POWER QUALITY IMPROVEMENT OF FOURTEEN BUS SYSTEM USING STATCOM

Sundarsingh Jebaseelan S.D.[1], Raja Prabu R.[2]

1Research Scholar, Sathyabama University, Chennai, India
[2]B.S.Abdur Rahman University, Chennai, India
E-mail: [1]sundarjeba@yahoo.co.in

Abstract

This work deals with the power quality improvement of fourteen bus systems with and without STATCOM using multi level inverter VSI circuit. The VSI is extremely fast in response to reactive power change. Multilevel inverters with a large number of steps (more than 50 levels) can generate high quality voltage waveforms, good enough to be considered as suitable voltage template generators. This paper is focused on minimizing the number of power supplies and semiconductors for a given number of levels. An active harmonic elimination method is applied to determine the firing angles for each level to eliminate any number of specific higher order harmonics of multilevel converters with unequal dc voltages. A Static Compensator (STATCOM) is a device that can provide reactive support to a bus. It consists of voltage source inverters connected to an energy storage device on one side and to the power system on the other. STATCOM is a device which can supply the required reactive power at low values of bus voltage and can also absorb active power if it has large energy storage. It also required having less harmonic contents in the output and higher compensation VA capacity. When the reactive power of the load is changing continuously, a suitable fast response compensator is needed. STATCOM, TCTC, UPFC, TCSC, SVC are the compensators belonging to FACTS devices. Models for the STATCOM is developed using MATLAB simulink. The simulation of the STATCOM is performed in the Simulink environment and the results are presented.

Key words: Reactive power, STATCOM, VSI, MATLAB.

I. INTRODUCTION

The possibility of controlling power flow in electric system without any rescheduling and topological changes can improve the power system performances [1]. It has been proved that, instead of building new transmission lines, an efficient usage of the existing line to their thermal limit is possible [1-3].

FACTS, which are power electronic based devices can change parameters like impedance, voltage and phase angle. Therefore they have the ability to control power flow pattern and enhance the usable capacity of the existing lines. The important feature of FACTS is that they can vary the parameters rapidly and continuously, which will allow a desirable control of the system operation.

FACTS devices are good to improve the power system efficiency, improve power factor and reduced in harmonics. Reactive power is used to control the voltage levels on the transmission system to improve the efficiency of the system.

The main application of power electronics in new configuration known as Flexible AC Transmission Systems (FACTS) offers the possibility of meeting such demands. In order to increase the power transfer capability normally FACTS devices are employed.

Benefits of FACTS devices

- Better utilization of existing transmission system
- Increased transmission system by reliability and availability.
- Increased quality of supply.

Among all the FACTS devices, The STATCOM has the higher potential to be exceptionally reliable with the added capacity to sustain reactive current at low, reduce land use and increased relocatability and be developed as a voltage and frequency support [1-3].

The static synchronous compensator (or) STATCOM is a shunt connected reactive power compensation device. It is capable of generating or absorbing reactive power.

This paper deals with the effect STATCOM in a fourteen bus system and how well it has improve the system performance on the basis of voltage and reactive power control. A static compensator is an important member of the family of controllers known as flexible AC transmission system (FACTS). An ideal STATCOM can be considered as a three phase sinusoidal voltage source that can control its magnitude as well as its phase displacement. The STATCOM is basically a DC-AC voltage source converter with an energy storage unit, usually a DC capacitor. It operates as a controlled. Synchronous Voltage Source (SVS) connected to the line through a coupling transformer [4-5].

The static synchronous compensator (or) STATCOM is a shunt connected reactive power compensation device. It is capable of generating or absorbing reactive power.

The above literature does not deal with multi level inverter of STATCOM. The work proposes multi level inverter for the control of reactive power.

II. STATCOM

A. Emerging FACTS controller

One of the many devices under the FACTS family, a STATCOM is a regulating device which can be used to regulate the flow of reactive power in the system parameters. In the transmission systems, STATCOM's handle only exchange the reactive power and provide voltage support to the busses by modulating bus voltages during dynamic disturbance in order to provide good transient characteristics, improve the transient stability and improve the power quality of the system.

STATCOM is a shunt connected reactive power compensation device. It is capable of generating & absorbing the reactive power. It can be improve the power system in the areas are

- Dynamic voltage control in transmission and distribution.
- Power oscillation damping in transmission system.
- Transient stability.
- Voltage flicker control.
- Control not only reactive power but also active power in the connected lines.

B. Principle of operation

The power circuit diagram for STATCOM as shown in the below diagram. It is a controlled reactive power source. It provides the reactive power generation and absorption by means of electronic process of the voltage and current waveforms in a voltage source.

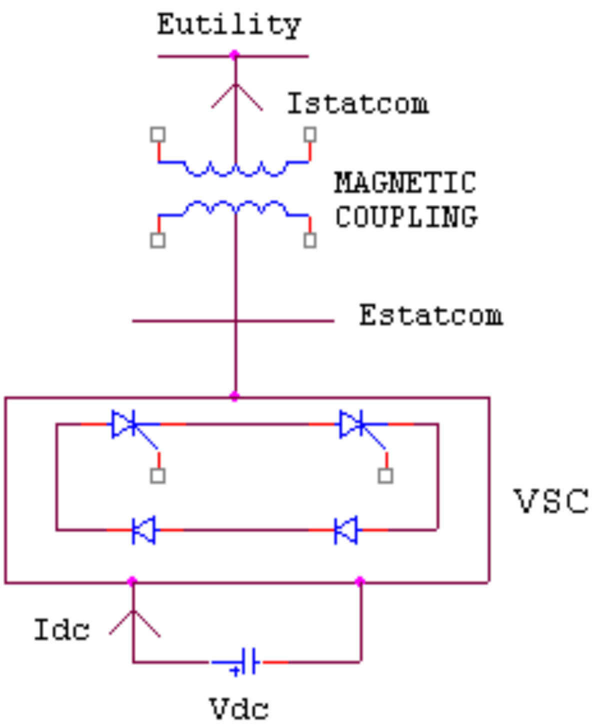

Fig. 1. Power circuit diagram

A single line diagram of STATCOM is shown in the below diagram, where Vsc is connected to the utility bus through the magnetic coupling transformer. It is a compact design, small foot print, low noise and low magnetic impact. The exchange of reactive power between the converter and AC system can be controlled by varying the three phase output voltage, E_S of the converter.

If the amplitude of the output voltage is increased above that the utility bus voltage, then the current flows through the reactance from the converter to the ac system and the converter act as a capacitance and generates reactive power for the ac system.

If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows through the reactance from the ac system to the converter and the converter act as inductance and it absorbs the reactive power for the ac system.

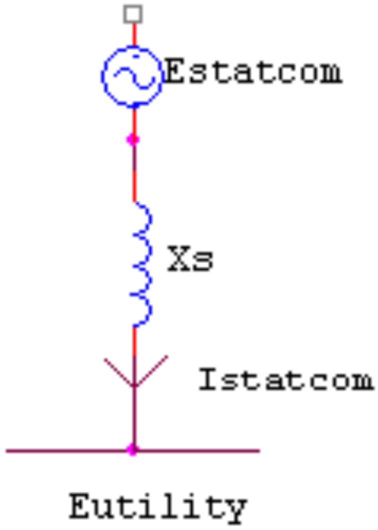

Fig. 2. Line diagram of STATCOM

If the output voltage equals the ac system, then the reactive power exchange becomes zero. On that condition STATCOM is to be in a floating state.

STATCOM controller provides voltage support by generating or absorbing reactive power at the point of common coupling without the need of large external reactors or capacitor banks.

III. MULTI LEVEL INVERTER

A. Multi level inverter

The principal function of the inverters is to generate an ac voltage from a dc source voltage. If the dc voltage is composed by many small voltage sources connected in series, it becomes possible to generate an output voltage with several steps. Multilevel inverters include an arrangement of semiconductors and dc voltage sources required to generate a staircase output voltage waveform. The below diagram shows the schematic diagram of voltage source-inverters with a different number of levels.

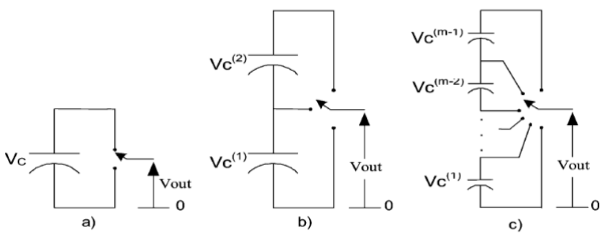

Fig. 3. Basic Multilevel Inverters

(a) Two levels, (b) Three levels, and (c) m Levels

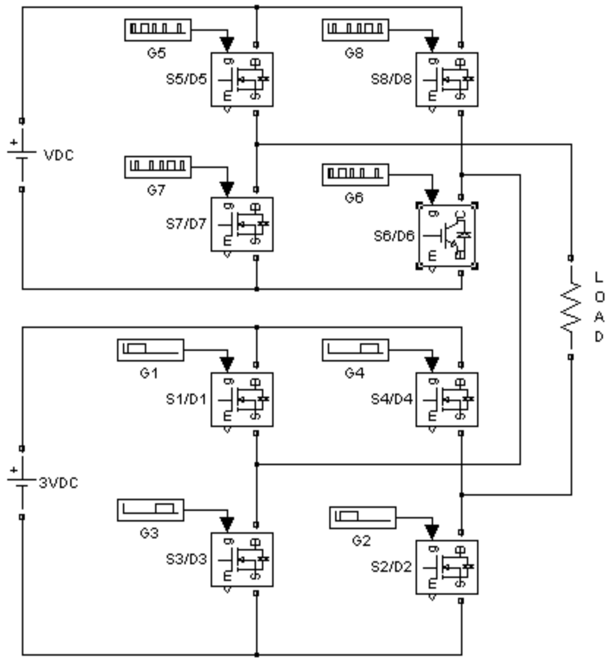

Fig. 4. Circuit Diagram of MLI

A cascaded multilevel inverter consists of a series of H-bridge (single phase full bridge) inverter units. The general function of this multilevel inverter is to synthesize a desired voltage from several dc sources (SCDs), which may be obtained from batteries, fuel cells. Fig.4.1 shows optimized topology of single-phase cascaded inverter. The ac terminal voltages of each bridge are connected in series. Unlike the diode clamp or flying-capacitors inverter, the cascaded inverter does not require any voltage-clamping diodes or voltage balancing capacitors. This configuration is useful for constant frequency applications such as active front-end rectifiers, active power filters, and reactive power compensation. In this case, the power supply could also be voltage regulated dc capacitor. The circuit diagram consists of two cascade bridges. The load id is connected in such a way that the sum of output of these bridges will appear across it. The ratio of the power supplies between the auxiliary bridge and the main bridge is 1:3. One important characteristic of multilevel converters using voltage escalation is that electric power distribution and switching frequency present advantages for the implementation of these topologies.

B. Principle of operation Multi level inverter

The phase output voltage is synthesized by the sum of two inverter outputs. Each inverter bridge is capable of generating three different levels of voltage outputs. The main bridge can generate +3Vdc, 0, –3Vdc and the auxiliary bridge can generate +Vdc, 0, –Vdc. By using appropriate combinations of switching devices many voltage levels are obtained. When the positive group switches are turned on the voltage across that particular bridge is positive. When the negative group switches are turned on the voltage across that particular bridge is negative. When S1, S2 are turned on the voltage across the main bridge is +3Vdc. When S3, S4 are turned on the voltage across the main bridge is –3Vdc. When S5, S6 are turned on the voltage across the auxiliary bridge is +Vdc. When S7, S8 are turned on the voltage across the auxiliary bridge is –Vdc. To obtain +2Vdc the switch combinations S1, S2, S7 & S8 are turned on.. To obtain –2Vdc the switch combinations S3, S4, S5 & S6 are turned on. are turned on. The following table shows the switching strategy of transistors at each level. The status of the switch is '0', that switch is in OFF condition. The status of the switch is '1', that switch is in ON condition.

Tabel I. Switching Strategies of Transistors at each Level.

Voltage Level	S_1	S_2	S_3	S_4,	S_5	S6	S7	S8
$-3V_{dc}$	0	0	1	1	0	0	0	0
$-2V_{dc}$	0	0	1	1	1	1	0	0
$-1V_{dc}$	0	0	0	0	0	0	1	1
0	0	0	0	0	0	0	0	0
$+1V_{dc}$	0	0	0	0	1	1	0	0
$+2V_{dc}$	1	1	0	0	0	0	1	1
$+3V_{dc}$	1	1	0	0	0	0	0	0

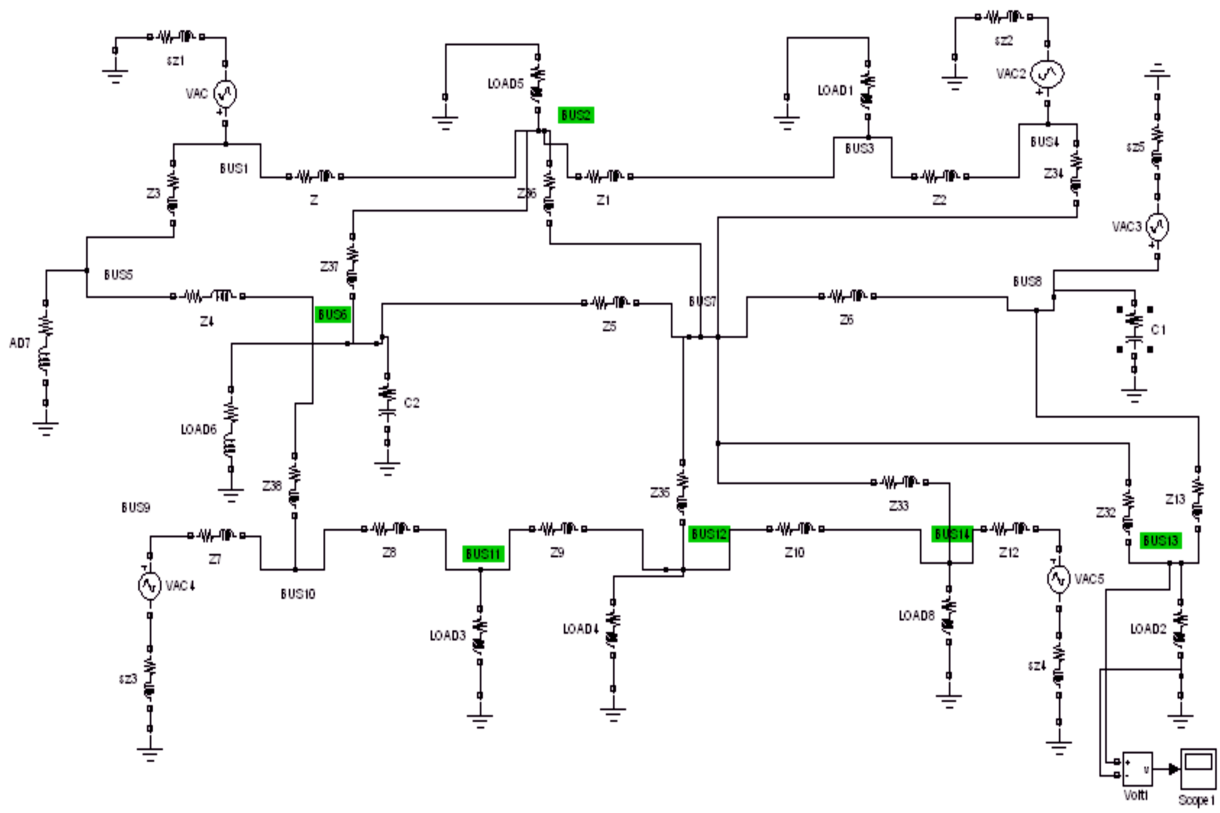

Fig. 5. Circuit without STATCOM model

IV. SIMULATION RESULTS

A. 14 bus system without controller

The simulation is done by using mat lab simulink and the results are presented. Each line is modeled by its series impedance. The load is represented by the combination of R and L. The shunt capacitances of the line are neglected. Circuit model of fourteen bus system without controller is shown in Fig 5. The voltage waveform across bus 2 without controller are shown in Fig 6. The Real and Reactive power at bus 2 without controller are shown in Fig 7. The voltage waveform across bus 11 without controller are shown in Fig 8. The Real and Reactive power at bus 11 without controller are shown in Fig 9.The technical specifications of fig 5 are as follows

$$R = 1000\ \Omega \qquad L = 100\ \text{mH}$$

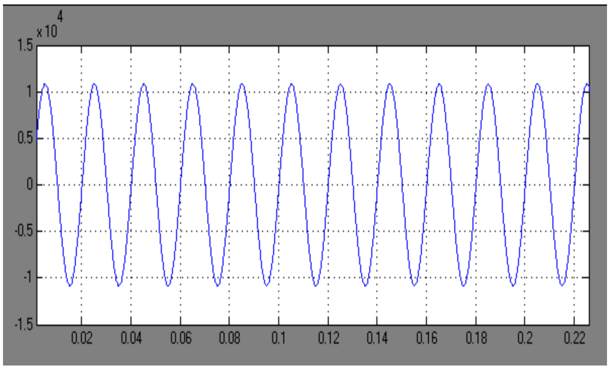

Fig. 6. Voltage waveform in bus 2

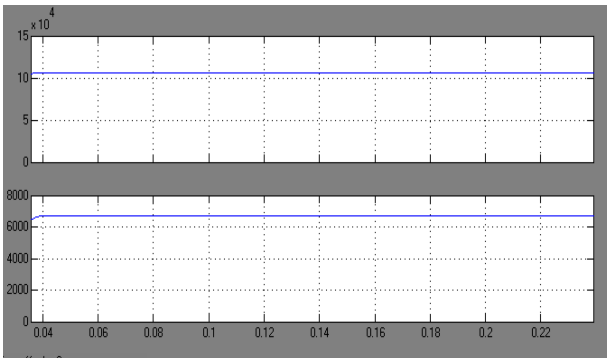

Fig. 7. Real and Reactive power in bus 2

B. 14 bus system with STATCOM

The circuit with STATCOM is shown in Fig 10. In the fourteen bus system, the STATCOM is installed in bus 13. The Voltage waveform across bus 2 with controller is shown in Fig 11. The Real and Reactive

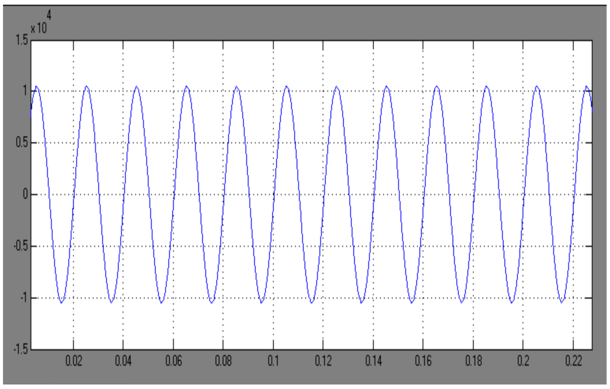

Fig. 8. Voltage waveform in bus 11

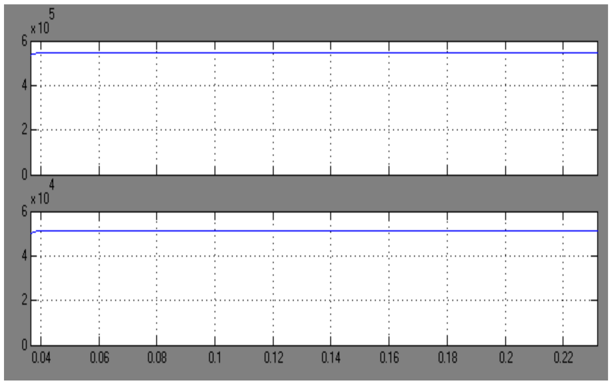

Fig. 9. Real and Reactive power in bus 11

power at bus 2 with controller are shown in Fig 12. The Voltage waveform across bus 2 with controller is shown in Fig 13. The Real and Reactive power at bus 2 with controller are shown in Fig 14. The matlab simulink diagram for VSI fed STATCOM model is shown in the Fig 15.The D C input voltage for multi level inverter as shown in the figure 16 and figure 17. The driving pulse for M1 and M2 as shown in the figure 18.The output voltage for multi level STATCOM is shown in the Fig 19. The summary of Reactive power and voltage for fourteen bus system is given in Table II. The Fig 19 shows the graph between Buses and reactive powers. The Fig 20 shows the graph between Buses and voltages. It can be seen that the reactive power is increased at bus 13 due to the presence of STATCOM. The increase in the Reactive power is due to the increased voltage of that bus. From the Table I it is seen that the voltage is increased at bus 3 due to the presence of STATCOM.

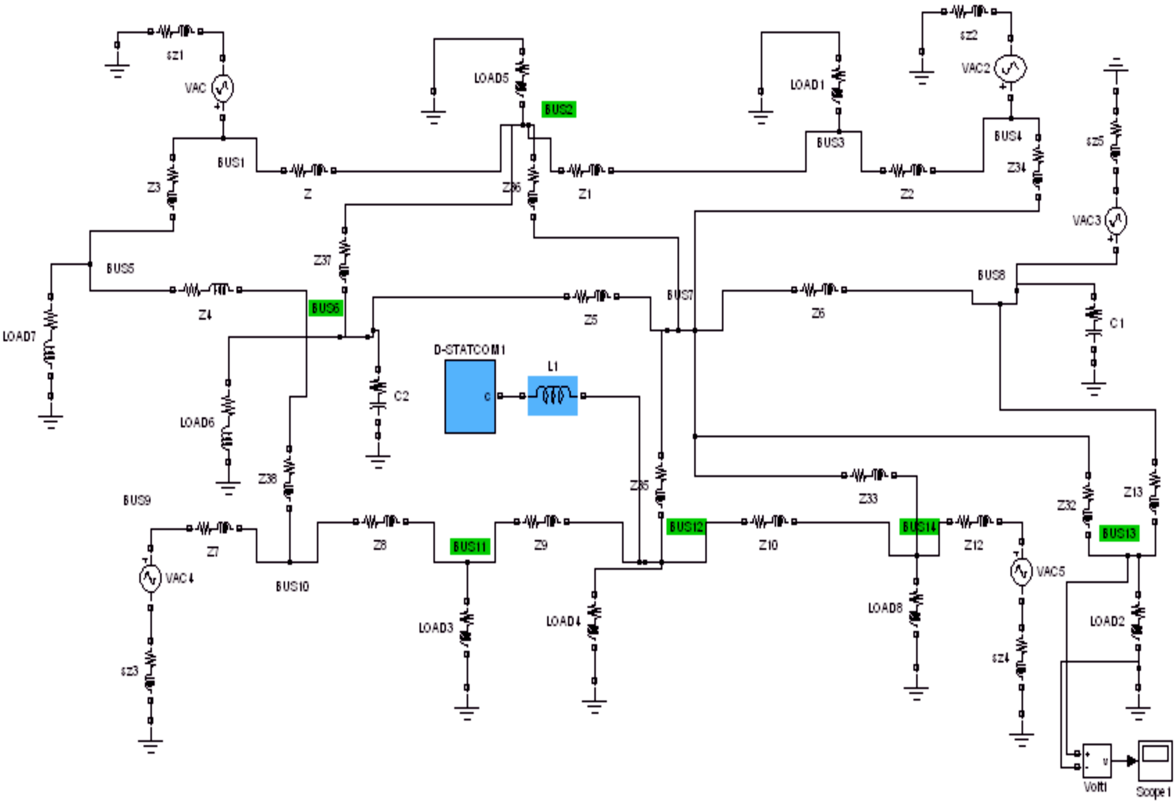

Fig. 10. Circuit model with STATCOM

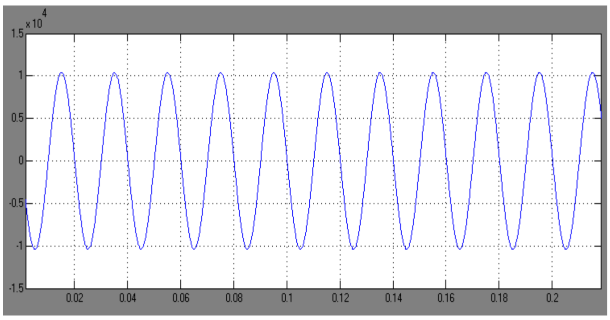

Fig. 11. Voltage waveform in bus 2

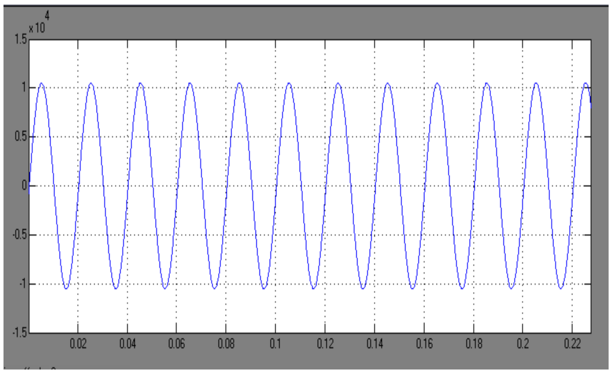

Fig. 13. Voltage waveform in bus 11

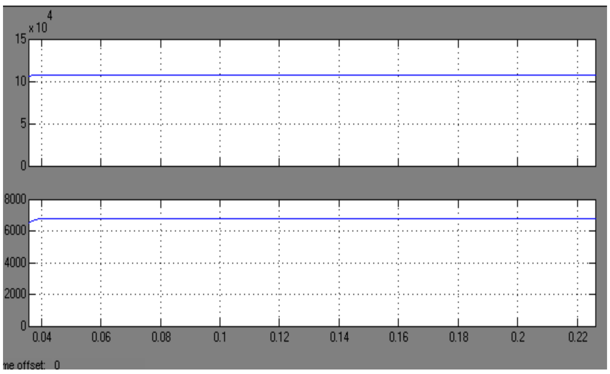

Fig. 12. Real and Reactive power in bus 2

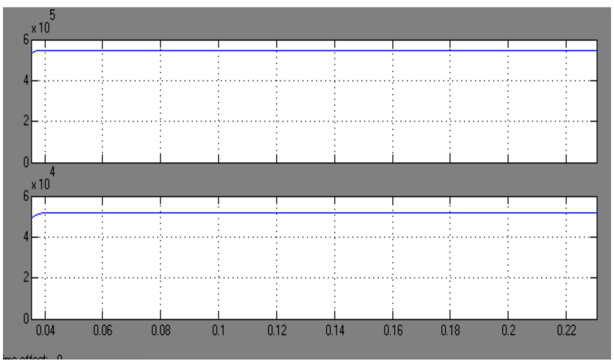

Fig. 14. Real and Reactive power in bus 11

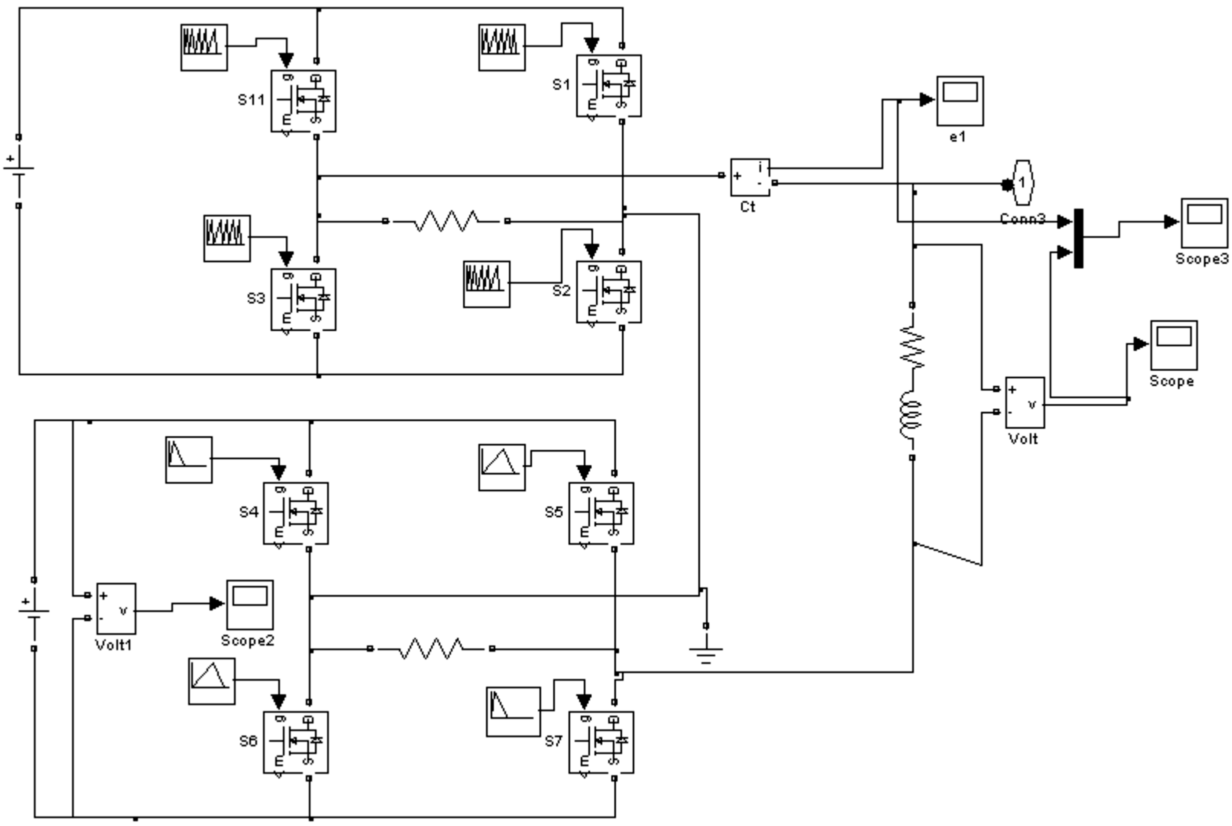

Fig. 15. Circuit diagram for Multi level inverter

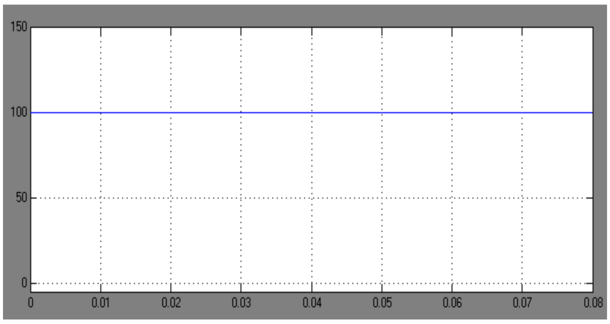

Fig. 16. DC input voltage 1for MLI

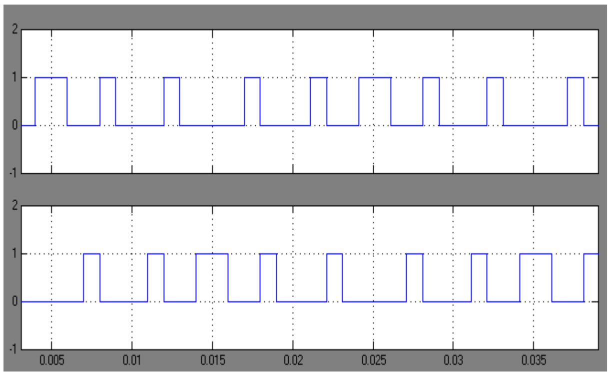

Fig. 18. Driving pulses M1 and M2 for MLI

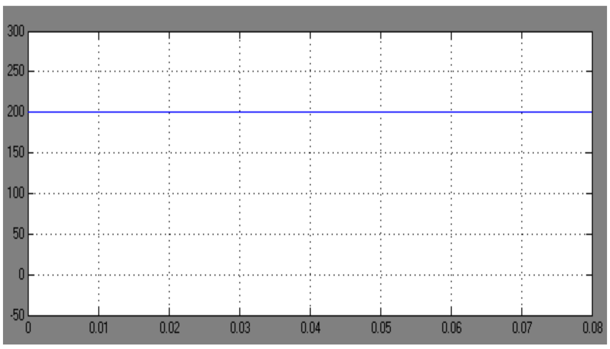

Fig. 17. DC input voltage 2 for MLI

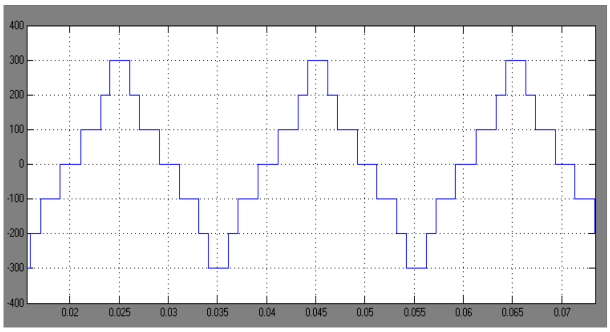

Fig. 19. Output voltage for MLI

Tabel II. Summary of Reactive Powers and Voltages

Bus no	Q (MVAR) without STATCOM	Q (MVAR) with STATCOM	Voltage (KV) without STATCOM	Voltage (KV) with STATCOM
2	0.066	0.0676	7314	7349
6	1.27	1.29	6652	6672
11	0.0513	0.052	7411	7441
12	0.01	0.011	7417	7454
13	0.029	0.030	7658	7805
14	0.058	0.059	7345	7392

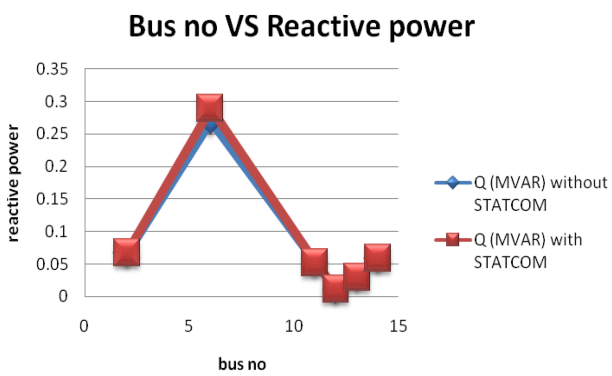

Fig. 20. Graph between Reactive Power & Buses

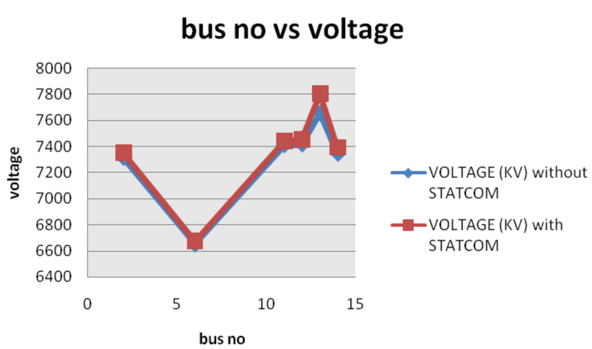

Fig. 21.. Graph Between Buses & Voltages

V. CONCLUSION

Power system with STATCOM are analyzed and the circuit model for the system is developed using the blocks available in MATLAB. Fourteen bus system with and without STATCOM are simulated and the results are presented. The sag is reduced by using STATCOM.This system has reduced reliability and improved power quality. The simulation results are in line with the predictions. Voltages and Reactive power increase when the STATCOM is connected to the respective buses. The scope of the present work is the digital simulation of systems with STATCOM using mat lab.

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S.D.Sundarsingh Jebaseelan has obtained his B.E degree from Bharathiyar University in the year 2002. He obtained his M.E degree from Annamalai University in the year 2005. Presently he is a research scholar at Sathyabama University. He is working in the area of Reactive power compensation.

Dr.R.Raja Prabu has obtained his B.E.degree from Annamalai University in the year1988. He obtained his M.E degree from Annamalai University in the year 1990. He received Ph.D. degree in High Voltage Engineering from College of Engineering, Guindy, Anna University. Currently, he is working as Professor and Head in the Department of E.E.E, B.S.Abdur Rahman University, Chennai. He is a member of IEEE, CIGRE, I.E (I) and I.S.T.E. His research interests include Outdoor Insulation, Digital Protection, Bio - Electrics, Power Quality and Nano-Dielectrics. He has been awarded various fellowships by AICTE, DST, CSIR and TNSCST. He has got more than 25 Research Publication to his credit.