MULTILEVEL INVERTER BASED STATCOM FOR POWER QUALITY ENHANCEMEMT IN MULTI BUS SYSTEM

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Abstract: This paper deals with simulation of STATCOM in multi bus system for power quality enhancement. The unique structure of the multi level voltage source inverter (VSI) permits it to attain high voltages with low harmonic content. The STATCOM injects reactive power in to the proposed 14 bus system. The simulation of the STATCOM is performed in the MATLAB/Simulink environment and the results are presented. The computational and analytical results are tabulated for comparison.

Keywords: STATCOM, Power quality, voltage source inverter.

1. NOMENCLATURE

FACTS – Flexible AC Transmission System
STATCOM – Static Synchronous Compensator
VSI – Voltage Source Inverter.

2. INTRODUCTION

In recent years, electrical utilities and large industries face a number of challenges related to reactive power. The energy, environment, efficiency, deregulation of power utilities have delayed to create the both generation facilities and new transmission lines. There are emerging technologies available, which can aid electric companies to deal with these problems. One of such technologies is Flexible AC Transmission System (FACTS). There are a number of FACTS devices available, including the Static Synchronous Compensator (STATCOM). STATCOM may be one of the most popular & vital FACTS-devices, which has many installations in electric utilities worldwide. STATCOM is a power electronics based flexible alternating current transmission systems (FACTS) device widely used for the purpose of reactive power compensation in the power systems. Considering the practical applications of the STATCOM in power systems, it is of importance and interest to investigate the possible multi-control functions of the STATCOM as well as model these functions in power system steady state operation and control, such that the various control capabilities can be fully employed, The Static Synchronous Compensator (STATCOM) using IGBT (or) GTOs (Gate-Turn-off Thyristors) is a principal state-of the-art FACTS equipment. The system planners and designers are using additional tool for shunt reactive power compensation in transmission and distribution systems. Presently being applied to regulate transmission voltage to permit greater power flow in a voltage limited transmission network and 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. In the proposed work, capacitor clamped multilevel inverter scheme is presented which takes advantage of balancing the switching duty ratio among its various levels.A usage power device focuses on low voltage distribution and is a more cost-effective technology when it comes to the very large power users. With custom power solutions in place, the end-user sees better voltage regulation, near zero power interruptions, low harmonic voltages and acceptance of rapidly fluctuating and non-linear loads. To synthesize multilevel output AC voltage using different levels of DC inputs, semiconductor devices must be switched on and off in such a way that desired fundamental is obtained with minimum harmonic content.

This paper is aimed at the development of multilevel STATCOM for power quality enhancement. The performance is then compared with the analytical results. The results reveal that the three-level STATCOM offers higher efficiency and reduced voltage and current harmonic levels. The concept of the proposed multilevel STATCOM is supported by MATLAB/SIMULINK results.

3. STATCOM OPERATION

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. A STATCOM is usually used to control transmission bus voltage by reactive power shunt compensation. A single-line STATCOM power circuit consists of a coupling transformer, an inverter and a DC capacitor, which are shown in Fig.1.(a)
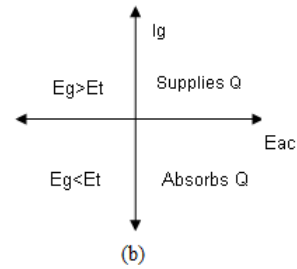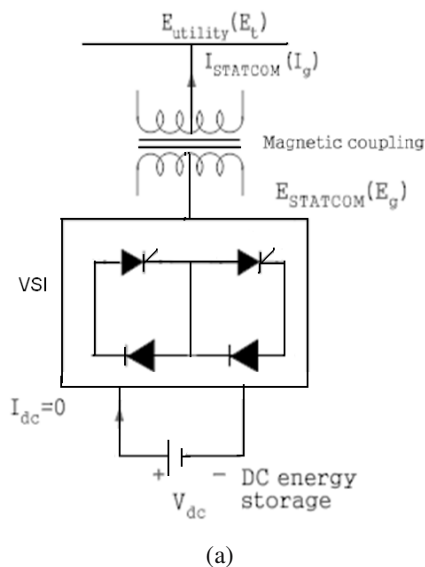

(a)

(b)

Fig.1. *(a) STATCOM - a power circuit (b) a power exchange*

Fig.2. A STATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage-source inverter (VSI). A STATCOM is seen as an adjustable voltage source behind a reactance—meaning that capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby giving a STATCOM a compact design, or small footprint, as well as low noise and low magnetic impact.

Fig.3. The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage, *Es*, of the converter, as shown in Fig.1. (b). That is, if the amplitude of the output voltage is increased above that of the utility bus voltage, *Et*, then a current flows through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the ac system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive power from the ac system. If the output voltage equals the ac system voltage, the reactive-power exchange becomes zero, in which case the STATCOM is said to be in a floating state. Adjusting the phase shift between the converter-output voltage and the ac system voltage can similarly control real-power exchange between the converter and the ac system.

Fig.4. In other words, the converter can supply real power to the ac system from its dc energy storage if the converter-output voltage is made to lead the ac-system voltage. On the other hand, it can absorb real power from the ac system for the dc system if its voltage lags behind the ac-system voltage. A STATCOM provides the desired reactive power by exchanging the instantaneous reactive power among the phases of the ac system.

4. REACTIVE POWER CONTROL USING MULTILEVEL INVERTER STATCOM

Multilevel Inverter is one of the most vital topology in the family of cascade Multilevel Inverters. In

further, the Multilevel Inverters are classified in to (i) Diode-clamped, (ii) Flying capacitors and (iii) Cascade multilevel inverter (CMLI). CMLI has a modular structure and requires least number of components as compared to other two topologies.

The VSI has the same rated-current capability when it operates with the capacitive- or inductive-reactive current. Therefore, a VSI having a certain MVA rating gives the STATCOM twice the dynamic range in MVAR.
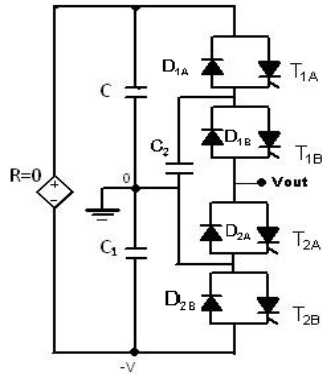

Fig.2. Three Level Inverter

A DC capacitor bank is used to support (stabilize) the controlled DC voltage needed for the operation of the VSI. The reactive power of a STATCOM is produced by means of power-electronic equipment of the voltage- source-inverter type. The VSI may be a 2-level or 3-level type, depending on the required output power and voltage. In this work, three level-inverter has proposed. A number of VSIs are combined in a multi-pulse connection to form the STATCOM.

Fig.2. shows the schematic diagram of one leg of three level-inverter. It consists of four switches per leg and two main diodes. Each of the switches consists of a power semiconductor device and an anti-parallel diode. The single PWM approach is used to generate the gating pulses for the switches T_{1A}, T_{1B}, T_{2A} and T_{2B}. Three level-inverter can produce voltage levels of +V, 0 and –V. These voltage levels can be obtained using two equal capacitors. The proposed three-level STATCOM shown in Fig.2. is simulated using the MATLAB/Simulink software. Table I shows the switching states and voltage levels of the capacitor clamped three level-inverter.

TABLE I – Switching states and voltage levels of the three level-inverter

Switch states				Voltage levels V_{out}
T_{1A}	T_{1B}	T_{2A}	T_{2B}	
ON	ON	OFF	OFF	+V
OFF	ON	ON	OFF	0
OFF	OFF	ON	ON	-V

5. SIMULATION RESULTS

Multi bus system is modelled and simulated using Simulink and the results are presented here. Fourteen bus system without STATCOM is shown in Fig.2a. Load voltage at bus 2 is shown in Fig.2b. Real and reactive powers in bus 2 are shown in Fig.2c. Load voltage at bus 11 is shown in Fig.2d. Real and reactive powers in bus 11 are shown in Fig.2e.
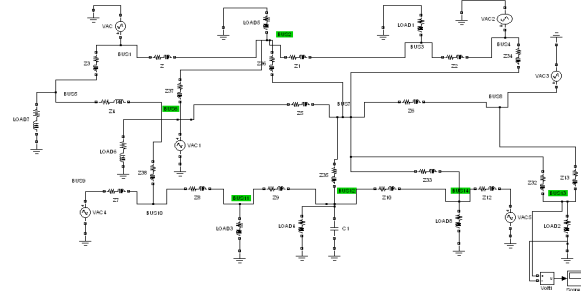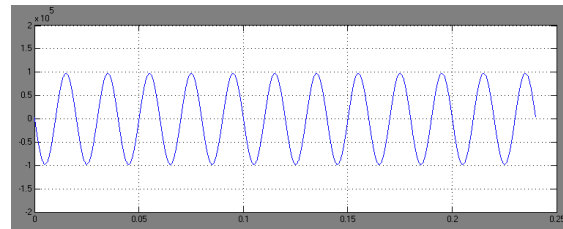

Fig.2a. 14 Bus system without STATCOM
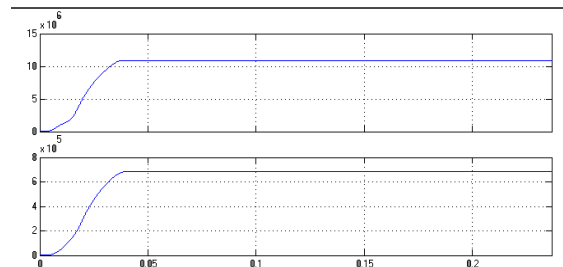

Fig.2b. Load voltage in Bus 2

Fig.2c. Real and Reactive power in Bus 2

Fig.2d. Load voltage in Bus 11
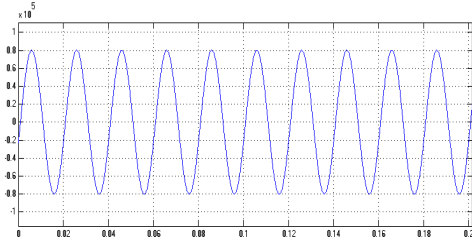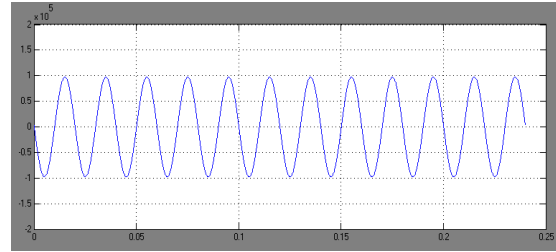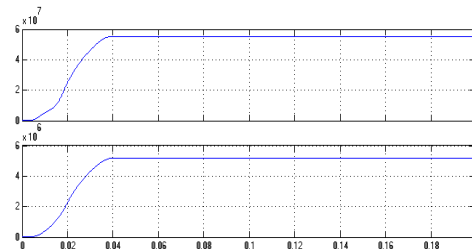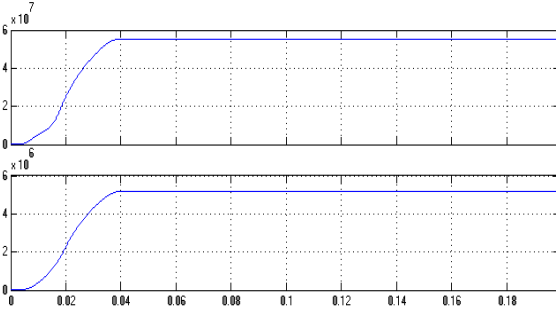

Fig.2e. Real and Reactive power in Bus 11

Fourteen bus system with STATCOM is shown in Fig.3a. The circuit of three level-inverter is shown in Fig.3b. Load voltage at bus 2 is shown in Fig.3c. Real and reactive powers at bus 2 are shown in Fig.3d. Load voltage in bus 11 is shown in Fig.3e. Real and reactive powers in bus 11 are shown in Fig.3f. Reactive power and voltages at different buses are summarized in Table II. The voltage and reactive power get increased by introducing the STATCOM.
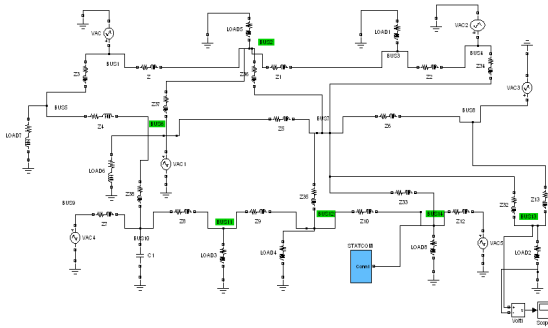
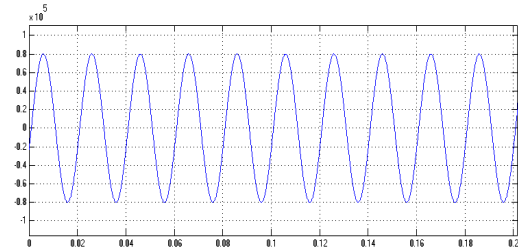

Fig.3a. 14 Bus system with STATCOM

Fig.3b. Three level inverter
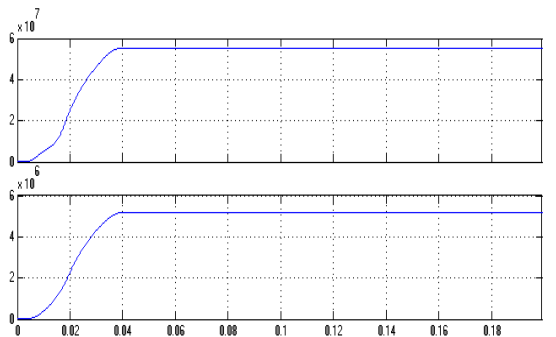

Fig.3c. Load voltage in Bus 2

Fig.3d. Real and Reactive power in Bus 2
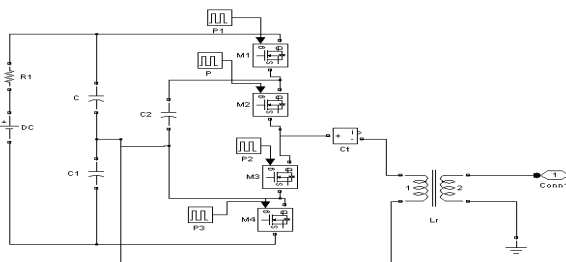

Fig.3e. Load voltage in Bus 11

Fig.3f. Real and Reactive power in Bus 11

TABLE II: Comparison of Reactive power

Bus No	Q(MVAR) without STATCOM	Q(MVAR) with STATCOM	Voltage (KV) without STATCOM	Voltage (KV) with STATCOM
11	5.178	5.20	74.45	74.62
12	1.014	1.02	74.49	74.76
13	2.837	2.89	76.38	76.45
14	5.93	5.99	73.77	74.27

Voltage profile of various buses is given in Fig.4a. Variation of bus voltage with the increase in the injected voltage is given in table III. Bus voltage versus injected voltage is shown in Fig.4b. It can be seen that the bus voltage increases with the increase in the injected voltage. The voltage is maximum at Bus 14 due to the presence of STATCOM at that bus.
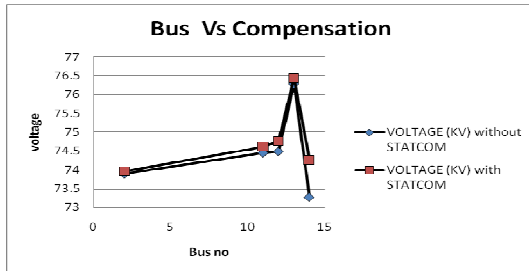

Fig.4a. Voltage Profile

TABLE III: Comparison with different injected voltages

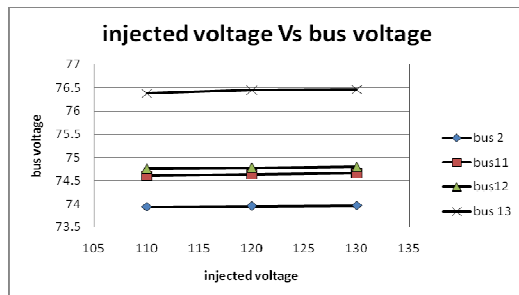| Bus no	Voltage (KV) with STATCOM at injected voltage of 110 KV	Voltage (KV) with STATCOM at injected voltage of 120 KV	Voltage (KV) with STATCOM at injected voltage of 130 KV
11	74.62	74.64	74.65
12	74.76	74.78	74.80
13	76.38	76.45	76.46
14	74.27	74.31	74.34

Fig.4b. Variation of Bus voltage with injection

6. CONCLUSION

Fourteen bus system is modelled and simulated using MATLAB Simulink. Multilevel inverter based STATCOM is used for the enhancement of power quality. It is found that the bus voltages near the STATCOM are improved. The bus voltage increases with the increase in the magnitude of injected voltage. Overall power quality can be improved by using more STATCOMs at the load buses.

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