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PWM Based Multilevel Feed Induction Drive Using Single Phase to Three Phase Converter

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Abstract-— **Most of the industrial dives use an induction motor because these motors are rugged, reliable, and relatively inexpensive. Induction motors are mainly used for constant speed applications because of unavailability of the variable-frequency supply voltage. But many applications need variable speed operations. Recently, power electronics and control systems have matured to allow these components to be used for motor control in place of mechanical gears. These electronics not only control the motor's speed, but can improve the motor's dynamic and steady state characteristics. Adjustable speed ac machine system is equipped with an adjustable frequency drive that is a power electronic device for speed control of an electric machine. It controls the speed of the electric machine by converting the fixed voltage and frequency to adjustable values on the machine side. High power induction motor drives using classical three - phase converters have the disadvantages of poor voltage and current qualities. To improve these values, the switching frequency has to be raised which causes additional switching losses. Another possibility is to put a motor input filter between the converter and motor, which causes additional weight. A further inconvenience is the limited voltage that can be applied to the induction motor determined by inconvenience is the limited voltage that can be applied to the induction motor determined by the blocking voltage of the semiconductor switches gives rise to the concept of multilevel inverter control which in turn controls the dynamic performance of motor. Recently many schemes have been developed to achieve multilevel voltage profile, particularly suitable for induction motor drive applications. The diode clamp method can be applied to higher level converters. As the number of level increases, the synthesized output waveform adds more steps, producing a staircase waveform. A zero harmonic distortion of the output wave can be obtained by an infinite number of levels. Unfortunately, the number of the achievable levels is quite limited not only due to voltage unbalance problems but also due to voltage clamping requirement, circuit layout and packaging constraints. In this paper, a three-phase diode clamped multilevel inverter fed induction motor is described. The diode clamped inverter provides multiple voltage levels from a series bank of capacitors. The voltage across the switches has only half of the dc bus voltage. These features effectively double the power rating of voltage source inverter for a given semiconductor device. The proposed inverter can reduce the harmonic contents by using multicarrier PWM technique. It generates motor currents of high quality. V/*f* is an efficient method for speed control in open loop. In this scheme, the speed of induction machine is controlled by the adjustable magnitude of stator voltages and its frequency in such a way that the air gap flux is always maintained at the desired value at the steady-state. Here the speed of an induction motor is precisely controlled by using three level diode clamped multilevel inverter.**

Index Terms— Diode clamped multilevel inverter, Induction motor, Multicarrier PWM technique.

I. INTRODUCTION:

The recommendation system is a particular type of information filtering technique that attempts to present
Power electronic converters, especially dc/ac PWM inverters have been extending their range of use in industry because they provide reduced energy consumption, better system efficiency, improved quality of product, good maintenance, and so on. Implementation of Multilevel Inverter-Fed Induction Motor Drive is using PWM technique and MOSFET based power inverter circuit. For a medium voltage grid, it is troublesome to connect only one power semiconductor switches directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations such as laminators, mills, conveyors, pumps, fans, blowers, compressors, and so on. As a cost effective solution, multilevel converter not only achieves high power ratings, but also enables the use of low power application in renewable energy sources such as photovoltaic, wind, and fuel cells which can be easily interfaced to a multilevel converter system for a high power application.

The most common initial application of multilevel converters has been in traction, both in

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locomotives and track-side static converters. More recent applications have been for power system converters for VAR compensation and stability enhancement, active filtering, high-voltage motor drive, high-voltage dc transmission, and most recently for medium voltage induction motor variable speed drives. Many multilevel converter applications focus on industrial medium-voltage motor drives, utility interface for renewable energy systems], flexible AC transmission system (FACTS) and traction drive systems.

The inverters in such application areas as stated above should be able to handle high voltage and large power. For this reason, two-level high-voltage and large-power inverters have been designed with series connection of switching power devices such as gate-turn-off gate commutated transistors and integrated gate bipolar transistors(IGBTs) MOSFET, because the series connection allows reaching much higher voltages. This paper makes a humble attempt to demonstrate a multilevel inverter with variable frequency control of three phase induction motor using PWM technique, one of the many techniques used to control the speed of a three phase induction motor. I aim to design and implement a variable frequency for three phase induction motor using PWM control technique for three phases MOSFET based Inverter using 3-phase induction motor drive.

I. PRINCIPLE OF OPERATION

- To vary motor speed, varied the stator supply frequency 'f' because Synchronous Speed = Ns = 120f / P.

Where P = no. of poles of Induction Motor

- To achieve maximum torque it is needed to keep air gap flux constant. This is done by keeping the voltage to frequency ratio constant i. e. Vs. / f = constant.

II. . OPERATION OF 3-PHASE INDUCTION MOTOR

Most induction motors in operation today are designed for 3-phase source of alternating voltage. The stator comprises of three phase winding distributed in such a way that current in stator winding produces an approximately sinusoidally varying flux density around the air gap between the stator and rotor. When three temporally varying currents shifted out of phase by 120^0. From each other flow through three symmetrically placed windings, a radially directed air gap flux density is produced that is also sinusoidally distributed around the gap and is rotating at an angular velocity equal to angular frequency ω_s of the stator current. Torque production in an induction in an induction is due to the interaction of the rotating stator field and current in rotor inductors. Torque is developed when rotor speed 'slips' behind the synchronous speed of the stator traveling field. Fig. 1 shows the torque-speed characteristic of an induction motor where ω_s is the speed of stator field (ω_s = 2 p f s) and ω_r is rotor speed.

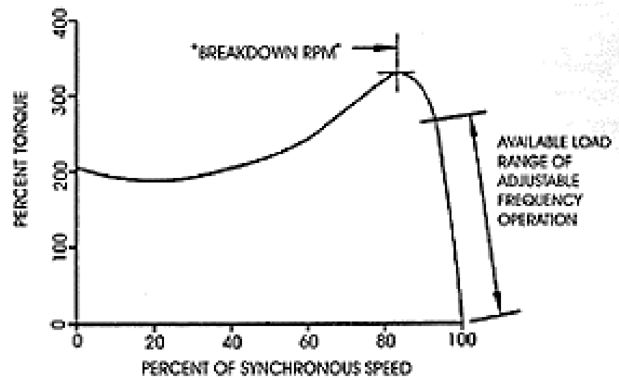

Fig. 1: Torque Speed Characteristics of an Induction Motor

The difference between two is usually relatively small and is the slip speed. The solid portion of characteristics is the main region of interest where the motor is operating at rated flux and at low slip. In this region the rotor speed is approximately proportional to stator supply frequency, except at very low speeds. The operating point of motor on its torque-speed characteristics is at the intersection of the load torque line and the motor characteristics for small amount of slip and at constant air gap flux the motor torque is proportional to the slip speed. In a variable speed system the motor is operated on a series of torque speed characteristics as the applied frequency is increased. A set of characteristics for three conditions are ω_{s1}, ω_{s2} and ω_s. The corresponding rotors speeds are ω_{r1}, ω_{r2} and ω_{r3}.

However in order that the air gap flux in the motor is maintained at its rated value then the applied voltage must be reduced in proportion to the applied frequency of traveling field. This condition for constant air gap flux gives the constant v/f requirement for variable speed control of A.C. induction motors. At low speeds this requirement may be modified by voltage boosting the supply to motor in order to overcome the increase

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proportion 'IR' voltage drop in the motor windings which occurs at low speed. Squirrel cage motors are widely used type of induction motors. We have used one such motor in our project. The rotor in such motor is made up of aluminum rods cast into the slots in outer periphery of the rotor. Cast aluminum end rings (which can also be designed to behave as fans) are used to short the aluminum bars at the both ends of the rotor. For larger squirrel cage motor, the aluminum rings are replaced by copper ones.

III. SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

Various methods are available for control of speed of an induction motor. These techniques take advantage of various aspects of induction motor operation. Briefly, the methods are;

- Phase controlled induction motor drive: This technique involves the control of the phase angle of supply voltage. A slip energy recovery scheme is used along with this to improve the drive efficiency

- Frequency controlled induction motor drive: This method involves changing synchronous speed by changing frequency of a.c. supply to induction motor to cause speed variation, as the true speed of the motor is very close to synchronous speed. Either voltage source inverters or current source inverters may be used. This project is based on a voltage source inverter using this method of speed control.

- Vector controlled induction motor drive: Independent control over flux and torque is possible in A.C. drives, as is possible in D.C. drives. The control is achieved by phasor control of rotor flux linkages. Vector control, or alternatively, field oriented control is achieved by suitably controlling the inverter to obtain correct values of frequency, phase, and current and hence control the flux phasor. This control technique has made A.C. drives superior to D.C. drives, as vector control drives provide independent control of flux and torque is improved dynamic response in comparison with equivalent D.C. drives.

IV. BLOCK DIGRAM

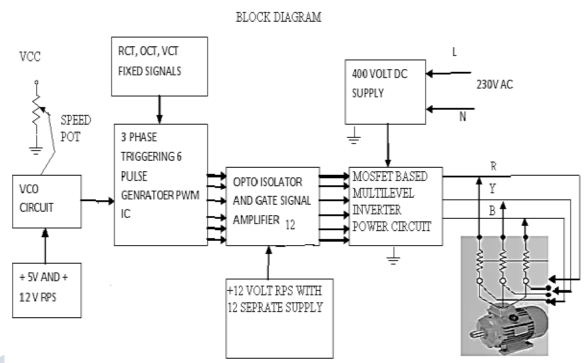

Fig. 2: Block Diagram

The block schematic of multilevel inverter fed three phase induction motor is as shown in figure. The complete system will consist of two sections; a power circuit and a control circuit. The power section consists of a power rectifier, filter capacitor, and three phase diode clamped multilevel inverter. The triggering circuit using PWM technique with VCO and opto-isolator circuitry, signal amplifier. To generate 12 gating pulses to drive MOSFET based power inverter circuit. The motor is connected to the multilevel inverter. An ac input voltage is fed to a three phase diode bridge rectifier, in order to produce dc output voltage across a capacitor filter. A capacitor filter, removes the ripple contents present in the dc output voltage. The pure dc voltage is applied to the three phase multilevel inverter through capacitor filter. The multilevel inverter has 12 MOSFET switches that are controlled in order to generate an ac output voltage from the dc input voltage.

A. Control circuit: PWM IC is the heart of the control circuit. It requires four input clock frequencies namely RCT, VCT, OCT, FCT. The first three frequencies namely RCT,VCT & OCT are set as fixed frequencies by using an arrangement of a 7414 hex Schmitt trigger, resistors presets and capacitors. As per the datasheet for Schmitt trigger we can see that it can be operated as an oscillator for frequency up to 1MHz. This suits our purpose as we required frequencies in the few hundred KHz range only. The design equation for selection of

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resistor and capacitor for required frequency setting is f = 1/ 1.7 RC. Clocks RCT and VCT are to be set at same value whereas OCT is usually kept at half of RCT value. The FCT clock is generally set at double the RCT clock and its output frequency can be varied to control the frequency of output waveforms for triggering the MOSFETs. Supply voltage can be given between 3V to 15V. I have selected Vcc as +5V for Schmitt trigger.

B. VCO: voltage control oscillator: FCT clock is design-using VCO IC NE 566, which has maximum operating frequency 1MHz and sinks current 1mA. Formula for output frequency is given as,

$$f_o = 2(Vcc - Vc) / (R_1C_1 Vcc)$$

C. Schmitt-Trigger Using SN74LS14: For PWM IC which is in the range of several Kilohertz. So we need four clock pulses to trigger it. i.e. reference clock.(RCT), voltage clock (VCT) and output delay clock (OCT).

D. Opto-Isolator, Signal Amplifier and Driver Circuit: MCT2E Opto-isolators are used to electrically isolate the control circuit from the power circuit in order to protect the control circuit from potentially fatal power surge from the power circuit. Next, we used TIP122 Darlington pair transistors after each isolator to boost current to level that is required to trigger the Power MOSFET IRF840 without loading on the opto-isolators. The outputs of the Darlington pairs are suitably connected to the Power MOSFET switches for correct operation of the inverter.

E. Control circuit power supply design: The ICs and other component we have used have different power supply requirements. The power supply requirements for these components are as follows, PWM IC operated on +5 volt and NE566 VCO supply voltage given +12 volt.

F. Power supplies for ICs HEF4752V, NE566, and 74LS14: Based on the supply requirements, we design the power supply using two regulators 7805 & 7812. Power supply for IC MCT2E and TIP 122: Based on the supply requirement as +12 volt separately we designed the power supply for opto-isolators and the TIP122 Darlington pairs connected at output of opto-isolators.

G. Four Winding Transformer: A specially designed transformer in our project is the Four Winding transformer. The specialty of the transformer is that it has a single primary winding and Four secondary winding; S1, S2, S3, S4. S1, S2, S3 the first three secondary windings are of 0-12V, 150mA each but the fourth and last winding has turns which carry 0-12V and 450mA. The total voltage and current input to the primary winding is 230V, 1.5A.

H. Inverter design: The rated motor current is 0.6amp, 0.25hp and its rated voltage 440V ac and 1500 RPM. Our dc power supply is derived from single phase ac mains and hence gives 310V unregulated dc at the filter capacitor. Based on this, the high frequency, IRF 840 MOSFET has been used as a power switch in the inverter.

I. D.C Power supply to inverter: *The* supply to the inverter is provided by a bridge rectifier directly connects to single phase ac mains. Ripples in dc output are smoothened by using a filter capacitor. The bride rectifier diodes used are 6A4 power diodes each rated for PIV 400V and 6A current. The 150µF smoothing capacitor has a voltage rating of 350V DC.

J. 3-phase induction motor (option) 0.25 HP 1440 RPM: The output received from the multi-level inverter is cascaded to the 3 phase induction motor. The 3 phase motor used has rating of 0.6 A, 0.25 HP, 1440 rpm.

K. Power Supply: In general, electronic circuits using tubes or transistors require a source of dc Power. For example, in tube amplifiers dc voltage is needed for plate, screen grid and control grid. Similarly, the emitter and collector bias in a transistor must also be direct current. Batteries are rarely used for the purpose as they are costly and require frequent replacement. In practice, dc power for electronic circuits is most conveniently obtained from commercial ac lines by using rectifier-filter system called a dc power supply. The rectifier-filter combination constitutes an ordinary dc power supply. The dc Voltage from and ordinary power supply remains constant so long as ac main voltage or load is unaltered. However, in many electronic applications, it is desired that dc Voltage should remain constant irrespective of changes in ac mains or load. Under such situations, voltage-regulating devices are used with ordinary power supply. This constitutes regulated dc. A power supplies and keeps the dc Voltage at fairly constant value. In this report, we shall

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focus our attention on the various voltage regulating circuits and I.C. regulators.

L. Type IN 4007 Silicon Rectifiers: These one-amp rectifier diodes are the product of combining the best of both silicon material processing and packaging technologies. The silicon die is a mesa oxide-passivity structure has additional nitride passivity and glass passivity over the junction. Years of volume production have shown the double plug package to have the highest inherent mechanical intensity of all hermetic-case diode.

M. Fixed Voltage Regulator: The positive voltage regulator 78 xx series with seven voltage options areas below. The 78xx series consists of three terminal positive voltage regulators with seven voltage options. These IC's are designed as fixed voltage regulator and with adequate heat sinking can deliver output currents in excess of 1 Amp. although these devices do not require external components can be used to obtain adjustable voltage and currents. These IC's also have thermal overload protection and internal short circuit current limiting.

V. PERFORMANCE AND RESULTS

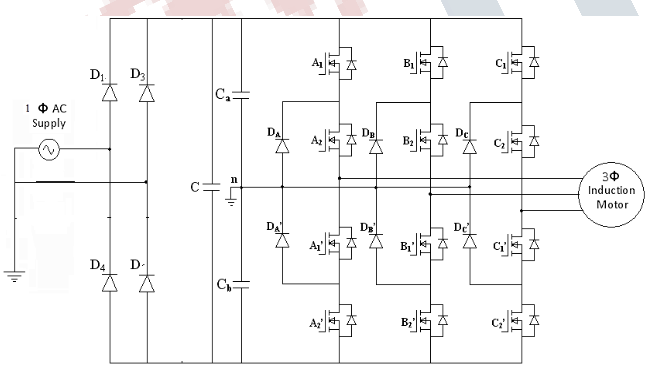

Fig. 3: Circuit Diagram

Figure 3 shows multilevel inverter fed three phase induction motor is as shown in figure. The complete system will consist of two sections; a power circuit and a control circuit. The power section consists of a power rectifier, filter capacitor, and three phase diode clamped multilevel inverter. The motor is connected to the multilevel inverter. An ac input voltage is fed to a three phase diode bridge rectifier, in order to produce dc output voltage across a capacitor filter. A capacitor filter, removes the ripple contents present in the dc output voltage. The pure dc voltage is applied to the three phase multilevel inverter through capacitor filter. The multilevel inverter has 12 MOSFET switches that are controlled in order to generate an ac output voltage from the dc input voltage. The control circuit of the proposed system consists of three blocks namely opto-coupler and gate driver circuit.

The PWM IC is used for generating gating signals required to drive the power MOSFET switches present in the multilevel inverter. The voltage magnitude of the gate pulses generated by the PWM pulse generator is normally 5V. To drive the power switches satisfactorily the opto-coupler and driver circuit are necessary in between the controller and multilevel inverter. The output ac voltage is obtained from the multilevel inverter can be controlled in both magnitude and frequency (V/*f* open loop control). The controlled ac output voltage is fed to the induction motor drive. The power switches are on, current flows from the dc bus to the motor winding. The motor windings are highly inductive in nature; they hold electric energy in the form of current. This current needs to be dissipated while switches are off. Diodes are connected across the switches give a path for the current to dissipate when the switches are off. These diodes are also called freewheeling diodes.

Table 1: Switching sequence of MOSFET

LEVEL NO.	MOSFET 'ON' for +ve half cycle	MOSFET 'ON' for -ve half cycle
LEVEL 1	**R + / R + 1**	**R - / R - 1**
LEVEL 2	**Y + / Y + 1**	**Y - / Y – 1**
LEVEL 3	**B + / B + 1**	**B - / B - 1**

Table 1 indicates the switching sequence of the MOSFET whereas fig 4 given below indicates the final output obtained with the switching sequence applied to the circuit. Which indicates the output waveform of 3 level inverter.

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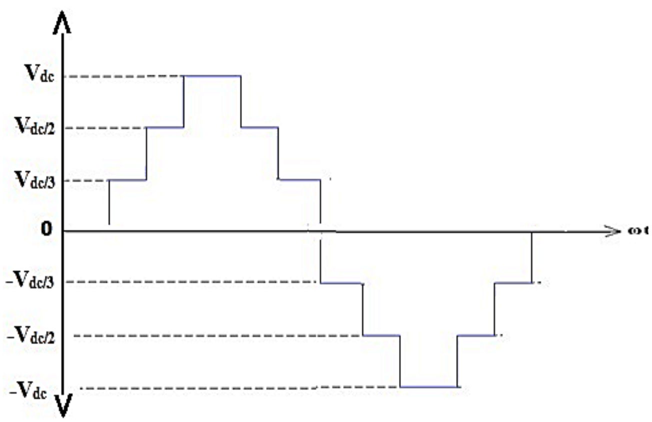

Fig. 4: output waveform 3 level inverter

VI. RESULT

FCT

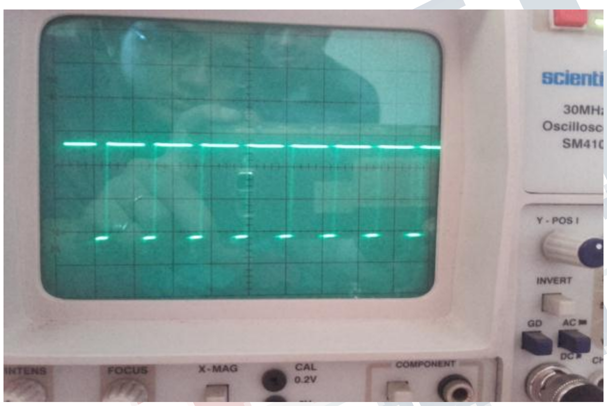

Fig. 5: output waveform 3 level inverter

Frequency clock time waveform of VCO circuitry typically 250 KHz required to change 'D' of PWM IC.

RCT:

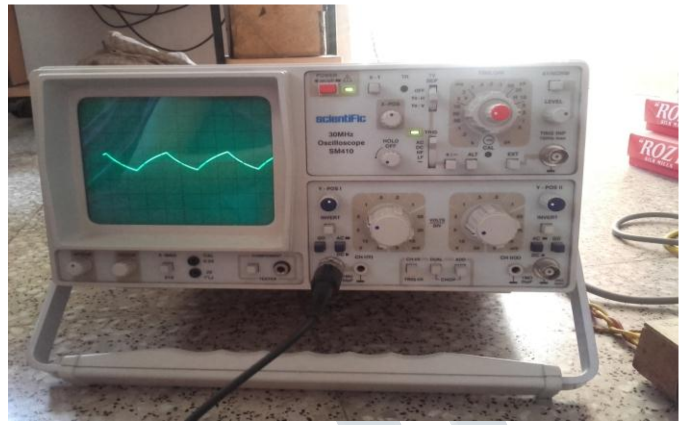

Fig 6: RCT at capacitor 'C'

Fig 7: Schmitt Trigger output.

Real clock time waveform typically of 250 KHz is applied to Schmitt trigger. It is a fixed amplitude/fixed frequency clock pulse.

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OCT/VCT

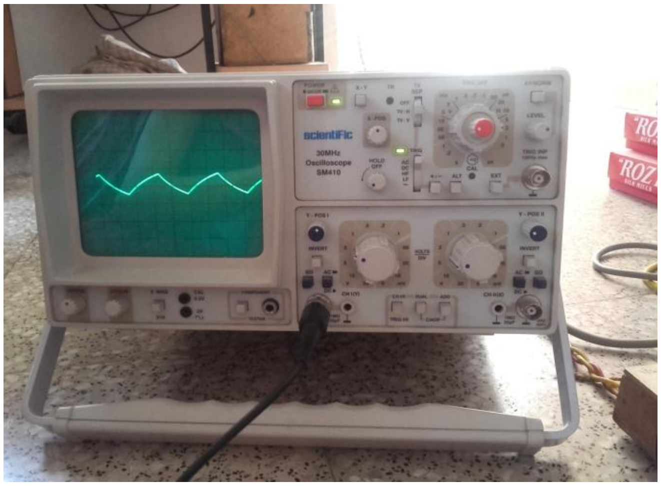

Fig 8: OCT/VCT at capacitor 'C'

OCT has a fixed frequency of 275 KHz which is output of Schmitt trigger whereas VCT is voltage clock time is also a 475 KHz fixed frequency clock pulses from Schmitt trigger & goes to PWM IC.

Fig 9: Schmitt Trigger output

PWM Output

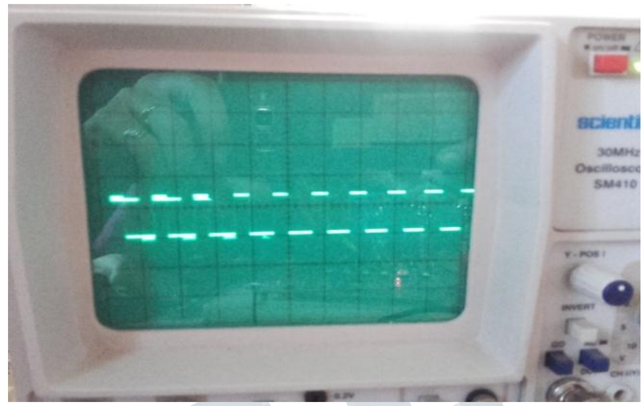

Fig 10: PWM output for A ≈ 1V

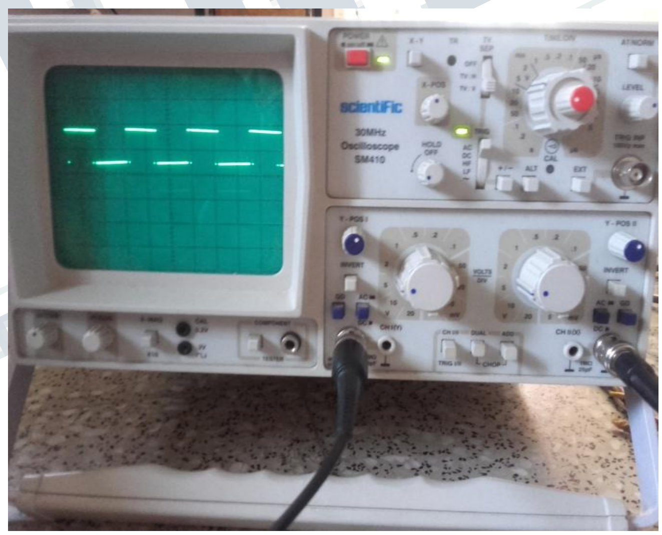

Fig 11: PWM output for A ≈ 6V

Figure 10 indicates the waveform of PWM output at R^+ to B^- before optocoupler indicating A ≈ 1V whereas figure11 indicates the waveform of PWM output at R^+ to B^- after optocoupler indicating A ≈ 6V. These RCT, OCT, VCT is treated as input to the PWM IC which indicates the output.

Fig 12: Output obtained

Above figure 12 indicates the three level output waveform as per expected combination of R, Y, B phases for the resistive load.

CONCLUSION

This paper provides a comprehensive analysis on the three-level diode clamped inverter, which also known as neutral-point clamped (NPC) inverter. The diode-clamped inverter provides multiple voltage levels through connection of the phases to a series of capacitors. Because of industrial developments over the past several years, the three level inverter is now used extensively in industrial application. The performance of the three-phase three-level twelve switch inverter has been explained and improved by employing PWM control scheme. The use of three-level inverters reduces the harmonic components of the output voltage compared with the two-level inverter at the same switching frequency. It needs no additional reactors or transformers to reduce the harmonic components. Then, it is suitable for high voltage and high power systems.

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