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Multilevel Inverter Fed Induction Motor Drive with Power Factor Correction

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ABSTRACT

In solid state induction motor drive, power factor correction is employed to improve the overall power factor. In this work, the authors proposed the idea of PFC converter at the input of multilevel inverter fed induction motor drive. Case studies of MLI fed induction motor with L filter, T filter and boost converter power factor controller are presented. The drive system has advantages like reduced THD and improved power factor.

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INTRODUCTION

Single Phase Induction machine (SPIM) is most widely used than other machines due to their advantages such as simplicity in construction, reliability in operation, lightness and cheapness. The speed control of such motors can be achieved by controlling the applied voltage on the motor by the use of power electronic devices. The AC line commutated phase angle control or integral cycle control with thyristor technology has been widely used in the voltage regulators. They suffer from several disadvantages such as retardation of firing angle, enormous harmonic in the motor and supply current and discontinuous power supply to the motor.

The symmetrical pulse width modulated control technique for AC choppers control the motor voltage by varying the duty cycle is discussed in (Jang, D.H., *et al*., 1991). The AC power is adjusted by a circuit which uses four switches and examines the fundamental character of circuit (Salazar, L., *et al*., 1993). A novel drive for single phase induction motor has an attractive feature that it affects both frequency and phase angle simultaneously (Abdel-Rahim, G.M., *et al*., 1995).

The development of medium voltage drives and different type of distributed generations have provided great opportunities for the implementation of medium- and high- power inverters. In these applications, the frequency of the pulse width modulation (PWM) is often limited by switching losses and electromagnetic interferences caused by high dv/dt. Thus, to overcome these problems , Selective harmonic elimination (SHE)-based optimal pulse width modulation (OPWM) are often utilized in both two level inverters and multilevel inverters to reduce the switching frequency and the total harmonic distortion (Rodriguez, J., *et al*., 2008; Tolbert, L.M., *et al*., 199; Peng, F.Z., 2001; Corzine, K.A., *et al*., 1998; Steinke, J.K., 1988; Steimer, M.P. and J.K. Steinke, 1993; Beinhold, G., *et al*., 2001; Koyama, M., *et al*., 2001; Bhagwat, P.M., V.R. Stefanovic, 1983; Peng, F.Z., 2001; Manjrekar, M.D., *et al*., 2000; Peng, F.Z. and J.S. Lai, 1994; Tolbert, L.M., *et al*., 2005).

A typical multilevel inverter utilizes voltage levels from multiple DC sources. These DC sources can be interconnected or isolated depending on circuit topologies. Because of the complexity of the problem, most studies on SHE methods for multilevel inverters are based on the assumptions that the dc voltage sources are balanced and there is only one switching angle per voltage level. But in real application, depending on the nature of the DC sources and operation conditions of the circuits, the DC sources could be unbalanced [20], (Filho, F.J.T., *et al*., 2008). Also, at low-modulation index ranges of multilevel inverters (Chiasson, J.N., *et al*., 2004; Sun, J., et la., 1996), where every limited voltage levels e.g, three or five are involved, the one switching per level schemes will be result in high - harmonics distortion.

The above literature does not deal with PFC converter multilevel inverter to the induction motor drive. This work proposes power factor correction

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converter fed multilevel inverter systems for the control of induction motor.

The paper is organized as follows: The second section deals with blocks of MLI fed drive system. induction motor. The driving pulses required by the MLI are generated using PIC. They are amplified by using driver. The third section gives about simulation results. The work is concluded in the last section.

2. Mli Fed Drive System:

The block diagram of MLI fed induction motor is shown in Fig1. AC voltage is rectified using an uncontrolled rectifier. The DC voltage is applied to the MLI. The output of MLI is applied to the

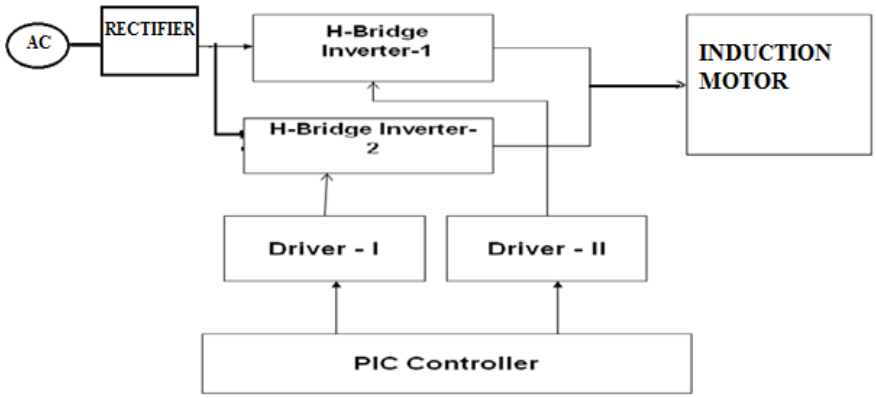

Fig.1: Block Diagram of the Induction Motor Drive System

Cascaded multilevel Inverter is used to obtain seven level output for driving the Induction motor. The output voltage can be expressed as

$$V_o = \sum_{i=0}^{n} E_i S_i \ldots\ldots\ldots\ldots (1)$$

Where S is the switching function i the node. It can have value of zero or one. The load voltages are the sum of output voltages of the bridges.

$$V_o = V_1 + V_2 \quad (2)$$

The torque Developed by the Induction motor is

$$T = K\,(I_2^2 r_2/s - I_2^2 r_2/(2-s)) \quad (3)$$

3. Discussion on Simulation Results:

Multilevel inverter fed induction motor system is shown in Fig.2a. The DC input voltages required at the input of MLI are obtained from a rectifier.

The multilevel inverter feeds a single phase induction motor load. Voltage and current measurements blocks are connected at the input to observe the phase angle between input voltage and current.

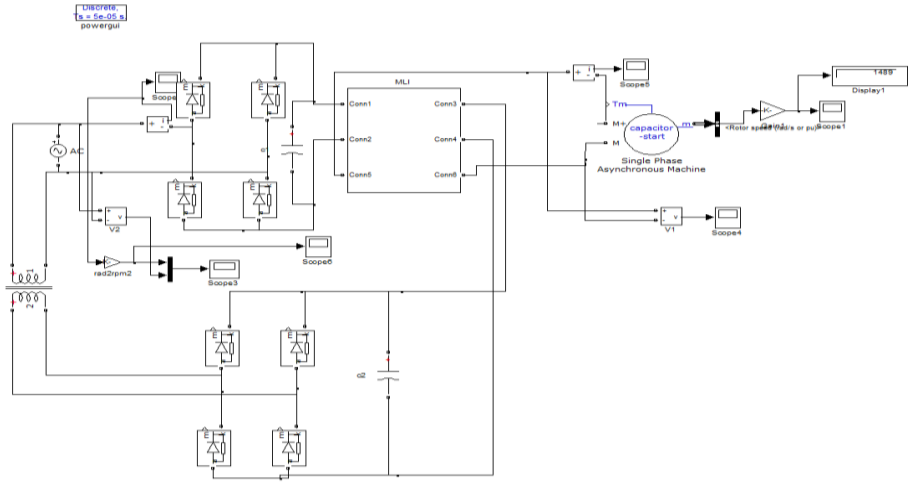

Fig. 2a: Circuit diagram without PFC

The voltage and current waveforms at the input source are shown in Fig.2b.The current is displaced by a large angle with respect to the voltage. The angle between voltage and current is 70^0. The power factor is 0.34.

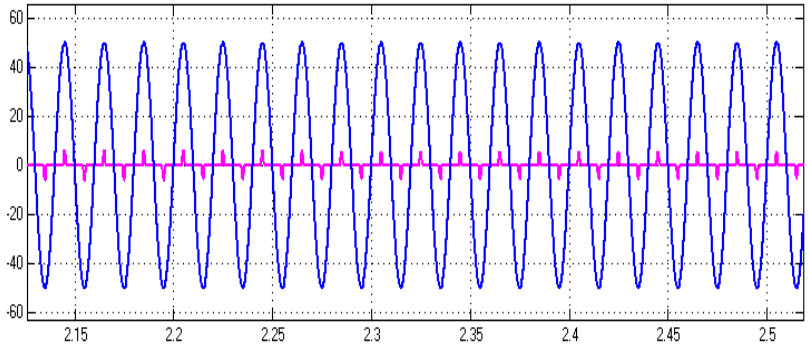

Fig. 2b: Input Voltage & Current Waveforms

The MLI circuit is shown in Fig.2c.This circuit uses two bridges and their outputs are cascaded to obtain multilevel output.

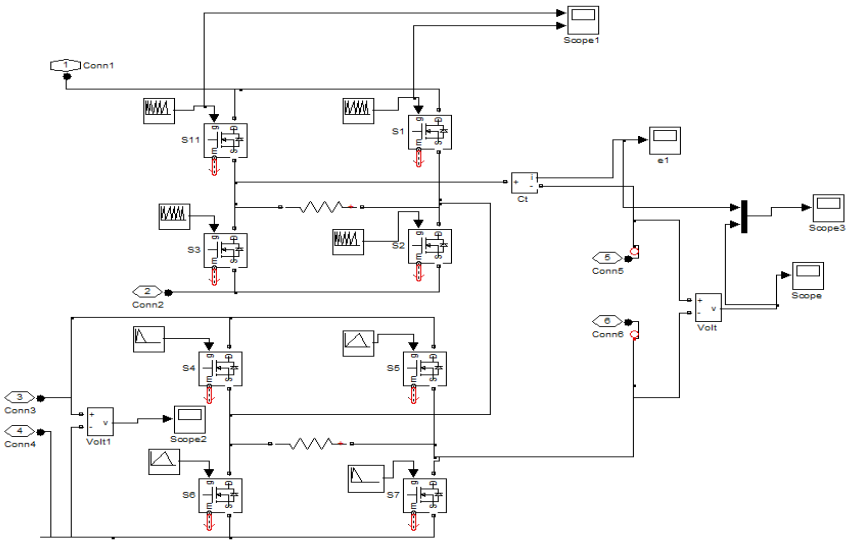

Fig. 2c: Multilevel Inverter

The circuit with series inductor at the input is shown in Fig3a. The source voltage and current waveforms are shown in Fig.3b. The phase angle between voltage and current reduces to 40^0. This reduction is due to the presence of L and C in the circuit.

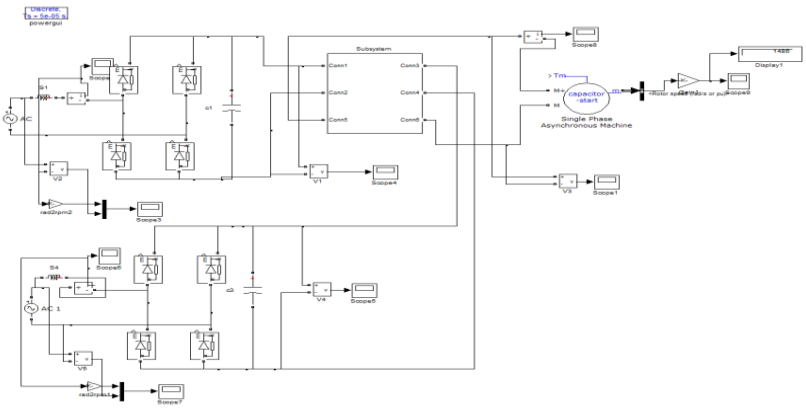

Fig. 3a: Circuit diagram with L Filter

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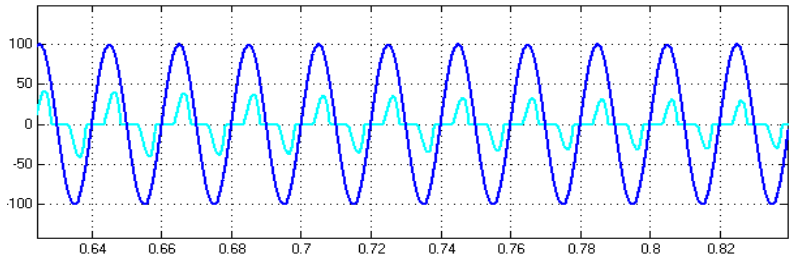

Fig. 3b: Input voltage & Current waveforms

The circuit diagram of MLI fed drive system with T filter is shown in Fig.4a.The source voltage and current waveforms are shown in Fig.4b. The phase angle between voltage and current reduces to 32^0. The corresponding power factor is 0.84 lagging.

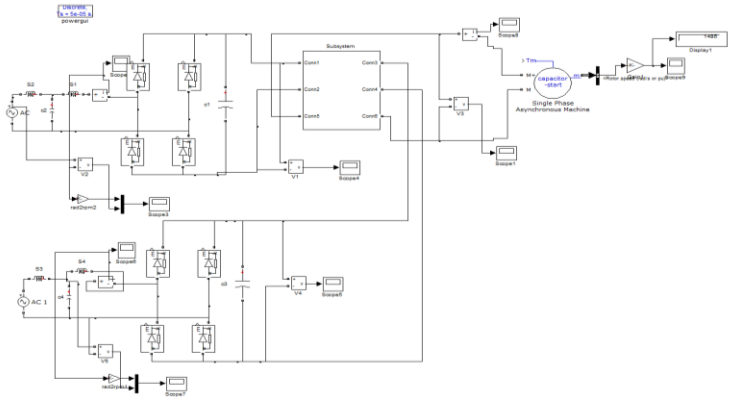

Fig. 4a: Circuit with T-Filter

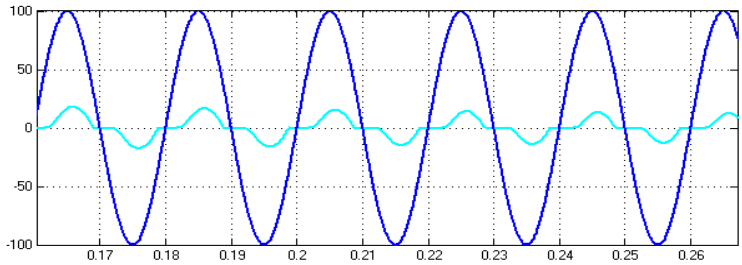

Fig. 4b: Input Voltage & Current waveforms

Boost converter based MLI fed single phase induction motor drive is shown in Fig.5a. A Boost converter is introduced at the input to perform PF correction.

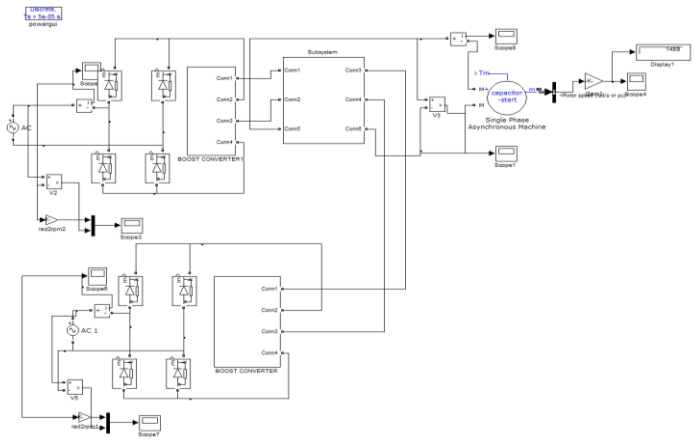

Fig. 5a: Circuit diagram with Boost Converter

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The input voltage and current waveforms are shown in Fig.5b. It can be seen that the voltage and current are almost in phase. Spectrum is shown in Fig.5c.

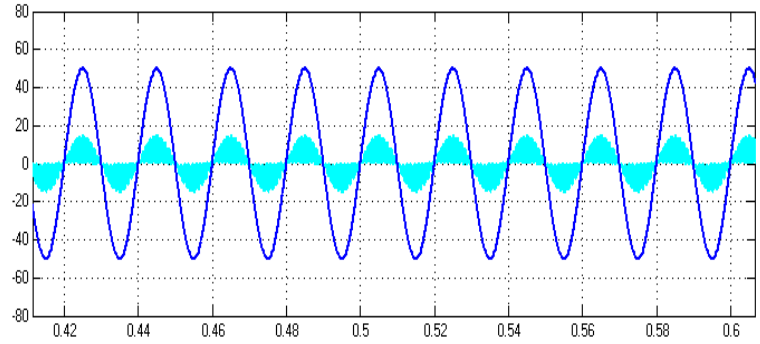

Fig. 5b: Input Voltage & Current Waveforms

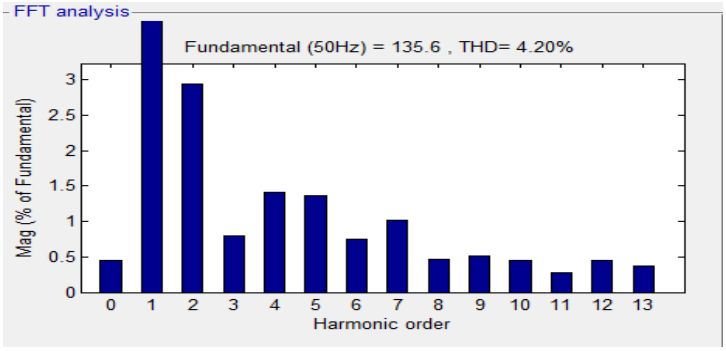

Fig. 5c: Frequency Spectrum

The output voltage of multilevel inverter is shown in Fig.5d and the current drawn by the motor is shown in Fig.5e. The current is smoothened by the inductance of the motor. The peak value of current is 15A. The speed response of the motor is shown in Fig.5f. The speed increases and settles at 1480RPM.

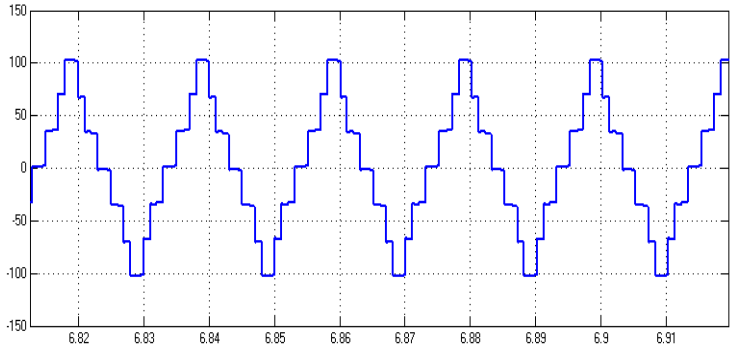

Fig. 5d: output Voltage

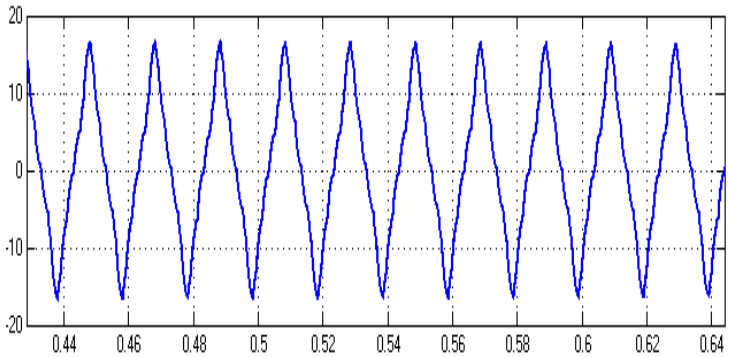

Fig. 5e: Current through the motor

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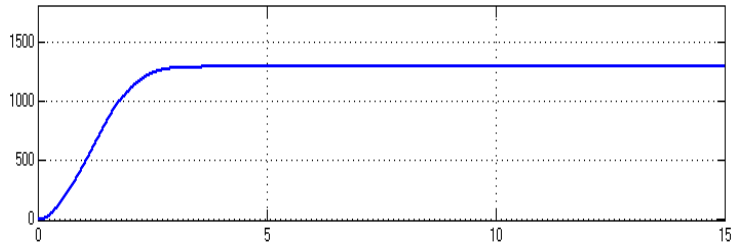

Fig. 5f: Speed of the Motor

4. Experimental Results:

The hardware for seven level inverter fed Induction Motor drive is fabricated and tested. The hardware consists of DC power supply board, PIC board & inverter board. Hardware snap shot is shown in Fig 6a.

Fig. 6a: Hardware Snap shot 7 Level Inverter

DC input voltage to the upper bridge of inverter is shown in Fig 6b.DC input voltage to the lower bridge of the inverter is shown in Fig 6c.

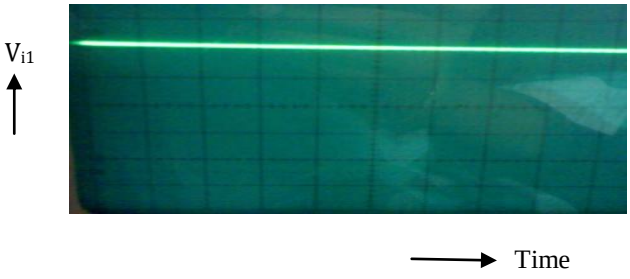

Fig. 6b: Input Voltage

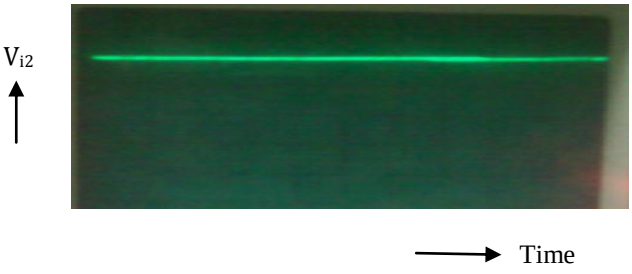

Fig. 6c: Input voltage

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The switching pulses applied to M1 & M2 are shown in Fig 6d. The switching pulses applied to M3 & M5 are shown in Fig 6e.

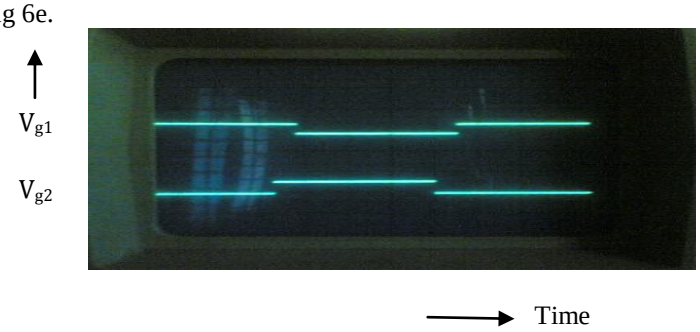

Fig. 6d: Switching pulses for M_1 & M2

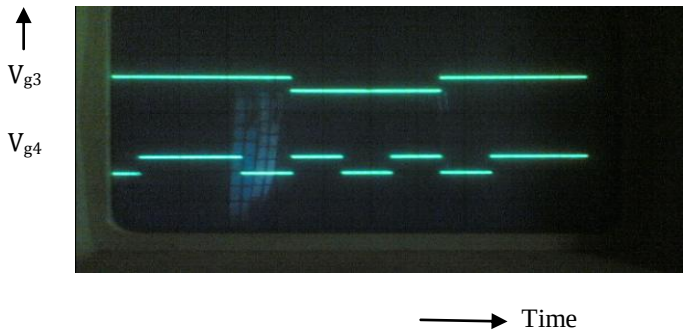

Fig. 6e: Switching Pulses for M_3 & M_5

The voltage applied to the induction motor is shown in Fig 6f. The spikes are due to inductance of the motor.

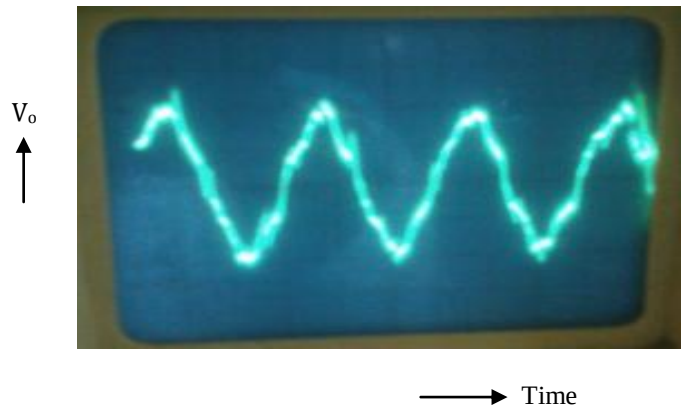

Fig. 6f: Inverter Output Voltage

Conclusion:

In this paper a PFC converter fed multilevel inverter is proposed for the control of single phase Induction motor drive. Larger levels in the inverter have reduced the THD in the output to 4.2%. The results of power factor correction system are presented. Pulse width modulation is used to control the speed of the induction motor. The simulation results are in close agreement with the predictions. The drive system advantages like reduced heating due to harmonics and improved power factor. Disadvantage of multilevel inverter is that requires six numbers of switches and three drivers ICs. The present work deals with open loop controlled drive system. The response with neural network and fuzzy controllers will be done in future.

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