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Implementation of Boost Converter Fed Induction Motor Drive

Engineering

KEYWORDS : Boost Converter, VSI, Microcontroller and Induction Motor.

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ABSTRACT

This paper presents the simulation of boost converter fed induction motor drive using Matlab / Simulink. The proposed induction motor drive model employs seven switches and incorporates an active current shaping feature. The boost converter at the input can give the required voltage at the input of the inverter and performs power factor correction. The proposed system of experimental model was implemented. The drive works satisfactorily at low input voltage since the boost converter maintains required voltage. The experimental results closely agree with the simulation results.

1 INTRODUCTION

The voltage source inverter (VSI) systems are used in a wide variety of applications as a front-end power-conditioning unit in electric drives, uninterruptible power supplies, high voltage DC transmission, Active power filters, reactive power compensators in power systems, Electric vehicles, Alternate energy systems and Industrial processes. The inverters realize dc-to-ac power conversion and in the most commonly used voltage source inverter configuration. The dc-input voltage can be obtained from a diode rectifier or from another dc source such as a battery [1]. A typical voltage source inverter system consists of rectifier, DC-link, inverter along with associated control circuit and the load. Most modern voltage source inverters are controlled using a wide variety of pulse width modulation schemes, to obtain output ac voltages of the desired magnitude and frequency shaped as closely as possible to a since wave [2]. In the literature [1] to [17], the implementation of boost converter fed induction motor is not presented. In the present work, the simulation and implementation results of boost converter fed induction motor are presented.

2. VOLTAGE SOURCE INVERTER

The VSI inverter has to generate nearly sinusoidal current which it can be controlled. The voltage and current are controlled with 120° difference in each phase. The operations three-phase inverter can be defined in eight modes [5] which show status of each switch in each operations mode. From operations mode, the current cannot flow to load in mode 0 and 7 while current can flow to load in mode 1 to 6. Then, it can draw two equivalent circuits for operations mode which mode 1 operation is the same as of those 2 and 4 and mode 3 is the same as 5 and 6. Whether during rectification or inversion, sinusoidal current shaping can be reduced to a voltage control in which the controlled voltage source is connected to an ac source through an inductance. In the inverter operation, the necessary phase-leg-short is naturally realized through anti-parallel diodes in the three-phase bridge. Accordingly, the same gate pulses as in the conventional VSI can be applied. On the other hand, the switch on the dc link must actively operate [6].

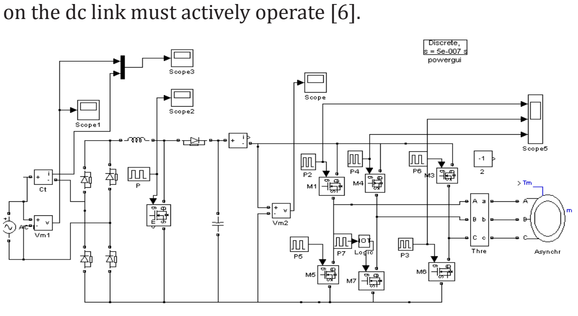

Fig. 1 Boost converter fed induction motor

3. BOOST CONVERTER FED MOTOR

The circuit model of three phase rectifier with boost fed induction motor is shown in Fig 1. The output of the converter is connected to the three phase induction motor. The power devices are assumed to be ideal, when they are conducting, the voltage across them is zero, they present an open circuit in their blocking mode. The phase voltages are derived from the line voltages in the following manner by assuming a balanced three-phase system [9]. The line voltages in terms of the phase voltages in a three-phase system with phase sequence abc are,

$$V_{ab} = V_{as} - V_{bs} \quad (1)$$

$$V_{bc} = V_{bs} - V_{cs} \quad (2)$$

$$V_{ca} = V_{cs} - V_{as} \quad (3)$$

where V_{ab}, V_{bc}, and V_{ca} are the various line voltages and V_{as}, V_{bs}, and V_{cs} are the phase voltages. Subtracting equation (3) from equation (1) gives

$$V_{ab} - V_{ca} = 2V_{as} - (V_{bs} + V_{cs}) \quad (4)$$

In a balanced three-phase system, the sum of the three phase voltages is zero:

$$V_{as} + V_{bs} + V_{cs} = 0 \quad (5)$$

Using equation (5) in (4) shows that the difference between line voltages Vab and Vca is

$$V_{ab} - V_{ca} = 3V_{as} \quad (6)$$

from which the phase a voltage is given by

$$V_{as} = \frac{V_{ab} - V_{ca}}{3} \quad (7)$$

Similarly, the b and c phase voltage are

$$V_{bs} = \frac{V_{bc} - V_{ab}}{3} \quad (8)$$

$$V_{cs} = \frac{V_{ca} - V_{bc}}{3} \quad (9)$$

The phase voltages derived from line voltages and the line-to-line voltages are 120 electrical degrees in duration, the phase voltages are six-stepped and of quasi-sine waveforms. These periodic voltage waveforms, when resolved into Fourier components, have the following form:

$$V_{a}(t) = \frac{2\sqrt{3}}{\pi} V_d \left(\sin \omega_s t - \frac{1}{5} \sin 5\omega_s t + \frac{1}{7} \sin 7\omega_s t - .... \right) \quad (10)$$

$$V_b\ (t) = \frac{2\sqrt{3}}{\pi} V_d \left\{ \sin(\omega_s t - 120^\circ) - \frac{1}{5}\sin(5\ \omega_s t - 120^\circ) + \frac{1}{7}\sin(7\ \omega_s t - 120^\circ \ldots \right\} \quad (11)$$

$$V_a\ (t) = \frac{2\sqrt{3}}{\pi} V_d \left\{ \sin(\omega_s t - 120^\circ) - \frac{1}{5}\sin(5\ \omega_s t - 120^\circ) + \frac{1}{7}\sin(7\ \omega_s t - 120^\circ \ldots \right\} \quad (12)$$

The phase voltages are shifted from the line voltages by 30 degrees, and their magnitudes are

$\frac{2\sqrt{3}}{\pi}$ Vdc.

Only the fundamental produces useful torque, and hence only it needs to be considered for the steady-state performance evaluation of inverter-fed ac motor drives. In this regard, the fundamental rms phase voltage for the six-stepped waveform is

$$V_{ph} = \frac{V_{as}}{\sqrt{2}} = \frac{2}{\pi} \cdot \frac{V_{dc}}{\sqrt{2}} = 0.45\ V_{dc} \quad (13)$$

Irrespective of the control strategies employed in the induction motor drive, the input voltages are periodic in steady state. Hence, direct steady-state performance evaluation is possible by matching boundary conditions. The input voltages are considered for steady-state performance evaluation of the induction motor drive system. Because of their symmetry for either half-wave or full-wave, the boundary-matching technique is ideal for evaluating the steady-state current vector directly, without going through the dynamic simulation from start-up.

4. SIMULATION RESULTS

In three phase inverter fed drive circuit, the low voltage AC is converted into DC using a diode bridge rectifier. It is boosted to the required value using the boost converter. DC is converted to variable voltage variable frequency AC using three phase VSI inverter. The output of inverter is fed to the three phase induction motor. The phase voltage and line to line voltage are shown in Fig 2. The dc output voltage from the rectifier is shown in Fig 3. The output voltage waveforms for inverter system are shown in Fig 4 and the current waveforms are shown in Fig 5. The rotor speed of the motor is shown in Fig 6. Fourier spectrum for the inverter system is shown in Fig 7.

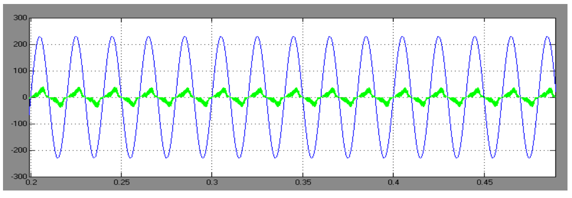

Fig. 2 Input Phase voltage waveform

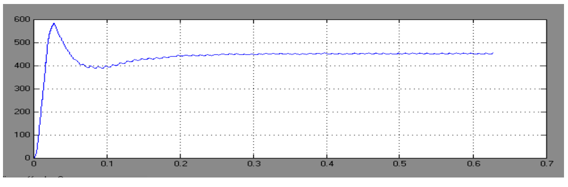

Fig. 3 DC Output Voltage waveform

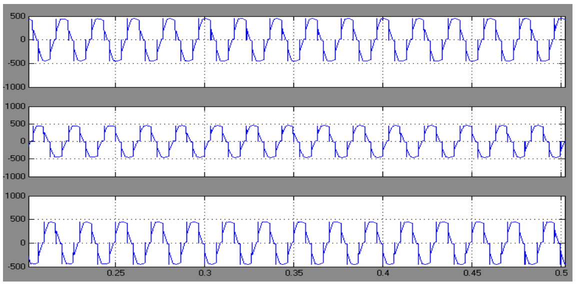

Fig. 4 Output voltages

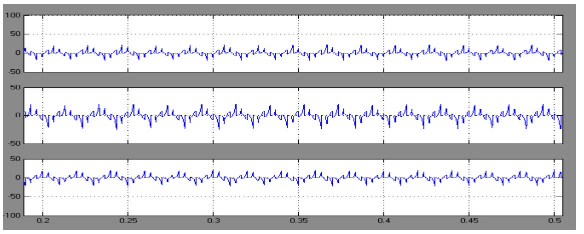

Fig. 5 Output current waveform

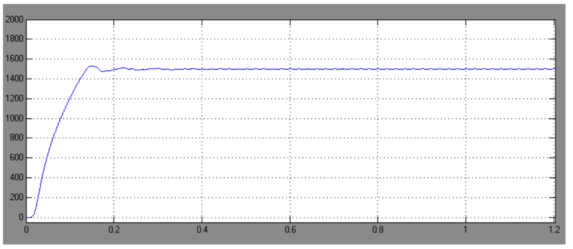

Fig. 6 Rotor speed waveform

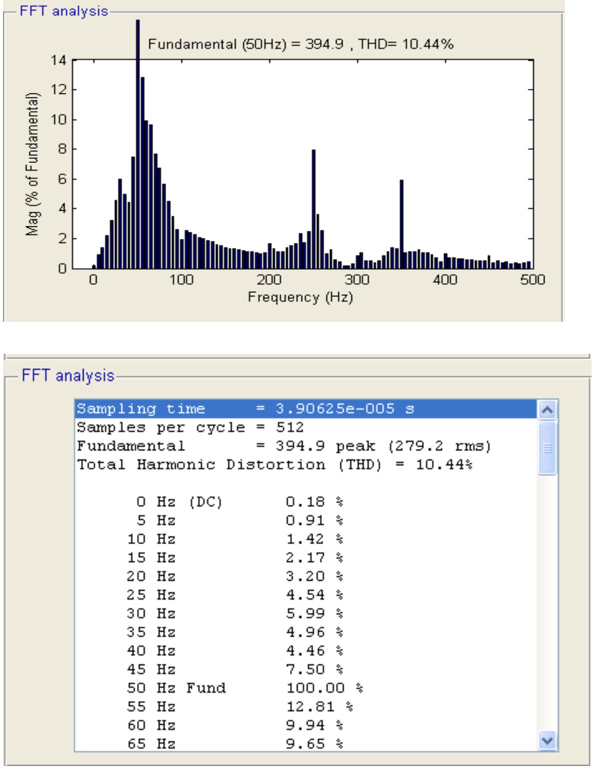

Fig. 7 Fourier Spectrum

5. EXPERIMENTAL RESULTS

Microcontroller based voltage source inverter fed induction motor system is fabricated and tested. The control circuit is shown in Fig 8. The top view of the hardware is shown in Fig 9. The oscillogram of driving pulses from the micro controller is shown in Fig 10. The oscillogram of phase voltage is shown in Fig 11. The Atmel microcontroller 89C2051 is used to generate the pulses. The microcontroller operates at a clock frequency of 12 MHZ. The pulses produced by the microcontroller are amplified using the driver IC IR 2110. The driver ICs amplifies the gate pulses to the required level.

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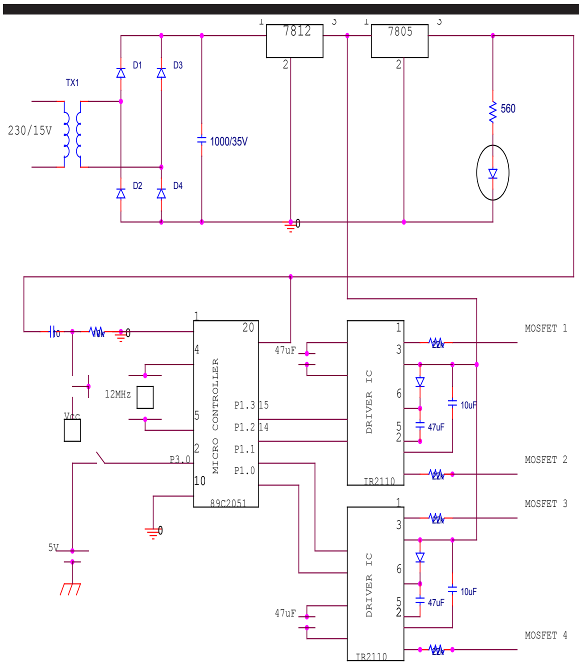

Fig. 8. Control circuit

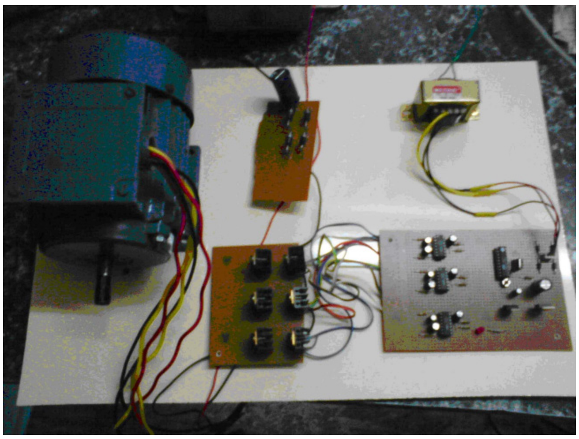

Fig 9. Hardware circuit

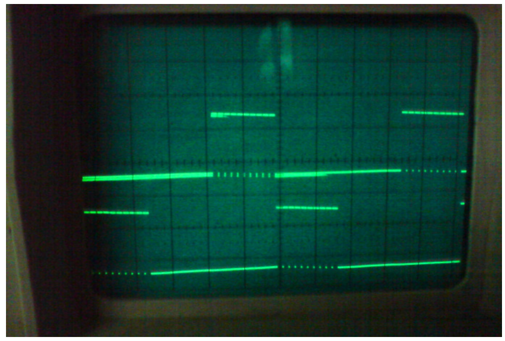

Fig 10. Osillogram of driving pulses

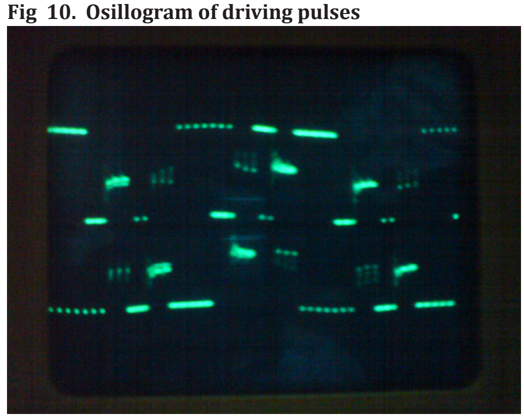

Fig 11. Osillogram of Phase Voltage

6. Conclusion

The circuit model for three phase boost converter system was developed. The analysis of voltage source inverter fed induction motor drive was presented. The boost converter fed induction motor drive is simulated using Matlab/Simulink. The simulation and experimental results for inverter system is presented. The frequency spectrum for the system is also presented. From the simulation studies it is observed that the harmonic distortion in the proposed system was less. The present work has suggested boost converter for inverter fed induction motor drive system to tackle the low input voltage and low power factor problem. A 1KW inverter fed induction motor system model is fabricated and tested. The experimental results coincide with the simulation results.

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