SIMULATION RESULTS OF EIGHT BUS SYSTEM USING PUSH-PULL INVERTER BASED STATCOM

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ABSTRACT

This paper deals with modeling and simulation of Voltage Source Inverter based STATCOM using Push-Pull inverter. The eight bus system is modeled and simulated using sim power system block set. Creation of voltage sag and compensation using STATCOM in eight bus system are presented. The present work proposes push-pull inverter for the control of STATCOM.The comparison of multi bus System with and without STATCOM is also presented.

Keywords - *FACTS, Static Synchronous Compensator (STATCOM), VSI, Push-pull Inverter.*

I INTRODUCTION

Today's power transmission and distribution system face increasing demands for more power, better quality with higher reliability at lower cost as well as low environmental impact. Developing countries especially can apply versatile voltage regulation and system stabilization measure, in order to utilize more effectively the latent capacity in existing transmission networks in preference to committing larger resources to new overhead lines and stations. The use of Power Electronics in the form of Thyristor controlled Reactors (TCR) and Thyristor Switched capacitor (TSC) in Static Var Compensation (SVC) as well is established. The application of power electronics in new configurations known as Flexible AC Transmission Systems (FACTS) offers the possibility of meeting such demands. FACTS devices are routinely employed in order to enhance the power transfer capability of the otherwise under-utilized parts of the interconnected network. Out of all FACTS devices, the STATCOM has the potential to be exceptionally reliable with the added capability to sustain reactive current at low Voltage (constant current not constant impedance), reduce land use and increased relocatability (footprint 40% of SVC) and be developed as a voltage and frequency support (by replacing capacitors with batteries as energy storage). Although currently being applied to regulate transmission voltage to allow greater power flow in a voltage limited transmission network in the same manner as a Static Var Compensator (SVC), the STATCOM has further potential.

By giving an inherently faster response and greater output to a system with a depressed voltage, the STATCOM offers improved quality of supply.

The major applications are: voltage stability enhancement, damping of torsional oscillations, power system voltage control, and power system stability improvement. These applications can be implemented with a suitable control (voltage magnitude and phase angle control) [2-3].

II. STATIC SYNCHRONOUS COMPENSATOR AND PUSH-PULL INVERTER

The Static Synchronous Compensator (STATCOM) is shunt connected reactive compensation equipment, which is capable of generating and /or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. The STATCOM provides operating characteristics similar to a rotating synchronous compensator without the mechanical inertia .The STATCOM employ solid state power switching devices and provide rapid controllability of the three phase voltages, both in magnitude and phase angle.

The STATCOM basically consists of a step-down transformer with a leakage-reactance, a three phase GTO/IGBT voltage source inverter (VSI), and a DC capacitor. The AC voltage difference across the leakage reactance produces reactive power exchange between the STATCOM and the power system, such that the AC voltage at the bus bar can be regulated to improve the voltage profile of the power system, which is the primary duty of the STATCOM.

However a secondary damping function can be added into the STATCOM for enhancing power system oscillation stability. The basic objective of a VSI is to produce a sinusoidal AC voltage with minimal harmonic distortion from a DC voltage.

The principle of STATCOM operation is as follows: The voltage is compared with the AC bus voltage system. When the AC bus voltage magnitude is above that of the VSI magnitude; the AC system sees the STATCOM as inductance connected to its terminals. Otherwise if the VSI voltage magnitude is above that of the AC bus voltage magnitude, the AC system sees the STATCOM as capacitance to its terminals. If the voltage magnitudes are equal, the reactive power exchange is zero. If the STATCOM has a DC source or energy storage device on its DC side, it can supply real power to the power system. This can be achieved by adjusting the phase angle of the STATCOM terminals and the phase angle of the AC power system. When phase angle of the AC power system leads the VSI phase angle, the STATCOM absorbs the real power from the AC system, if the phase angle of the AC power system lags the VSI phase angle, the STATCOM supplies real power to AC system. The real and reactive powers in STATCOM are given by the following equations 1 and 2.

$P_{12} = (V_1 V_2 / X_{12}) \sin(\delta_1 - \delta_2)$ -------- (1)

$Q_{12} = (V_2 / X)(V_1 - V_2)$ -------- (2)

System Bus V_{AC}

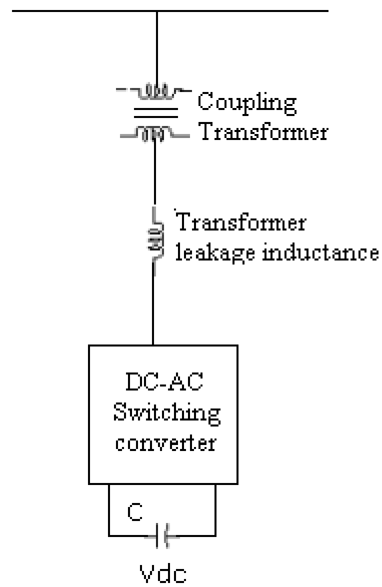

Fig1. Single - line diagram of a STATCOM.

The Voltage Source Converter or Inverter (VSC or VSI) is the building block of a STATCOM and other FACTS devices. A very simple inverter produces a square voltage waveform as it switches the direct voltage source on and off. The basic objective of a VSI is to produce a sinusoidal AC voltage with minimal harmonic distortion from a DC voltage.

In the last decade commercial availability of Gate Turn off thyristor (GTO) devices with high power handling capability, and the advancement of other types of power-semiconductor devices such as IGBT's have led to the development of controllable reactive power sources utilizing electronic switching converter technology [4]. These technologies additionally offer considerable advantage over the existing ones in terms of space reduction and performance. The GTO thyristor enable the design of solid-state shunt reactive compensation equipment based upon switching converter technology.

This concept was used to create a flexible shunt reactive compensation device named Static Synchronous Compensator (STATCOM) due to similar operating characteristics to that of a synchronous compensator but without the mechanical inertia. Single-line diagram of STATCOM is shown in Fig1.

The advent of Flexible AC Transmission systems (FACTS) is giving rise to a new family of power electronics equipment emerging for controlling and optimizing the performance of power system, e.g. STATCOM, SSSC and UPFC. The use of voltage source inverter (VSI) has been widely accepted as the next generation of the reactive power controllers of the power system to replace the conventional VAR compensator, Such as the thyristor-switched capacitors (TSC) and thyristor controlled reactors (TCR).

New type of STATCOM based on VSI with phase shifted SPWM is given by Liang[3], Modeling and simulation of DSTATCOM is dealt by Giroux[5].Introduction to multilevel inverter is given by [6]&[7],solution to power quality problem is given by [8],[9]&[10]. Dynamically voltage restoration with injection is given by [11],[12]&[13].Compensation of voltage sag by [15] & [16]. Power Electronic solution to power quality is given by [17].Analysis of thyristor based STATCOM is given by Song[18].overview of STATCOM technologies is given by Liu[19].Transfer capability improvement using FACTS is given by Arun[20].Multipulse-inverter based STATCOM is presented by Dananjayan[21].

The above literature does not deal with simulation of eight bus system using SIMULINK. This work deals with modeling and simulation of eight bus system using STATCOM.

The present work uses a push-pull inverter circuit comprising a transformer with a power output end coupled to a load and two power input ends. A power driver unit is connected between the two power output ends. A power supply unit, and the power driver unit receives a power signal and outputs two sets of drive signals having same frequency.

Circuit diagram of Push-Pull inverter is shown in Fig2.This circuit is also called parallel inverter since the capacitor appears in parallel with the transformer.$T_1$and T_2 conducts alternatively to produce the AC output.

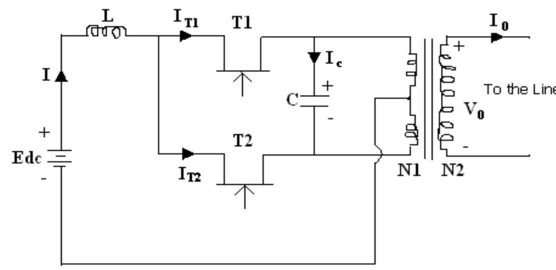

Fig.2 Push-Pull Inverter system

III. SIMULATION RESULTS

A eight bus system is considered for simulation studies. The circuit model of eight bus system is shown in Fig 3a. Each line is represented by series impedance model. Shunt capacitance of the line is neglected. Additional load is added in parallel with load-1 by closing the breaker in series with the load. Scopes are connected to display the voltages across the two loads. At t = 0.25sec, additional load is connected. Voltage across the load-1 decreases as shown in Fig 3b.This fall is due to the increased voltage drop.

Eight bus system with STATCOM is shown in Fig.4a.STATCOM is connected in the line between buses 4 & 8.The STATCOM using push-pull inverter is shown in Fig4b.The voltages across STATCOM, Load-1 and Load-2 are shown in Fig.4c. It can be seen that the voltage across load-1 decreases and resumes to the rated value due to the injection of voltage by the STATCOM. Thus the STATCOM is able to mitigate the voltage sag produced by the additional load. Power quality is improved since the voltage reaches normal value.

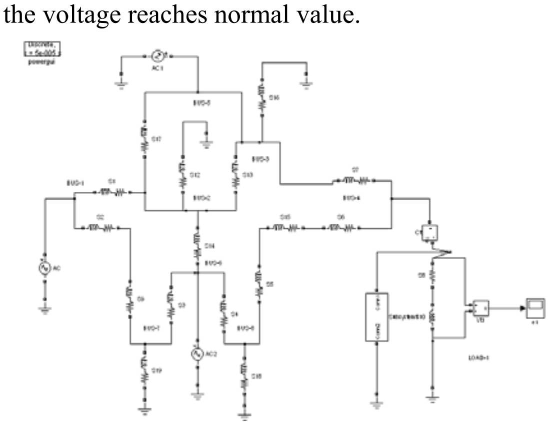

Fig.3a Model of 8-bus system without STATCOM

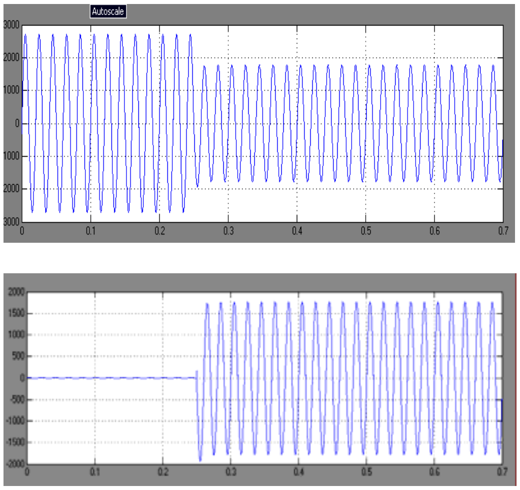

Fig.3b Voltage across Load-1 and Load-2

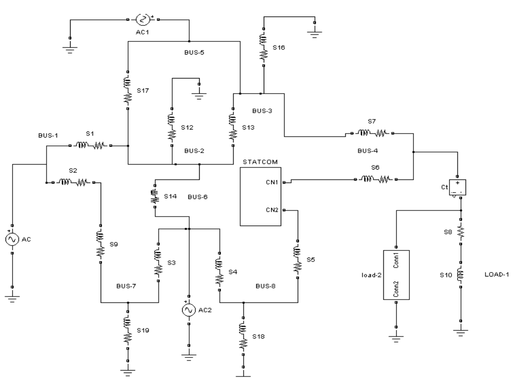

Fig.4a Model of 8-bus system with STATCOM

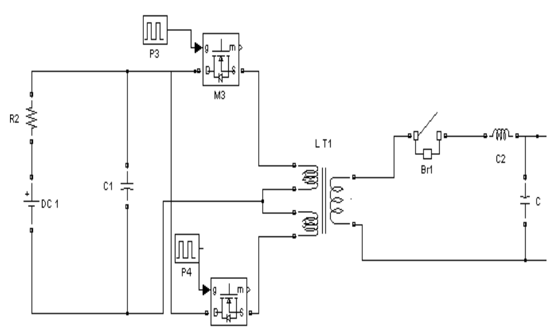

Fig.4b Push-Pull Inverter

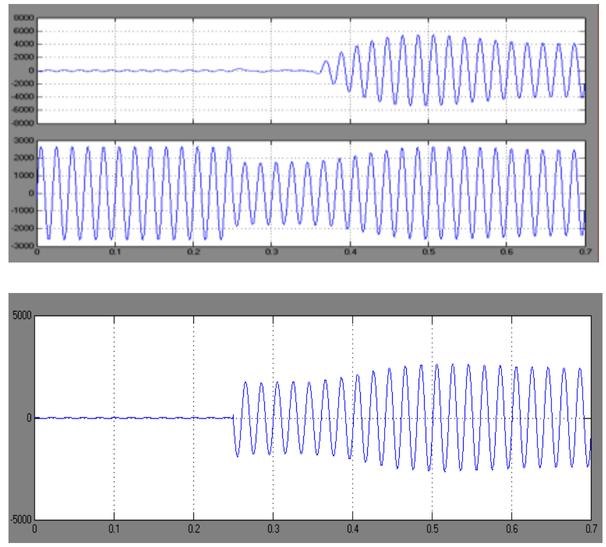

Fig.4c Voltage across STATCOM, Load-1 and Load-2

IV. CONCLUSION

This paper proposes push-pull inverter based STATCOM to improve the voltage stability in a multi-bus system. This system has advantages like reduced number of power transistors and reduced driver circuits. The load voltage reaches rated value with in 0.25sec. The simulation results of eight bus system with and without STATCOM are presented. The simulation studies indicate the usefulness of STATCOM to mitigate the voltage sag. The simulation results are in line with the predictions.

V. SCOPE FOR FURTHER WORK

The scope of this paper includes the simulation of single phase model. The simulation has considered balanced load. The hardware implementation is beyond the scope of this paper. The hardware may be implemented using PIC or Atmal microcontroller. Closed loop system may be simulated and implemented using suitable controllers.

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