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Voltage Source Inverter Fed Induction Motor Drive

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ABSTRACT: This paper presents a three phase voltage source inverter used to control the speed of an induction motor. Induction motor speed control can be done by various techniques, here uses controlling of voltage for speed control. Here the voltage source inverter is operated at 180 degree conduction mode that is each power electronic switch is operated for 180 degrees. Simple pulse width modulation (PWM) is implemented with 180 degree conduction mode pulses and by controlling the duty cycle of the PWM output voltage can be controlled hence speed of induction motor can be controlled. Control pulses for the switches are generated by using PIC16F877A. Since the output voltage of microcontroller is 5V, which is not feasible for the proper switching of the MOSFET, here uses a driver circuit which consist of TLP250.

KEYWORDS: Voltage source inverter, Induction motor, PWM, Driver circuit.

I.INTRODUCTION

The word inverter in the context of power-electronics denotes a class of power conversion circuits that operates from a dc voltage source or a dc current source and converts it into ac voltage or current. The function of inverter is reverse of what ac-to-dc converter does. Usually input to an inverter circuit is a dc source, but it is not uncommon to have this dc derived from an ac source such as utility ac supply. For example, the primary source of input power may be utility ac voltage supply that is converted to dc by an ac to dc converter and then inverted back to ac using an inverter. The final ac output may be of a different frequency and magnitude than the input ac of the utility supply. DC motors have been used during the last century in industries for variable speed applications due to its easy controllability of flux and torque by means of changing the field and armature currents respectively. Additionally, operation in the four quadrants of the torque speed plane including temporary standstill was achieved. Almost for a century, induction motor has been the workhorse of industry due to its robustness, low cost high efficiency and less maintenance. Earlier induction motors were mainly used for essentially constant speed applications because of the unavailability of the proper speed control techniques. The advancement of power electronics has made it possible to vary the speed of induction motor by varying supply voltage, supply frequency or both.

In AC grid connected motor drives, a rectifier consists of common diode bridge providing a pulsed DC voltage from the mains is required. Although the basic circuit for an inverter may seem to be simple, accurately switching these devices provides a number of challenges. Voltage source inverter can be classified into two stepped wave inverter and PWM inverter. Stepped wave inverter is also called square wave inverter and which has two operating modes, 180 degree conduction mode and 120 degree conduction mode. In 180 degree conduction mode each switch is operated for 180 degrees and it is 120 degree for the other. Some examples where voltage source inverters are used are: uninterruptible power supply (UPS) units, adjustable speed drives (ASD) for ac motors, electronic frequency changer circuits etc. Commercially available inverter units used in homes and offices to units to power some essential ac loads in case the utility ac supply gets interrupted are also familiar. In such inverter units, battery supply is used as the input dc voltage source and the inverter circuit converts the dc into ac voltage of desired frequency.

For adjustable speed applications, mostly induction machine, particularly the cage rotor type is used in industry. Induction machines are very cheap and rugged, and which is available from fractional horsepower to multi-megawatt capacity. In cage rotor type induction motors the rotor has a squirrel cage-like structure with shorted end rings. Induction motor stator has a three-phase winding, and placed in slots distributed sinusoidally. A sinusoidal three-phase

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balanced set of ac voltages applied to the three phase stator windings creates a magnetic field rotating at angular speed s = $4\pi f_s$ /P where f_s is the supply frequency in Hz and P is the number of stator poles.

Block diagram of a voltage source inverter fed induction motor drive is shown in Fig.1

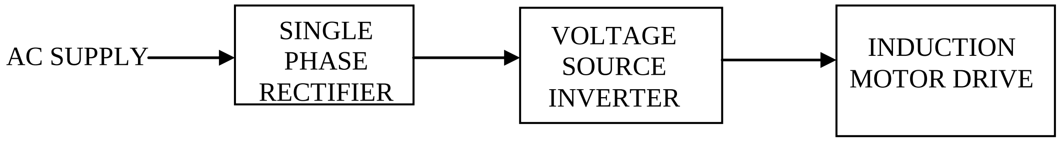

Fig. 1 Block diagram of VSI fed induction motor drive

II.LITERATURE SURVEY

Inverters are used to convert dc to ac by the proper switching of the power electronic switches. Figs. 2 and 3 shows two schematic circuits, which uses transistor-switches, for generation of ac voltage from dc input. In both the circuits, the transistors work in common emitter configuration and are interconnected in push-pull manner. For having a single control signal for the transistor switches, one transistor is of n-p-n type and the other of p-n-p type and their emitters and bases are shorted as shown in the figures. Both circuits require a symmetrical bipolar dc supply. Collector of n-p-n transistor is connected to positive dc supply (+E) and that of p-n-p transistor is connected to negative dc supply of same magnitude (-E). Load, which has been assumed resistive, is connected between the emitter shorting point and the power supply ground.

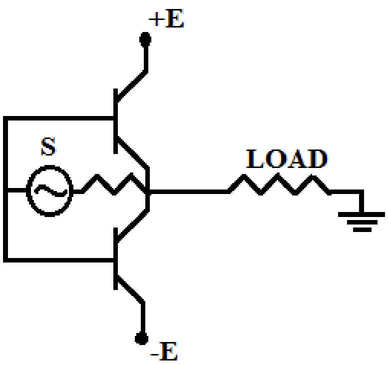

Fig. 2 Push pull active amplifier circuit

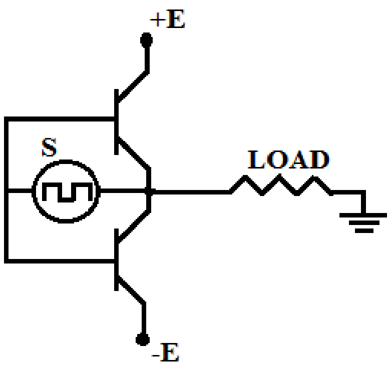

Fig. 3 Push pull switched mode circuit

Push-pull circuits have some technical demerits; first, it needs a bipolar dc supply with identical magnitudes of positive and negative supply voltages. The second demerit of the push-pull circuits is the requirement of two different kinds of transistors, one n-p-n type and the other p-n-p type. The switching speeds of n-p-n and p-n-p transistors are widely different unless they are produced carefully as matched pairs. These demerits can be overcome by a half bridge configuration shown in Fig. 4, in which one dc source is spitted into two by using two capacitors and identical switches can be used here usually mosfet's or igbt's.

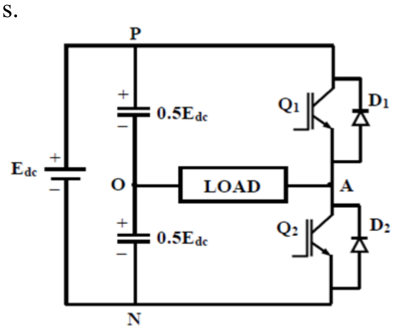

Fig.4 Half bridge circuit

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The requirement of splitting a single dc source in a half bridge circuit is eliminated if a full bridge circuit is used. Full bridge configurations of single phase and three phase inverter are shown below.

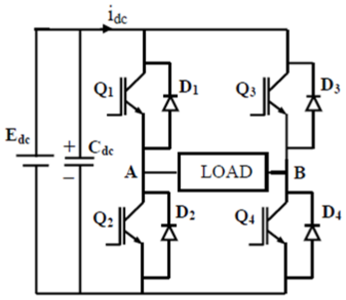

Fig.5 Single phase full bridge

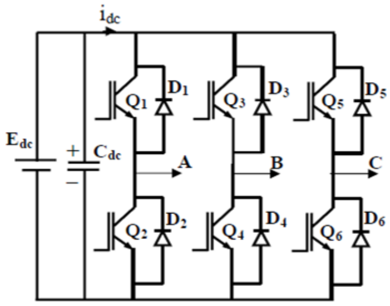

Fig.6 Three phase full bridge

II.SYSTEM DESCRIPTION

Voltage source inverters are most commonly used in industrial applications such as speed control of induction motor. For controlling speed of the induction motor it is necessary to vary the voltage or frequency.

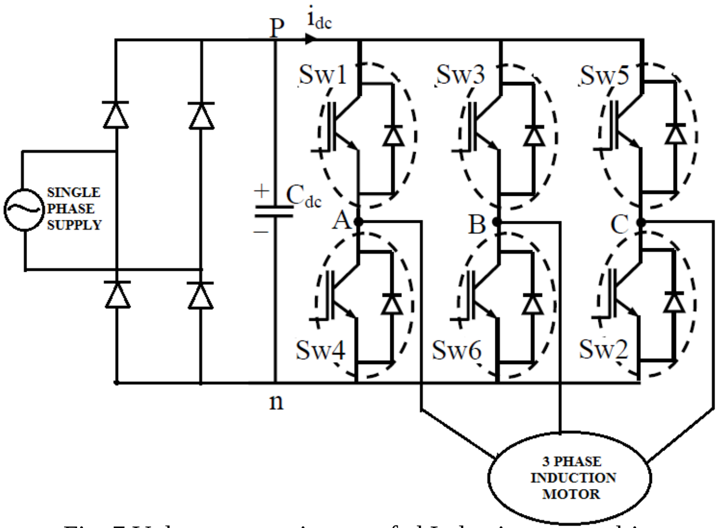

Fig. 7 Voltage source inverter fed Induction motor drive

Fig. 7 shows the three phase voltage source inverter fed induction motor drive. Single phase 230V, 50 Hz supply is used, which rectified into dc by using a diode bridge rectifier. Output of the diode bridge rectifier contains large amount of ripples. In order to get a ripple free dc, a capacitor filter is used here. This dc provided as input of the voltage source inverter. Voltage source inverter is operated in 180 degree conduction mode here. Output of the voltage source inverter is three stepped waves of sinusoidal characteristic and of 120 degree phase shift with each other, which is provided as input of the three phase induction motor.

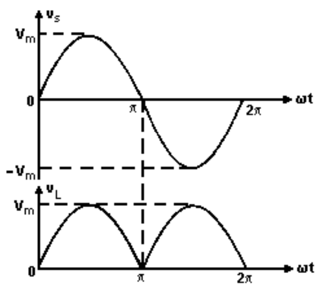

Fig. 8 Waveforms of the diode bridge rectifier

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A diode bridge rectifier is used at the input side in order to convert ac to dc as shown in Fig. 7. Waveforms of the diode bridge rectifier is shown in Fig. 8. As seen in Fig. 3 output of the rectifier contains ripples. Capacitor filter is used to make the output ripple free. Output of the capacitor filter is shown in Fig. 9.

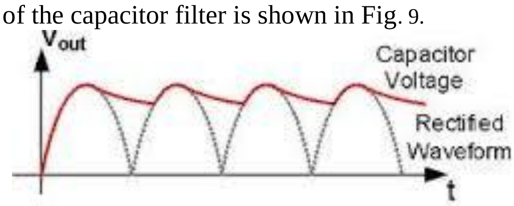

Fig. 9 Waveforms at the output of capacitor filter

Capacitor is designed according to the needed ripple factor and the output load. If the ripple factor is high, there is more ripples in the output. The capacitance C of the capacitor which is to reduce ripples is given by.

$$C = \frac{1}{4fR}[1 + \frac{1}{\sqrt{2}RF}]$$

Where f is the frequency, R is the load resistance and RF is the ripple factor.

Voltage source inverter is operated in 180 degree conduction mode here, it is shown in Fig. 10. Each switch is operated for 180 degrees. No two switches in the same leg operated simultaneously. At any time instant three switches are on in this mode. Inorder to reverse the output phase sequence, the switching sequence may simply be reversed. The gating signals and the resulting line voltages for stepped wave inverter in 180 degree conduction mode are shown in Fig. 11. The phase voltages are derived from the line voltages assuming a balanced three phase system. Considering the symmetry in the switch conduction pattern, it seems that at any time three switches conduct. It can be two from the upper group , which are connected to positive dc bus, and one from lower group or vice-versa (i.e., one from upper group and two from lower group). Based on the conduction pattern indicated in Fig. 6 there are six combinations of conducting switches during an output cycle:- [Sw5, Sw6, Sw1], [Sw6, Sw1, Sw2], [Sw1, Sw2, Sw3], [Sw2, Sw3, Sw4], [Sw3, Sw4, Sw5], [Sw4, Sw5, Sw6]. Each of these combinations of switches conducts for 60 degree in the sequence mentioned above to produce output phase sequence of ABC.

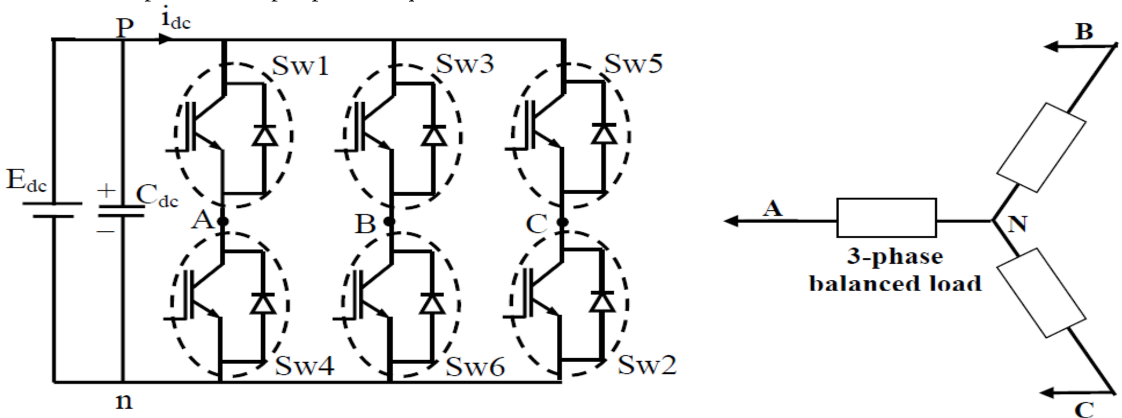

Fig. 10 Voltage source inverter

180 degree conduction mode waveforms of gate signals, phase voltages and line voltages are shown in Fig. 11. As in a single-phase square-wave inverter, switches in same leg of the three-phase inverter operate in a complementary manner. If the upper switch of a leg is on the lower switch will need to block the entire dc bus voltage and vice versa. So the switches must be rated to block the worst-case instantaneous magnitude of dc bus voltage. Some extra safety margin over the worst-case dc voltage is recommended. Each of the inverter-switch carries load phase current during half of the current cycle. So the switches must be rated to withstand the peak expected magnitude of instantaneous load phase current. In the case of a non unity power factor load, the diode placed in anti-parallel with the switch will conduct part of the switch current. Distribution of current between the diode and the controlled switch will depend on the load power factor at the operating frequency. Both diode as well as the controlled switch should be rated to carry the peak load current. Diodes also need to block a peak reverse voltage equal to worst case voltage across the switches.

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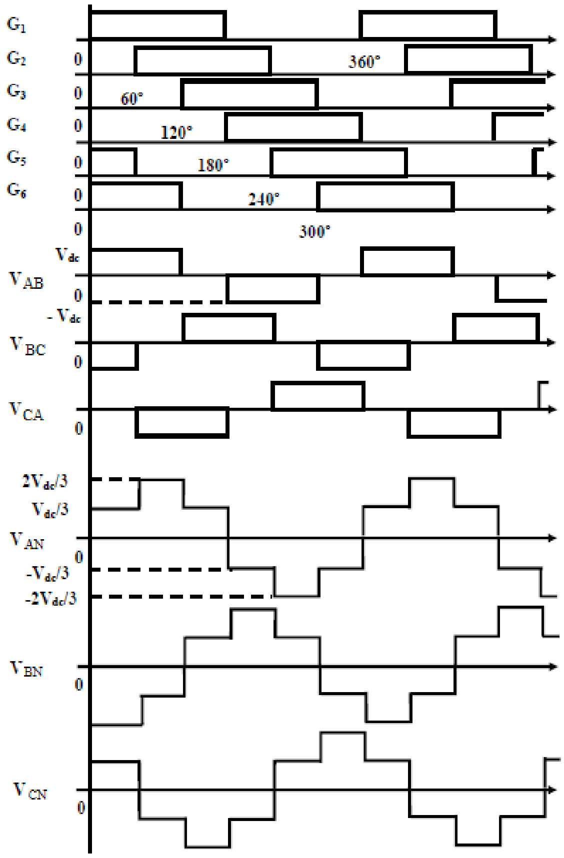

Fig. 11 Waveforms of voltage source inverter

Inverter switches are controlled by pulses from a PIC microcontroller. PIC micro controller outputs pulses similar to the gate pulses shown in the Fig. 11. Then these pulses are anded with a continuous PWM signal whose duty can be varied. So instead of the pulses shown in Fig. 11 switches gets PWM pulses. Since the duty ratio of PWM pulses can be varied, it is easy to vary the output voltage. By varying the output voltage, speed of induction motor can also be varied.

III.SIMULATION STUDIES

In order to check the reliability of the system simulations are to be done. Simulation diagram is shown in Fig. 12.

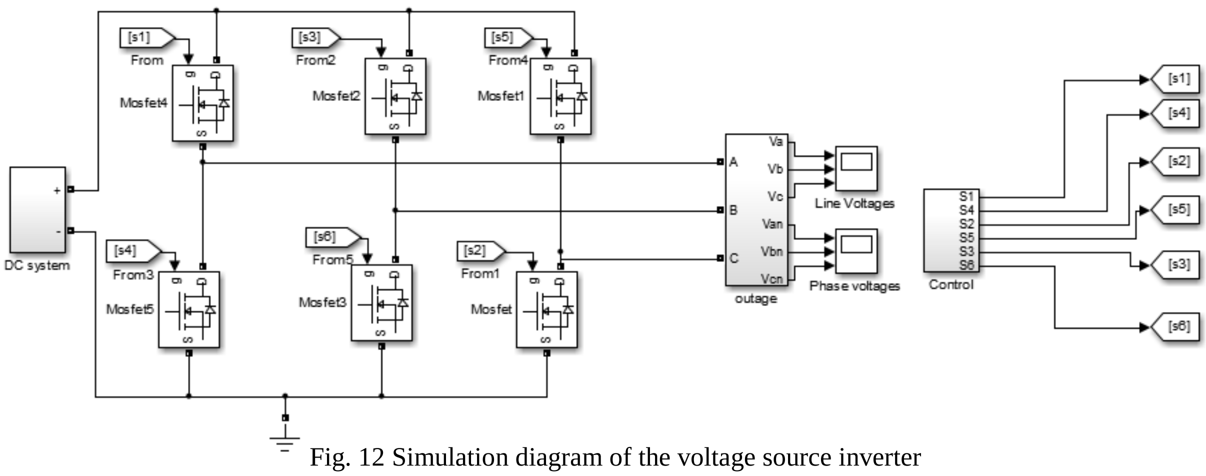

Fig. 12 Simulation diagram of the voltage source inverter

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Simulation diagram of the dc side is shown in Fig. 13. Input to the system is 230V single phase ac. This provides to a single phase full bridge diode rectifier. Diode rectifier converts ac into dc, but the output of diode rectifier usually contains large ripples, which is eliminated using capacitor filter.

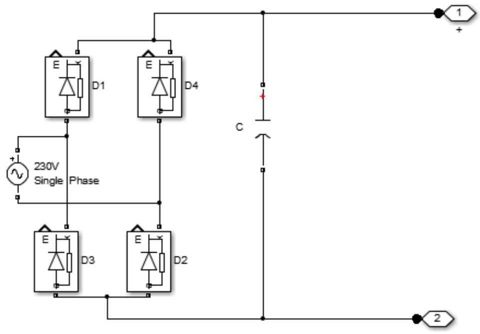

Fig. 13 Simulation diagram for dc side

Voltage source inverter is operated in 180 degree conduction mode here. Each switch is operated for 180 degree and three switches are on simultaneously for any time period. 180 degree conduction mode pulses are generated using pulse generators and then these pulses are anded with a PWM signal of frequency 1Khz. These signals are provides to the gate of the inverter switches. Control block is shown in Fig. 14.

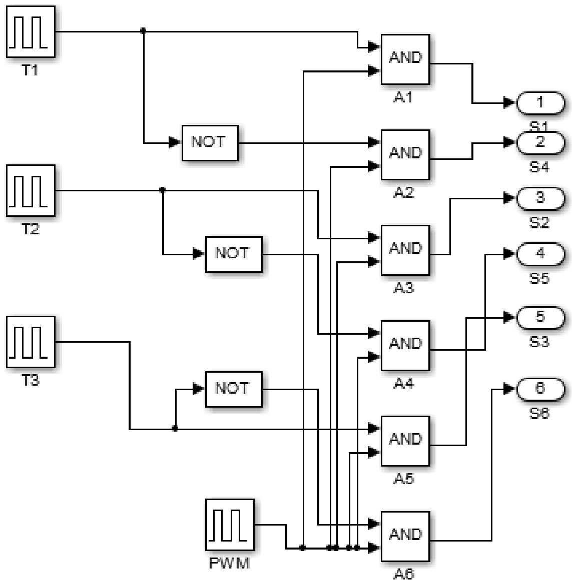

Fig. 14 Simulation diagram the control block

From the simulation output phase and line voltages of the voltage source inverter is obtained as shown in Fig. 15 and Fig. 16.

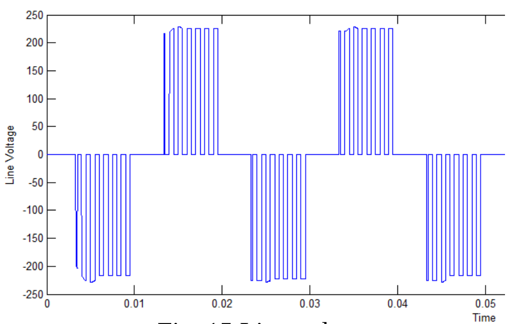

Fig. 15 Line voltage

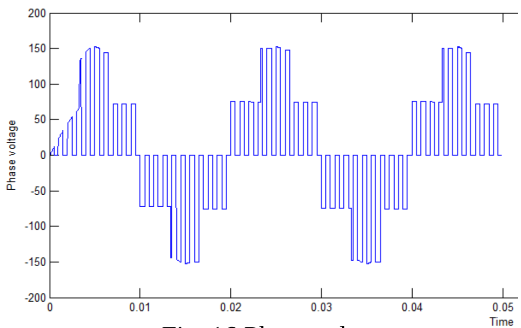

Fig. 16 Phase voltage

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IV.HARDWARE SETUP

A laboratory model of voltage source inverter in 180 degree conduction mode is fabricated and tested as shown in Fig.17.

Fig. 17 Hardware setup

Controls are provided by using PIC16F877A with 12MHz clock frequency. Control pulses are provided from PIC has a magnitude of 5V. Since MOSFET need a gate voltage above 10V for good performance a driver circuit is used. TLP250 is used as the driver circuit here. MOSFET used here is IRF630 with voltage rating of 200V and current rating of 9A. Hardware is shown in Fig 17. Input to the system is a single phase ac supply of 230V, 50Hz, it is provided from a auto transformer and this single phase ac supply is rectified into dc by using a diode bridge rectifier. Output of the diode bridge rectifier contains large amount of ripples. It should be eliminated before providing to the voltage source inverter. A capacitor filter is provided at the output of diode rectifier in order to minimize the ripples. Then the constant dc voltage at the output of the capacitor filter is provided as the input of the voltage source inverter. PWM pulses are generated with 1KHz switching frequency and it is also incorporated with 180 degree conduction mode pulses by using AND gates. So two AND gate IC 7408 is used here.

The line voltage and phase voltage obtained in the DSO is shown below.

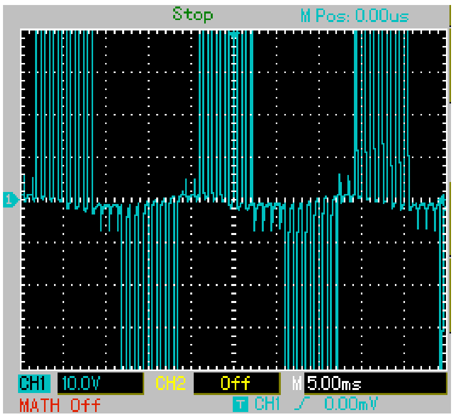

Fig. 18 Line voltage

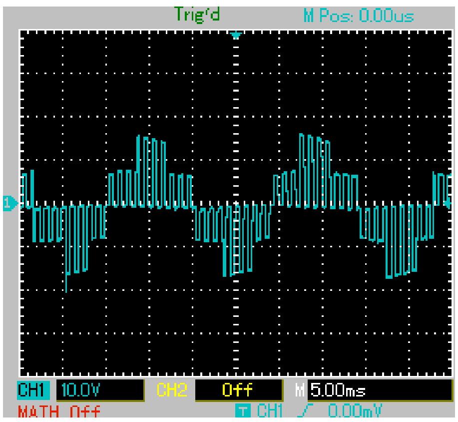

Fig. 19 Line voltage

The wave shape of phase voltage and line voltage obtained is similar to the standard waveform shown in Fig. 11.

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V. CONCLUSION

Voltage source inverter fed induction motor drive is fabricated and tested. Speed control is easily obtained by controlling the supply voltage to the motor. This is achieved by controlling the duty ratio of the PWM pulses. The hardware is reduced since single phase rectifier is used. The reliability is increased by using microcontroller as the on chip intelligent controller. Usually large heat sinks are used for the MOSFETS and other power electronic switches in high power applications. But by properly designing the driver circuit the need for large heat sinks is eliminated here. By implementing a special control of PWM with the 180 degree conduction mode, harmonics is reduced than a usual stepped wave inverter.

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