results show that the modeled STATCOM is capable enough to control the transmission line voltage dynamics as well as the same shunt controller can be used in VAR control mode. Vdc is regulated by controlling proper phase shift and transmission voltage is regulated by varying the modulation index. The response of controller is very fast due to apply direct control method. The simulation results also prove that the shunt device with proposed switching scheme functions successfully as the real time voltage controller and it improves the dynamic stability with a wide range of control the reactive power. The magnitude of voltage oscillation in simulation and other figures are zoomed along y axis to observe the oscillation clearly but actually the oscillations are very low. Three single phase converters are used rather than three phase converter to reduce switching ripples.

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