THD REDUCTION IN NINE LEVEL INVERTER-FED INDUCTION MOTOR DRIVE

NEELASHETTY KASHAPPA
Faculty, EEE department, Guru Nanak Dev Engineering College, Bidar Karnataka-585401, India.

ABSTRACT: This paper deals with Total Harmonic Distortion (THD) reduction in nine-level inverter-fed induction motor drive. Nine-level voltage source inverter-fed induction motor drive is modeled and simulated using matlab simulink and the results are presented. The FFT spectrums for the outputs are analyzed to study the reduction in harmonics. The hardware is implemented and the results are presented. The experimental results are compared with the simulation results.

Keywords: THD, Induction motor, Voltage source inverter, multilevel inverter, Matlab Simulink.

1. 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.

2. 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;

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

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

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

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.

3. SIMULATION RESULTS OF NINE LEVEL INVERTER SYSTEM

Block diagram of 9-level three phase inverter-fed induction motor drive is shown in Figure 1. The induction motor is fed from 9-level inverter. The circuit of 9-level inverter is shown in Figure 2. Driving pulses given to the switching devices are shown in Figure 3. The output voltage waveforms of the inverter are shown in Figure 4. The stator current waveforms are shown in Figure 5. Speed response of the induction motor drive is shown in Figure 6. The rotor speed increases and settles at 1470 rpm. The frequency spectrum for the output of 9-level inverter is shown in Figure 7. The THD in 9-level inverter is found to be 5.8 percent.

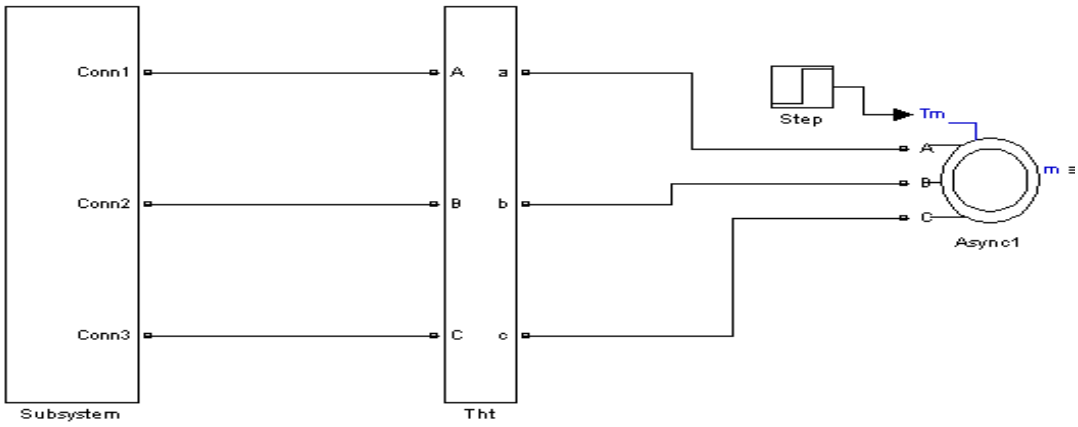

Figure 1. Block diagram of Nine Level inverter-fed induction motor

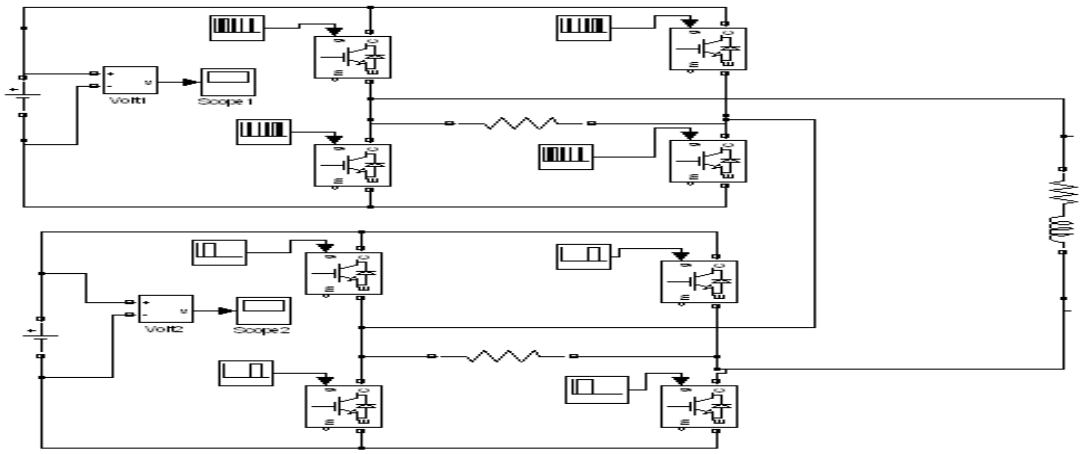

Figure 2. Nine Level Inverter

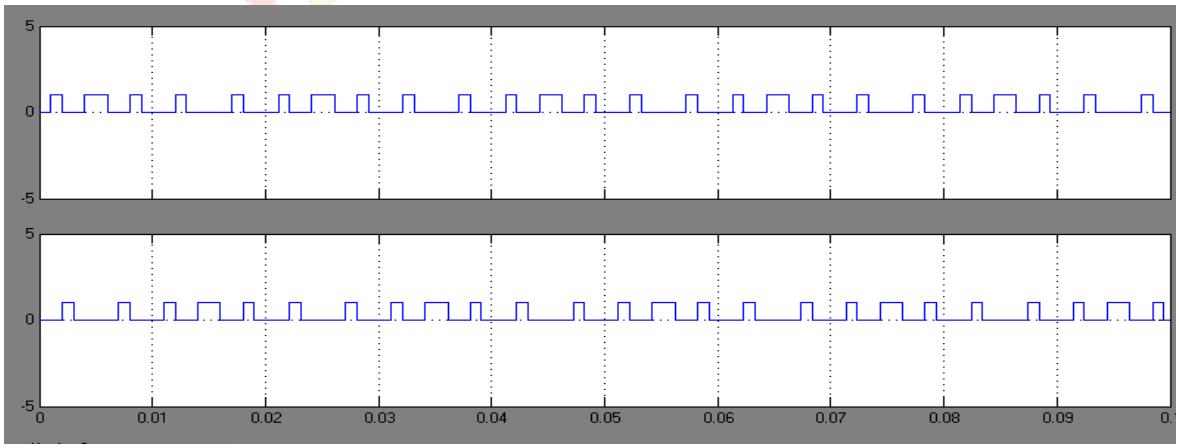

Figure 3. Driving pulses for switching devices

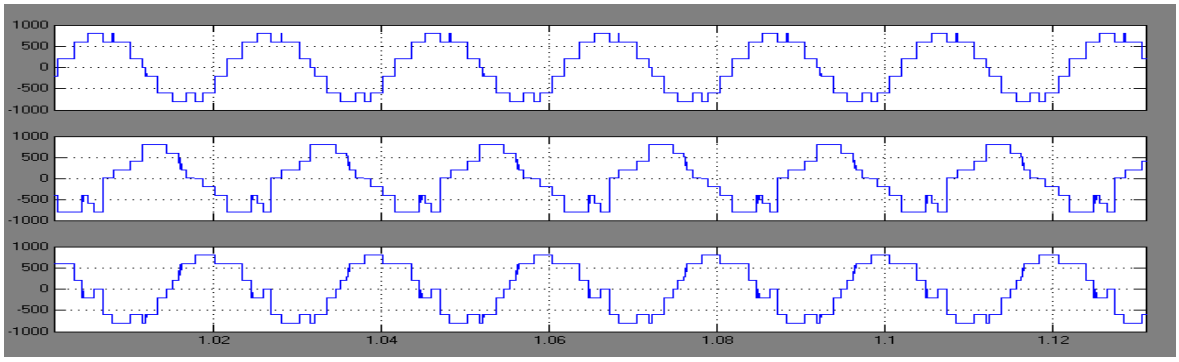

Figure 4 .Output voltage waveforms of nine level inverter system

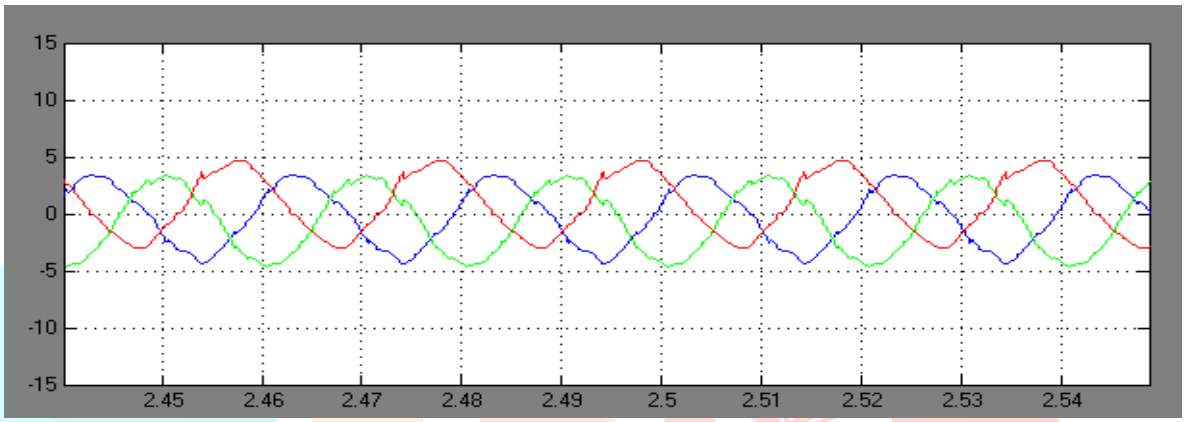

Figure 5. Stator current waveforms of nine level inverter system

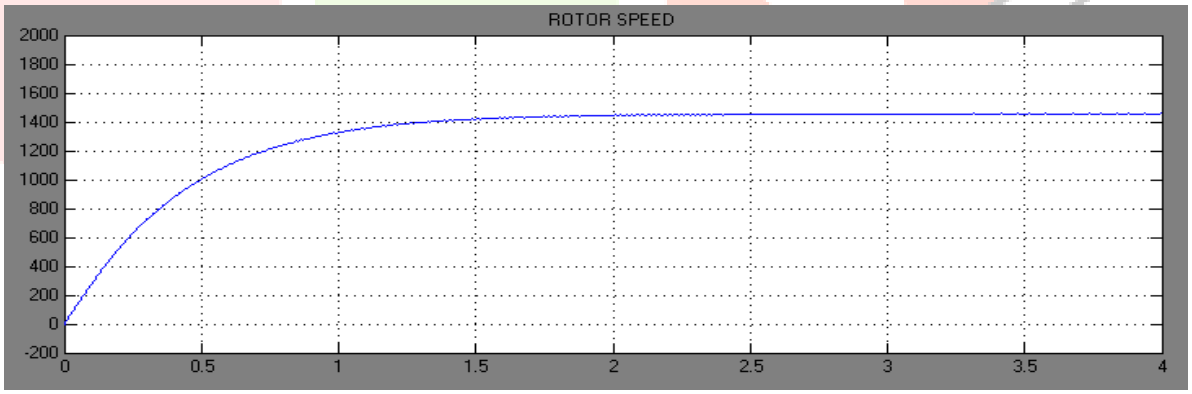

Figure 6. Rotor speed of nine level inverter system in rpm

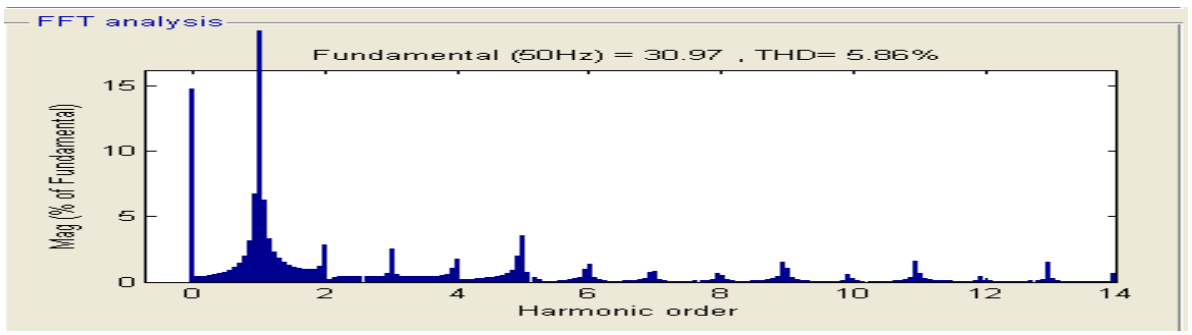

Figure 7. FFT analysis for Nine level inverter system

4. HARDWARE IMPLEMENTATION OF NINE LEVEL INVERTER SYSTEM

The hardware is fabricated and tested. Top view of the hardware is shown in Figure 8. The hardware consists of micro controller module, pulse amplifier module and switching module. Driving pulses for MOSFET 1 and MOSFET 5 are shown in Figure 9 and 10 respectively. Output voltages of main inverter and auxiliary inverter are shown in figures 11 and 12 respectively. The nine level output voltage is shown in Figure 13.

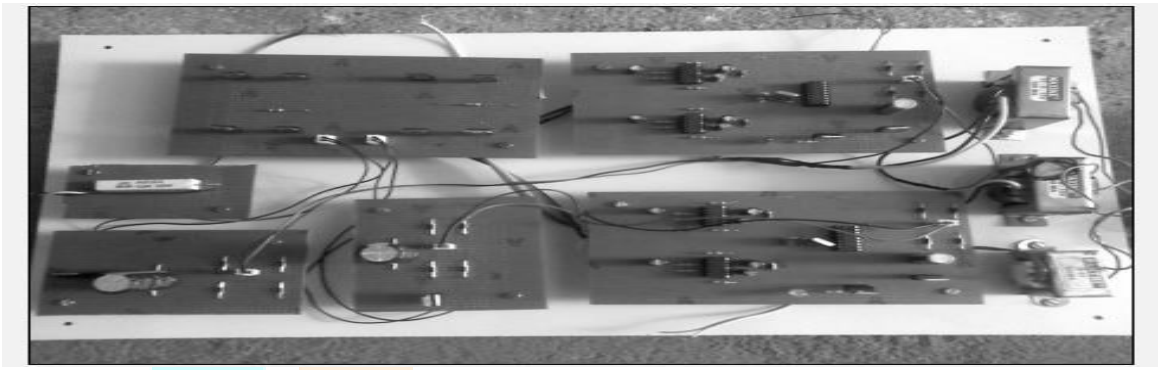

Figure 8. Hardware snapshot of nine level inverter

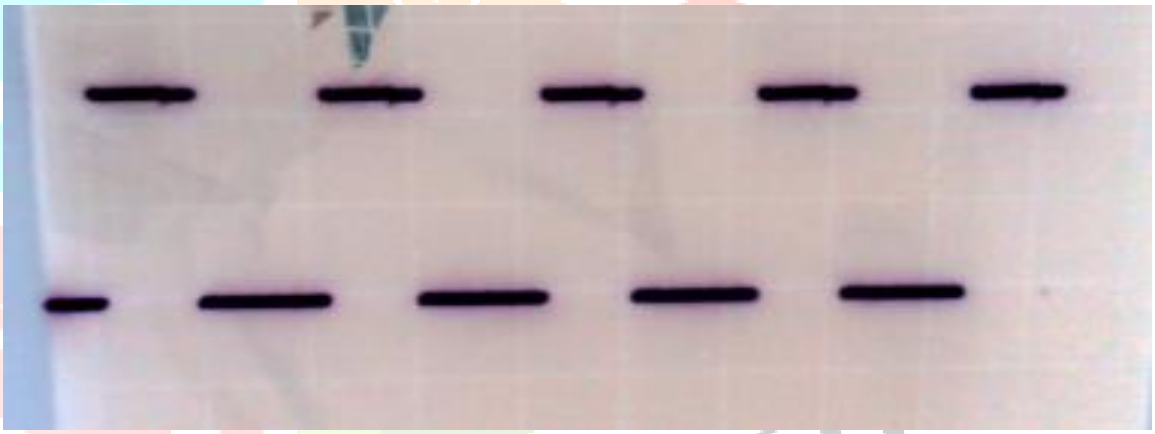

Figure 9. Driving pulses for MOSFET 1 of nine level inverter

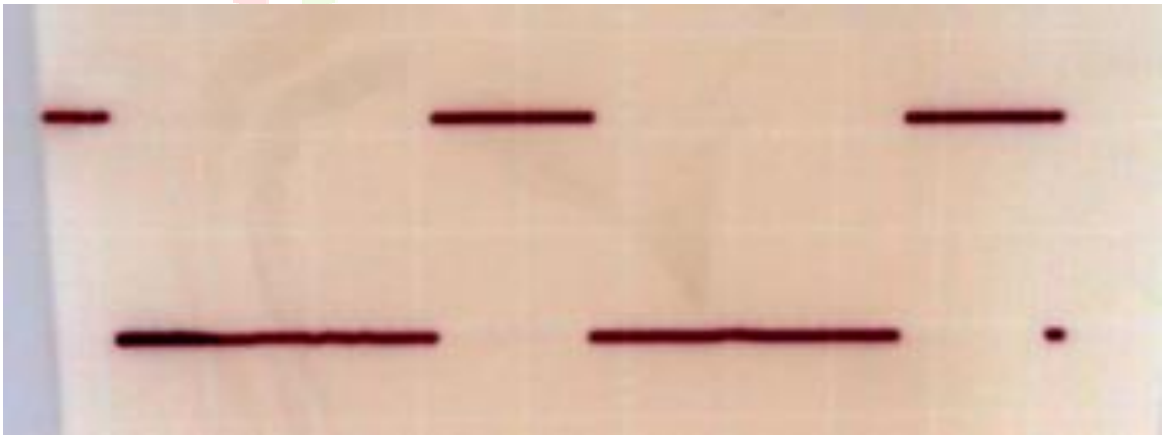

Figure 10. Driving pulses for MOSFET 5 of nine level inverter

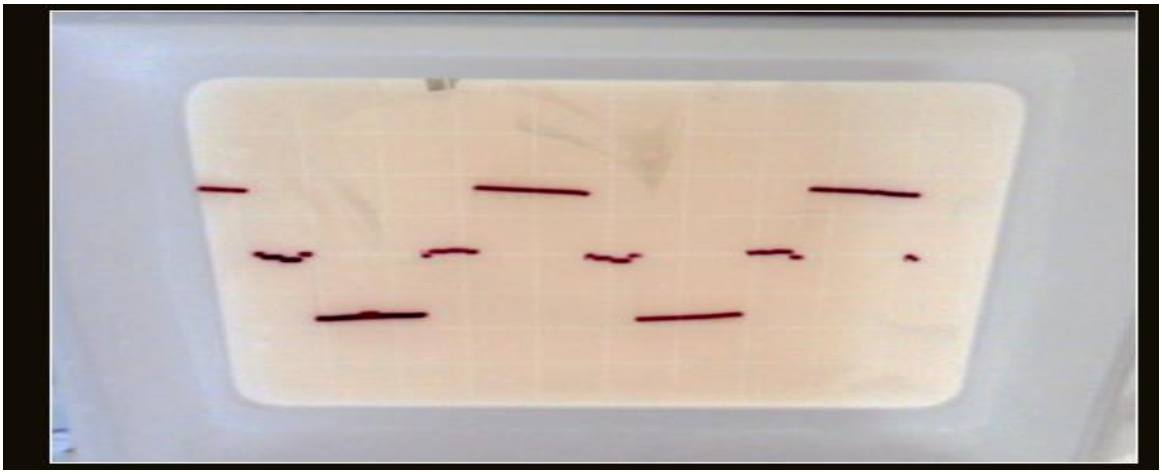

Figure 11. Output voltage of main inverter of nine level inverter

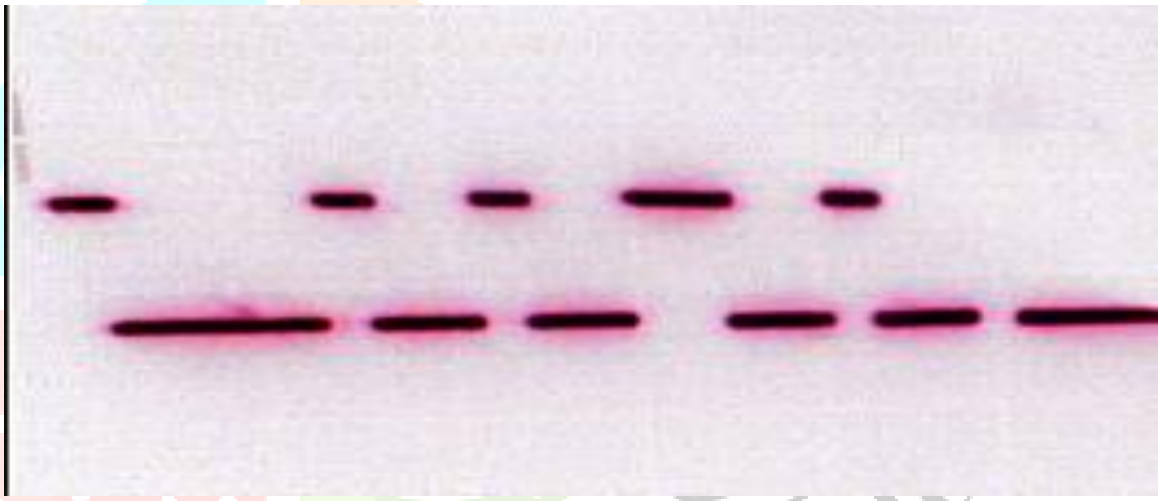

Figure 12. Output voltage of auxiliary inverter of nine level inverter

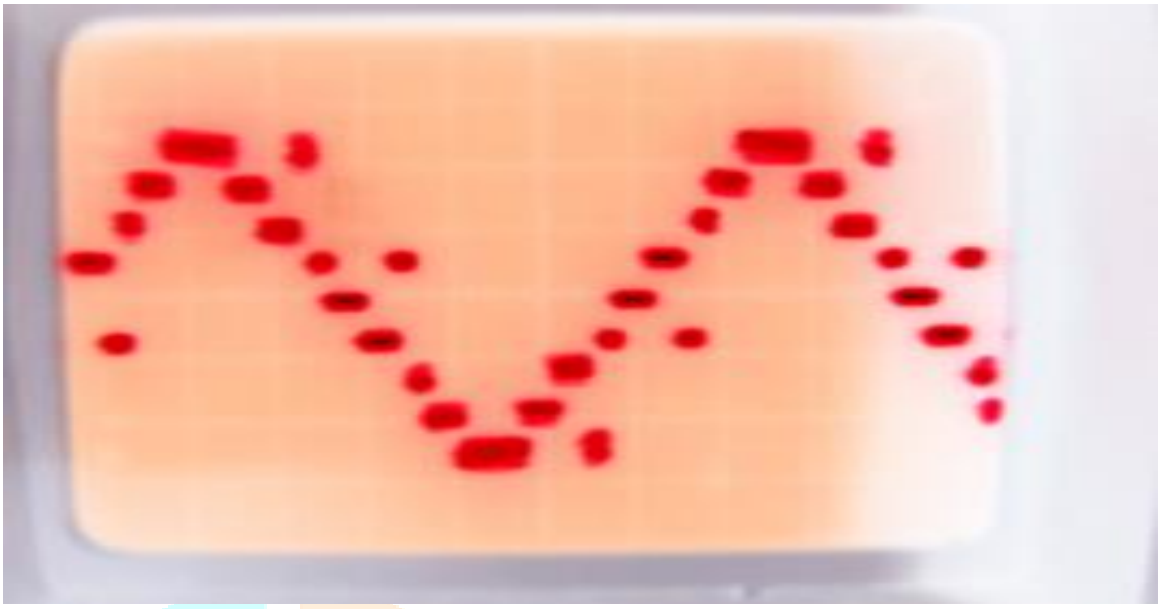

Figure 13. Output voltage of nine level inverter

5 CONCLUSION

9-level inverter-fed induction motor drive is 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 classical VSI fed drive system. Therefore the heating due to 9-level inverter system will be less. 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 simulation and implementation of 9-level inverter fed induction motor drive systems. 9-level inverter system is a viable alternative since it has better performance.

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