

Static and dynamic analysis of proposed STATCOM design

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Abstract

This paper imposes a multilevel H-bridge converter with star configuration. These compensators have an important role in increasing the power quality in power systems because of having features investigated in various studies and because of the proper implementation of power functions, especially in compensating the voltage flicker. In particular, for STATCOM applications the phase leg of the converter is constituted by a number of single-phase full-bridge converters connected in cascade.

This paper is about theorizing at the control level, which eventually ends in producing the proper gate signals to control the switching of the electronic power switches in the STATCOM. This STATCOM has been implemented for use in both dynamic load conditions and static load conditions. The results show that it has very efficiently managed the supply of the power in and to the dynamic system as well as constant load conditions. The power output from the device has been concluded to be significantly improved.

Keywords

STATCOM, Dynamic load.

1. Introduction

1.1 Multilevel converters (MLC)

Multilevel converters, also known as converters, are becoming increasingly popular day after day because of their excellent features, as they tend to meet the high performance and high voltage required in industrial sectors compared to a two level voltage source Converter that results in lowering switching losses, higher efficiency by using passive filters[1-3]. In general, converters are used to convert the DC power supply into an AC adapter. From the application point of view, multilevel converters are mainly used [4-10]. The multilevel has been implemented in different topologies in the respective applications. Basically, the converter must consist of power semiconductor switches and DC voltage sources. Some of the main features of Multilevel Converter are

- The multilevel Converters can acquire the voltage and current with low THD.
- Efficiency of the Converter depends upon the switching frequency.

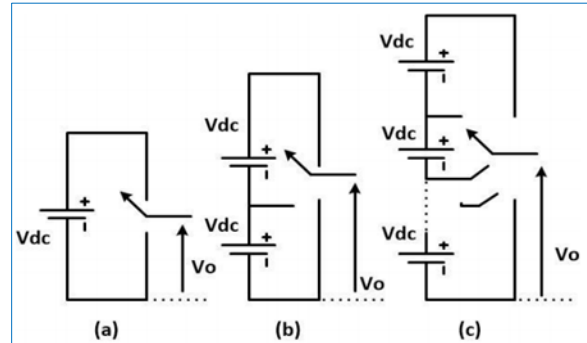


Figure 1 Basic view of an Converter with (a)two levels (b)three levels (c)n levels

- The input current drawn by them has low distortion.
- There exists no EMI problem.
- Common mode voltages are reduced and hence the stresses on the motor bearings are reduced.

1.1.1 Diode-clamped multilevel converter

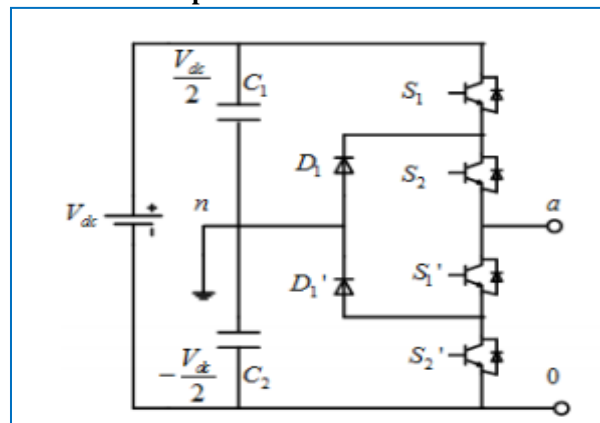


Figure 2 Circuit diagram of the diode-clamped multilevel converter

The clamping diodes D_1 and D_1' play as an important role in this kind of converter which can clamp the switch voltage to half of the DC link voltage. The output voltage $v_{an} = V_{dc}/2$ is served as an example. In this case, the switch S_1 and S_2 should be closed. D_1 is used to balance out the voltage sharing between the two switch S_1' and S_2' .

1.1.2 Capacitor-clamped multilevel converter

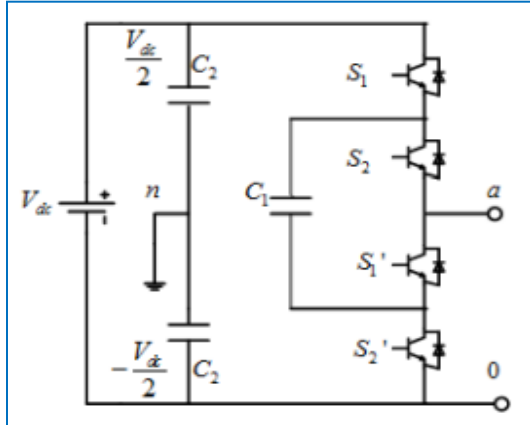


Figure 3 Circuit Diagram of the Capacitor-Clamped Multilevel Converter

The three-level capacitor-clamped multilevel converter is shown in Figure 3 One advantage of this kind of topology is that it can provide some redundancies for a certain output voltage. Taking the three-level Capacitor-Clamped Converter as an example, for $v_{an} = 0$, either pair (S_1, S_1') or (S_2, S_2') needs to be turned on. The number of redundancies will increase as the output voltage level increases.

1.1.3 Cascaded multilevel converters

This is the serial connection of single-phase H bridge units with separate DC sources (SDCS). These SDCS can be batteries, capacitors, fuel cells or solar cells.

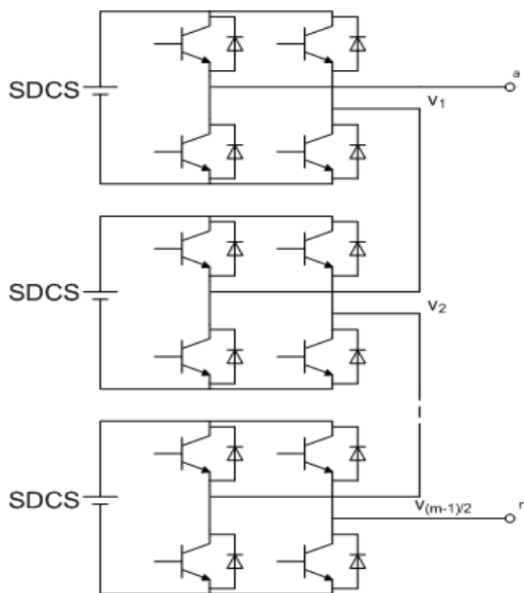


Figure 4 Circuit diagram of the cascaded h-bridge converter

Each unit produces three output voltages: $+V_{dc}$, 0 and $-V_{dc}$. The number of these units is determined by production cost and operating voltage. The multilevel cascade converter has recently become very popular in medium voltage, high power and speed control applications. A cascaded MLC consists of a single phase phase to phase converter of each phase. Each H bridge consists of a separate DC source.

1.2 Applications of MLC

The multilevel cascade converter can be used in a wide range of applications. It is superior for medium and high power applications, presumably (FACTS) Flexible AC drive system controller [11-15]. Multilevel converters are particularly because the number of levels increases, the better the quality of the power waveforms and the lower the harmonic distortion. In advertising, multi-level converters have entered into electricity control applications. The different topologies are used in different applications. Cascaded multi-level converters are used primarily in FACT and STATCOM applications.

1.3 Modulation methods

▪ Selective harmonic elimination

The basic idea of SHE is the prediction and preliminary calculation of the quarter-cycle switching angles by means of Fourier analysis to guarantee the elimination of low order unwanted harmonics [17-21]. The first step is to find the Fourier series of the multilevel waveform based on unknown switching angles. The next step is to reset the unwanted Fourier coefficient by making the fundamental component equal to the desired reference value.

▪ Phase shifted pulse width modulation

Phase Shifted PWM is one of the most commonly used modulation schemes in CHB multilevel inverters because it is very suitable for topological modularity. For each module, the reference signal is the same. However, the carrier waveform (usually the triangular waveform) for each module would have a phase shift to provide the pitch characteristic of the output voltage. The degree of displacement between the different modules depends on the modulation method for the single H-bridge inverter.

2.Objectives

- The present work focuses on following main objectives:
- To design a three phase BRIDGE type STATCOM device using IGBT's which would be favorable for smooth reactive power compensation when it is modeled with the three phase AC grid.

- To provide a control mechanism such that the device is able to provide maximum efficiency when grid is tied to static as well as dynamic load conditions.
- To improve the voltage and current output at the static and dynamic load terminal.
- To enhance the system efficiency by improving its control mechanism.

3.Literature review

Presents a new control method for static compensators based on the cascade H bridge converter. These converters are conventionally switched to fundamental frequency frequencies, but the development of power semiconductors has allowed to increase the switching frequencies and the nominal powers of these devices, which allows the use of modulation width techniques. pulses. This paper mainly focuses on dc-bus voltage balancing problems and proposes a new control technique (individual voltage balancing strategy), which solves these balancing problems, maintaining the delivered reactive power equally distributed among all the H-bridges of the converter [1].

Reviewed the latest contributions to determine the current state of the art and technological trends and to provide readers with a complete and in-depth overview of where the multi-level conversion technology is located. This paper gives a brief overview of the established multilevel converters that are very focused on their current state in industrial applications, and then put the debate on the new converters who have found their way into the industry at the center. Furthermore, new and promising topologies are discussed. Recent advances in modulation and control of multilevel converters are also discussed [2].

Refers to a multi-stage cascade converter with a plurality of DC voltage values (multi voltage cascade converter) for a static synchronous static compensator with 6.6 kV transformer and lower distribution (D- STATCOM). A control method is provided to provide DC three-cell voltage control to the STATCOM operation, thus eliminating DC power sources from all H-bridge cells. Simplified configuration without DC sources makes STATCOM small and light [3].

Compared to four converter topologies for implementation of flexible AC transmission systems (FACTS) Controls: three multi-level topology (multi-point stapled (MPC), string and nested cells) and

well-defined multi-level pulse topology established. Based on the need to implement very high power converters, the switching frequency is limited to the line frequency. The study covers the number of devices, the nominal values of the DC filters, the voltage regulation limits, the active power transfer via the DC bus and the intermediate circuit voltage balancing. The focus is on sizing capacitors due to its impact on the cost and size of the FACTS controller[4].

Presented the most important topologies like diode-clamped Converter (neutral-point clamped), capacitor-clamped (flying capacitor), and cascaded multi cell with separate DC sources. New topologies are also discussed as asymmetric hybrid cells and multilevel converters switched by software. This document also introduces the key control and modulation techniques developed for this family of transducers: multilevel modulation with sinusoidal wave amplitude, selective harmonic elimination and vector spatial modulation [5].

4.Methodology

Star connection is shown in Figure 1, equipment capacity can be improved by a simple increase in the number of link module, and it is low cost, easy to implement and small footprint.

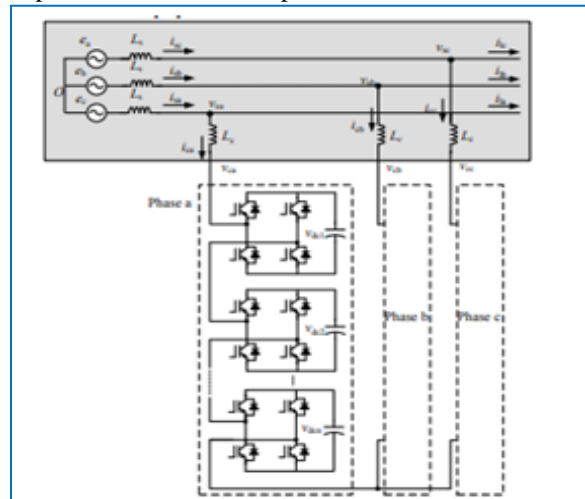


Figure 5 Cascaded STATCOM topology

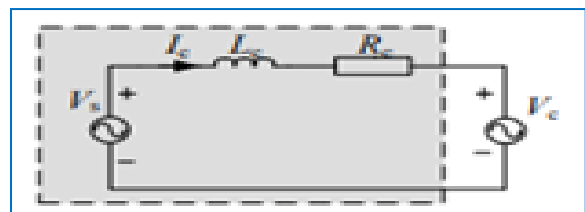


Figure 6 Equivalent circuit of STATCOM

Ideally, an equivalent circuit diagram of the STATCOM is shown in Figure 2. L_c and R_c are the total inductance and resistance in the apparatus main loop (including the connecting reactance and the inverter impedance), v_s is the grid voltage, v_c is output voltage of the STATCOM, i_c is absorption current of the STATCOM equipment.

The phase and amplitude of the current absorbed by STATCOM from the grid can be controlled by changing the STATCOM output voltage amplitude and phase with respect to v_s . And the nature and magnitude of the reactive power can be further controlled.

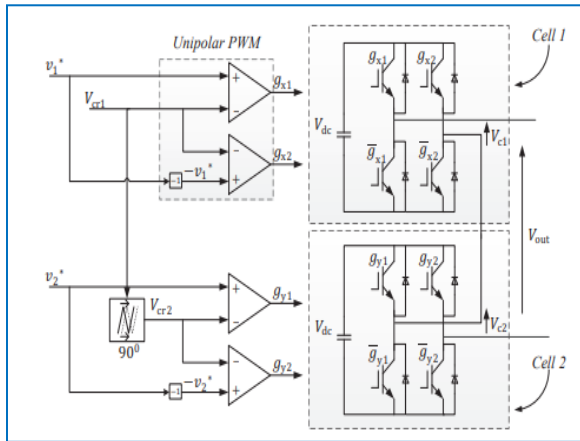


Figure 7 PWM for one phase of a STATCOM based on unipolar PWM

Phase-Shifted PWM (PS-PWM): This method is a natural extension of the traditional bipolar and unipolar PWM techniques. This modulation technique is one of the most commonly used modulation techniques for multilevel converters with half or H-bridge cells.

4.1 Dynamic load modeling

The Three-Phase Dynamic Load block implements a three-phase, three-wire dynamic load whose active power P and reactive power Q vary as function of positive-sequence voltage. Negative- and zero-sequence currents are not simulated. The three load currents are therefore balanced, even under unbalanced load voltage conditions.

The load impedance is kept constant if the terminal voltage V of the load is lower than a specified value V_{min} . When the terminal voltage is greater than the V_{min} value, the active power P and reactive power Q of the load vary as follows:

$$P(s) = P_0 \left(\frac{V}{V_0} \right)^{r_p} \frac{1 + T_{p1}s}{1 + T_{p2}s}$$

$$Q(s) = Q_0 \left(\frac{V}{V_0} \right)^{r_q} \frac{1 + T_{q1}s}{1 + T_{q2}s}$$

4.2 Static load modelling

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits a constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

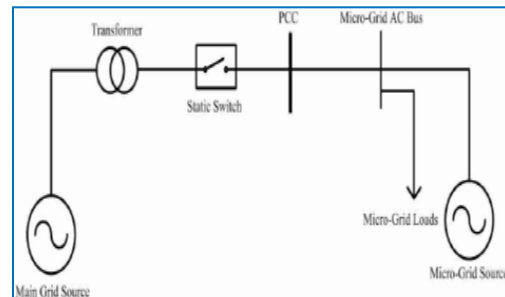


Figure 8 Micro grid static load system

5. Results

The modelled system consists of two renewable energy resources making the system more reliable. The results of the analysis has been discussed below in two cases.

- [1] Firstly the architecture and control system of the proposed system has been described.
- [2] CASE 1: Discusses the output of the system having dynamic load conditions and the output reactive as well as reactive power.
- [3] CASE 2: Discusses the output of the system having static load conditions and the output reactive as well as reactive power.

Proposed design

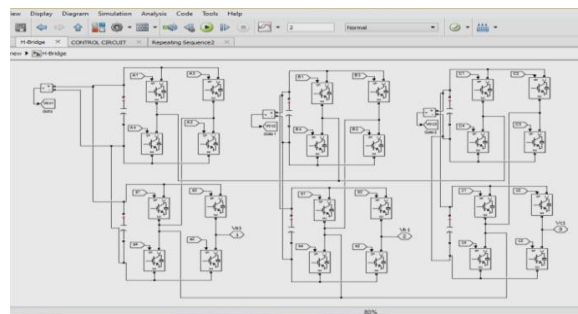


Figure 5 Architecture of STATCOM

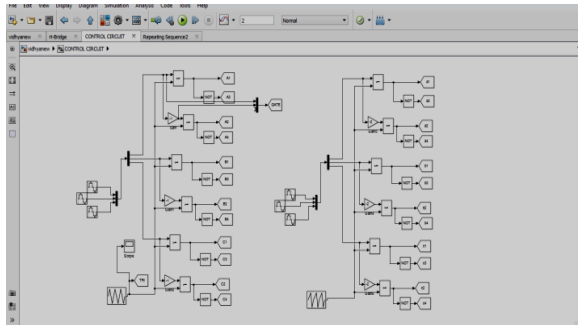


Figure 6 Controlling system of gate pulses



Figure 8 Waveform of pulses provided to the IGBT

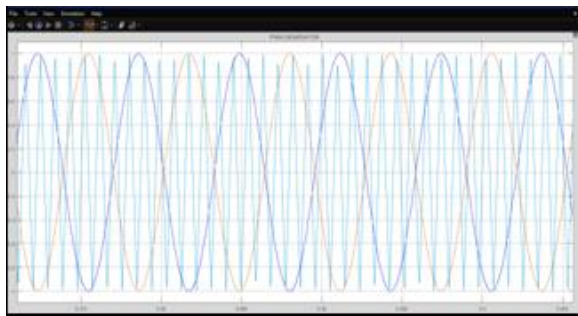


Figure 7 Carrier waves to provide gate signals for A1, A2, A3, A4, B1, B2, B3, B4, C1, C2, C3, C4

CASE 1: System Modelled With Dyanmic Load

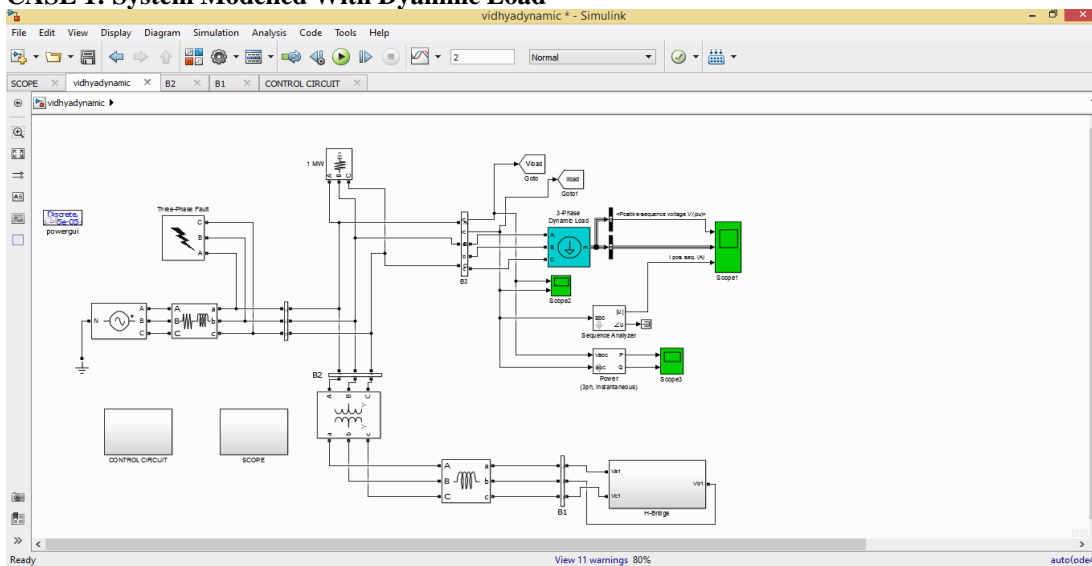


Figure 8 MATLAB/SIMULINK model of grid connected STATCOM with dynamic load conditions

The system has been subjected to dynamic load conditions which provides better application of system in real time applications. The value of initial positive sequence voltage V_0 is adjusted to be 0.98441 pu with phase -1.41063 degrees. Specifies the minimum voltage at which the load dynamics

commences. The load impedance is constant below this value is specified to be 0.7 Volts.

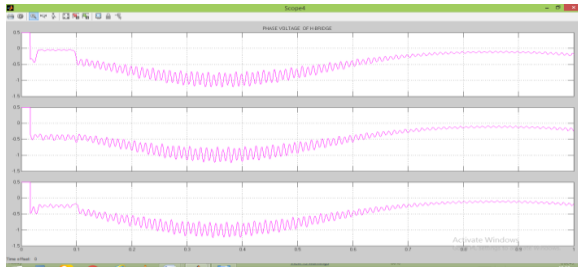


Figure 9 Active Power output from STATCOM device at bus B1

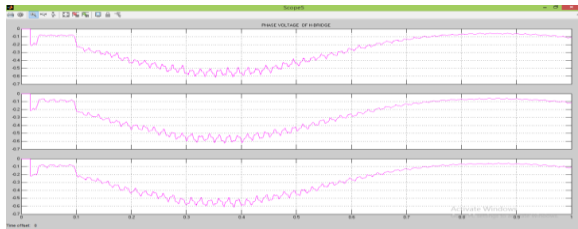


Figure 10 Reactive power output from STATCOM device at bus B1

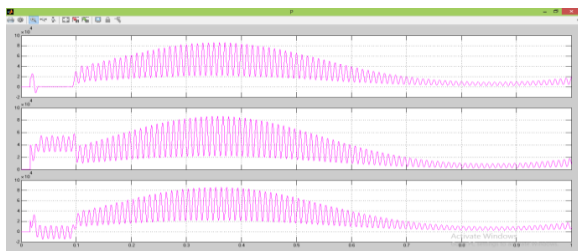


Figure 11 Active Power output from the STATCOM device fed into the grid at bus B2

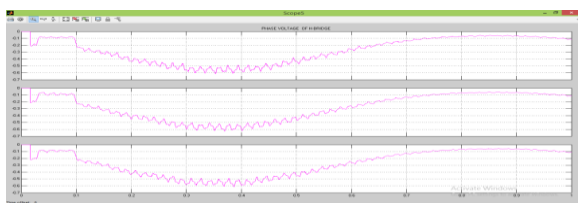


Figure 12 Reactive Power output from STATCOM device at bus B1

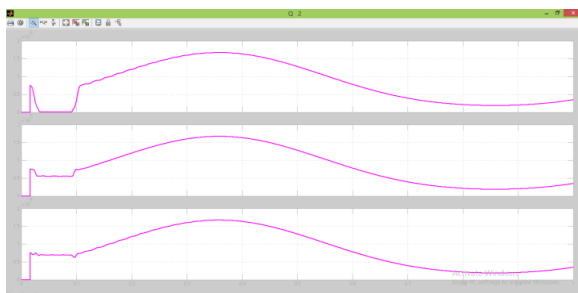


Figure 13 Reactive Power output from the STATCOM device fed into the grid at bus B2

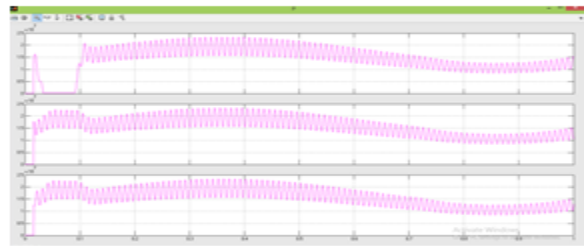


Figure 14 Active power output from the STATCOM device fed into the grid at bus B3

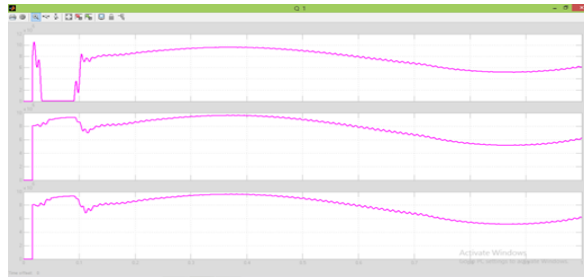


Figure 15 Reactive Power output from the STATCOM device fed into the grid at bus B3

Case 2: Sysytem Modelled With Static Load Conditions

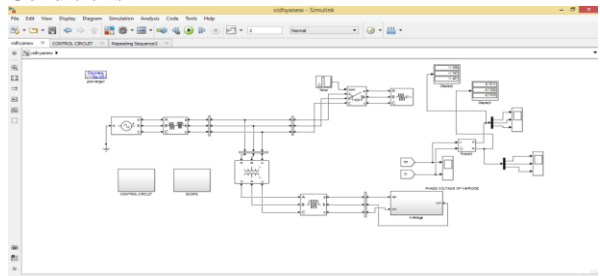


Figure 16 MATLAB/SIMULINK model of grid connected STATCOM with static load conditions

For the simulation purpose, a three phase RLC load is connected at the load terminal at bus B3, with nominal phase to phase voltage of about 1000 Volts and nominal frequency of 50 hertz.

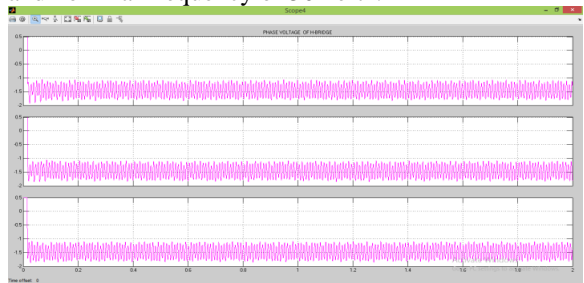


Figure 17 Active Power output from STATCOM device at bus B1

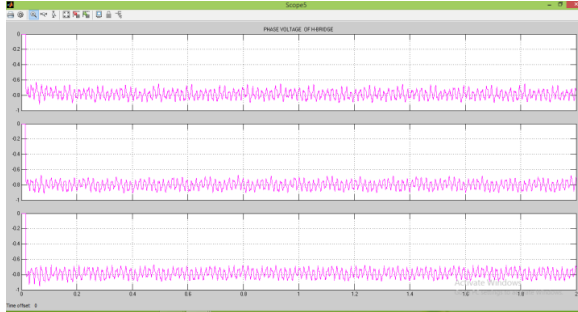


Figure 17 Reactive Power output from STATCOM device at bus B1

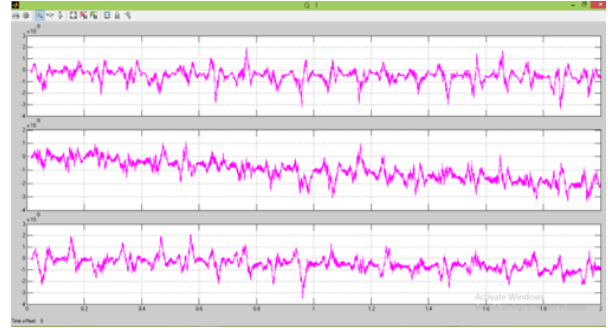


Figure 20 Reactive Power output from the STATCOM device fed into the grid at bus B3

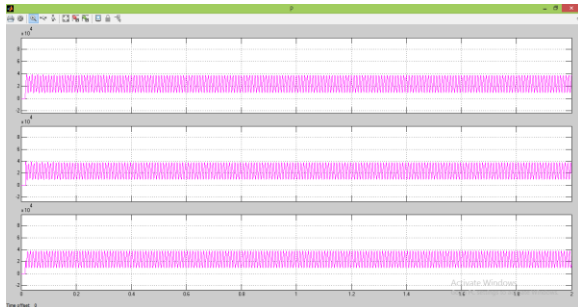


Figure 18 Active Power output from the STATCOM device fed into the grid at bus B2

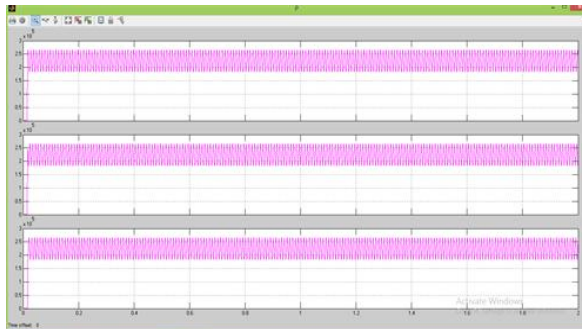


Figure 19 Active Power output from the STATCOM device fed into the grid at bus B3



Figure 20 Reactive Power output from the STATCOM device fed into the grid at bus B2

6. Conclusion

This paper presented a configuration and control scheme of bridge type STATCOM in three-phase power system.

Bus	Dynamic system		Static system	
	Active Power (p.u)	Reactive Power (p.u)	Active Power (p.u)	Reactive Power (p.u)
B1	-0.6475	0.3966	-1.286	-0.731
B2	63490	12420	3732	7258

By this method, STATCOM can operate flexibly under normal power system condition and does not need wide margin of dc capacitor voltage under large asymmetrical condition. The validity is examined by digital simulation under one line fault circuit condition. The simulation results showed the effectiveness of proposed STATCOM.

The modeled system is capable to supply power to the load in changing environment effectively with increased active and reactive power output from the bridge.

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