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Simulation Analysis of Nine Switch Inverter for Induction Motor Drive

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Abstract—Due to higher demand of power supply in India, it is necessary to design system with low cost, reduced losses and higher efficiency. In this paper, a nine switch inverter is introduced which is made from nine switches for controlling two ac loads with independent mode. It has the advantage that the number of switching devices is reduced by two as compared to two three phase inverter. There is wide range of application of such type of inverter in hybrid vehicle, textile industry, paper industry etc.

Keywords- *Independent control(IC), Induction motor(IM), Nine-switch inverter(NSI), Pulse-width modulation(PWM)*

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I. INTRODUCTION

Nowadays, Inverters are used to convert dc to ac in transmission of power and control the power for ac loads. The development of electric vehicles (EV) and hybrid electric vehicles (HEV) has offered many challenges to the power electronics industry. In recent decades, much research efforts have been taken directed towards finding an isolated dc-ac converter that effectively processes the energy. In a three phase inverter, drives only one load it cannot control more than one load. In many applications more than two loads are used, which require independent control[1]. The applications such as traction system, hybrid vehicle, helicopters, robotics etc deals with more than one motor. There are two methods of controlling two ac loads: providing two separate inverters to drive each motor and connecting the two motors in parallel and driving them through a single inverter[2].The first method increases cost of experimental apparatus. The second method cannot provide independent control of the two motors. Thus, a nine switch inverter is proposed that controls two loads independently. While designing power electronics circuitry it is focused to reduce the number of active and passive element.

The step ahead in this field is by designing a five leg inverter which adopts a sharing configuration, where two three-phase motors are controlled by four independent phase-legs and a fifth shared phase-leg. Ten switching devices are used for the five leg inverter, whereas only nine are used for the nine switch inverter. So, the nine switch inverter has the advantage that one switching device can be reduced compared to the five leg inverter[4]. This topology has the merits of low cost, easily controlled and high reliability. In this topology, the switch count is reduced by one as compared to previous modification and by three as compared to conventional method[2][3][4][5]. This reduces the components required for the gate driver circuit and cost.

This paper proposes a nine-switch inverter which is composed from nine semiconductor switches. The nine-switch inverter is composed of two inverters with three common switches between them. The validity of the proposed topology is verified through simulations.

II. BASIC TOPOLOGY

The structure of proposed *nine-switch inverter* is presented in Fig.1. This structure consists of two three-phase inverters combined with three common switches (RM, YM and BM). The upper portion in Fig. 1 is called *Inv1*, and the lower part is called *Inv2*. The *Inv1* consists of switches RH, YH, BH, RM, YM and BM. and *Inv2* consists of switches RM, YM, BM, RL, YL and BL. Thus the switches RM, YM and BM are shared by Inv1 and Inv2.The balanced loads are supplied from these inverters.

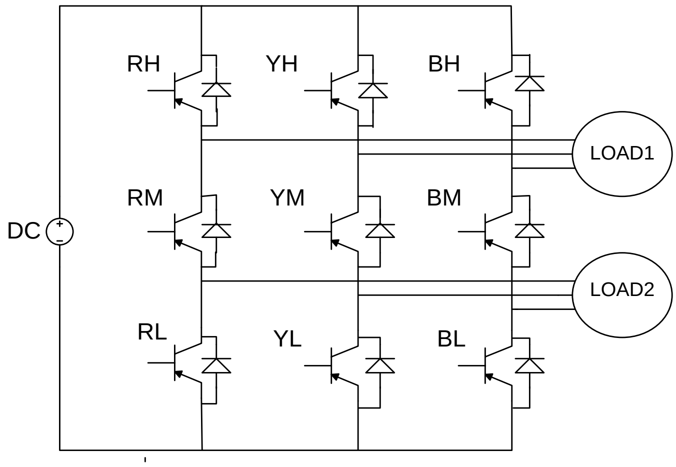

Fig. 1 Main circuit of proposed nine-switch inverter

III. BASIC CIRCUIT FOR PULSE GENERATION

Fig.2. shows the basic circuit for pulse generation. The gate signals for upper switches i.e. RH, YH and BH of a leg are generated by comparing the carrier signal and upper reference signal in a comparator. The gate signals for lower switches i.e. RL, YL and BL are generated by comparing the carrier signal and lower reference signal. The gate signals for middle switches i.e. RM, YM and BM are generated by taking the logical XOR of the gate signals generated for upper and lower switches. Using this method, only two switches are ON in one leg[8].

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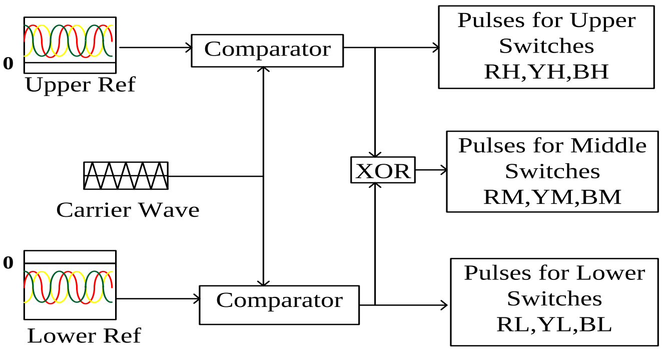

Fig. 2 Basic circuit for pulse generation

IV. BASIC PATTERN OF SWITCHING

The two sinusoidal reference signals V_U^{ref} and V_L^{ref} are required for controlling the output voltages of nine switch inverter. The pulse width modulation of *Inv1* is obtained at the upper part of a triangular wave, and the pulse width modulation of *Inv2* is calculated at its lower part, as shown in Fig. 3. Let voltage reference for *Inv1* is V_U^{ref} and voltage reference for *Inv2* is V_L^{ref}. Assume that V_U^{ref} and V_L^{ref} are given by

$$V_U^{ref} = A_1 \sin(2\pi f_U + \phi_1)$$

$$V_L^{ref} = A_2 \sin(2\pi f_L + \phi_2)$$

where A1 and A2 are the amplitudes, f_U and f_L are frequencies and Φ_1 and Φ_2 are phases.

The gating signal for the switch RH is generated by comparing reference signal (V_U^{ref}) with the upper half of the triangular waveform. Similarly, by comparing lower reference signal (V_L^{ref}) with lower half of the triangular waveform to get the pulse for switch RL. The gating signal for the middle switches is obtained by XORing the signal obtained for upper and lower switches[1]. For e.g. Gating pulse for switch RM is the XOR of the gating pulse for RH & RL. In Fig.3, Inv2 reference wave is lower than carrier wave if pulse-width modulation for Inv1 is calculated. Inv1 reference wave exceeds carrier if pulse-width modulation Inv2 is calculated. Therefore, when Inv1 is driven in mode 1 as shown in Fig.4, switches RL, YL, BL are in the ON state and when Inv2 is driven in mode 2 as shown in Fig.5, switches RH, YH, BH are in the ON state [1]. The basic pattern of switching is given in Fig.3.

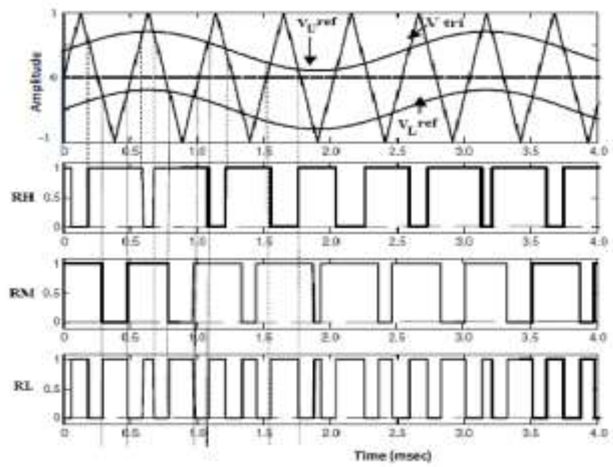

Fig. 3 Reference signal for Inv1 (V_U^{ref}), Reference Signal for Inv2 (V_L^{ref}) and carrier signal (Vtri)

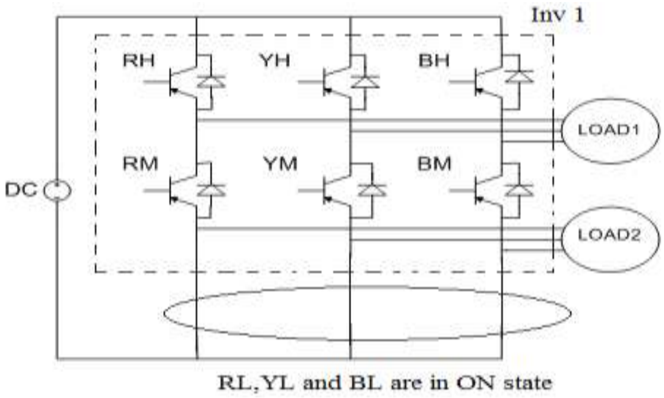

Fig. 4 Mode 1

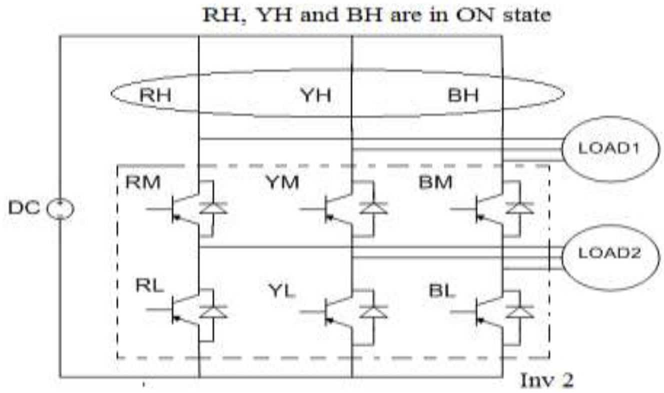

Fig. 5 Mode 2

V. SIMULATION

TABLE I. SIMULATION PARAMETERS

Parameters	Value
DC Source Voltage	800 [V]
Frequency of Carrier	10 [kHz]
Induction Motor Details	3 Phase,4 [kW], 400 [V],50 [Hz]
Frequency of Upper Reference Wave	50 [Hz]
Frequency of Lower Reference Wave	50 [Hz]

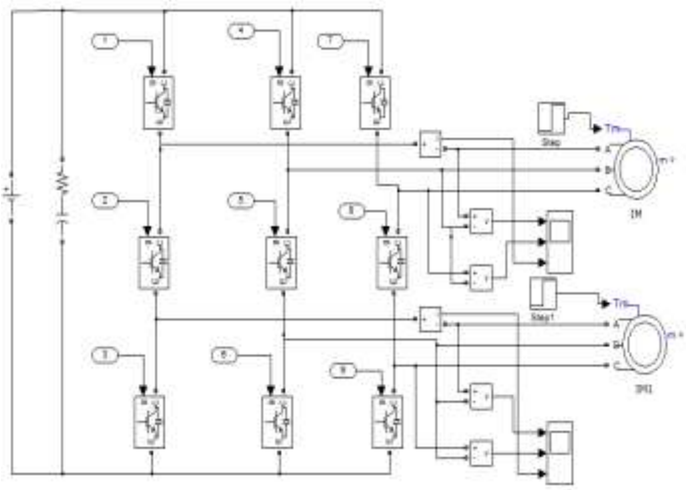

Fig. 6 MATLAB/simulink block of Nine Switch Inverter

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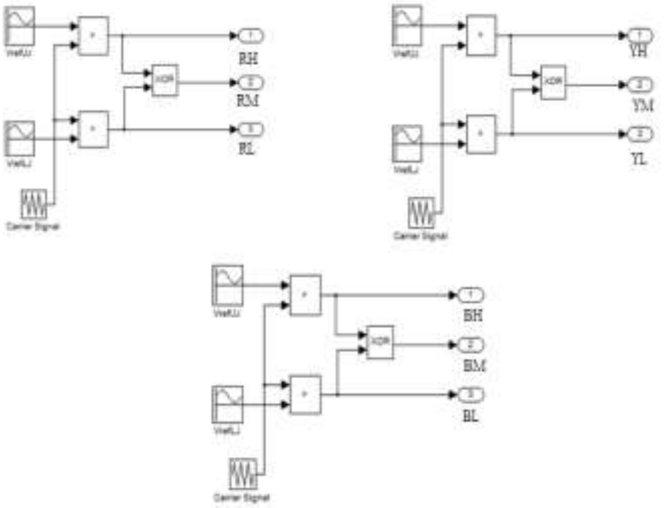

Fig. 7 MATLAB/ simulink block of PWM scheme employed in Nine Switch Inverter.

A simulation of nine-switch inverter in MATLAB is performed to verify the validity of the proposed inverter for induction motor. Here, a simulation is done for three situations. Induction Motor used has a rated output of 4 [kW]. In above simulation, different conditions of reference waves are taken for each inverter. Table I shows the simulation parameters.

- Simulation done when upper and lower reference wave are of same frequency and both IM's are not loaded.
- Simulation done when upper and lower reference wave are of different frequency and both IM's are not loaded.
- Simulation done when upper and lower reference wave are of different frequency and both IM's are loaded at different instants.

A. *Simulation for when upper and lower reference wave are of same frequency and both motors are not loaded.*

The reference wave for *Inv1* is a three-phase sine wave with an amplitude 4 [V] and a frequency of 50 [Hz], and the reference wave for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 Hz. Here, induction motors are driven with the frequencies of *Inv1* and *Inv2*. Speeds of upper and lower IM's are shown in Fig. 8 and Fig. 9. Torques of upper and lower IM's are shown in Fig. 10 and Fig. 11.

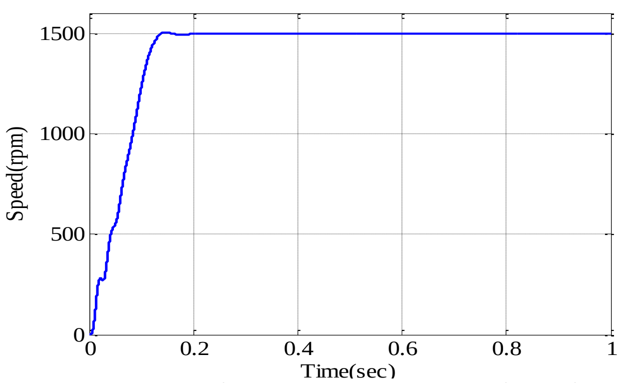

Fig. 8 Simulated speed of Upper Induction Motor. The reference for *Inv1* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

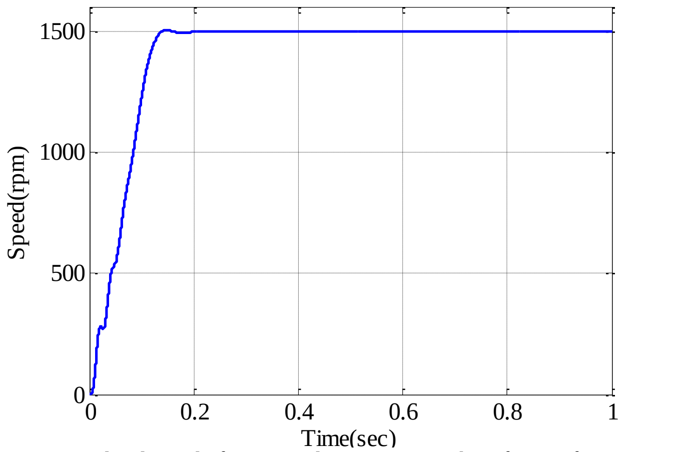

Fig. 9 Simulated speed of Lower Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

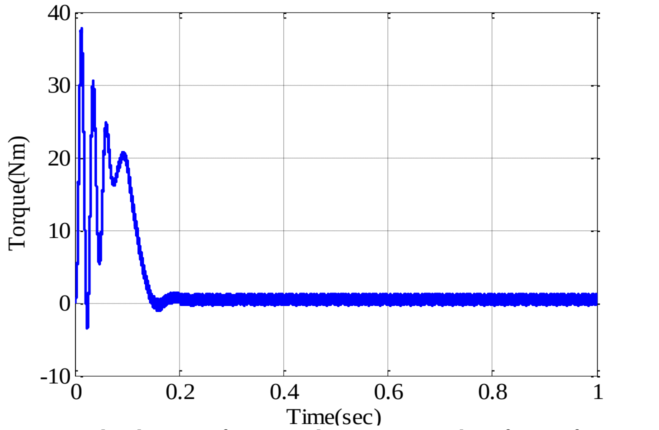

Fig. 10 Simulated torque of Upper Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

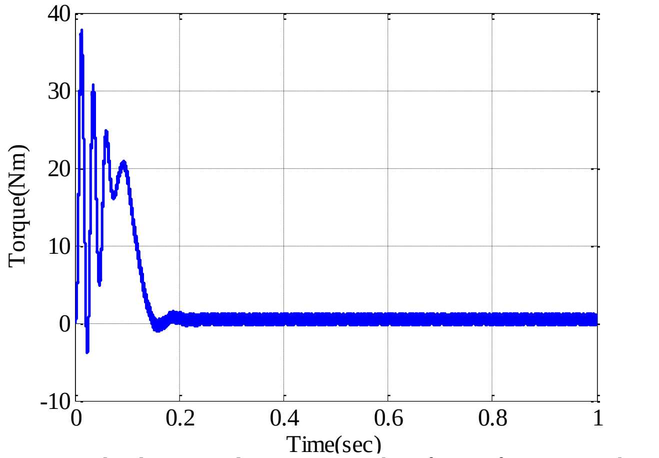

Fig. 11 Simulated torque Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

B. *Simulation for when upper and lower reference wave are of different frequency and both motors are not loaded.*

The reference wave for *Inv1* is a three-phase sine wave with an amplitude 4 [V] and a frequency of 50 [Hz], and the reference wave for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 100 Hz. Here, induction motors are driven with the frequencies of *Inv1* and *Inv2*. Speeds of upper and lower IM's are shown in Fig. 12 and Fig.

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13. Torques of upper and lower IM's are shown in Fig. 14 and Fig. 15.

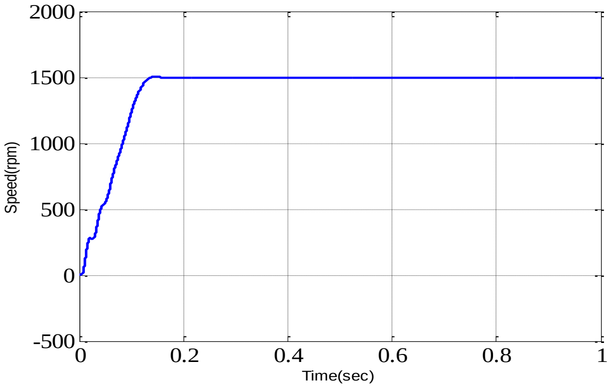

Fig. 12 Simulated speed of Upper Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

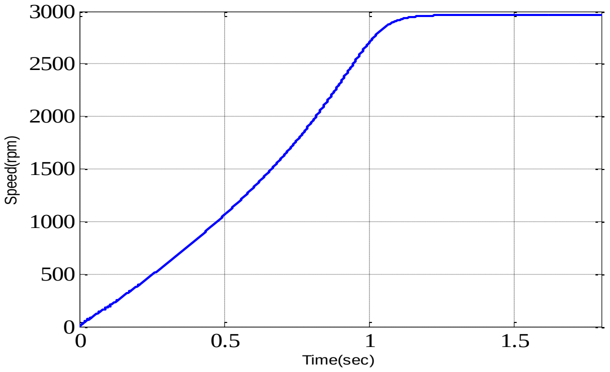

Fig. 13 Simulated speed of Lower Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 100 [Hz].

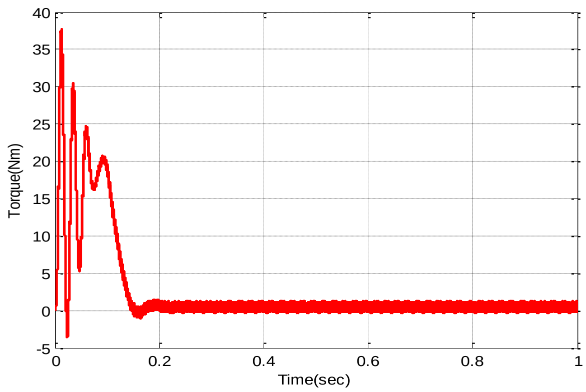

Fig. 14 Simulated speed of Upper Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

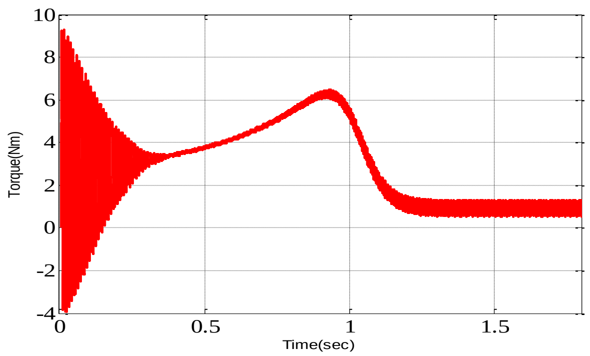

Fig. 15 Simulated speed of Lower Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 100 [Hz].

C. Simulation when upper and lower reference wave are of same frequency and both IM's are loaded at different instants.

The reference wave for *Inv1* is a three-phase sine wave with an amplitude 4 [V] and a frequency of 50 [Hz], and the reference wave for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 Hz. Here, induction motors are driven with the frequencies of *Inv1* and *Inv2*.

Torque of 10 Nm is applied to upper induction motor at t=0.15 sec. Torque of 10 Nm is applied to lower induction motor at t=0.35 sec. Torque applied to upper induction motor does not affect the performance of lower induction motor. Toque applied to lower induction motor does not affect the performance of upper induction motor. Speeds of upper and lower IM's are shown in Fig. 16 and Fig. 17. Torques of upper and lower IM's are shown in Fig. 18 and Fig. 19.

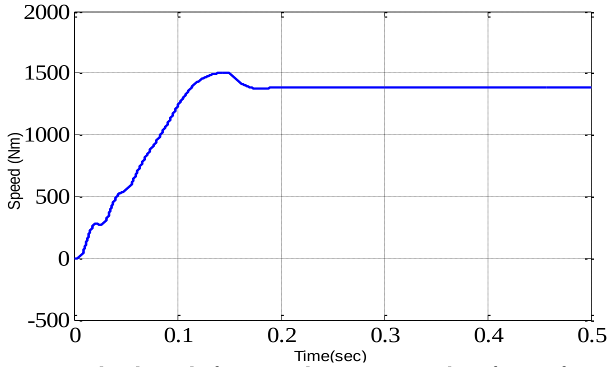

Fig. 16 Simulated speed of Upper Induction Motor. The reference for *Inv1* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

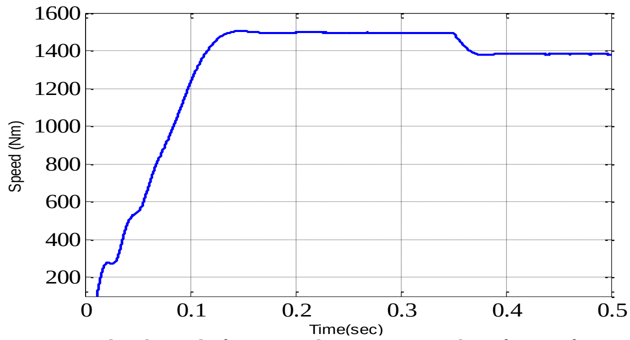

Fig. 17 Simulated speed of Lower Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

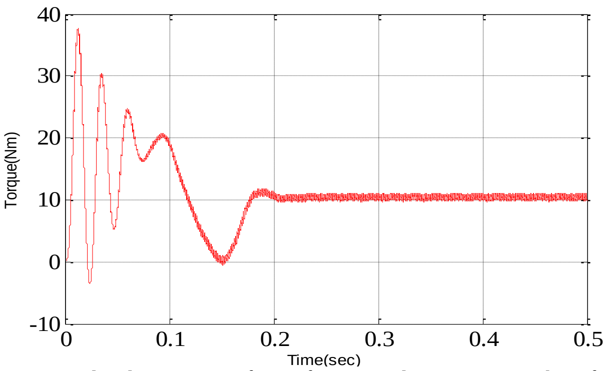

Fig. 18 Simulated torque waveform of Upper Induction Motor. The reference for *Inv1* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

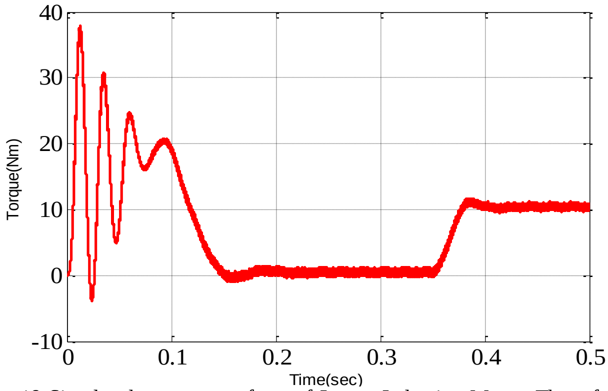

Fig. 19 Simulated torque waveform of Lower Induction Motor. The reference for *Inv2* is a three-phase sine wave with an amplitude of 4 [V] and a frequency of 50 [Hz].

VI. CONCLUSION

This paper proposes a nine switch inverter and a PWM method that can independently control two three-phase loads. The simulation has been performed to verify the validity of the proposed inverter. The results confirmed that the nine-switch inverter can independently control amplitude and frequency for two three-phase loads.

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