Research Journal of Applied Sciences, Engineering and Technology 3(2): 123-131, 2011
ISSN: 2040-7467

Received: August 23, 2010 Accepted: January 27, 2011 Published: February 20, 2011

Comparison of 3-Level and 9-Level Inverter-Fed Induction Motor Drives

[1]Neelashetty Kashappa and [2]K. Ramesh Reddy
[1]EEE Department, GND Engineering College, Bidar-585401, Karnataka, India
[2]EEE Department, GNITS, Shaikpet, Hyderabad - 500 008, Andhra pradesh (state), India

Abstract: This study deals with comparison of 3-level inverter- fed induction motor drive with 9-level inverter-fed induction motor drive. A conventional Voltage Source Inverter (VSI) fed induction motor drive is modelled and simulated using matlab simulink and the results are presented. 9-level inverter is also simulated and the corresponding results are presented. The FFT spectrums for the outputs are analyzed to study the reduction in the harmonics.

Key words: Induction motor, matlab simulink, multilevel inverter, voltage source inverter

INTRODUCTION

Adjustable Speed Drives (ASDs) are the essential and endless demand of the industries and researchers. They are widely used in the industries to control the speed of conveyor systems, blower speeds, machine tool speeds and other applications that require adjustable speeds. In many industrial applications, traditionally, DC motors were the work horses for the Adjustable Speed Drives (ASDs) 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 motor speed. Applications of solid state converters/inverters for adjustable speed induction motor drive are wide spread in electromechanical systems for a large spectrum of industrial systems. Comparision of fundamental and high frequency carrier based techniques for NPC inverters is given by Feng and Vassilions (2000). Influence of number of stator windings on the characteristics of motor is given by Golubev and Ignatenko (2000). Modified CSI-fed induction motor drive is given by Gopukumar *et al*. (1984). Multilevel inverter modulation schemes to eliminate common mode voltage is given by Zhang *et al*. (2000). Modulation scheme for six phase induction motor is given by Mohapatra *et al*. (2002). Improved reliability in solid state ac drives is given by Thomas (1980). A multilevel converter for large electric drives is given by Tolbert *et al*. (1999). Active harmonic elimination for multilevel inverters is given by DuLeon *et al*. (2006). Implementation of multilevel inverter-fed induction motor is given by Pandian and Reddy (2008).

The poor quality of output current and voltage of an induction motor fed by a classical two-level inverter is due to the presence of harmonics. The presence of significant amount of harmonics makes the motor to suffer from severe torque pulsations, especially at low speed, which manifest themselves in cogging of the shaft. It will also causes 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.

Nowadays multilevel inverters are the promising alternative and cost effective solution for high voltage and high power applications including power quality and motor drive problems. Multilevel structure allows raising 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 (Dixon and Moran, 2006). The performance of multilevel inverters enhances as the number of levels of the inverter increases. In this paper the harmonic content of a 3-level inverter is compared with a 9-level inverter and it is found that the Total Harmonic Distortion (THD) of a 9-inverter is less and is lower than that of a 3-level inverter.

Corresponding Author: Neelashetty Kashappa, EEE Department, GND Engineering College, Bidar-585401, Karnataka, India

MULTILEVEL INVERTER

Multilevel inverters have drawn tremendous interest in the power industry. They present a new set of features that are well suited for use in reactive power compensation. 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 and Gopukumar, 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:

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

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:

$$B_n = \{[4V_{dc}]/n\pi\}[\sum_{j=1}^{\infty} Cos(n\alpha_1)]$$

where
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% of its maximum value, it needs to solve the following equation with modulation index M = 0.8:

$$Cos(5_{\alpha 1}) + Cos(5_{\alpha 2}) + Cos(5_{\alpha 3}) + Cos(5_{\alpha 4}) = 0$$
$$Cos(7_{\alpha 1}) + Cos(7_{\alpha 2}) + Cos(7_{\alpha 3}) + Cos(7_{\alpha 4}) = 0$$
$$Cos(11_{\alpha 1}) + Cos(11_{\alpha 2}) + Cos(11_{\alpha 3}) + Cos(11_{\alpha 4}) = 0$$
$$Cos(\alpha_1) + Cos(\alpha_2) + Cos(\alpha_3) + Cos(\alpha_4) = 0.8*4$$

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 *et al*. (2009). Low harmonic single phase multilevel inverter is given by Bashi *et al*. (2008). Literature review does not deal with comparison of 3-level inverter with 9-level inverter system. This work

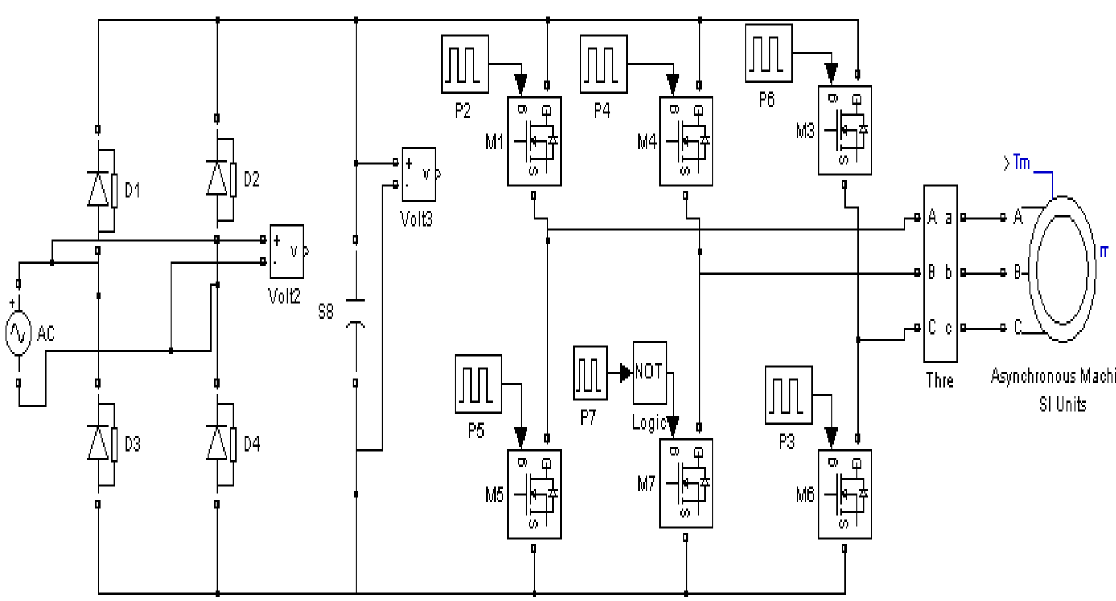

Fig. 1a: Vsi- fed induction motor drive

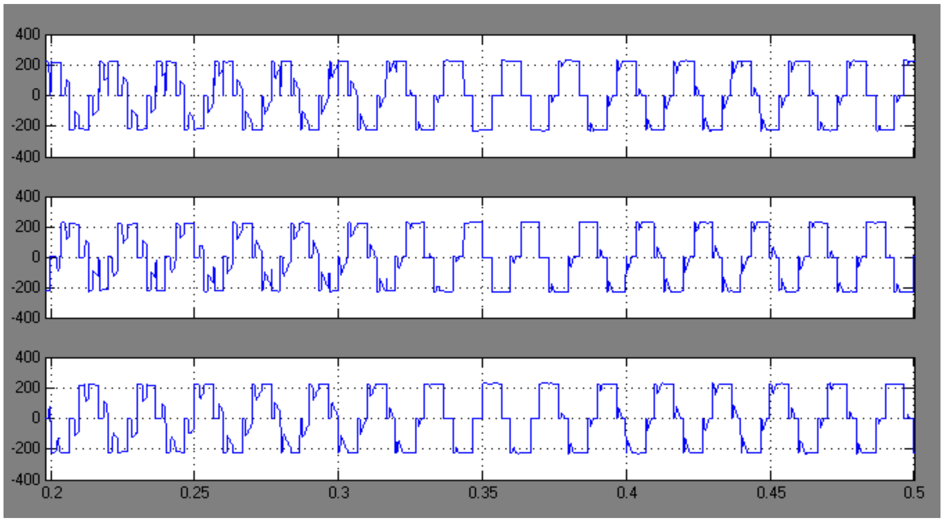

Fig. 1b: Phase voltage waveforms

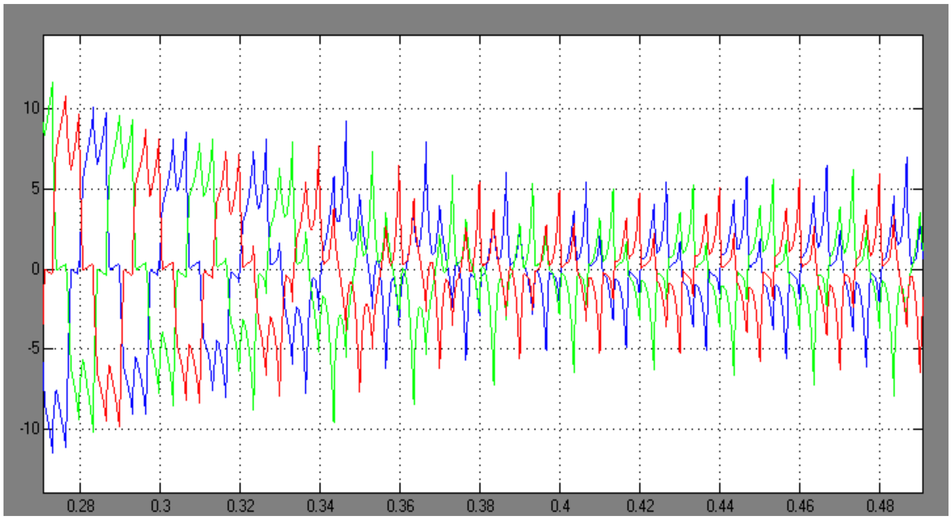

Fig. 1c: Stator current waveforms

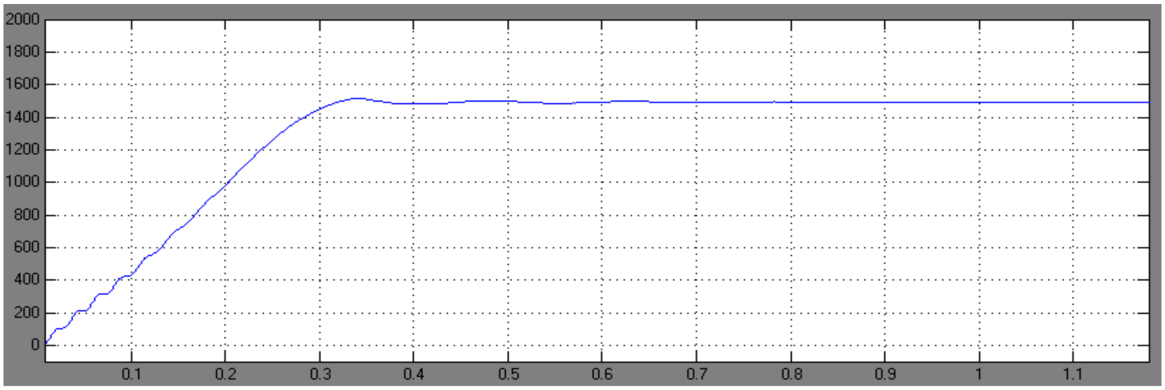

Fig. 1d: Rotor speed in rpm

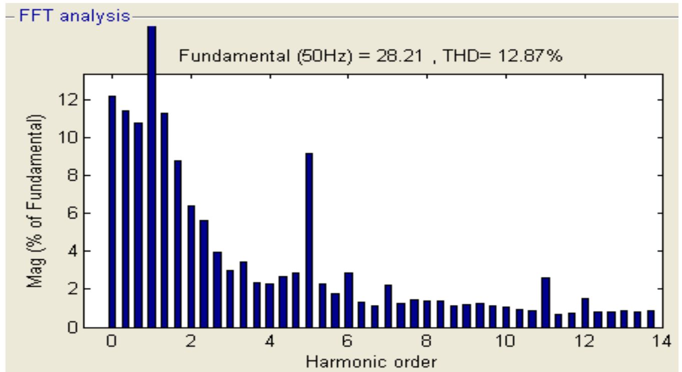

Fig. 1e: FFT analysis for the current

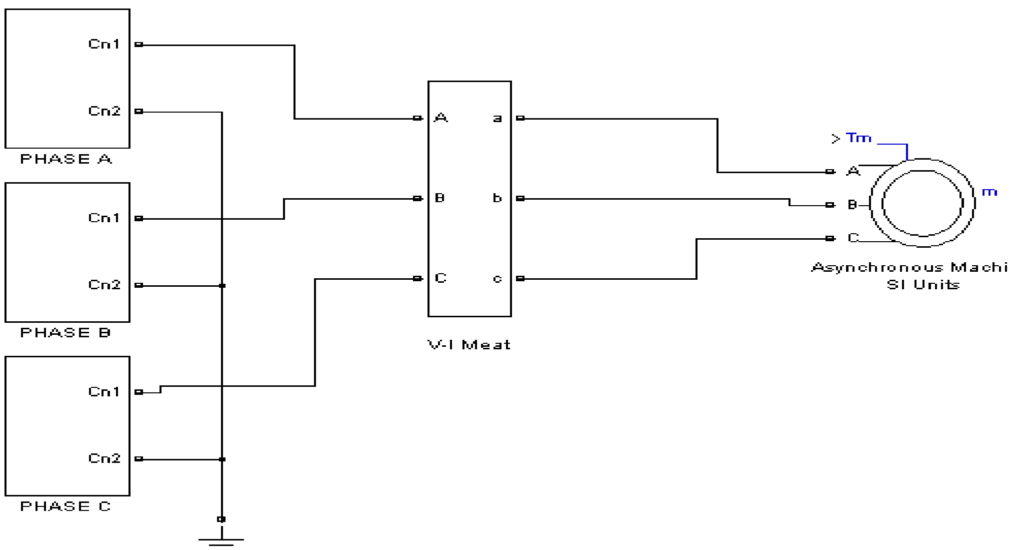

Fig. 2a: Three phase multilevel inverter fed induction motor

compares 3-level inverter fed induction motor with 9-level inverter fed induction motor.

SIMULATION RESULTS

Inverter-fed induction motor drive: VSI fed induction motor drive is shown in Fig 1a. The diode rectifier with capacitive filter acts as the voltage source. Three phase inverter operating in 120^0 mode is used to feed the induction motor drive. Phase voltage waveforms are shown in Fig 1b and the stator phase currents are shown in Fig 1c. Variation in the speed is shown in Fig 1d. The speed increases and settles at 1470 rpm. FFT analysis is done for the current and the corresponding spectrum is shown in Fig 1e. It can be seen that the magnitude of fundamental current is 28 Amperes. The total harmonic distortion is 12.8%.

Multilevel inverter fed induction motor drive is shown in Fig 2a. The circuit elements of one phase of the inverter are shown in Fig. 2b. The firing pulses given to the second inverter are displaced by 36º with respect to the firing pulses given to the first inverter. Phase voltages are shown in the Fig. 2c. The stator currents are shown the Fig. 2d. The variation in rotor speed is shown in the Fig. 2e. The magnitude spectrum for the stator current is shown in the Fig. 2f. It can be seen that the THD value is 7.4%. Therefore the THD is reduced by 42%. From the spectrum, it can be seen that the amplitude of low frequency components are higher than the high frequency components.

Nine level inverter-fed induction motor drive: Block diagram of 9-level three phase inverter fed induction motor drive is shown in Fig. 3a. The induction motor is

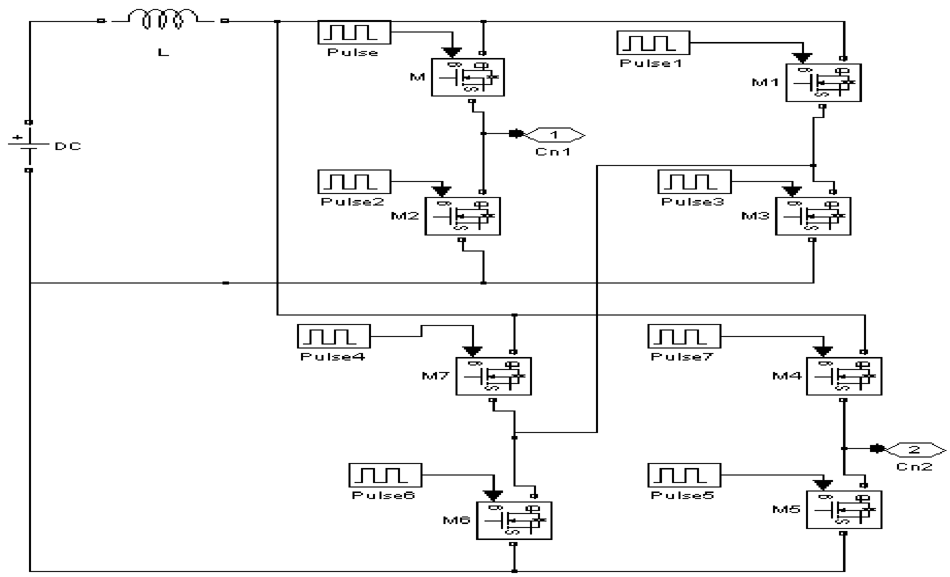

Fig. 2b: Circuit for one phase

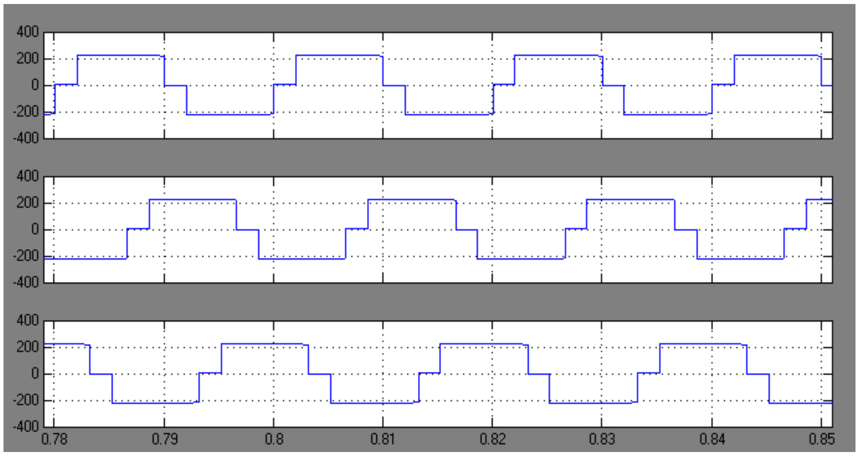

Fig. 2c: Phase voltages waveforms

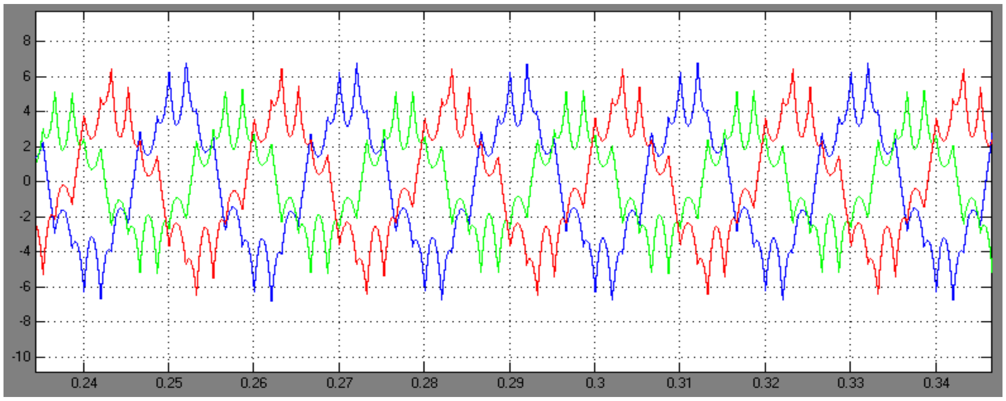

Fig. 2d: Stator current waveforms

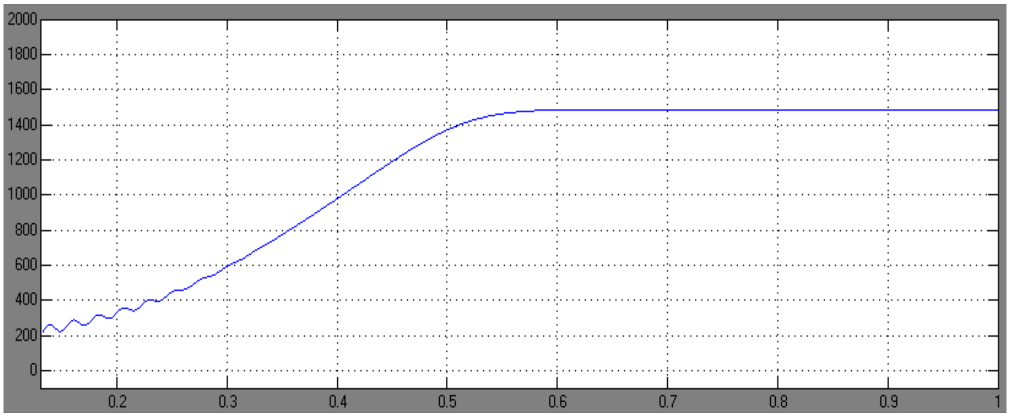

Fig. 2e: Rotor speed in rpm

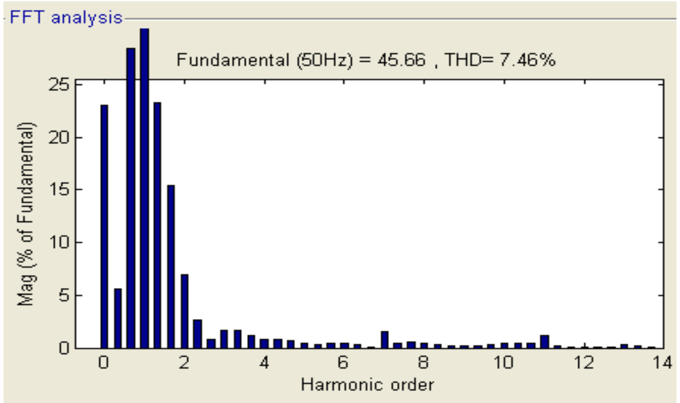

Fig. 2f: FFT analysis for stator current

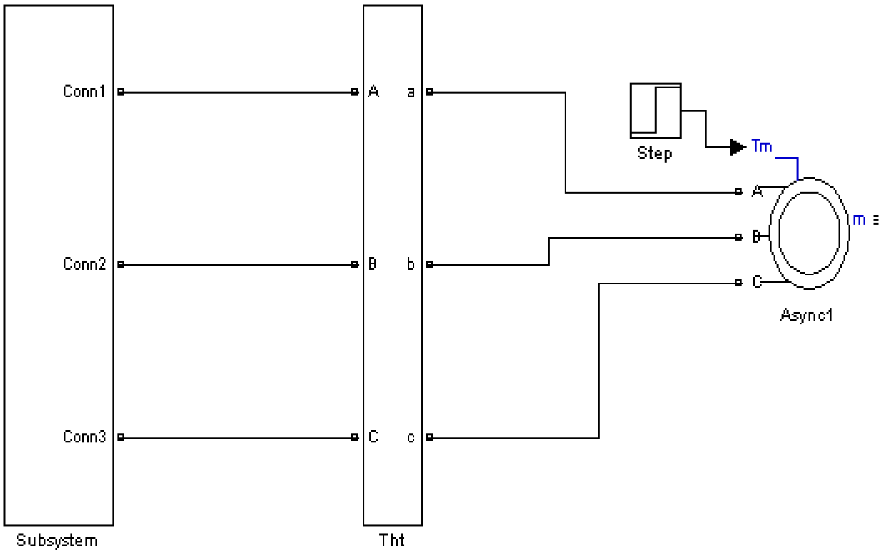

Fig. 3a: 9-level inverter-fed induction motor

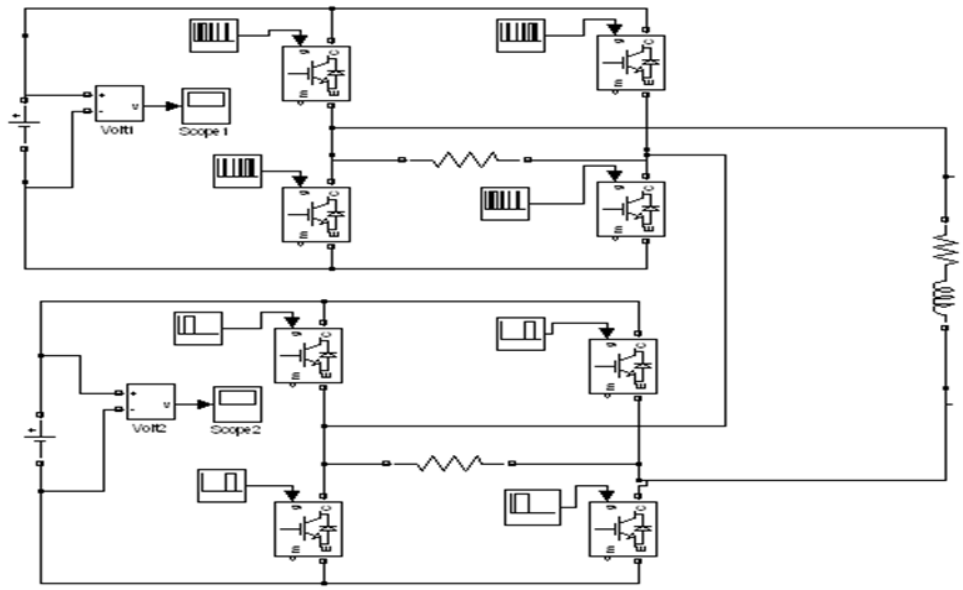

Fig. 3b: 9-level inverter

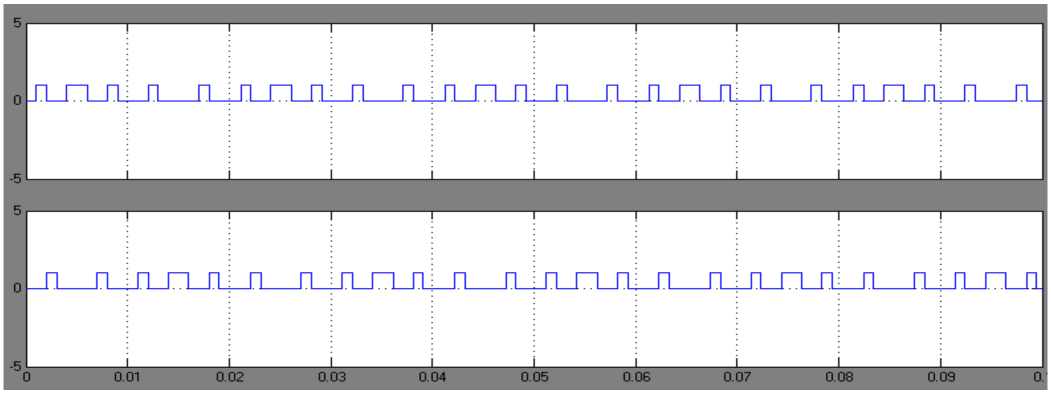

Fig. 3c: Driving pulses for S_1 and S_2

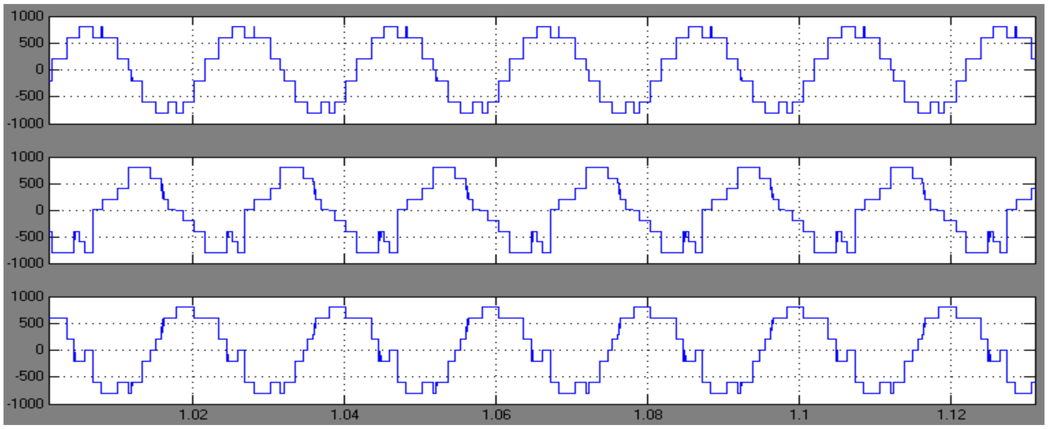

Fig. 3d: Output voltage waveforms

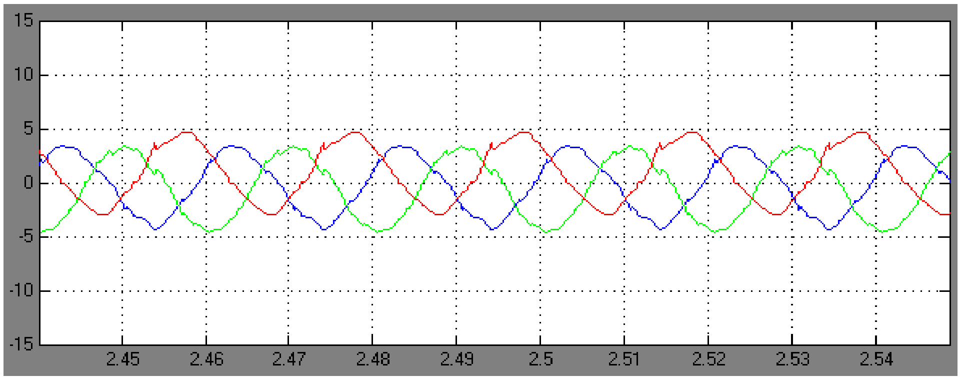

Fig. 3e: Stator current waveforms

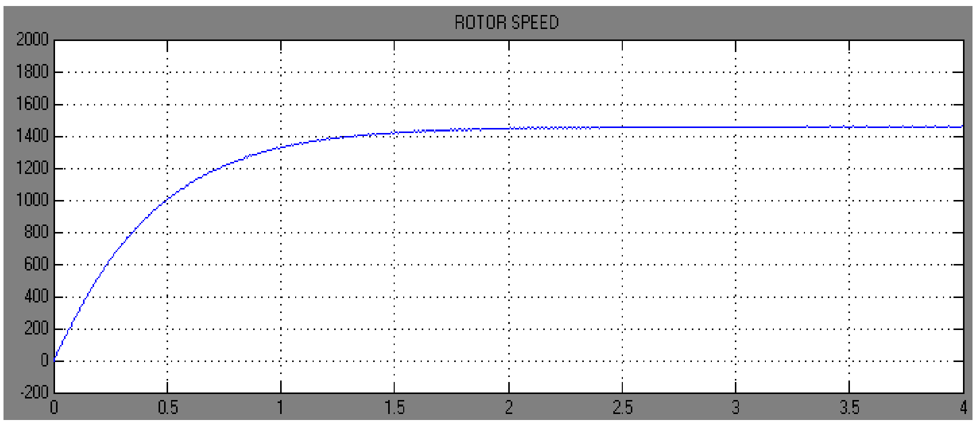

Fig. 3f: Rotor speed in rpm

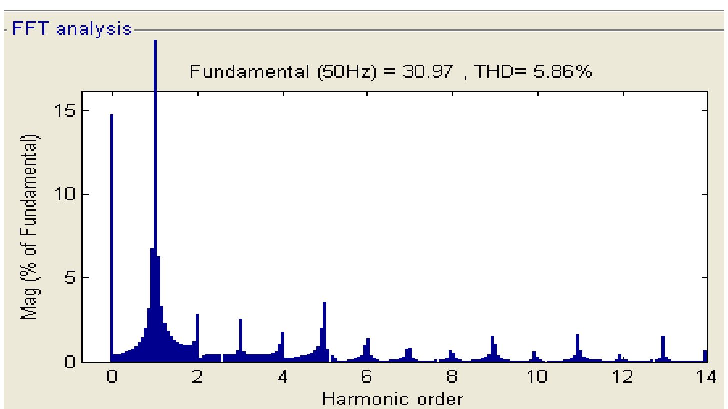

Fig. 3g: FFT analysis for 9-level inverter

fed from 9-level inverter. The circuit of 9-level inverter is shown in Fig. 3b. Driving pulses given s_1 and s_2 are shown in Fig. 3c. The output voltage waveforms of the inverter are shown in Fig. 3d. The stator current waveforms are shown in Fig. 3e. Speed response of the induction motor drive is shown in Fig. 3f. The rotor speed increases and settles at1470 rpm. The frequency spectrum for the output of 9-level inverter is shown in Fig. 3g. The THD in 9-level inverter is found to be 5.8% and hence it is reduced by 27% as compared to 3-level inverter system.

CONCLUSION

9-level and 3-level inverter-fed induction motor drive are simulated using the blocks of simulink. The results of multilevel inverter systems are compared with the results of VSI based drive system. It is observed that the total harmonic distortion produced by the 9-level inverter system is less than that of a 3-level VSI fed drive system. Therefore the heating due to 9-level inverter system is less than that of a 3-level VSI fed drive system. The simulation results of voltage, current, speed and spectrum are presented. This drive system can be used in industries where adjustable speed drives are required to produce output with reduced harmonic content. The scope of this work is the modeling and simulation of 3-level and 9-level inverter and VSI fed induction motor drive systems. Experimental investigations will be done in future. 9-level inverter system is a viable alternative since it has better performance than the 3-level inverter system.

ACKNOWLEDGEMENT

The experimental study was done at power electronics lab, JNTU, Hyderabad during 2009-2010. The authors would like to thank the HOD, electrical and electronics engineering department of JNTU Hyderabad for providing the facilities.

REFERENCES

Bashi, S.M., N. Mariun and N.F. Alhalali, 2008. On low harmonic single phase multilevel power inverter. Asian J. Sci. Res., 1(3): 274-280.

Dixon, J. and L. Moran, 2006. High-level multi-step inverter optimization using a minimum number of power transistors. IEEE Tran. Power Electron., 21(2): 330-337.

DuLeon, Z., M. Tolbert and J.N. Chiasson, 2006. Active Harmonic Elimination for Multilevel Converters. IEEE Tran. Power Electron., 21(2): 459-469.

Feng, C. and G.A. Vassilions, 2000. On the Comparison of fundamental and high frequency Carrier based techniques for multilevel NPC Inverters. IEEE PES Conf., 2: 520-525.

Golubev, A.N. and S.V. Ignatenko, 2000. Influence of number of stator winding phases on noise characteristic of an asynchronous motor. Russ. Electr. Eng., 71(6): 41-46.

Gopukumar, K., S.K. Biswas, S. Satishkumar and V. Joseph 1984. Modified current sourceinverterfed induction motor drive with reduced torque pulsation. IEE Proc., 313(4): 150-164.

Jagadish, K., D. Biswarup and A. Pramod, 2009. On the harmonic reduction technique for a cascade multilevel inverter. Int. J. Recent Trends Eng., 1(3).

Mohapatra, K.K., K. Gopukumar, V.T. Somashekhar and L. Umanand, 2002. A Modulation scheme for six phase induction motor with an open-end winding. 25th Annual Conference IECON 02 Spain, pp: 810-815.

Pandian, G. and R. Reddy, 2008. On the implementation of multilevel inverter-fed induction motor drive. J. Indus. Technol., 24(2): 79-85.

Rashid, M.H., 1996. Power Electronics Circuits Devices and Applications. 2nd Edn., PHI, New Delhi, pp: 566-572.

Shivakumar, E.G., K. Gopukumar, S.K. Sinha and V.T. Ranganathan, 2001. Space vector PWM control of dual inverter fed open-end winding induction motor drive. IEEE APEC Conf., 1: 399-405.

Somashekhar, V.T. and K. Gopukumar, 2003 Three level inverter configuration cascading two two-level inverter. IEE Proc. Elect. Power Appl., 150(3): 986-993.

Thomas, M.J., 1980. Improved reliability in solid state ac drives by means of multiple independent phase drive units. IEEE Trans. Ind. Appl., 16(3): 321-331.

Tolbert, L., F. Peng and T. Habetler, 1999. Multilevel converters for large electric drives. IEEE Tran. Indus. Appl., 35(1): 497-505.

Zhang, H., A.V. Jouanne, D. Shaoan, A.K. Wallace and F. Wang, 2000. Multilevel inverter modulation schemes to eliminate common mode voltages. IEEE Tran. Indus. Appl., 36: 1645-1653.