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Power Quality Improvement Using Multiple Statcoms

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ABSTRACT

This work deals with Power quality improvement using multiple STATCOMs and also power quality improvement of thirty bus system using D-STATCOM. The thirty bus system is modeled using the elements of SIMULINK. This model is used for conducting the simulation studies. The simulation results of the thirty bus system with and without D-STATCOM are presented. Power Quality improvement is observed by adding D-STATCOM in the existing network.

KEYWORDS: *Distribution Static Synchronous Compensator (D-STATCOM), Power Quality (PQ), FACTS, Voltage source converter (VSC), Current source converter -(CSC).*

I. INTRODUCTION

The electric power system has grown in size and complexity with a huge number of interconnections to meet the increase in the electric power demand. Moreover, the role of long distance and large power transmission lines become more important. Now a days the requirement for power quality becomes more and more important to keep safety of the electrical devices and consumer satisfaction. Electric Power quality is a term which has captured increasing attention in power engineering in the recent years. Even though this subject has always been of interest to power engineers; it has assumed considerable interest in the 1990's. Electric power quality means different things for different people. To most electric power engineers, the term refers to a certain sufficiently high grade of electric service but beyond that there is no universal agreement. The measure of power quality depends upon the needs of the equipment that is being supplied. What is good power quality for an electric motor may not be good enough for a personal computer. Usually the term power quality refers to maintaining a sinusoidal waveform of bus voltages at rated voltage and frequency. Electric power quality (EPQ) problems mainly include unbalance voltage and current, flicker, harmonics, voltage sag, dip, swell, and power interruption [1]. These power quality problems may cause abnormal operations of facilities or even trip protection devices. Hence, the maintenance and improvement of electric power quality has become an important scenario today.

The development and use of Flexible AC Transmission System (FACTS) controllers in power transmission systems had led to many applications of these controllers to improve the stability of power networks. Various flexible ac transmission system (FACTS) devices, such as static synchronous compensators (STATCOMs), static synchronous series compensators (SSSCs), and unified power-flow controllers (UPFCs) are increasingly used in power systems because of their ability to stabilize power transmission systems and to improve power quality in power distribution systems. STATCOM technology is gradually employed to increase power transfer capability and provide voltage support fast acting solid state, thyristor switches of the FACTS devices are known to improve both the transient as well as dynamic performance of a power system. *STATCOM* (*Sta*tic Synchronous *com*pensator) is one of the most important Flexible AC transmission system (FACTS) devices [2,3] because of its ability to regulate voltages in transmission lines, to improve transient stability and to compensate variable reactive power. These devices are also interesting at the distribution level, where fast compensation of large, fluctuating industrial loads (such as electric arc furnaces and rolling mills) can be achieved, substantially improving upon the performance achievable with conventional thyristor-based converters. For low-medium power applications at the distribution level, such devices (sometimes called D-STATCOM (*D*istribution Statcom) or also active filters) are able also to perform compensation for the load current harmonics produced by distorting load, to comply with harmonic standards. The static synchronous compensator (STATCOM) provides shunt compensation in a way similar to the static var compensators (SVC), but utilizes a voltage source converter rather than shunt capacitors and reactors [4,5]. STATCOM is an active device, which can control voltage magnitude and, to a small extent, the phase angle in a very short time and, therefore, has the ability to improve the system damping as well as voltage profiles of the system. It has been reported that STATCOM can offer a number of performance advantages for reactive power control applications over the conventional SVC because of its greater reactive current output at depressed voltage, faster response, better control stability, lower harmonics and smaller size, etc.This paper analyzes the key issues in the Power Quality problems, as one of the prominent power quality problems, the origin, consequences and mitigation techniques of voltage sag problem has been discussed in detail. The STATCOM is 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 depressed voltage and offers improved quality of supply. The FACTS controllers are shown in Fig.1.The main applications of the STATCOM are; Distribution STATCOM (D-STATCOM) exhibits high speed control of reactive power to provide voltage stabilization and other type of system control. The DSTATCOM protects the utility transmission or distribution system from voltage sag and /or flicker caused by rapidly varying reactive current demand. During the transient conditions the D-STATCOM provides leading or lagging reactive power to active system stability, power factor correction and load balancing and /or harmonic compensation of a particular load [6,7].

Table 1 : FACTS Controllers

Name	Type	Main Function	Controller Used	Comments
SVC	Shunt	Voltage Control	Thyristor	Variable Impedance Device
TCSC	Series	Power Flow Control	Thyristor	Variable Impedance Device
TCPAR	Series and Series	Power Flow Control	Thyrisotr	Phase Control
STATCOM	Shunt	Voltage Control	GTO	Variable Voltage Source
SSSC	Series	Power Flow Control	GTO	Variable Voltage Source
UPFC	Shunt and Series	Voltage and Power Flow Control	GTO	Variable Voltage Source

II. OPERATING PRINCIPLES OF THE D-STATCOM:

The STATCOM is the solid-state-based power converter version of the SVC. The concept of the STATCOM was proposed by Gyugyi in 1976. Operating as a shunt-connected SVC, its capacitive or inductive output currents can be controlled independently from its connected AC bus voltage. Because of the fast-switching characteristic of power converters, the STATCOM provides much faster response as compared to the SVC. In addition, in the event of a rapid change in system voltage, the capacitor voltage does not change instantaneously; therefore, the STATCOM effectively reacts for the desired responses. For example, if the system voltage drops for any reason, there is a tendency for the STATCOM to inject capacitive power to support the dipped voltages [8, 9, and 10].

Theoretically, the power converter employed in the STATCOM can be either a VSC or a current-source converter (CSC). In practice, however, the VSC is preferred because of the bi directional voltage-blocking capability required by the power semiconductor devices used in CSCs. To achieve this kind switch characteristic, an additional diode must be connected in series with a conventional semiconductor switch, or else the physical structure of the semiconductor must be modified. Both of these alternatives increase the conduction losses and total system cost In general, a CSC derives its terminal power from a current source, i.e., a reactor. In comparison, a charged reactor is much lossier than a charged capacitor. Moreover, the VSC requires a current-source filter at its AC terminals, which is naturally provided by the coupling transformer leakage inductance, while additional capacitor banks are needed at the AC terminals of the CSC. In conclusion, the VSCs can operate with higher efficiency than the CSCs do in high-power applications. A suitable VSC is selected based on the following considerations: the voltage rating of the power network, the current harmonic requirement, the control system complexity, etc.

Basically, the STATCOM system is comprised of three main parts: a VSC, a set of coupling reactors or a step-up transformer, and a controller. In a very-high-voltage system, the leakage inductances of the step-up power transformers can function as coupling reactors. The main purpose of the coupling inductors is to filter out the current harmonic components that are generated mainly by the pulsating output voltage of the power converters [11, 12]. The STATCOM is connected to the power networks at a PCC, where the voltage-quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches of the power converter accordingly. The single line diagram of the STATCOM system is illustrated in Figure 1. In general, the VSC is represented by an ideal voltage source associated with internal loss connected to the AC power via coupling reactors.

In principle, the exchange of real power and reactive power between the STATCOM and the power system can be controlled by adjusting the amplitude and phase of the converter output voltage. In the case of an ideal lossless power converter, the output voltage of the converter is controlled to be in phase with that of the power system. In this case, there is no real power circulated in the STATCOM; therefore, a real power source is not needed. To operate the STATCOM in capacitive mode or var generation, +Q, the magnitude of the converter output voltage is controlled to be greater than the voltage at the PCC. In contrast, the magnitude of the output voltage of the converter is controlled to be less than that of the power system at the PCC on order to absorb reactive power or to operate the STATCOM in inductive mode, -Q. However, in practice, the converter is associated with internal losses caused by non-ideal power semiconductor devices and passive components. As a result, without any proper controls, the capacitor voltage will be discharged to compensate these losses, and will continuously decrease in magnitude. To regulate the capacitor voltage, a small phase shift d is introduced between the converter voltage and the power system voltage. A small lag of the converter voltage with respect to the voltage at the PCC causes real power to flow from the power system to the STATCOM [13], while the real power is transferred from the STATCOM to the power system by controlling the converter voltage so that it leads the voltage at the PCC. Figure 2 illustrates phasor diagrams of the voltage at the PCC, converter output current and voltage in all four quadrants of the PQ plane.

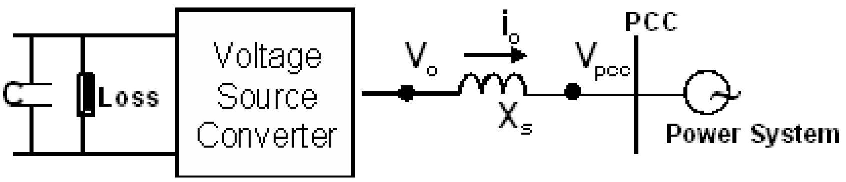


Fig. 1: Single-line diagram of the voltage-source converter-based D-STATCOM

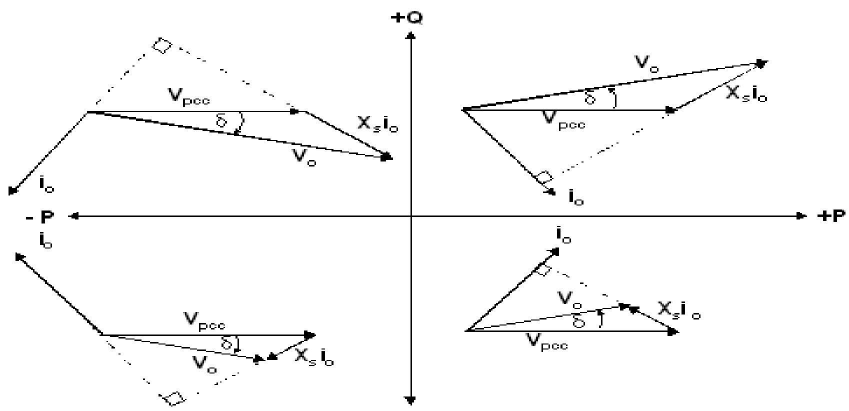


Fig. 2: Phasor diagram for power exchanges

The above literature [1] to [24] does not deal with power quality improvement using multiple STATCOMs. This work presents power quality improvement using mulatiple STATCOMs and also shown modeling and simulation of thirty bus system employing a D-STATCOM.

III. SIMULATION RESULTS

The 30 bus system is considered for simulation studies. The circuit model of 30 bus system without D-STATCOM is shown in Fig 3a. Each line is represented by series impedance model. The shunt capacitance of the line is neglected. The reactive power (Q) at busses 4,17 and 25 are shown in Figs.3b, 3c, and 3d

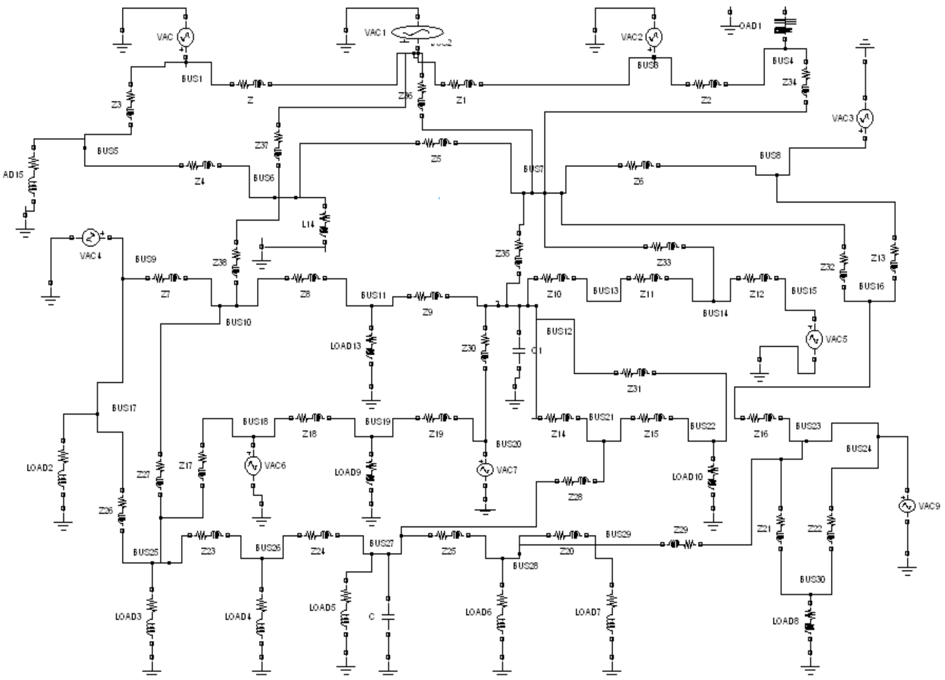
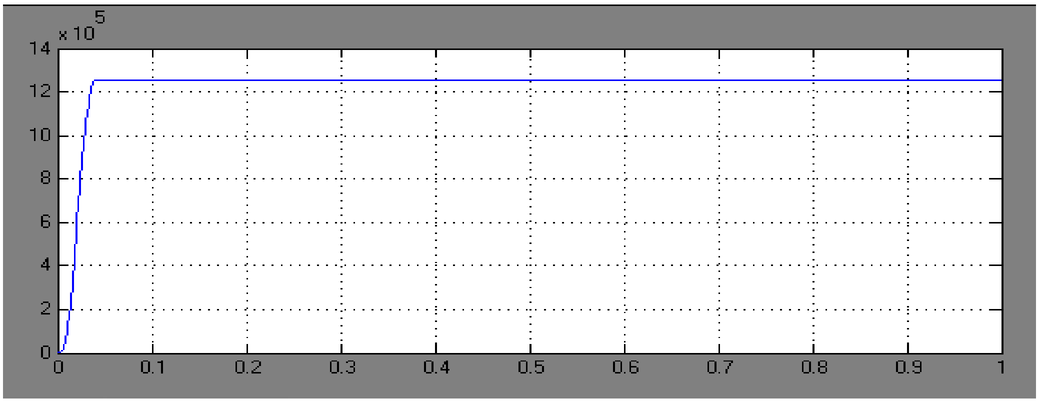


Fig. 3a: 30 bus system without D-STATCOM



Time in sec

Fig. 3b: Reactive power at bus 4

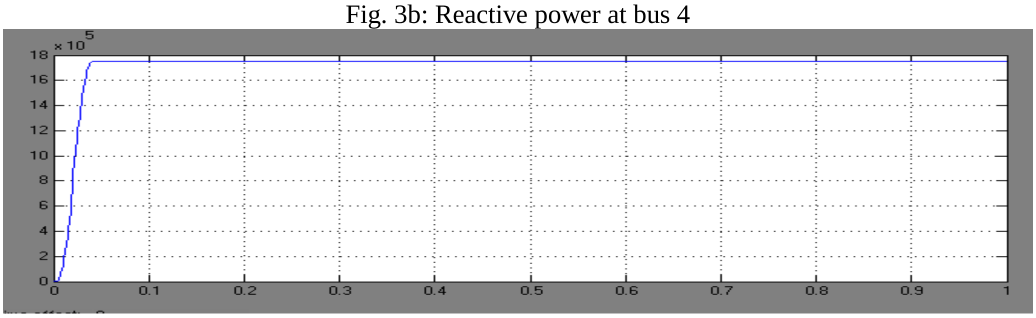


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Fig. 3c: Reactive power at bus 17

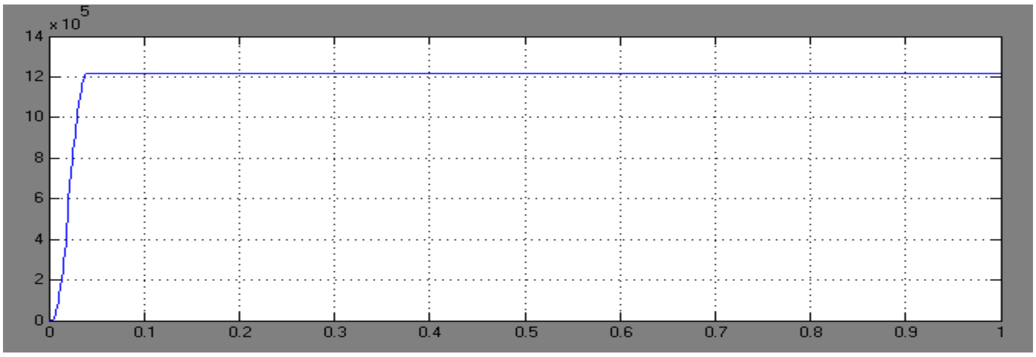

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Fig. 3d: Reactive power at bus 25

Thirty bus system with D-STATCOM is shown in Fig. 4a. The D-STATCOM is added to the bus 29 to improve power quality. The reactive power of the loads connected to the nearby buses is studied. The reactive power in the buses 4, 17 and 25 are shown in Figs. 4b, 4c, and 4d respectively. Thirty bus system with three D-STATCOMs is shown in Fig. 5a. The reactive power in the buses 4, 17 and 25 are shown in Figs. 5b, 5c, and 5d respectively. The summary of the reactive power in various buses is given in Table 2. It can be seen that the reactive power increases in the buses near the D-STATCOM. The increase in reactive power is due to increase in the voltage of the nearby buses.

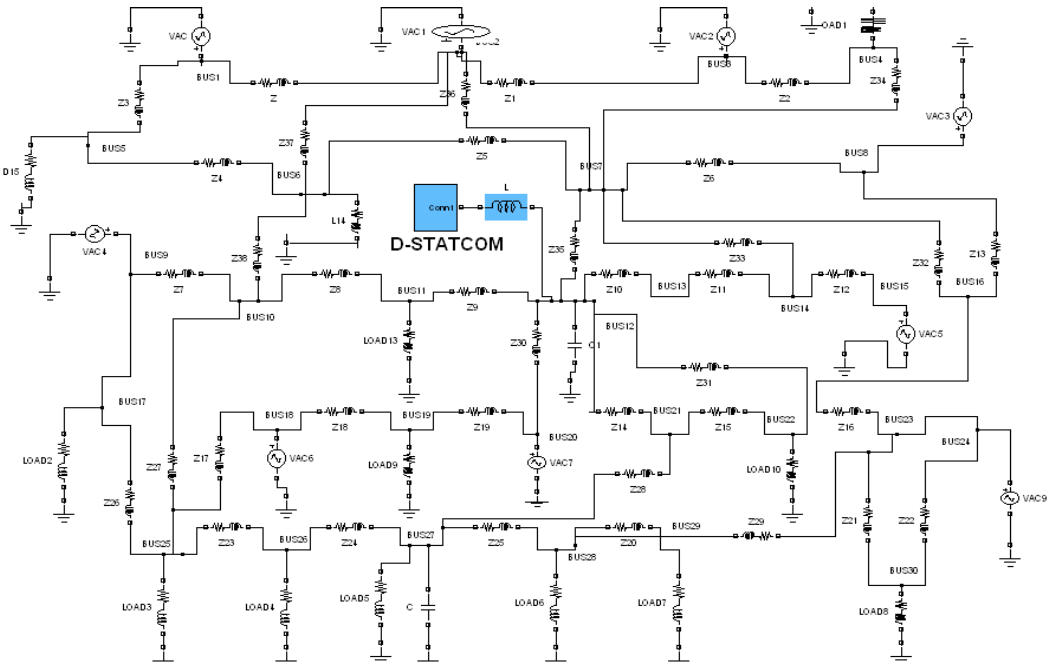

Fig. 4a: 30 bus system with D-STATCOM

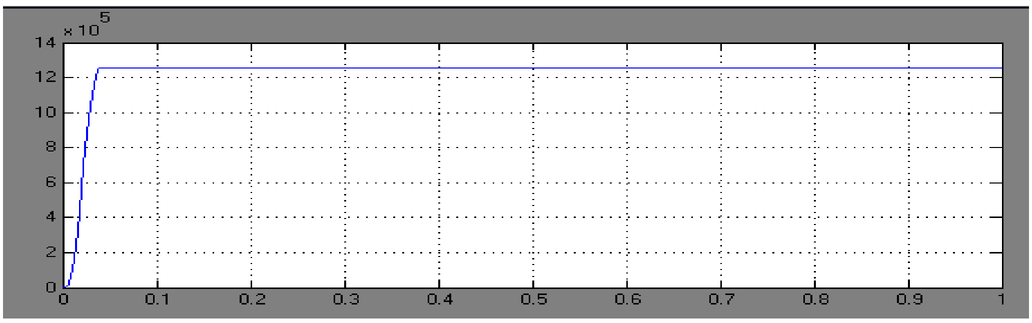

Fig. 4b: Reactive power at bus 4

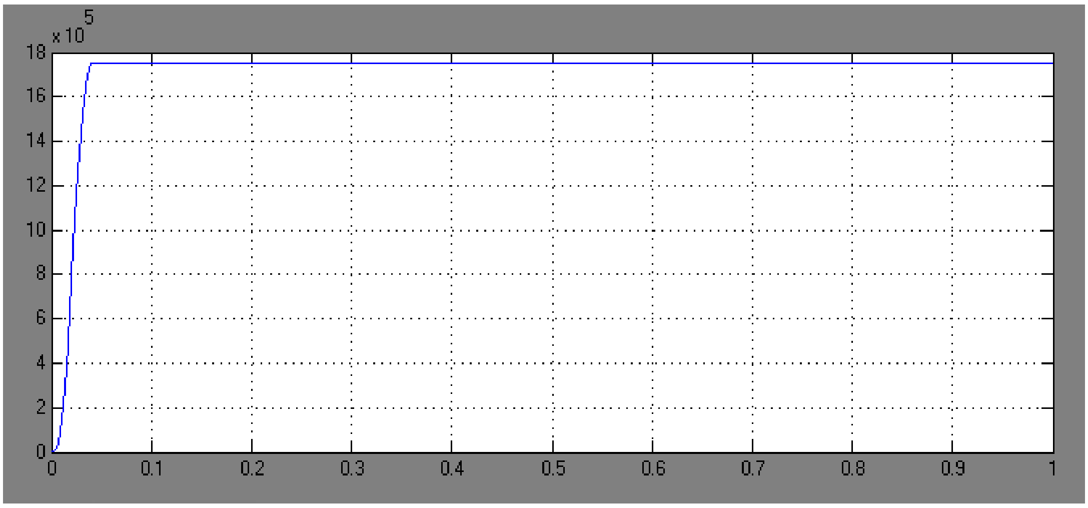

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Fig. 4c: Reactive power at bus 17

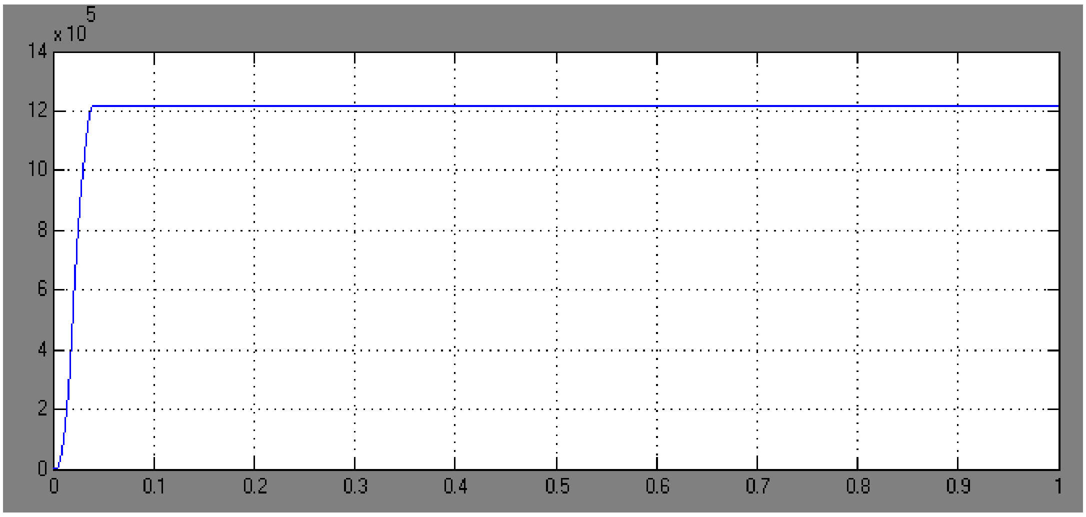

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Fig. 4d: Reactive power at bus 25

Bus no	Reactive power without D-STATCOM MVAR	Reactive power with D-STATCOM MVAR
Bus-4	1.256	1.257
Bus-5	1.136	1.139
Bus-11	1.065	1.072
Bus-17	1.745	1.749
Bus-19	1.323	1.343
Bus-22	1.343	1.027
Bus-25	1.018	1.218
Bus-27	1.217	1.102
Bus-30	0.933	0.974

Table 2: Summary of reactive Power (Q)

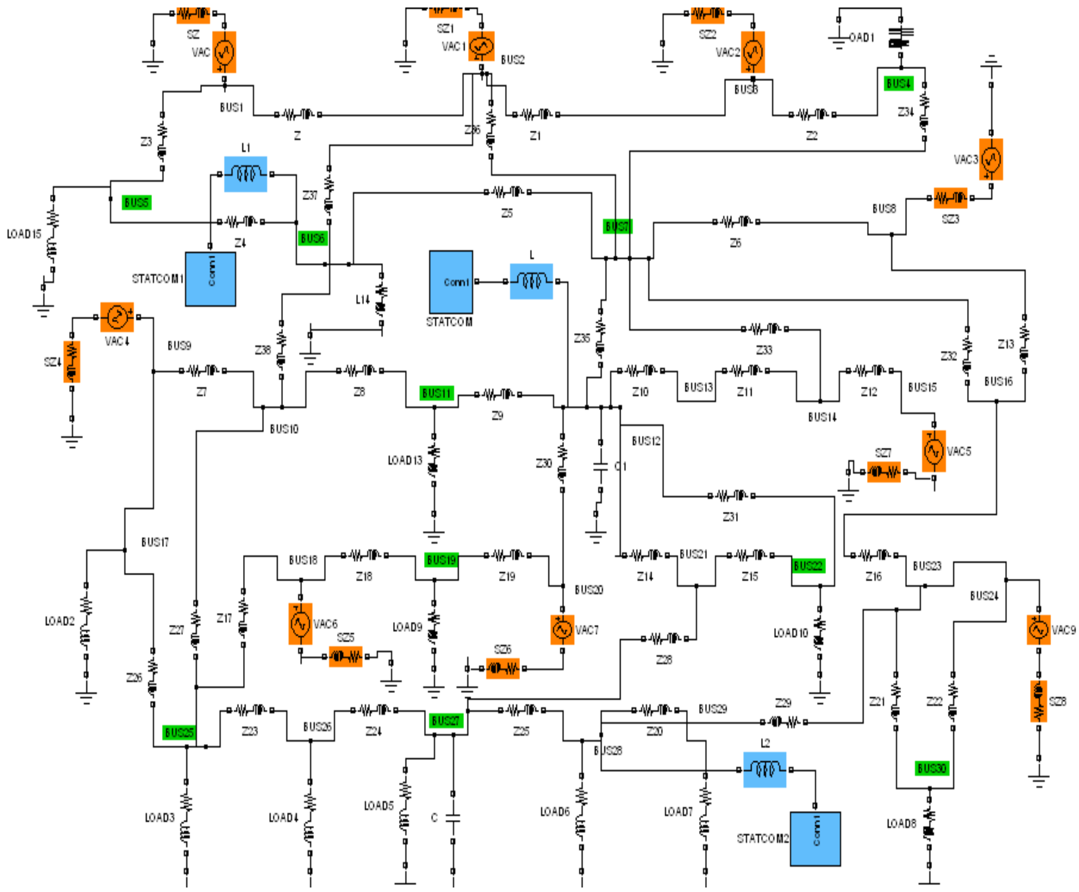

Fig. 5a: Thirty bus system with three STATCOM

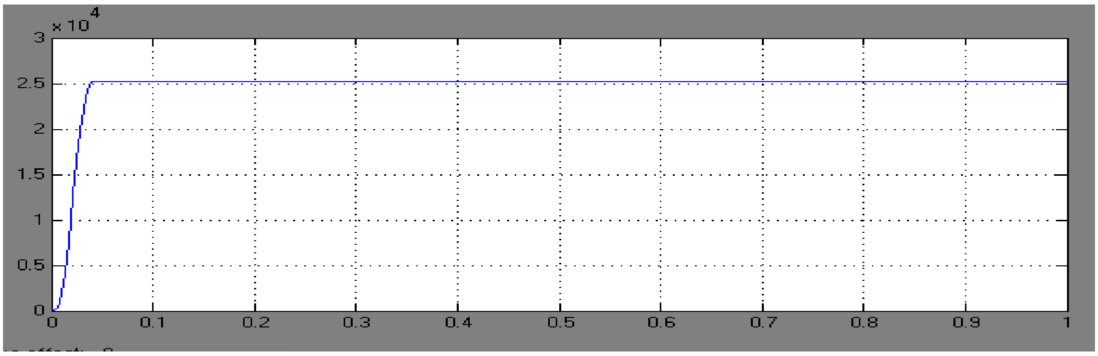

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Fig. 5b Reactive Power at bus 7

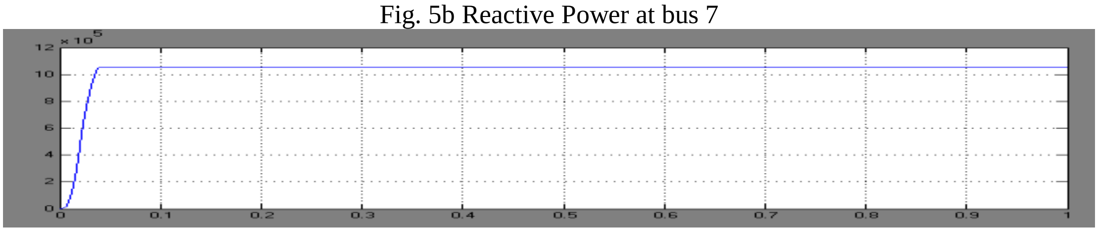

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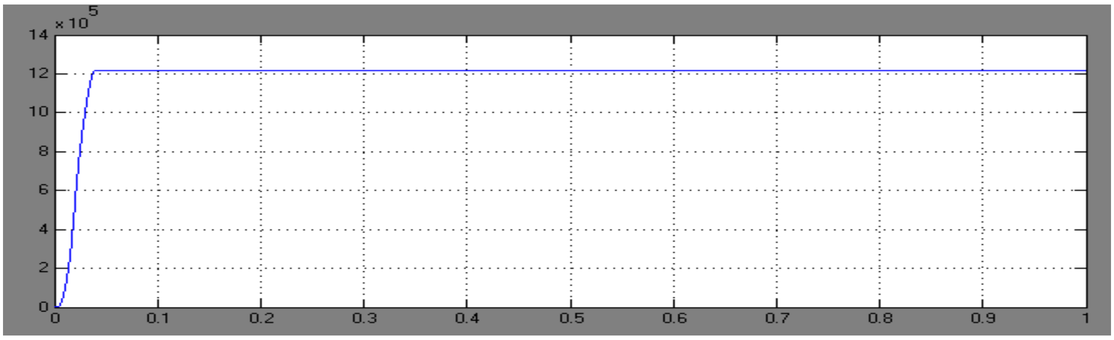
Fig. 5c: Reactive Power at bus 17



Time in sec

Fig. 5d: Reactive Power at bus 25

Tablae2 : Reactive Power with and without STATCOM

Bus no	Reactive power without STATCOM MVAR	Reactive power with one STATCOM MVAR	Reactive power with three STATCOM MVAR
Bus-4	**1.21**	**1.22**	**1.26**
Bus-5	**1.09**	**1.095**	**1.2**
Bus-11	**1.00**	**1.06**	**1.13**
Bus-17	**1.57**	**1.573**	**1.58**
Bus-19	**1.27**	**1.28**	**1.285**
Bus-22	**0.97**	**0.977**	**0.98**
Bus-25	**1.12**	**1.27**	**1.29**
Bus-27	**1.025**	**1.03**	**1.04**
Bus-30	**0.88**	**0.890**	**0.893**

IV. CONCLUSION

Thirty bus system is modeled and simulated using MATLAB SIMULINK and the results are presented. The simulation results of Thirty bus system with and without D-STATCOM are presented.Thity bus system with and without three STATCOM are presented Voltage stability is improved by using D-STATCOM. This system has improved reliability and power quality. The simulation results are in line with the predictions. The scope of present work is the modeling and simulation of thirty bus system. This concept can be extended to 64 bus system.

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