Speed control of Induction Motor drive using five level Multilevel inverter

Siddayya hiremath[1], Dr. Basavaraj Amarapur[2]
[1,2]Dept of Electrical & Electronics Engg ,Poojya Doddappa Appa college of Engg, Gulbarga, karnataka,India

Abstract — *In this paper, simulation of five level diode clamped Multilevel inverter for three phase Induction Motor is presented. To obtain high quality sinusoidal output voltage. Multicarrier Sinusoidal Pulse Width Modulation (SPWM) technique is proposed for five level inverter. An open loop speed control can be achieved by using variable frequency method. Variable frequency applied to the three phase Induction Motor with constant supply voltage. The proposed system is effective replacement conventional method produces high switching losses results. The simulation results reveal that the proposed system is effectively control the Motor speed and enhance the performance. The effectiveness system is verified through Simulation .*

Keywords — *diode clamped Multilevel inverter; Induction Motor; Multicarrier PWM technique; variable frequency technique;*

I. Introduction

Recently the" Multilevel converter" has tremendous interest in power industry [6].The Multilevel converters produces synthesis sinusoidal voltage for different levels of voltages. The concept of Multilevel converter has been introduced in 1975 and basically three types of Multilevel converter namely Cascded Multilevel converter, Diode clamped Multilevel converter, Flying capacitor Multilevel converter.

Majority of industrial drives uses AC Induction Motor because of they are easy to construction, reliable and relatively inexpensive and they are mainly used for constant speed applications. The main drawback of Induction Motor unavailability of variable frequency supply, and cannot applied for variable speed applications. In earlier method, the mechanical gear system were used to obtain variable speed. The speed of Induction Motor can achieved easily due to development of power electronics devices. Speed of Induction Motor can achieved by using rectifier and inverter circuit. These circuits provides variable voltage and variable frequency to Induction Motor.

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, etc. As a cost effective solution, Multilevel converters not only achieves high power ratings, but also enables the use of low power application in renewable energy sources such as photovoltaic cells, wind energy which can easily interfaced to Multilevel converter system for a high power application.[5]

Most common applications of Multilevel converter are high voltage Motor drive, high voltage DC transmission, medium voltage Induction Motor variable speed drives, interface for renewable energy systems, flexible AC transmission system, and drives for traction.

The Multilevel voltage source inverters unique structure allows them to reach high voltage and power levels without use of transformer. They specially suited to high voltage electrical drives at low output voltage. Multi-level inverter can easily provide the high power require of a large Electric Voltage (EV) or (Extra high voltage) EHV drive. As the number of levels increases, the synthesized output waveform has more steps, which produces a staircase wave that approaches the desired waveform. Also, as more steps are added to the waveform, the harmonic distortion of the output wave decreases, approaching zero as the number of levels increases. As the number of levels increases, the voltage that can be spanned by connecting devices in series also increases. The structure of the Multilevel inverter is such that no voltage sharing problems are encountered by the active devices.[3]

II. MULTILEVEL CONCEPT

Shows a schematic diagram of one phase leg of inverters with different number of levels, for which the action of the power semiconductors is represented by an ideal switch with several positions. A two-level inverter generates an output voltage with two values (levels) with respect to the negative terminal of the capacitor, while the three-level inverter generates three voltages, and so on.[2]

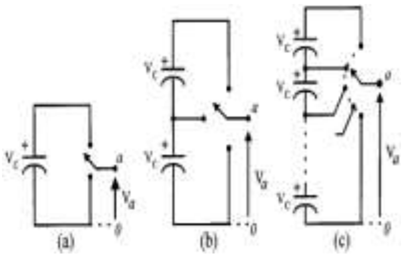

Figure 1 One phase leg of an inverter with (a) two levels, (b) three levels, and (c) m levels.

The Multilevel inverters can be classified into three types such as

- ➢ Diode clamped Multilevel inverter.
- ➢ Flying capacitors Multilevel inverter.
- ➢ Cascaded Multilevel inverter.

A. Basic Principle

An m-level diode clamped converter typically consist of m-1 capacitors, 2(m-1) switching device and (m-1)(m-2) clamping diodes. The Figure 2. shows three phase five level diode clamped converter in which the DC bus consist of four capacitor C_1 ,C_2, C_3 and C_4. For a dc bus voltage the voltage across each capacitor is $V_{dc}/4$.[9]

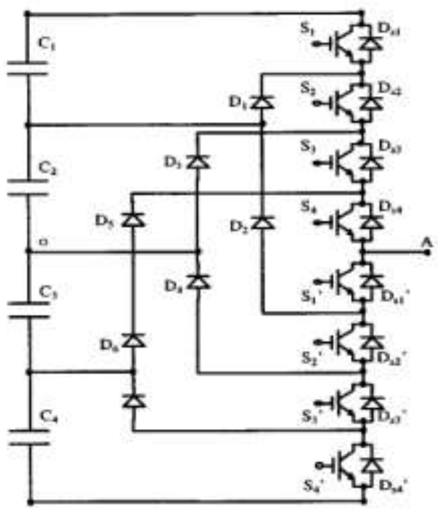

Figure 2 structure of 1-leg five level diode clamped Multilevel inverter

The numbering of order of the switches S_1,S_2,S_3,S4,S_1',S_2',S_3' and S_4' .Each device voltage stress will be limited to one capacitor voltage level. $V_{dc/}4$ through clamping diodes.[7][8]

B. Principle of operation

To produce staircase output voltage, let us consider only one leg of the five level diode clamped inverter as shown in figure 2. The steps synthesis the five level voltages are as follows.

1. For an output voltage $V_O = V_{dc}$ turn on all upper switches S_1,S_2,S_3,S4
2. For an output voltage $V_O = 3V_{dc}/4$ turn on three upper switches, S_2,S_3, S_4 and one lower switch S_1'
3. For an output voltage $V_O = V_{dc\ /2}$ turn on two upper switches S_3,S_4, and two lower switches S_1', S_2'
4. For an output voltage $V_O = V_{dc/4}$ turn on one upper switches S_4, and three lower switches S_1',S_2' S_3'
5. For an output voltage V_O =0 turn on all lower switches S_1,S_2,S_3,S_4

Table 1 list the voltage level corresponding switching states. State condition 1 means switch ON and 0 means switch OFF. using a phase leg a as the example. The four complementary pairs are (S_1, S_1') (S_2, S_2') (S_3, S_3') (S_4, S_4').

S1	S2	S3	S4	$S_{1'}$	$S_{2'}$	$S_{3'}$	$S_{4'}$	V_o
1	1	1	1	0	0	0	0	V_{dc}
0	1	1	1	1	0	0	0	$3V_{dc}/4$
0	0	1	1	1	1	0	0	$V_{dc}/2$
0	0	0	1	1	1	1	0	Vdc/4
0	0	0	0	1	1	1	1	0

Table 1 five level converter voltage levels and corresponding switching states

C. Features

The most attractive feature of Multilevel inverters.

1. They can generate output voltage switch extremely low distortion and lower dv/dt.
2. They can operate with a lower switching frequency.
3. They generate smaller Common Mode (CM) voltage thus reducing the stress in the Motor bearings.

D. Advantages and disadvantages

Advantages and disadvantages o Multilevel inverter as follows.

Advantages.

1. When number of levels is high enough, harmonic content will be low enough to avoid the need for filters.
2. Efficiency is high because all devices are switched at fundamental frequency.
3. Reactive flow can be controlled.
4. Control method simple

Disadvantages.

1. Excessive clamping diodes are required when number of levels is high.

III. BLOCK DIAGRAM OF PROPOSED SYSTEM

The block diagram of proposed system is as shown in figure 3. Which consist of two sections; a power circuit and driver circuit. The power section consists of a single-phase power supply,bridge rectifier, boost circuit and five level diode clamped Multilevel inverter. and driver circuit consist of sinsoidal Pulse width modulation and. Motor is connected to output of Multilevel inverter.

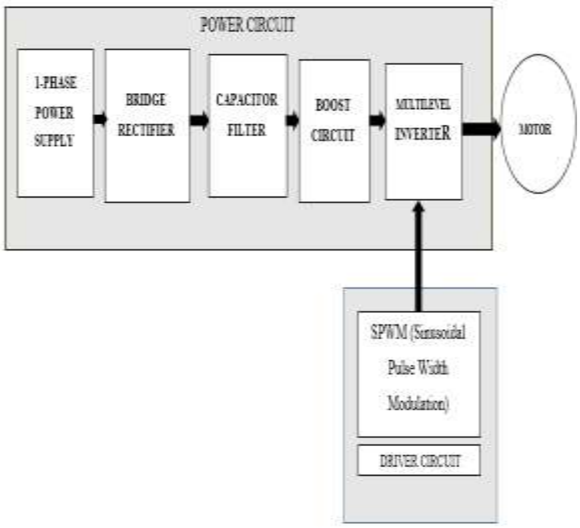

Figure 3 Block diagram of simulation proposed system.

Single-phase natural supply voltage is given to the input of rectifier circuit. Normally 230V, 50HZ available. Input of the rectifier is 230V ac voltage and rectifier circuit 230V ac is converted into 230V pulsating DC. Output of the rectifier circuit connected to the input of boost circuit as shown in figure 3 .supply voltage of rectifier is given by equation (1)

$$V_s = V_m \sin \omega t \qquad (1)$$

The average value of the bridge rectifier output voltage V_{dc} is given by equation (2)

$$V_{dc} = \frac{2V_m}{\pi} \qquad (2)$$

Output of rectifier contains harmonics DC link filter can be used to smooth out of DC component output voltage of rectifier. The DC filters are usually C-type filter.

Boost circuit also known as step-up chopper. Basically chopper is convert the input DC voltage is into fixed or variable DC output voltage hence chopper is called DC-DC converter. In boost circuit output V_o can be greater than the supply voltage V_s. as shown in figure 4

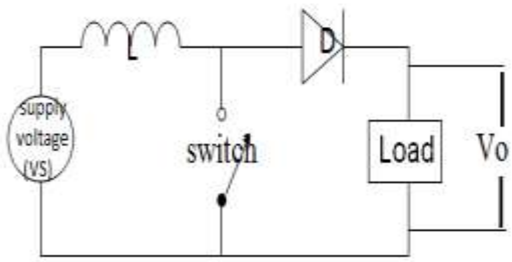

Figure 4 Basic step-up chopper circuit

. Inductance connected series with supply voltage. A switch (MOSFET, GTO etc) is connected across inductance and supply. In boost circuit output voltage V_o is greater than input voltage and output voltage of step-up chopper is given by equation (3)

$$V_o = V_s + L\, DI_L/DT \qquad (3)$$

Multilevel inverters are being considered for an increasing number of applications due to their high power capability associated with lower output harmonics and lower commutation losses. Multilevel inverters have become an effective and practical solution for increasing power and reducing harmonics AC loads

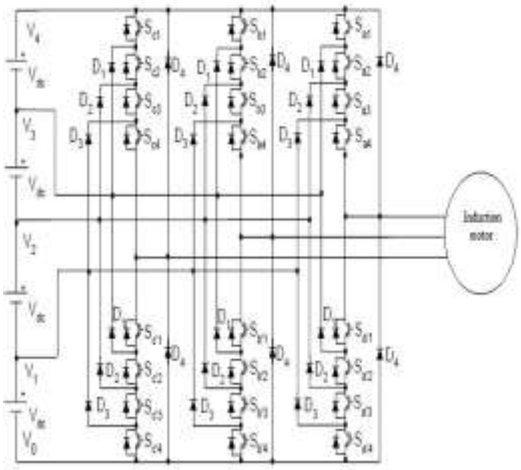

Figure 5 five level Multi-level inverter

Five level Multilevel inverter circuit as shown In figure 5. It has totally 3-legs; each leg contains 8switches total 24 switches are used to generate the three phase output voltage. Each leg produces single phase voltage and totally three leg produces three phase output voltage with 120^0 phase shift each other.[6]. Output of three phase Multilevel inverter is connected to input of Induction Motor. Speed of Induction Motor can be controlled by different method such as variable voltage variable frequency constant v/f etc and this system variable frequency method is used to control speed of Induction Motor.[1]

Pulse Width Modulation is modulation technique it is used encode the message signal into pulsating signal. The main purpose is to allow the control of power supplied to electrical devices. The main advantage of PWM is that power loss in the switching device very low. PWM technique can be implemented into inverter circuit to control the output voltage and different applications such as Induction Motor, stand by power supply and uninterruptable power supply. Common used PWM technique such as. [6]

1. Single Pulse width modulation
2. Multiple Pulse width modulation
3. Sinusoidal Pulse width modulation
4. Modified sinusoidal Pulse width modulation
5. Phase displacement controlled

Sinusoidal Pulse width modulation is most common modulation technique. This technique is implemented into three phase Multilevel inverter to control speed of Induction Motor.

Advantages of Multicarrier PWM techniques.

1. Easily extensible to high number of levels.
2. Easy to implement.
3. To distribute the switching signals correctly in order to minimise the switching losses
4. To compensate unbalanced dc sources.

IV. PROPOSED SCHEME

The complete system of proposed simulation diagram of Induction Motor drive using five level diode clamped Multilevel inverter circuit as shown in figure 6. The complete system consist of power circuit and control circuit. Power section consists of power rectifier, filter capacitor, boost circuit and three phase five level diode clamped inverter, control circuit consist of sinusoidal Pulse width modulation (SPWM). The Motor is connected to the output of inverter. An ac input voltage 230V AC, 50HZ, is applied to the input of bridge rectifier, rectifier circuit consist of bridge rectifier and capacitor filter. Rectifier circuit converts 230V AC is converted into 230V pulsating DC. Some ac components are removed by using capacitor filter circuit and capacitor circuit produces 230V smoothing DC voltage. Input of boost converter is 230V DC boost circuit converts lower voltage into higher voltage such as 230V DC to 400V DC and output boost circuit connected to the input of three phase Multilevel inverter. Multilevel inverter circuit produces three phase five level sinusoidal output voltage.[6]

Driver circuit consist of sinusoidal Pulse width modulation (SPWM) technique can be implemented into Multilevel inverter. Three phase five level sinusoidal output voltage is given to Induction Motor. Speed of Induction Motor can be controlled by using variation of frequency in Pulse width modulation. Sinusoidal Pulse width modulation technique can be implemented to speed control of Induction Motor.

IMPLEMENTATION

Matlab Simulink is used to simulate proposed system by using Simulink library components and basic simulation models in library. Simulation of rectifier circuit basically bridge connection of diodes are used and input of supply voltage given to four diodes and output of rectifier waveforms are verified through by using scope and capacitor filter is designed to reduce ac component in dc voltage and boost circuit designed by using MOSFET switch and inductance values,

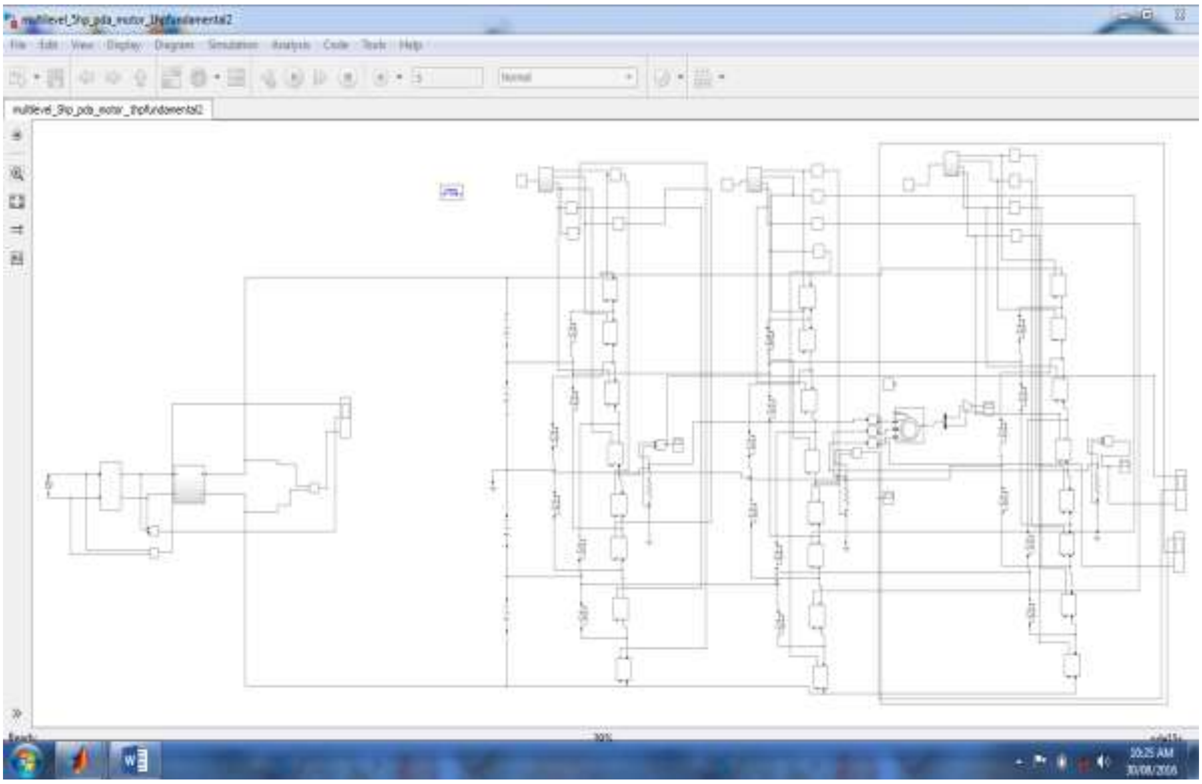

Figure 6 complete simulation diagram of Induction Motor drive using five level Multilevel inverter

Waveforms of rectifier, capacitor filter, and boost circuit voltage waveforms are measured in a scope, output voltage of boost converter can varied by using switching frequency of MOSFET. Output of boost circuit fed to the input of diode clamped five level diode clamped multilevel inverter. Simulation of diode clamped multilevel inverter 24 MOSFET switches, 18 clamping diode, 4 capacitors are arranged in diode clamped topology of multilevel inverter. Output of three phase multilevel inverter is connected to the input of induction motor, speed of induction motor can be controlled by using variable frequency and different speed can be measured by correspondent frequency.

Driver circuit for three phase multilevel inverter, sinusoidal Pulse Width Modulation technique is implemented to generate the gating pulses. These gating pulses are drive to the 24 switches of three phase inverter. Complete proposed system verified through MATLAB Simulink library function and verified in discussion of results.

V. RESULTS AND DISCUSSIONS.

Figure 7 shows the PWM circuit generate the gate signals for the Multilevel inverter switches. To control a three phase Multilevel inverter with an output voltage of five levels; four carrier are generated and compared at each time to wave above zero reference waveforms. Once carrier Above the zero reference and one carrier wave bellow the reference[4]. These carrier are in same frequency, amplitude and phases. The simulated model of SPWM simulation circuit as shown

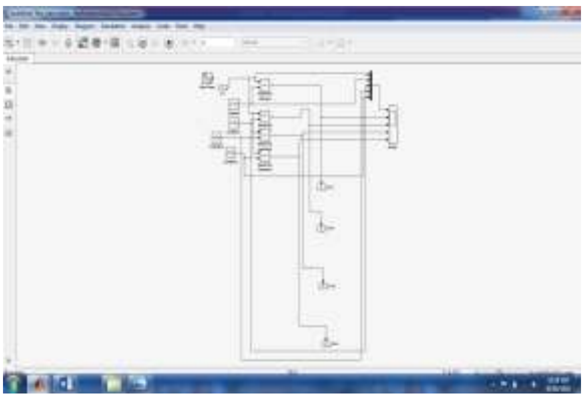

Figure 7 Multicarrier SPWM simulation circuit

In above simulation circuit of sinusoidal Pulse width modulation. In this simulation circuit sinusoidal signal with four reference signals are used, reference signal such as .75 , .25 ,-.75, -.25 these reference signals are compared with sinusoidal signal by using relational operator and finally produces four gating Pulses for different devices. Each leg of inverter have 8 devices. Each device required gating Pulses with help of not gate as shown in complete simulation circuit

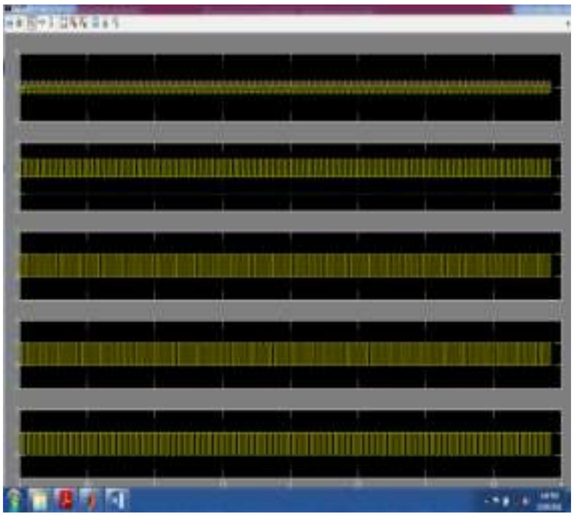

Figure 8 output wave form of SPWM circuit

Figure 8 shows simulation waveforms of sinusoidal Pulse width modulation circuit and generate the gating Pulses for devices. Four different gating Pulses are presented.

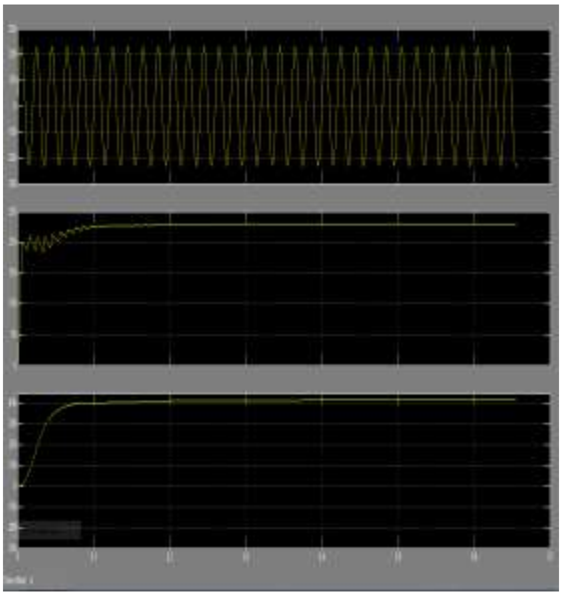

Figure 9 Simulation of rectifier and Boost ciruit waveforms.

Simulation waveform of rectifier and boost circuit are as shown in figure 9. Which Rectifier 230V ac into 230V dc and boosted to 400dc using booster. The simulated waveforms presents of input supply voltage 230v AC , 230V dc, and boost circuit waveforms are presented.

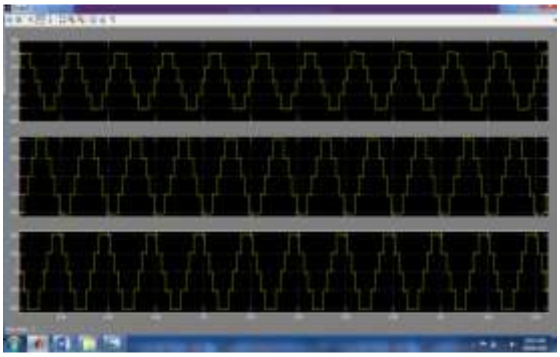

Figure 10 simulation waveform three phase Multilevel inverter with 50Hz.

Simulation waveform of three phase multilevel inverter are as shown above figure 10. Three phase five level waveforms are 120^0 phase shift each other output of three phase multilevel inverter waveforms are connected to Induction Motor these waveforms are to drive the Induction Motor

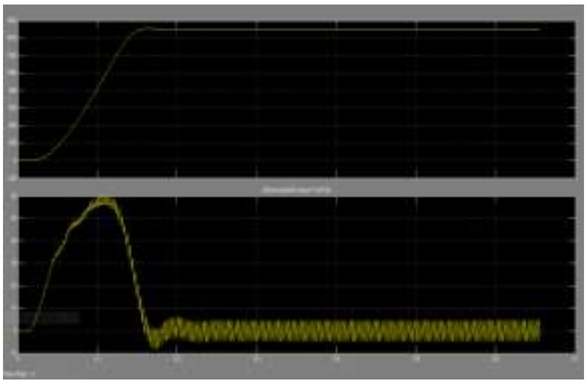

Figure 11 speed-torque curve of Induction Motor with 50 HZ

Speed and torque curve of Induction Motor are as shown in figure 11. Frequency 50hz applied to the Motor. Motor running maximum speed and its required high starting current as shown

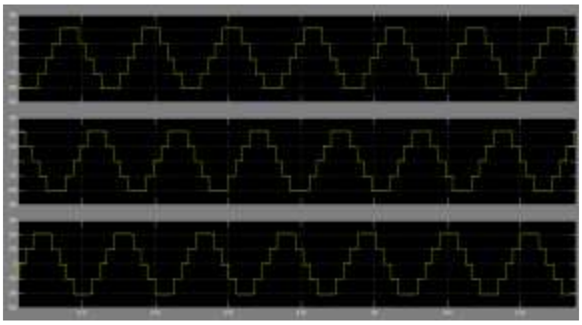

Figure 12 simulation waveform three phase multilevel inverter with 45Hz

Simulation waveform of three phase multilevel inverter as shown above figure 12. Three phase five level waveforms are 120^0 phase shift each other output of three phase multilevel inverter waveforms are connected to Induction Motor these waveforms are drive to the Induction Motor.

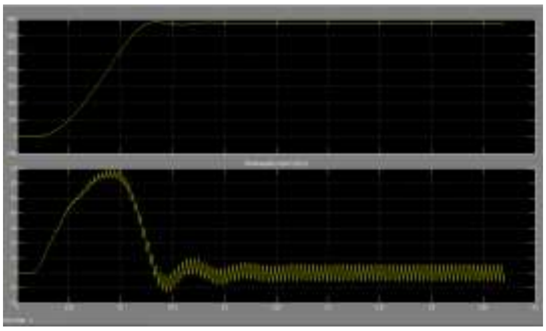

Figure 13 speed-torque curve of Induction Motor with 45 Hz

Speed and torque curve of Induction Motor as shown in figure 13. In this presentation two values of frequency 45 H_z ,50 $H_{z..}$ the corresponding inverter output waveforms and speed of Induction Motor are presented in figure 10,11,12 & 13 respectively, similarly other value of frequency the correspond Motor speed are tabulated in table 2

S.NO	FREQUENCY	SPEED OF INDUCTION MOTOR (RPM)
1	30	900
2	35	1050
3	40	1200
4	45	1380
5	50	1480

Table 2 shows speed of Induction Motor for different frequency

VI. CONCLUSION

In this paper five level diode clamped multilevel inverter has been presented for drive applications and multilevel inverter can be drive for Induction Motor. The multicarrier SPWM technique can be implemented for producing gate Pulses and High quality five-level output voltages are obtained. Speed control of Induction Motor achieved by using variable frequency. The simulation results are effectively controls the speed of Induction Motor and this drive system can be used energy saving in torque load. The proposed system can be used in boiler feed pumps conveyors, rolling mills, printing machines etc .

VII. REFERENCES

[1].Ashwini N.Kadam "Simulation and implementation of Multilevel inverter based Induction Motor drive." International journal of industrial electronics and electrical Engg ISSN 2347-6982 volume-2 Jan-2014. Page no 67-72

[2]. Jose, Steffen and Sernet, Bin Wu, Jorge and Samir Kouro, "Multilevel Voltage–SourceConverter Topologies for Industrial Medium - Voltage Drives," *IEEE Trans on Industrial Electronics,* vol.54 , no.6, Dec 2007. Page no-2930

[3]. Kazunori Hasegawag and, Hirofumi Akagihave "Low speed rated torque operation of a Motor drive using five level diode clamped PWM inverters with frond end rectifier." 8th international conference on power electronics-ECCE Asia May 30-june 2011 Korea Page no .1371-1377.

[4].Engin ozedmir, sule ozedemir, and leon m. Tolbert, "Fundamental frequency modulated six level diode clamped multilevel inverter for three phase standalone photovoltaic system" IEEE Transactions On Industrial Electronics, Vol 56 No.11, November 2009 page no -4407

[5]. S.ebanezar pravin ,and R.narciss starbell "Induction Motordrive using seven level multilevel inverter for energy saving in variable torque load application" ICCCET, 18th & 19th march.2011 Page no 352-357

[6]. Muhammad H..Rashid "power electronics circuits device. And apllications" Pearson Education ISBN 978-81-317-02446-8.

[7]. S. Ogasawara and H. Akagi, "Analysis of variation Of neutral point potential in neutral-point-clamped voltage source PWM inverters," in *Conf.Rec. IEEE IAS Annu. Meeting*, 1993, vol. 2, page no. 965–970

[8] C. Newton, M. Sumner, and T. Alexander, "Multi level converters: A real solution to high voltage drives?" in *Inst. Electr. Eng. (IEE) Colloq. New Power Electron. Tech. Dig.*, no. 1997/091, pp. 3-1–3-5, 1999.

[9] J.S.Lai and F. Z. Peng, "Multilevel converters—A new breed of power converters," *IEEE Trans. Ind. Appl.*, vol. 32, no. 3, pp. 509–517, May/Jun.2002. Page no 2348-2356

[10] Bimal K. Bose: "Modern Power Electronics and AC Drives", PHI, 2002