



Back Propagation Control Algorithm for Power Quality Improvement Using DSTATCOM

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Abstract: This paper “Back-Propagation Control Algorithm for Power Quality Improvement Using DSTATCOM” presents an implementation of three-phase Distribution Static Compensator (DSTATCOM) using back-propagation (BP) control algorithm for its functions such as harmonics elimination, load balancing and reactive power compensation for power factor correction (PFC) and zero voltage regulation (ZVR) under nonlinear loads. A BP based control algorithm is used for extraction of fundamental weighted value of active and reactive power components of load currents which are required for estimation of reference source currents. Power converter based custom power devices (CPDs) are useful for reduction of power quality problems such as power factor correction, harmonics compensation, voltage sag/swell compensation, resonance due to distortion, voltage flicker reduction within specified limits. These CPDs include DSTATCOM, DVR and UPQC in different Configurations. Many non model and training based alternative control algorithms are reported in the literature with application of soft computing technique such as neural network, fuzzy logic and adaptive neuro-fuzzy etc.,. For better power quality improvement as power factor correction and to maintain rated PCC voltage a VSC based DSTATCOM has been introduced.

Keywords: DSTATCOM, power factor correction, zero voltage regulation

I. INTRODUCTION

The project titled “Back-Propagation Control Algorithm for Power Quality Improvement Using DSTATCOM” aimed at obtaining the control is carried out by the implementation of a three phase distribution static compensator (DSTATCOM) using a back propagation (BP) control algorithm for its functions such as harmonic elimination, load balancing and reactive power compensation for power factor correction, and zero voltage regulation under nonlinear loads.

A BP-based control algorithm is used for the extraction of the fundamental weighted value of active and reactive power components of load currents which are required for the estimation of reference source currents. Power converter based custom power devices (CPDs) are useful for reduction of power quality problems such as power factor correction, harmonics compensation, voltage sag/swell compensation, resonance due to distortion, voltage flicker reduction within specified. These CPDs include DSTATCOM, DVR and UPQC in different Configurations. Many non model and training based alternative control algorithms are reported in the literature with application of soft computing technique such as neural network, fuzzy logic and adaptive neuro-fuzzy etc.,. For better power quality improvement as power factor correction and to maintain rated PCC voltage a VSC based DSTATCOM has been introduced. A prototype of DSTATCOM is developed using a digital signal processor, and its performance is studied under various operating conditions.

II. OPTIMAL PLACEMENT OF DSTATCOM IN AN INDIAN POWER SYSTEM FOR LOAD AND VOLTAGE BALANCING

Power quality is of increasing importance in worldwide distribution. The present distribution systems are facing severe power quality problems such as poor voltage regulation, high reactive power demand, harmonics in supply voltage and current, and load unbalancing. Therefore, maintenance of power quality is becoming of increasing importance in worldwide distribution systems. Industrial consumers with more automated processes require high quality power supply else equipments such as microcontrollers, computers and motor drives may get damaged. High quality power delivery includes balanced voltage supply to consumers. Connection of unbalanced load at a bus may cause unbalanced voltage and current drawn by other loads connected at that bus. Switching of unbalanced load at a bus may also result in unbalanced voltage at some other buses.

Unbalanced voltages contain negative and zero sequence components which may cause additional losses in motors and generators, oscillating torques in Alternating Current (AC) machines, increased ripples in rectifiers, saturation of transformers, excessive neutral currents and malfunctioning of several type of equipments. With

the advancement in power electronics, new controllers known as Flexible AC Transmission System (FACTS) have been developed. These controllers have been proved to be quite effective in power flow control, reactive power compensation and enhancement of stability margin in AC networks. Power electronics based controllers used in distribution systems are called custom power devices. Custom power devices have been proved to be quite effective in power quality enhancement. The custom power devices may be series, shunt, and series-shunt or series-series type depending upon their connection in the circuit. Most prominent custom power devices include Distribution Static Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC). There are several papers reported in literature on placement of custom power devices in balancing of unbalanced load in radial distribution systems. Load voltage balancing using DVR against unbalanced supply voltage in radial distribution system has been considered. Placement of DSTATCOM in weak AC radial distribution system for load voltage and current balancing has been considered in . Balancing of source currents using DSTATCOM in radial distribution system has been considered in. Unbalancing has been caused by connection of unbalanced and non-linear load. Load compensation using DSTATCOM against unbalancing caused by opening of one of the phase of the load in radial distribution system has been considered. Balancing of supply across an unbalanced 4- phase load along with power factor improvement using DSTATCOM has been suggested. A Voltage Source Converter (VSC) based controller has been proposed to balance terminal voltage of an isolated standalone asynchronous generator driven by constant speed prime mover. A non-linear and unbalanced load has been connected at the generator terminals to create unbalance in supply voltages. The paper uses three phase four wire four leg VSC topology for a DSTATCOM application.

III. DSTATCOM MODEL

In the present work, DSTATCOM has been represented as three independently controllable single phase current sources injecting reactive current in the three phases at the point of coupling. The proposed DSTATCOM model has been shown in figure 2.1. The control scheme consists of three control switches which can be set on/off as per compensation requirement.

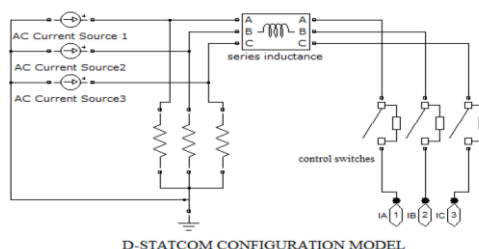


Fig. 2.2 Proposed DSTATCOM Model

IV. Back-Propagation Control Algorithm for Power Quality Improvement Using DSTATCOM

A voltage source converter (VSC)-based DSTATCOM is connected to a three phase ac mains feeding three phase linear/nonlinear loads with internal grid impedance which is shown in Fig. 3.1. The performance of DSTATCOM depends upon the accuracy of harmonic current detection. For reducing ripple in compensating currents, the tuned values of interfacing inductors (L_f) are connected at the ac output of the VSC. A three phase series combination of capacitor (C_f) and a resistor (R_f) represents the shunt passive ripple filter which is connected at a point of common coupling (PCC) for reducing the high frequency switching noise of the VSC. The DSTATCOM currents (i_{Cab}) are injected as required compensating currents to cancel the reactive power components and harmonics of the load currents so that loading due to reactive power component/harmonics is reduced on the distribution system. For the considered three phase nonlinear load with approximately 24 kW, the compensator data are given in Appendix A.

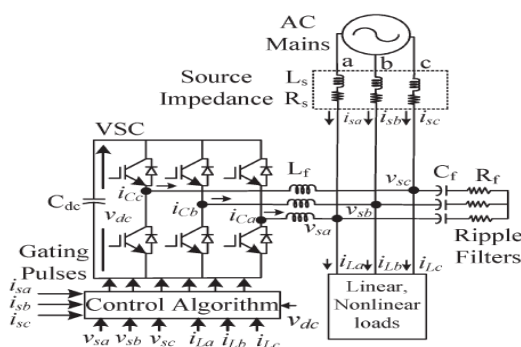


Fig. 2.3 Schematic Diagram of VSC-Based DSTATCOM.

V. PERFORMANCE OF DSTATCOM

MATLAB with SIMULINK and Sim Power System toolboxes is used for the development of the simulation model of a DSTATCOM and its control algorithm. The performance of the BP algorithm in the time domain for the three phase DSTATCOM is simulated for PFC and ZVR modes of operation under nonlinear loads. The performance of the control algorithm is observed under nonlinear loads.

The dynamic performance of a VSC-based DSTATCOM is studied for PFC mode at nonlinear loads. The performance indices are the phase voltages at PCC (v_s), balanced source currents (i_s), load currents (i_{La} , i_{Lb} , and i_{Lc}), compensator currents (i_{Ca} , i_{Cb} , and i_{Cc}), and dc bus voltage (V_{dc}) which are shown in Fig. 3.1 under varying load (at $t = 3.7$ to 3.8 s) conditions.

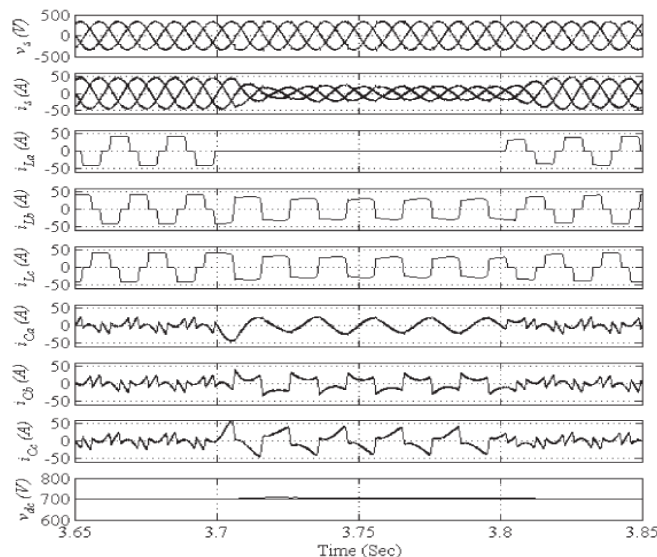


Fig. 3.1 Dynamic Performance Of DSTATCOM Under Varying Nonlinear Loads In PFC Mode.

VI. SIMULATION RESULTS

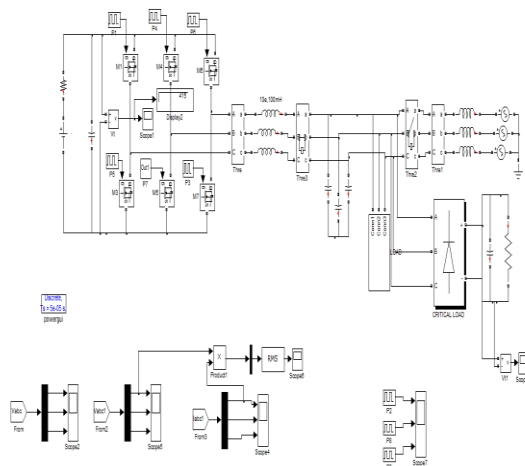


Fig. 4.1 Circuit Diagram of Open Loop Method of Grid Connected System With PWM Control Method

The circuit diagram shown in the figure 4.2 explains the open loop method of grid connected system with PWM control method. The circuit has six switching devices with their respective control signals. Moreover, the circuit has load at the end.

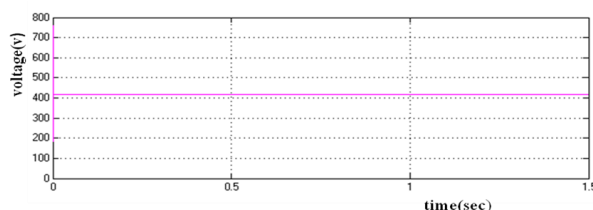


Fig. 4.2. Input Voltage

An input voltage of 400v for PWM inverter is shown in the figure 4.3. The time in seconds and voltage in volts are plotted along x-axis and y-axis respectively.

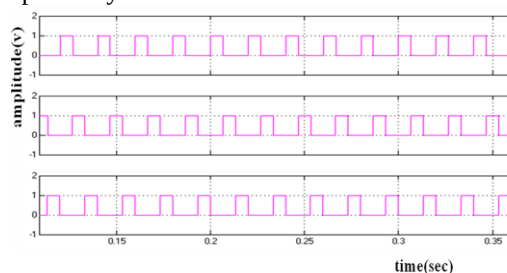


Fig. 4.3 Switching Pulse For Inverter(M1,M3,M5)

The graph depicted shows the switching pulses for the PWM inverter. The switching devices used are MOSFET. The time in seconds and amplitude in volts are plotted along x-axis and y-axis respectively.

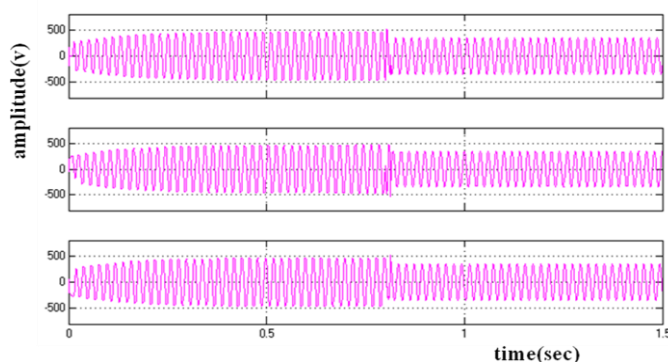


Fig. 4.4 Output Voltage

The output voltage of grid connected system is shown in the figure 4.5. The voltage in volts is plotted in y-axis and time in seconds is plotted in x-axis. At the time of 0.6 second load 2 gets switched ON and the voltage of load 1 becomes sag.

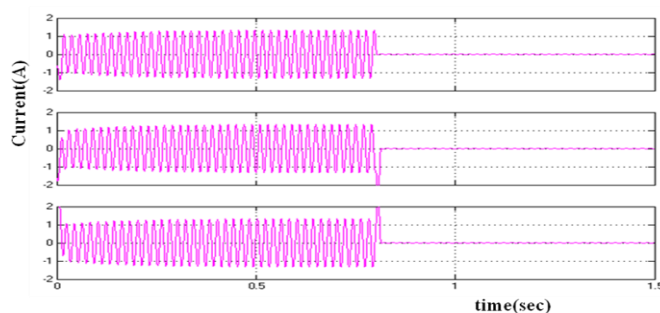


Fig. 4.5 Output Current

The figure 4.6 shows the output current of grid connected system. The time in seconds is plotted in x-axis and current in ampere is plotted in y-axis. Initially the value of current is one ampere. At the time of switching ON the load 2, the output current of load 1 is reduced to zero

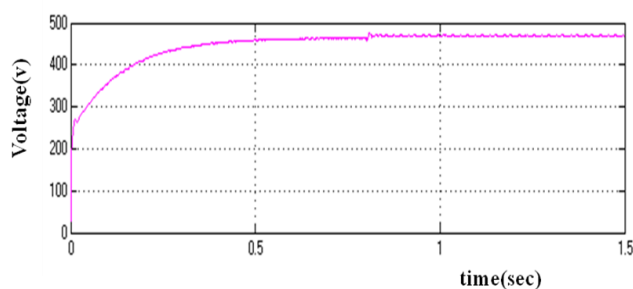


Fig. 4.6 Critical Load Output Voltage

The critical non-linear load output voltage of grid connected system is shown in the fig 4.7. The time in seconds and voltage in volts are plotted along x-axis and y-axis respectively.

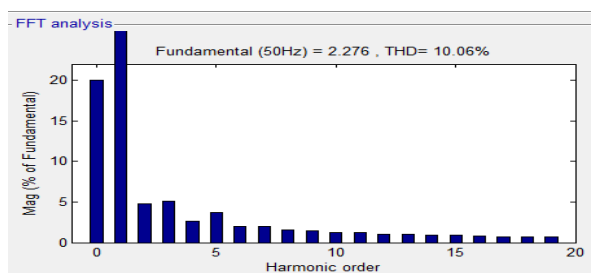


Fig. 4.7 Total Harmonic Distortion (THD)

The graph in the fig 5.8 shows the Total Harmonic Distortion (THD) of output current for the grid connected system. The order of harmonics is plotted along x-axis and magnitude (% of fundamentals) along y- axis.

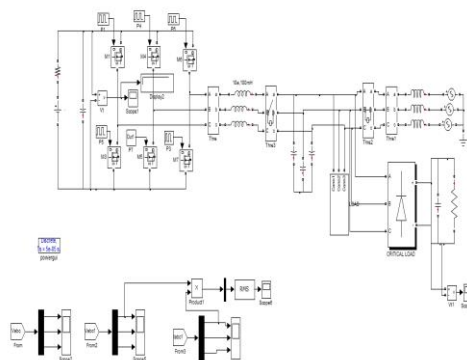


Fig. 4.8 Circuit Diagram of Closed Loop Method of Grid Connected System with PWM Control Method

The circuit diagram shown in the figure 4.8 explains the closed loop method of grid connected system with PWM control method. The circuit has six switching devices with their respective control signals. Moreover, the circuit has load at the end.

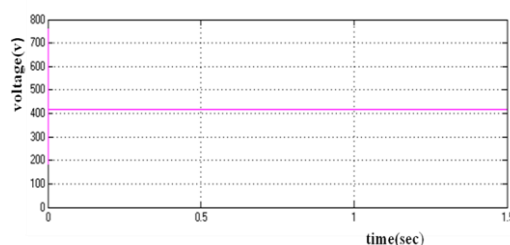


Fig. 4.9 Input Voltage

An input voltage of 400v for PWM inverter is shown in the figure 4.9. The time in seconds and voltage in volts are plotted along x-axis and y-axis respectively.

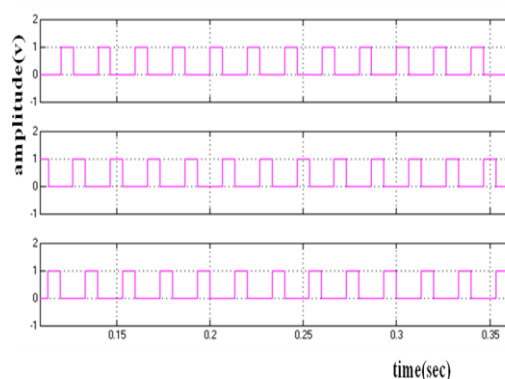


Fig. 4.10 Switching Pulse For (M1,M3,M5)

The figure 4.10 depicted shows the switching pulses for the PWM inverter. The switching devices used are MOSFET. The time in seconds and amplitude in volts are plotted along x-axis and y-axis respectively.

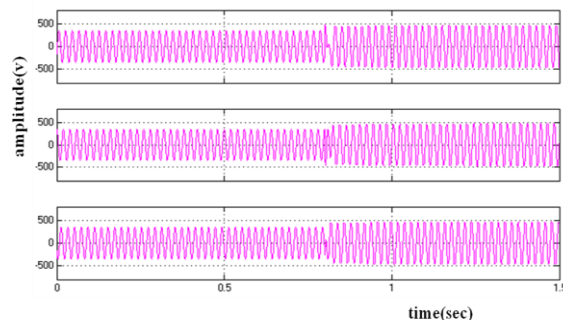


Fig. 4.11 Output Voltage

The output voltage of grid connected system is shown in the fig. 4.11. The voltage in volts is plotted in y-axis and time in seconds is plotted in x-axis. At the time of 0.6 second load 2 gets switched ON and the magnitude of voltage of load 1 gets increased.

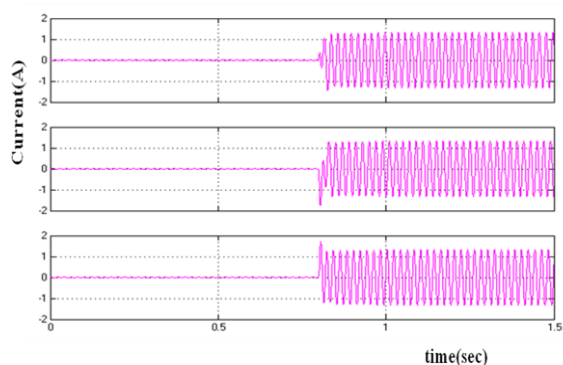


Fig. 4.12 Output Current

The figure 4.12 shows the output current of PWM inverter when grid closed. The time in seconds is plotted in x-axis and current in ampere is plotted in y-axis. Initially the value of current is zero ampere. At the time of switching ON the load 2, the output current of load 1 gets increased.

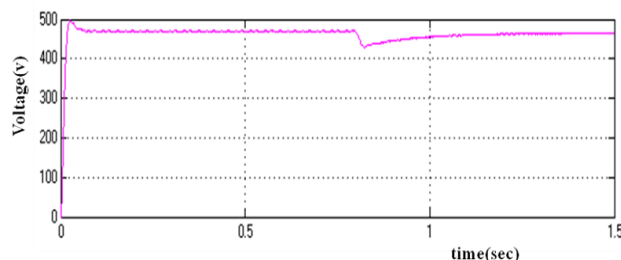


Fig. 4.13 Critical Load Output Voltage

The critical non-linear load output voltage of grid connected system is shown in the fig. 4.13. The time in seconds and voltage in volts are plotted along x-axis and y-axis respectively.

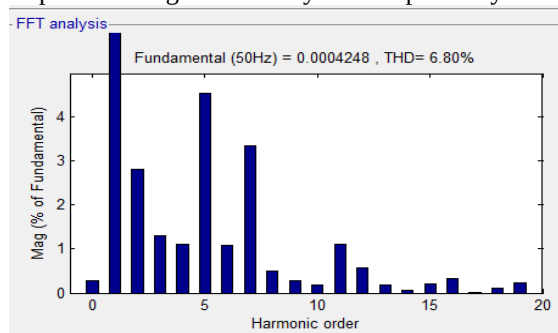


Fig. 4.14 Total Harmonic Distortion(THD)

The graph in the fig.4.14 shows the Total Harmonic Distortion (THD) of output current for the PWM inverter when the grid is closed. The order of harmonics is plotted along x-axis and magnitude (% of fundamentals) along y-axis.

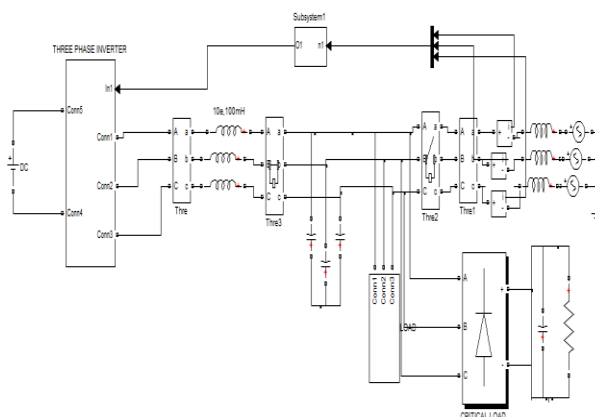


Fig. 4.15 Cicuit Diagram With Grid Closed Space Vector Modulation(Svm) Control Method

Space Vector Modulation is an algothim for the control of pulse width modulation. It is used for the creation of alternate current(AC) waveforms; most commonly to drive three phase AC powered motors at varying speeds from DC using multiple class D amplifiers. There are various variations of SVM that result different quality and computational requirements. One active area of development is in the reduction of total harmonic distortion created by the rapid switching inherent to this algothim. To implement SVM, a reference signal V_{ref} is sampled with a frequency f_s . the reference signal may be generated from three separate phase reference. The reference vector is then sythensized using a combination of the two adjcent active switching vectors and one or both zero vectors.

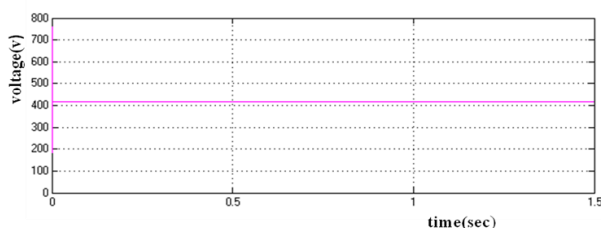


Fig. 4.16 Input Voltage

An input voltage of 400v for SVM inverter is shown in the fig. 4.16. The time in seconds and voltage in volts are plotted along x-axis and y-axis respectively.

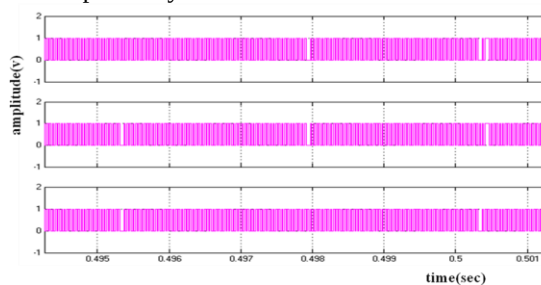


Fig. 4.17 Switching Pulse for M1,M3, M5

The graph depicted shows the switching pulses for the SVM inverter. The switching devices used are MOSFET. The time in seconds and amplitude in volts are plotted along x-axis and y-axis respectively.

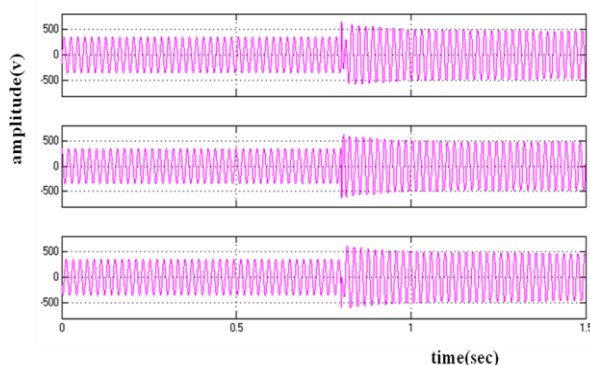


Fig. 4.18 Output Voltage

The output voltage of SVM inverter is shown in the fig. 4.19. The voltage in volts is plotted in y-axis and time in seconds is plotted in x-axis. At the time of 0.6 second load 2 gets switched ON and the magnitude of voltage of load 1 gets increased.

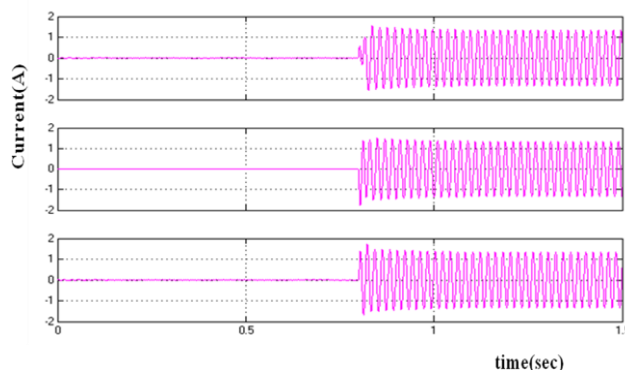


Fig. 4.19 Output Current

The figure 4.20 shows the output current of PWM inverter when grid closed. The time in seconds is plotted in x-axis and current in ampre is plotted in y-axis. Initially the value of current is zero ampre. At the time of switching ON the load 2, the output current of load 1 gets increased.

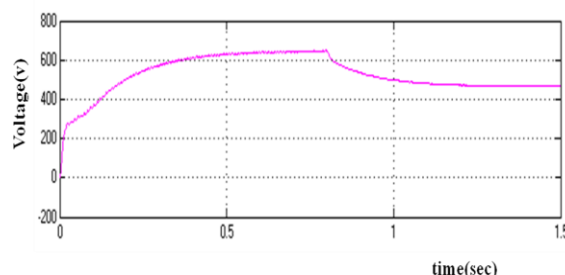


Fig. 4.20 Critical Load Output Voltage

The critical non-linear load output voltage of grid connected system is shown in the fig. 4.21. The time in seconds and voltage in volts are plotted along x-axis and y-axis respectively.

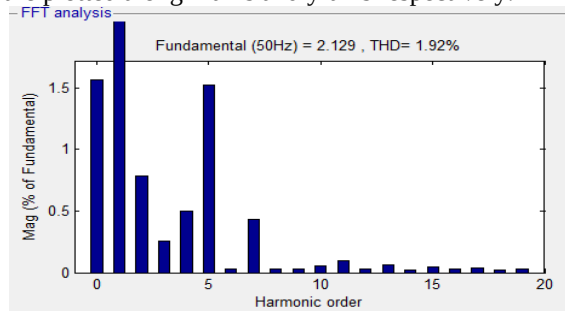


Fig. 4.21 Total Harmonic Distortion(THD)

The graph in the fig 4.21 shows the Total Harmonic Distortion (THD) of output current for the SVM inverter. The order of harmonics is plotted along x-axis and magnitude (% of fundamentals) along y- axis. It is evident from the diagram the usage of SVM method enables us getting reduced harmonic in the order of 6.80% integrate.

VII. CONCLUSION

This project has presented the procedures for Back-Propagation Control Algorithm for Power Quality Improvement Using DSTATCOM system. A VSC-based DSTATCOM has been accepted as the most preferred solution for power quality improvement as PFC and to maintain rated PCC voltage. A three phase DSTATCOM has been implemented for the compensation of nonlinear loads. Performance of DSTATCOM under nonlinear loads: (a-c) i_{sa} , i_{sb} , and i_{sc} with v_{ab} ; (d-f) i_{La} , i_{Lb} , and i_{Lc} ; and (g-i) i_{Ca} , i_{Cb} , and i_{Cc} . (j-l) Harmonic spectra of i_{sa} , i_{La} , and v_{ab} . ing a BPT control algorithm to verify its effectiveness. The proposed BPT control algorithm has been used for the extraction of reference source currents to generate the switching pulses for IGBTs of the VSC of DSTATCOM. Various functions of DSTATCOM such as harmonic elimination and load balancing have been demonstrated in PFC and ZVR modes with dc voltage regulation of DSTATCOM. From the simulation and implementation results, it is concluded that DSTATCOM and its control algorithm have been

found suitable for the compensation of nonlinear loads. Its performance has been found satisfactory for this application because the extracted reference source currents exactly traced the sensed source currents during the steady state as well as dynamic conditions. The dc bus voltage of the DSTATCOM has also been regulated to the rated value without any overshoot or undershoot during load variation. Large training time in the application of the complex system and the selection of the number of hidden layers in the system are the disadvantages of this algorithm. The Basic circuit and modified circuit elements are designed using relevant equations. The simulation circuits are developed using elements of simulink library. The Simulation is successfully done and open loop / closed loop simulation results are presented. The Simulation results coincide with the theoretical results.

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