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HARMONIC ANALYSIS OF MULTI LEVEL INVERTER-FED INDUCTION MOTOR DRIVE

[1] NEELASHETTY KASHAPPA, [2] SHUBHA KULKARNI, [3]MEGHA
[1,2,3]*Faculty, EEE department, Guru Nanak Dev Engineering College, Bidar-585401, Karnataka (state), India*
[1]neelshettyk@gmail.com [2]shuba_kul@yahoo.com [3]meghagndeee2007@gmail.com

ABSTRACT- **This paper deals with harmonic analysis of a nine-level inverter-fed induction motor drive. The performance parameter considered for the analysis includes Total Harmonic Distortion (THD), rotor speed and the efficiency of the the induction motor drive system. Matlab Simulink is used for the simulation of the drive and FFT spectrums for the outputs are analyzed to study the reduction in harmonics. The hardware module is also implemented using embedded controller and the simulation results are compared with experimental results.**

keywords: **Total harmonic distortion, , Induction motor, voltage source inverter, multilevel inverter, matlab simulink**.

I. INTRODUCTION

In many industrial applications Adjustable Speed Drives (ASDs) are playing a dominant role in controlling the speed of conveyor systems, blower speeds and machine tools that requires adjustable speeds. They have a greater impact and playing a major role in revolutionizing the control strategies for various industrial processes. Traditionally, DC motors were the work horses for the adjustable speed drives due to their excellent speed and torque response. But, they have the inherent disadvantage of commutator and mechanical brushes, which undergo wear and tear with the passage of time. In most cases, AC motors are preferred to DC motors, in particular, an induction motor due to its low cost, low maintenance, lower weight, higher efficiency, improved ruggedness and reliability. All these features make the use of induction motors a mandatory in many areas of industrial applications.

The advancement in power electronics and semiconductor technology has triggered the development of high power and high speed semiconductor devices in order to achieve a smooth, continuous and stepless variation in induction motor speed. Applications of solid state converters/inverters for adjustable speed induction motor drives are useful in a large spectrum of industrial systems. Comparison of fundamental and high frequency carrier based techniques for NPC inverters is given by Feng, 2000. Influence of number of stator windings on the characteristics of motor is given by Golubev, 2000. Modified current source inverter-fed induction motor drive is given by Gopukumar, 1984. Multilevel inverter modulation schemes to eliminate common mode voltages is given by Zhang, 2000. Modulation scheme for six phase induction motor is given by Mohapatra, 2002. Improved reliability in solid state AC drives is given by Thomas, 1980. Multilevel converters for large electric drives are given by Peng, 1999. Active harmonic elimination for multilevel inverters is given by Tolbert, 2006. Implementation of multilevel inverter-fed induction motor is given by Reddy, 2008. Comparison of 3-level and 9-level inverter-fed induction motor drives is given by Neelshetty k, 2011. Performance of voltage source multilevel inverter-fed induction motor drive using simulink is given by Neelshetty k, 2011.

In the traditional two-level inverters generation of harmonics and switching losses are the matter of concern. The presence of harmonics distorts the output voltage waveform and makes the motor to suffer from severe torque pulsations, especially at low speed, which manifest themselves in cogging of the shaft. It will also cause undesired motor heating and electromagnetic interference (Shivakumar et al., 2001). The reduction in harmonics calls for large sized filters, resulting in increased size and the cost of the system.

Multilevel approach is believed to be the promising alternative and cost effective solution for high voltage and high power applications. They have drawn tremendous interest in the power industry. Multilevel structure allows to raise the power handling capability of the system in a powerful and systematic way. The advancements in the field of power electronics and microelectronics made it possible to reduce the magnitude of harmonics with multilevel inverters, in which the number of levels of the inverters are increased rather than increasing the size of the filters (Juan Dixon et al., 2006). The performance of multilevel inverters enhances as the number of levels of the inverter increases. In this work, the hardware is implemented using an embedded micro controller and the experimental results are presented.

II. MULTILEVEL INVERTER

Presently industry has begun to demand higher power rating converters with reasonably good efficiency, reduced EMI and less distorted output waveforms. Multilevel voltage source inverter's unique structure allows them to reach high voltage and high currents. Multilevel inverters will significantly reduce the magnitude of harmonics and increases the output voltage and power without the use of step-up transformer. A multilevel inverter consists of a series of H-bridge inverter units connected to three phase induction motor. The general function of this multilevel inverter is to synthesize a desired voltage from several DC sources. The AC terminal voltages of each bridge are connected in series. Unlike the diode clamp or flying-capacitors inverter, the cascaded inverter does not require any voltage clamping diodes or voltage balancing capacitors (Somashekhar et al., 2003). This configuration is useful for constant frequency applications such as active front-end rectifiers, active power filters, and reactive power compensation.

Choosing appropriate conducting angles for the H-bridges can eliminate a specific harmonic in the output waveform (Rashid, 2004). The required conduction angles can be calculated by analyzing the output phase voltage of cascade inverter assuming that four H-bridges have been used, the output voltage V_{ao} can be given as

$$V_{ao} = V_{a1} + V_{a2} + v_{a3} + V_{a4} + V_{a5} \ldots$$

Since the wave is symmetrical along the x-axis, both Fourier coefficient A_0 and A_n are zero. Just the analysis of B_n is required. It is given as

$$B_n = \{[4V_{dc}]/n\pi\}[\sum \mathrm{Cos}\,(n\alpha_1)]$$

J = Number of DC sources.

N = Odd harmonic order.

Therefore, to choose the conducting angle of each H-bridge precisely, it is necessary to select the harmonics with certain amplitude and order, which needs to be eliminated. To eliminate 5th, 7th, and 11th harmonics and to provide the peak fundamental of the phase voltage equal to 80 percent of its maximum value, it needs to solve the following equation with modulation index M=0.8

$$\mathrm{Cos}(5_{\alpha1}) + \mathrm{Cos}(5_{\alpha2}) + \mathrm{Cos}(5_{\alpha3}) + \mathrm{Cos}(5_{\alpha4}) = 0$$
$$\mathrm{Cos}(7_{\alpha1}) + \mathrm{Cos}(7_{\alpha2}) + \mathrm{Cos}(7_{\alpha3}) + \mathrm{Cos}(7_{\alpha4}) = 0$$
$$\mathrm{Cos}(11_{\alpha1}) + \mathrm{Cos}(11_{\alpha2}) + \mathrm{Cos}(11_{\alpha3}) + \mathrm{Cos}(11_{\alpha4}) = 0$$
$$\mathrm{Cos}(\alpha_1) + \mathrm{Cos}(\alpha_2) + \mathrm{Cos}(\alpha_3) + \mathrm{Cos}(\alpha_4) = 0.8*4$$

In this case, one of the very efficiently used control strategies is the space vector based control, which can be implemented using digital signal processor. Harmonic reduction technique for a cascade multilevel inverter is given by Jagadish Kumar, 2009. Low harmonic single phase multilevel inverter is given by Bashi, 2008. Literature [1] to [18] does not deal with embedded implementation of 9-level inverter system. This work compares experimental results with simulation results

III. SIMULATION RESULTS

The per phase circuit model of cascaded 9 level inverter with induction motor load is Fig 1a. In this figure the induction motor is represented using the equivalent circuit. Driving pulses given to M_1 and M_3 are shown in Fig 1b. The output voltage of main bridge inverter is shown in shown in Fig 1c. The output voltage of auxiliary bridge inverter is shown in shown in Fig 1d. The output voltage of 9 level iverter is shown in shown in Fig 1e. it can be seen that the output has 9 levels. The single phase output current is shown in Fig 1f. Speed response of the induction motor drive is shown in Fig 1g. The rotor speed increases and settles at 1485 rpm. The frequency spectrums for the stator voltage of 9-level inverter is shown in Fig 1h. The voltageTHD in 9-level inverter is found to be 5.86 percent. The frequency spectrums for the stator current of 9-level inverter is shown in Fig 1i. The current THD in 9-level inverter is found to be 3.71 percent.

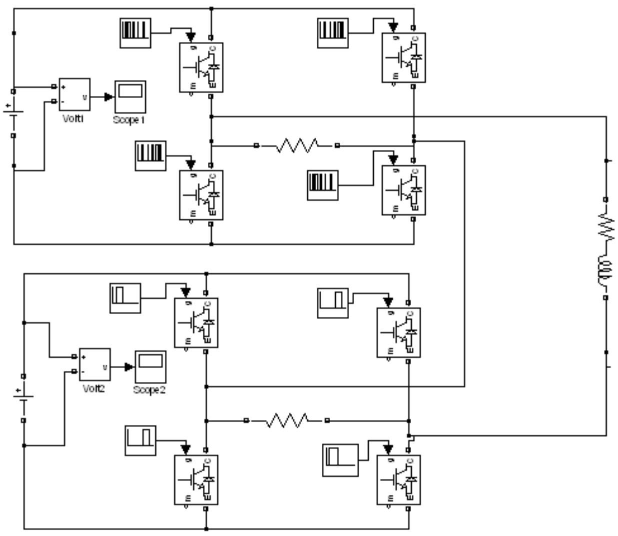

Fig 1a. Single phase structure of 9-Level inverter with induction motor load

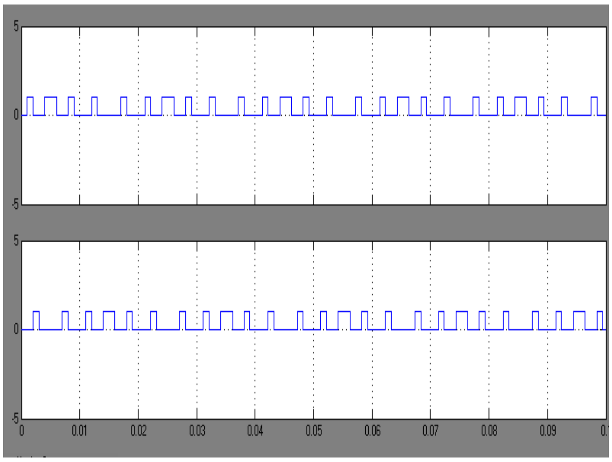

Fig 1b. Driving pulses for M_1 & M_3 of 9 level inverter

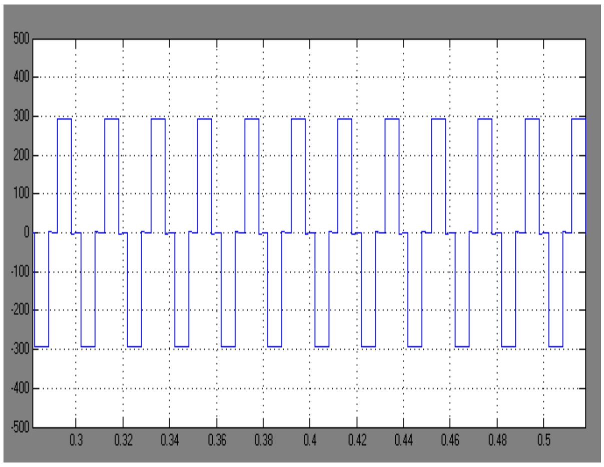

Fig 1c. Main bridge inverter output voltage of 9 level inverter

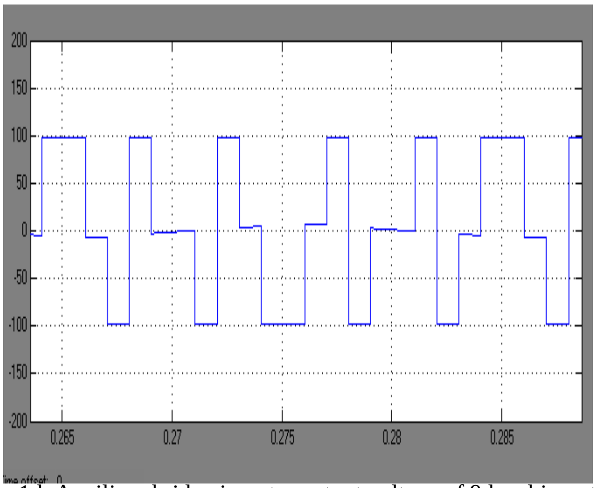

Fig 1d. Auxiliary bridge inverter output voltage of 9 level inverter

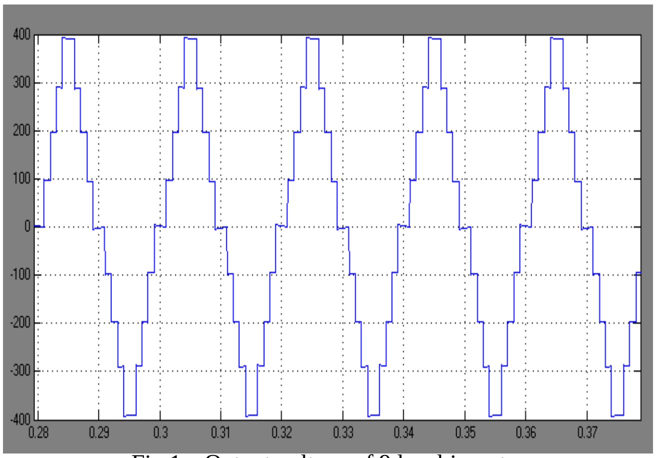

Fig 1e. Output voltage of 9 level inverter

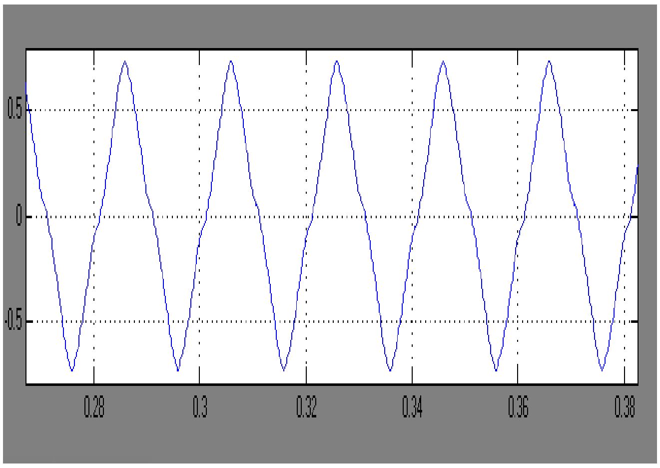

Fig 1f. Output current of 9 level inverter

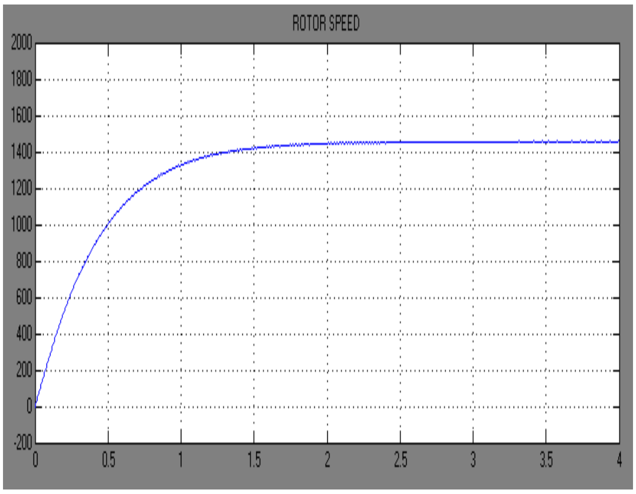

Fig 1g. Rotor speed of 9 level inverter in rpm

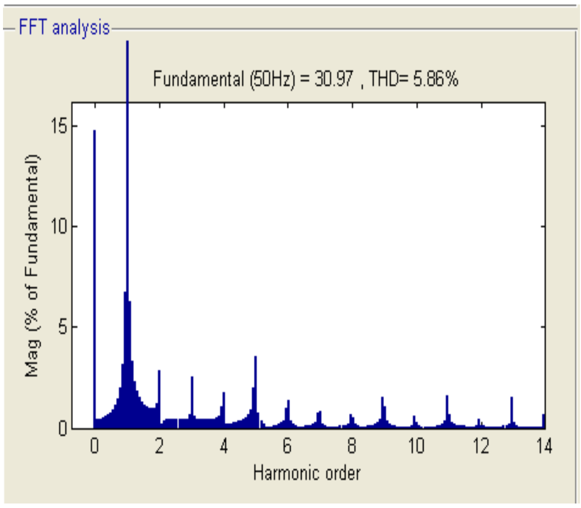

Fig 1h. FFT spectrum for stator voltage of 9-level inverter

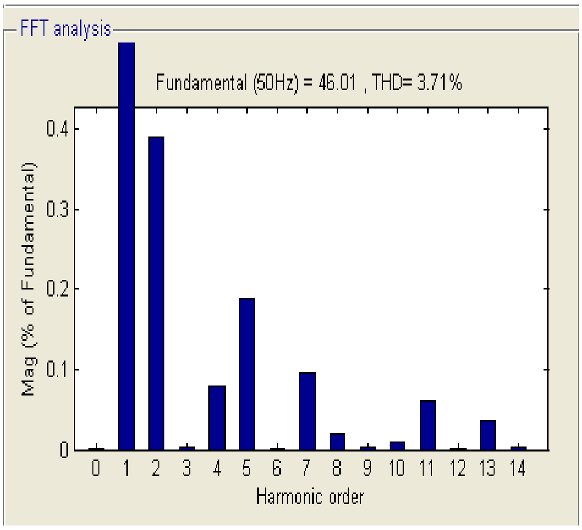

Fig 1i.. FFT spectrum for stator current of 9-level Inverter

IV. HARDWARE IMPLEMENTATION

The hardware is fabricated and tested. Top view of the hardware is shown in Fig 2a.The hardware consists of micro controller module, pulse amplifier module and IGBT module. Driving pulse for M_1 is shown in fig 2b and and the driving pulse for M_3 is shown in Fig 2c. Output voltages of main bridge inverter is shown in Fig 2d and output voltage of auxiliary bridge inverter is shown in Fig 2e. The output voltage of nine level inverter is shown in Fig 2f. The experimental values of voltage THD and current THD of 9 level inverter fed induction motor drive system are 4.91 and 3.58 respectively.


Fig 2a. Hardware snap shot of 9 level inverter

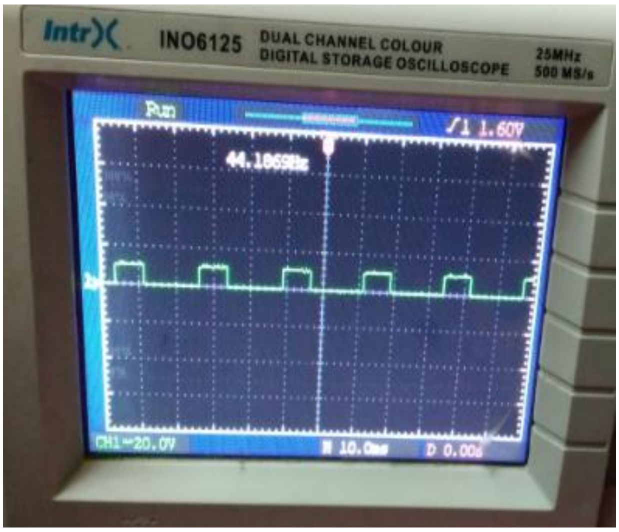

Fig 2b.Switching pulse for M_1 of 9 level inverter

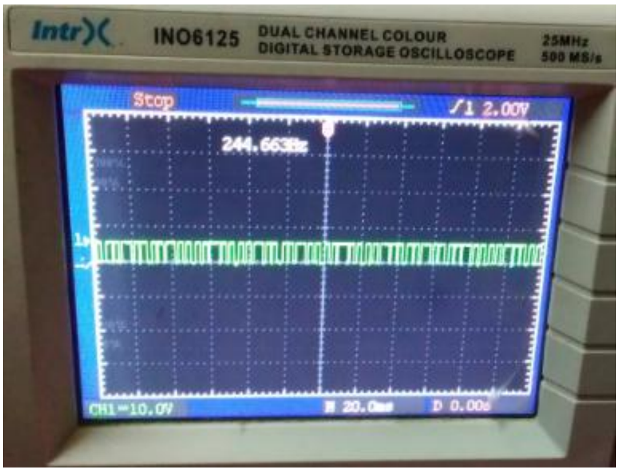

Fig 2c.Switching pulse for M_3 of 9 level inverter

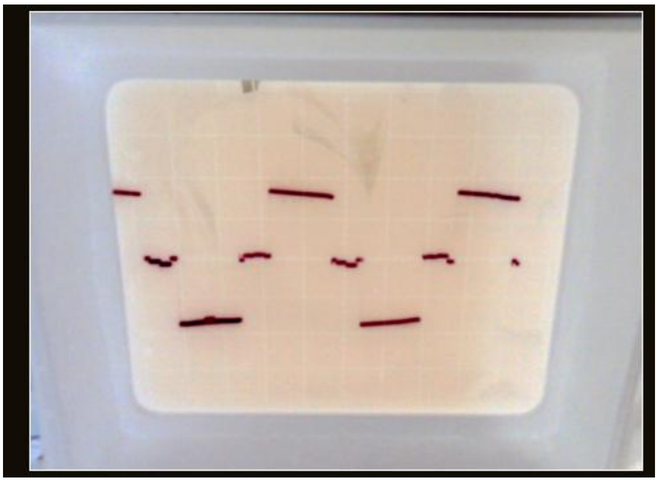

Fig 2d. Output voltage of main bridge of 9 level Inverter

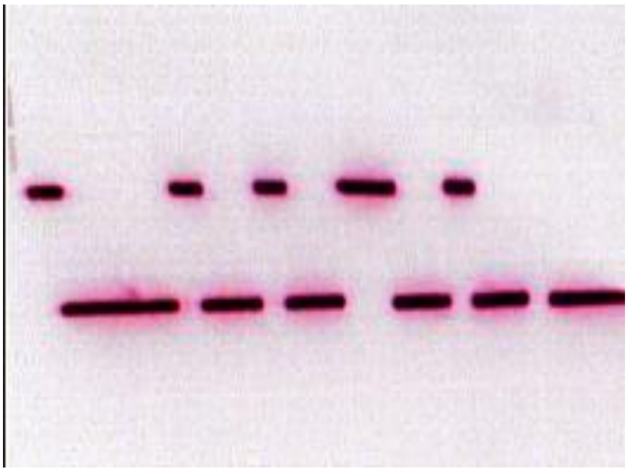

Fig 2e. Output voltage of auxiliary bridge of 9 level inverter

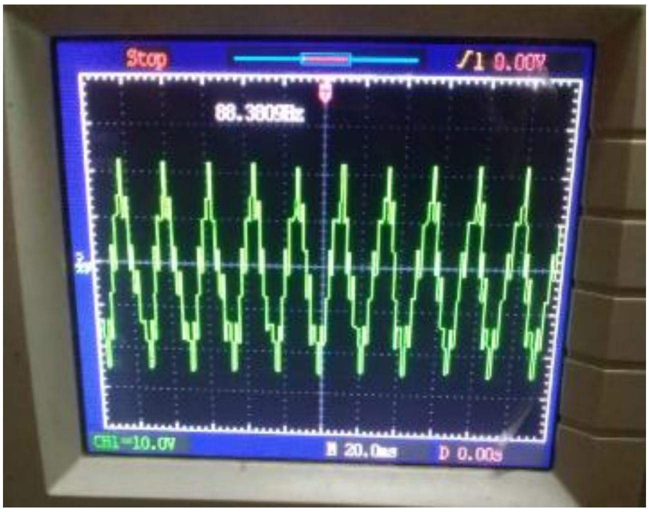

Fig 2f. Output voltage of 9-level inverter

V. CONCLUSION

Nine-level inverter-fed induction motor drive is designed, modeled and simulated using the blocks of simulink. The results of stator voltage, stator current, rotor speed and FFT spectrums are presented. A laboratory prototype of nine level inverter system is fabricated and tested to validate the simulation results. By the laboratory test the efficiency of nine level inverter fed induction motor is found to be 84.58 percent and rotor speed is found to be 1485 rpm. The experimental values of voltage THD and current THD of 9 level inverter system are 4.91 and 3.58 percent respectively. These values are well within the limits imposed by IEEE-519 standards. As the total harmonic distortion produced by the 9-level inverter system is less the heating due to 9-level inverter system will be less. The simulation and experimental results of 9 level inverter fed induction motor drive system indicate that it is most effective and efficient system. Therefore a nine level cascaded inverter with unequal DC sources is propsed in industries where adjustable speed drives are required to produce output with reduced harmonic content.

REFERENCES

1. Chunmei Feng and Vassilions G Agelidis (2000) *On the Comparison of fundamental and High frequency Carrier based techniques for multilevel NPC Inverters*. IEEE PES Conf. 2, 520-525.
2. Golubev AN and Ignatenko SV(2000) *Influence of number of stator winding phases on noise characteristic of an asynchronous motor*. Russian Electrical Engg. 71(6)41- 46.
3. Gopukumar K, Biswas SK, Satishkumar S and Joseph Vithyanthil (1984) *Modified current source inverter-fed induction motor drive with reduced torque pulsation*. IEEE Proc. 313 (4), 150-164.
4. Haoran Zhang, Annette Von Hounne, Shaoan Dai et al.(2000) *Multilevel inverter Modulation schemes to Eliminate Common Mode Voltages*. IEEE Transactions on Industry Applications 36, 1645-1653.
5. Juan Dixon and Luis Moran (2006) *High-Level Multi-step Inverter Optimization Using a Minimum Number of Power Transistors*. IEEE Trans on Power Electronics. 21, (2), 330-337.
6. Mohapatra. KK, Gopukumar K, Somashekhar VT and Umanand L (2002), *A Modulation scheme for six phase induction motor with an open-end winding*. 25th Annual Conference IECON 02 Spain. pp: 810-815.
7. Muhammad H Rashid (1996) *Power Electronics Circuits Devices and Applications.* Second Edition, PHI, New Delhi. pp: 566 – 572.
8. Shivakumar E.G, Gopukumar K, Sinha S.K and Ranganathan V.T (2001) *Space vector PWM control of dual inverter fed open-end winding induction motor drive*. IEEE APEC Conf. 1, 399-405.
9. Somashekhar V.T and Gopukumar K (2003) *Three level inverter configuration cascading two two-level inverter*.
10. Thomas M Jahns (1980) *Improved reliability in solid state ac drives by means of multiple independent phase drive units*. IEEE Transactions on Industrial Applications. 16 (3), 321-331.
11. Tolbert L, Peng F and Habetler T (1999) *Multilevel converters for large electric drives.* IEEE Transactions on Industrial Applications. 35 (1), 497-505.
12. Zhong DuLeon, M. Tolbert, and John N. Chiasson, (2006) *Active Harmonic Elimination for Multilevel Converters*. IEEE Transactions on Power Electronics. 21 (2), 459-469.
13. G. Pandian and Ramesh Reddy (2008) *on the implementation of multilevel inverter-fed induction motor Drive*. Journal of Industrial Technology. 24(2), 79-85.
14. M. G. Hosseini Aghdam, S. H. Fathi and G. B. Gharehpetian (2009) *on the modified harmonic elimination method with a wide range of modulation indices for multilevel inverter with unequal DC sources*. Latin American Applied research. 39(!), 65-74.
15. Jagadish kumar, Biswarup Das and Pramod Agarwal (2009) *on the Harmonic reduction Technique for a cascade multilevel inverter*. International Journal 0f Recent Trends in Engineering. Vol 1, Number 3.
16. S.M.Bashi, N. Mariun, N. F. Alhalali (2008) *on low harmonic single phase multilevel power inverter.* Asian journal of Scientific Research. Vol 1, issue 3, 274-280.
17. Neelshetty k, Ramesh Reddy K (2011) *on comparison of 3-level and 9-level Inverter-fed Induction motor drives*. Research Journal of Applied Sciences, Engineering and Technology, 3(2): 123-131
18. Neelshetty k, Ramesh Reddy K (2011) *on Performance of Voltage Source Multilevel Inverter-fed Induction Motor Drive using simulinkS.* ARPN Journal of Engineering and Applied Sciences, Vol 6, No 6, pp:50-57.