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The Amalgamation Performance Analysis of the LCI and VSI Fed Induction Motor Drive

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***Abstract*— In this paper combination of a load-commutated inverter (LCI) and a voltage-source inverter (VSI) are employed for performance analysis of induction motor drive. Induction motors are the starting point to design an electrical drive system which is widely used in many industrial applications. In modern control theory, different mathematical models describe induction motor according to the employed control methods. Vector control strategy can be applied to this electrical motor type in symmetrical three phase version or in unsymmetrical two phase version. The operation of the induction motor can be analyzed similar to a DC motor through this control method. In this control scheme the electromagnetic torque and stator flux magnitude are estimated with only stator voltages and currents and this estimation does not depend on motor parameters except for the stator resistance. There is an increasing trend of using SVPWM, because of their easier digital realization and better DC bus utilization. The study of SVPWM technique reveals that this technique utilizes DC bus voltage more efficiently and generates less harmonic distortion when compared with sinusoidal PWM techniques. The SVPWM technique has become one of the important PWM techniques for Three Phase Voltage Source Inverter for the control of AC induction motor, Brushless DC motor, Switched Reluctance motor and Permanent Magnet Synchronous motor. In this paper having collection of different schemes in SVPWM. Specifically various schemes are Center aligned two level SVPWM, Level shifted multi-carrier concepts based SVPWM.**

This paper having simulation results of all the three schemes of SVPWM by using MATLAB/SIMULINK software. The performance of Three Phase Voltage Source Inverter fed induction motor drive based on various SVPWM schemes are analyzed by various reference parameters like DC bus utilization. The simulation results are provided to validate the proposed model approaches.

***Index Terms*-- Diode rectifier, Induction motor, Load commutated inverter (LCI), SVPWM technique, Voltage source inverter (VSI).**

I. Introduction

Over the past decades DC machines were used extensively for variable speed applications due to the decoupled control of torque and flux that can be achieved by armature and field current control respectively. DC drives are advantageous in many aspects as in delivering high starting torque, ease of control and nonlinear performance. But due to the major drawbacks of DC machine such as presence of mechanical commutator and brush assembly, DC machine drives have become obsolete today in industrial applications. The voltage source inverter fed Induction motor drives most commonly controlled through the pulse width-modulation technique. Load-commutated inverter (LCI)-based induction motor drives have been used in high-power applications, because of an economical and reliable current source inverter using IGBT-diode and the rugged induction motors [5]. The LCI-based drive employs converter grade utilizes soft switching by natural commutation of the IGBT-diode. Voltage Source Inverter (VSI) fed Induction Motor drive is an attractive solution for low power applications because of the availability of fast switching devices like IGBT and MOSFET. But for medium and high power applications, VSI can not switch as fast as in the case of low power counterpart due to increased switching loss. Furthermore, for medium voltage applications, the devices of required voltage rating for two levels VSI are not readily available. Multilevel VSI [1] are used in medium voltage applications as the device voltage stress decreases with the increase in the number of levels of multilevel VSI.

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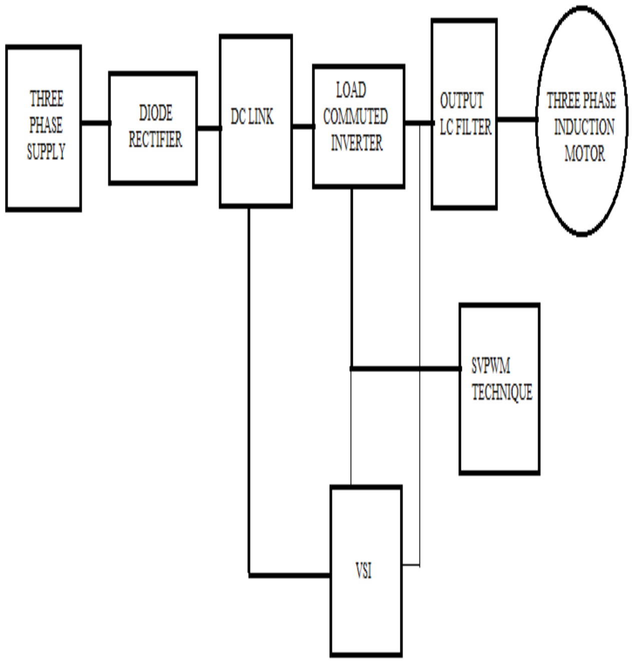

Figure 1 Control block diagram of LCI and VSI fed induction motor

II. Proposed System Architecture

The proposed drive system consisting of a diode rectifier, an LCI, a VSI, an LC filter and three phase induction motor are shown in Fig. 1. The VSI is connected with the LCI in parallel through capacitor DC link.LCI and VSI energized through the same DC link output but the different element. A large inductor DC link is employed for the load commutated inverter. LCI, in order to convert uncontrolled DC voltage to controlled DC current. The DC-link current regulated by the inductor is supplied to the LCI. As a result, both the VSI and the LCI can be fed from the single-diode rectifier. The VSI generates sinusoidal phase voltage to the induction motor.

The amplitude and frequency of the VSI output voltage is continuously regulated by the motor speed control. In addition, the phase angle of the VSI output voltage is set from adjusting the firing angle of the LCI to provide a safe LCI commutation angle. Therefore, the leading power factor for the LCI operation is entirely obtained by the VSI over the whole speed range of the induction motor. Based on the leading power factor by the VSI, the presented system can operate the LCI without the dc-commutation circuit as well as output capacitors. Therefore, the employed system can successfully solve all problems caused by the output capacitors and the forced dc-commutation circuit of the conventional LCI-based induction motor. Another advantage by bringing the VSI is to generate sinusoidal motor currents for all speed regions to large induction motor drives. The parallel assembly of the LCI and the relatively small-size VSI is expected to fulfill the high-power applications, where a stand-alone VSI cannot be utilized to generate sinusoidal motor currents. In addition, the sinusoidal motor voltages are also achieved through the LC filter.

III. SVPWM CONTROL TECHNIQUE

PWM drive is advantageous in many ways, for example it obtains its dc input through uncontrolled rectification of commercial AC mains and has good power factor, good efficiency, relatively free from regulation problems, it has the ability to operate the motor with nearly sinusoidal current waveform. The conventional PWM techniques are suitable for open loop control, for the implementation of a closed loop controlled AC drive Space vector PWM (SVPWM) technique is applied. In this technique, the switching patterns for the bridge inverter are generated from the knowledge of stator voltage space phasor. A reference voltage vector is generated to generate a field synchronous with the rotating voltage vector by utilizing the different switching states of a three phase bridge inverter [15]. The SVPWM is considered as a better technique of PWM implementation as it has advantages over SPWM in terms of good utilization of dc bus voltage, reduced switching frequency and low current ripple. When three phase supply is given to the stator of the induction machine, a three phase rotating magnetic field is produced. Due to this field flux, a three phase rotating voltage vector is generated which lags the flux by 90º. This field can also be realized by a logical combination of the inverter switching which is the basic concept of SVPWM. The three phase bridge inverter has eight possible switching states: six active and two zero states. The six switches have a well-defined state ON or OFF in each configurations. At a particular instant, only one switch in each of the three legs is ON. Corresponding to each state of the inverter, there is one voltage space vector. For example for state zero it is V0, for state 1 it is V1 and so on. These switching state vectors have equal magnitude but 60º apart from each other [8]. These vectors can be written in generalized form as follows:

$$V_k = V_{dc} e^{j\left(\frac{k-1}{3}\right)\pi} \qquad k = 1, 2, \ldots\ldots, 6$$

$$= 0 \qquad k = 0, 7$$

Where k = inverter state number.
Vdc = dc link voltage of the inverter
The inverter state vectors can be drawn as shown in fig.2

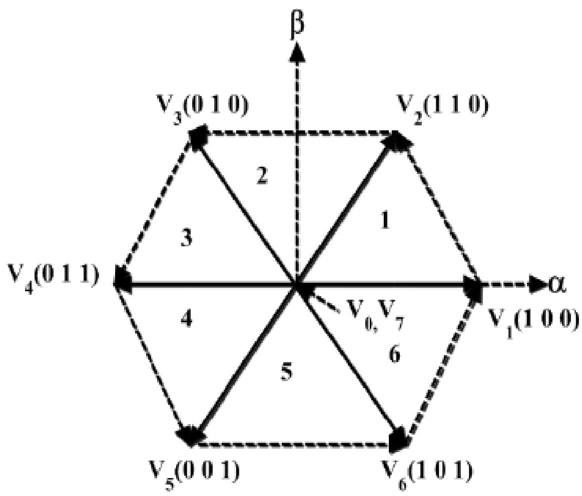

Figure 2 Inverter switching state vectors

The control processing unit calculates the basic parameters to apply a switching state. The input data to the control processing unit is the reference space vector. During various iterations, the unit determines the sector number, triangle number of the subhexagon. The sector number and triangle number identify the correct switching sequence. The flowchart is given for an *n*-level inverter and can be used for any *n*-levels without change. The flow diagram of the proposed algorithm to find minimum THD is shown in Figure 3

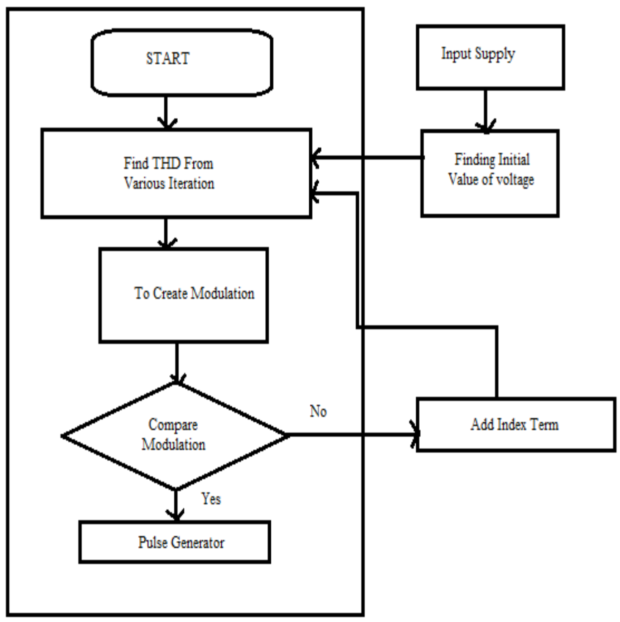

Figure 3 Flowchart of SVPWM Algorithm

IV. SYSTEM MODEL

In this section simulation circuit model is developed to examine the amalgamation performance of the LCI and VSI fed induction motor drive. A three-phase squirrel-cage induction motor rated 3 hp, 220 V, 60 Hz, 1725 rpm is fed by a load commutated inverter and voltage source inverter. The firing pulses to the inverter are generated by the SVPWM modulator block of the SPS library. The chopping frequency is set to 6000 Hz and the input reference vector to magnitude-angle. Speed control of the motor is performed by the constant V/Hz block.

MODEL FOR HYBRID PERFORMANCE OF INDUCTION MOTOR DRIVE

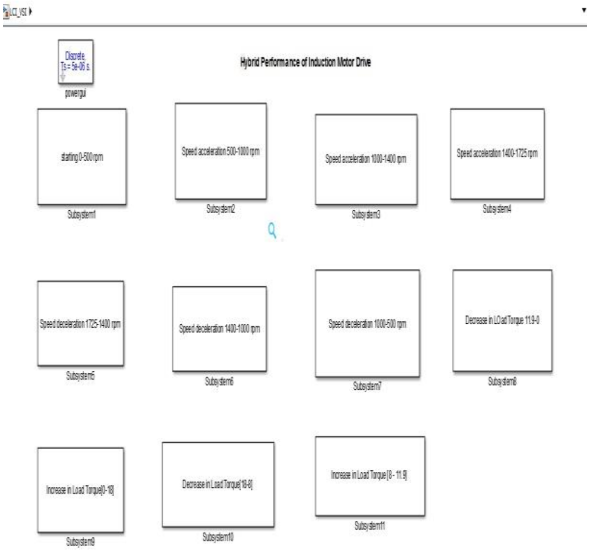

Figure 4 Main Model

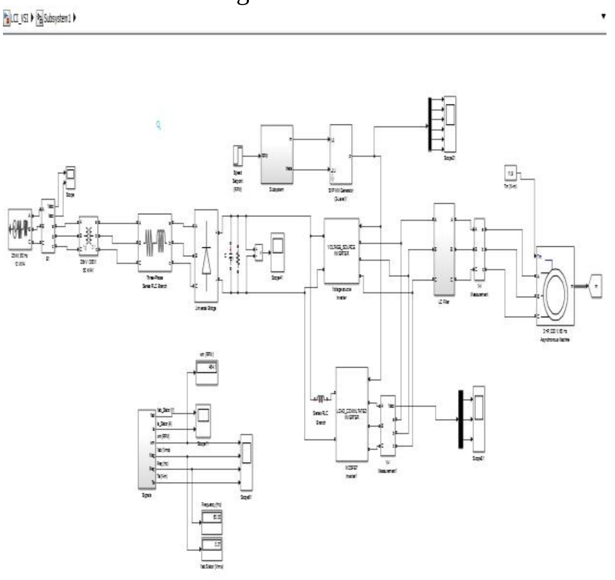

Figure 5 starting (0-500rpm) Model

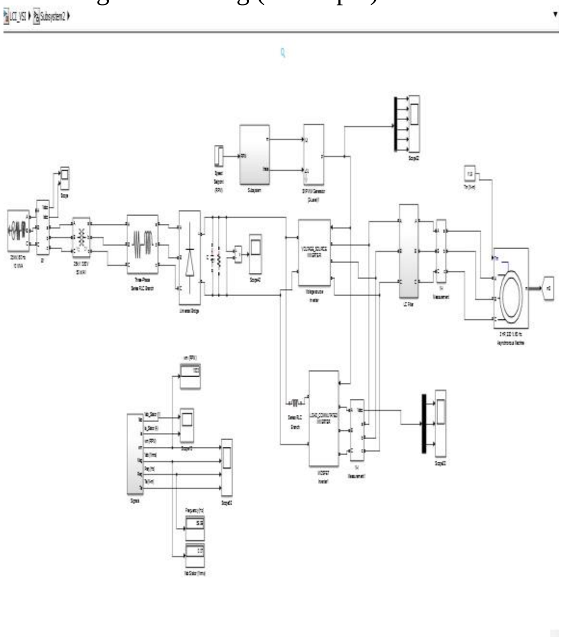

Figure 6 Speed Acceleration (500 rpm - 1000rpm)

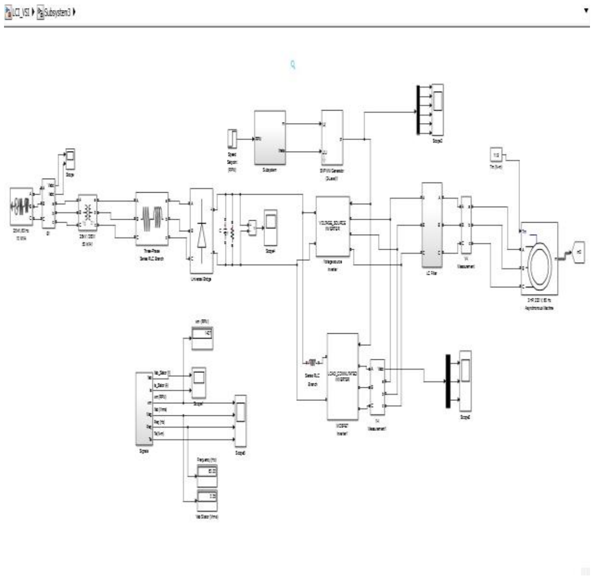

Figure 7 Speed Acceleration (1000 rpm -1400rpm)

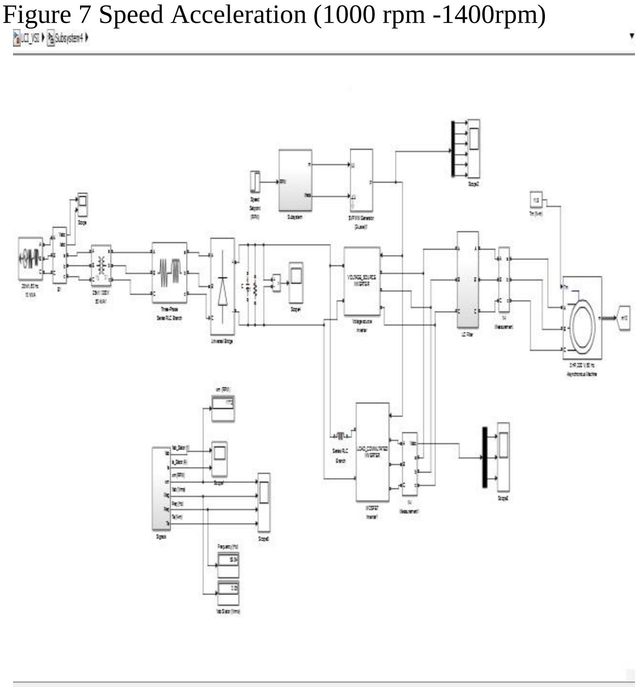

Figure 8 Speed Acceleration (1400 rpm -1725rpm)

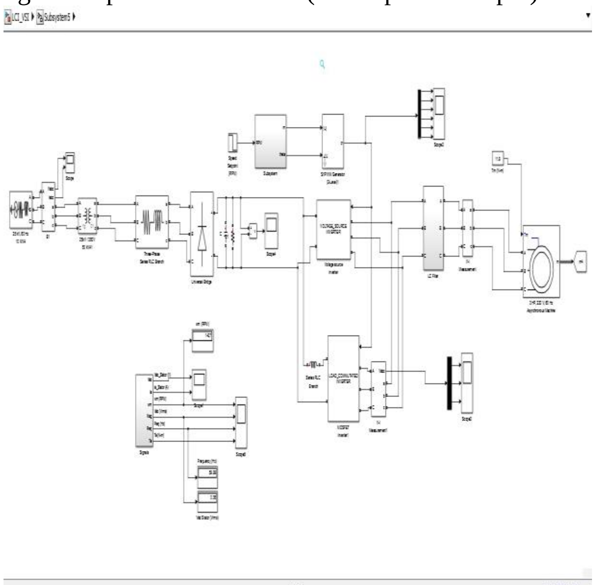

Figure 9 Speed Deceleration (1725 rpm -1400rpm)

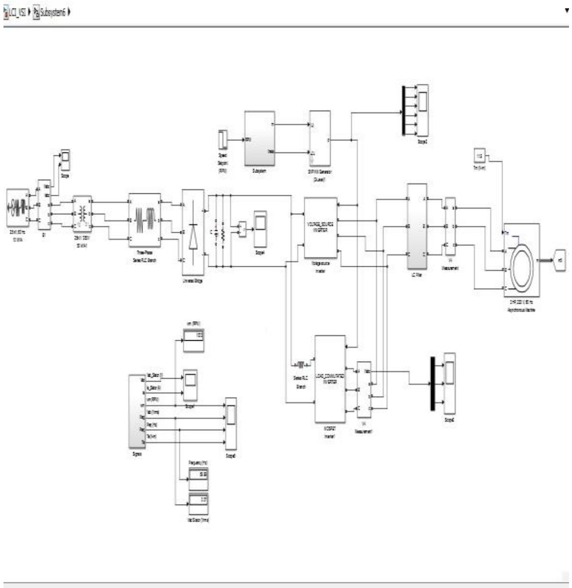

Figure 10 Speed Deceleration (1400 rpm -1000rpm)

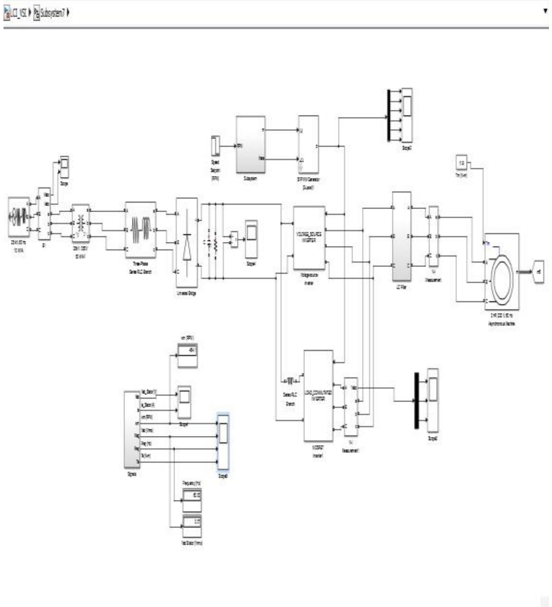

Figure 11 Speed Deceleration (1000 rpm -500rpm)

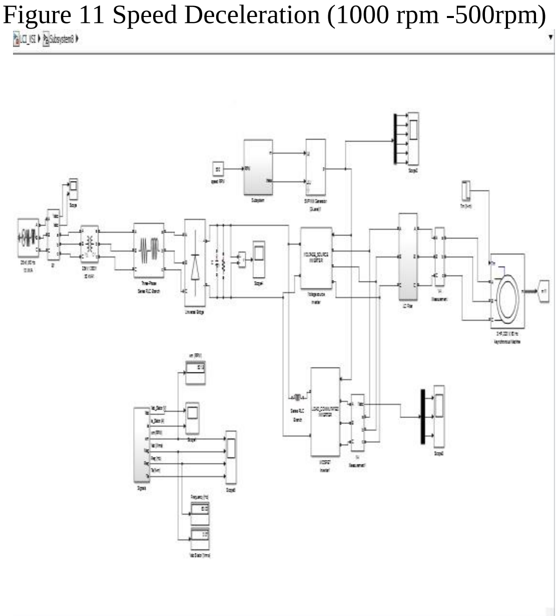

Figure12 Deceleration in Load Torque (11.9N-m - 0N-m)

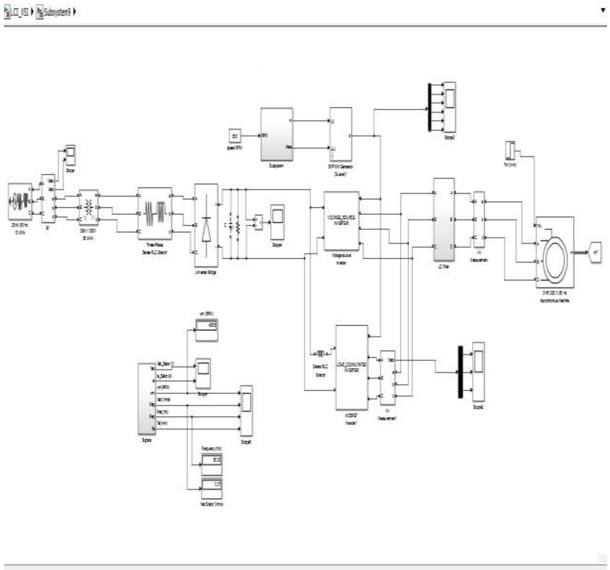

Figure 13 Acceleration in load torque (0N-m -18N-m)

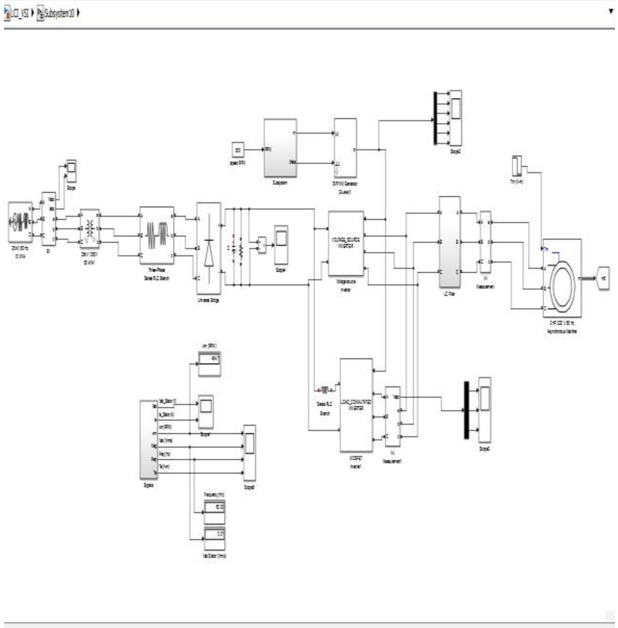

Figure 14 Deceleration in load torque (18N-m - 8N-m)

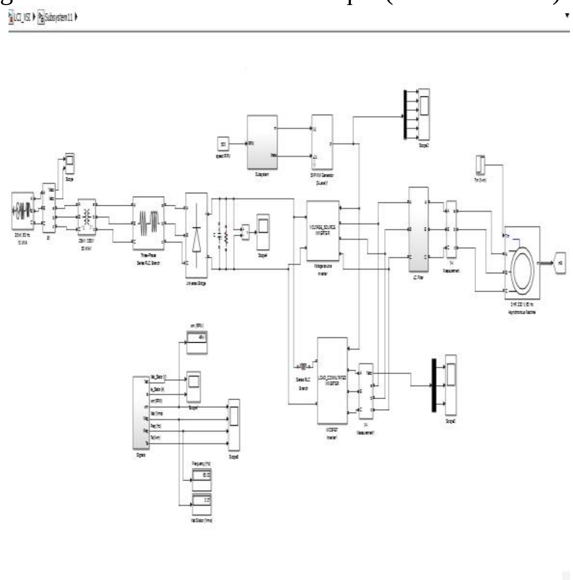

Figure 15 Acceleration in load torque (8N-m - 11.9N-m)

V. RESULTS

DRIVE PERFORMANCE

Case–1: Starting (0 to 500 rpm)

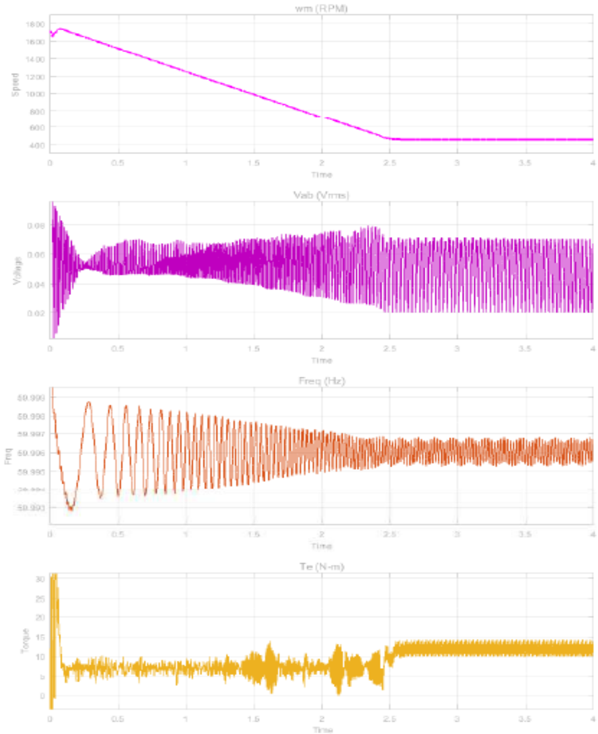

Figure 16 Speed Acceleration 0 to 500 rpm

Case–2: Speed acceleration (500rpm to 1000 rpm)

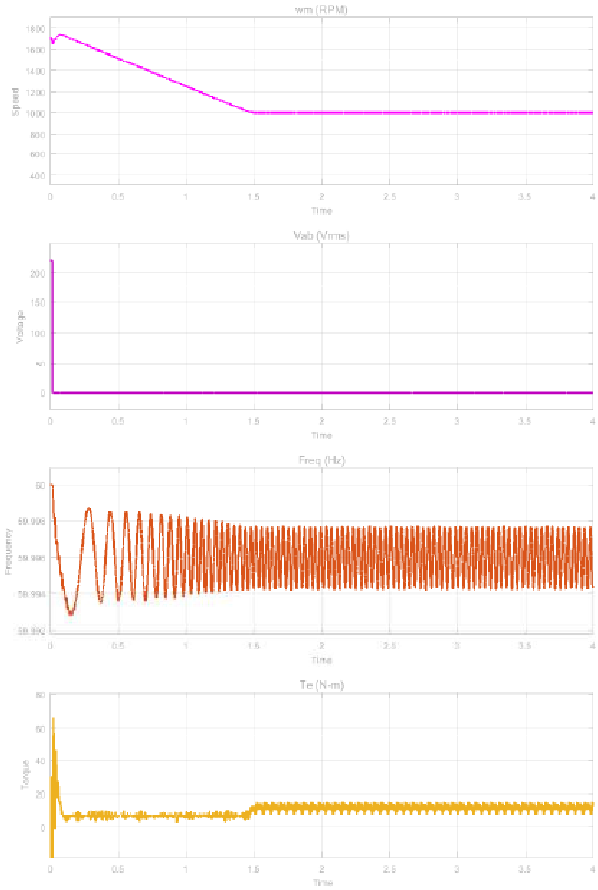

Figure 17 Speed Acceleration 0 to 500 rpm

Case–3: Speed acceleration (1000rpm to 1400 rpm)

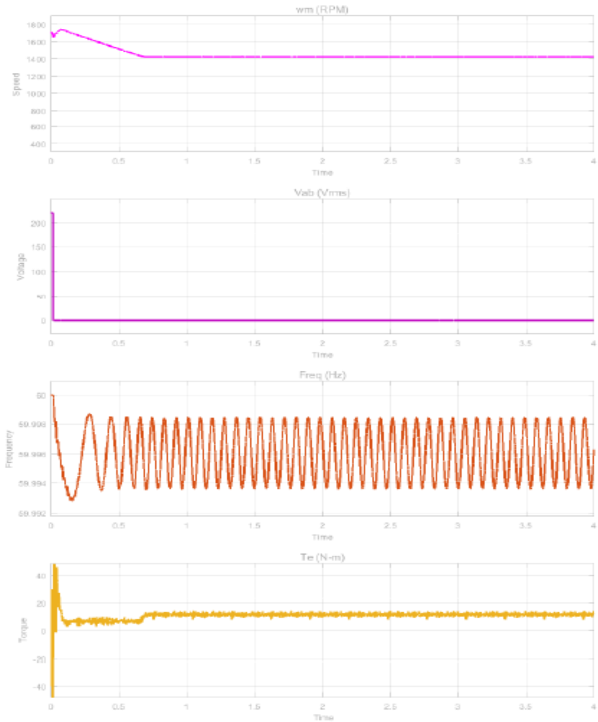

Figure 18 Speed Acceleration 0 to 500 rpm

Case–4: Speed acceleration (1400rpm to 1725 rpm)

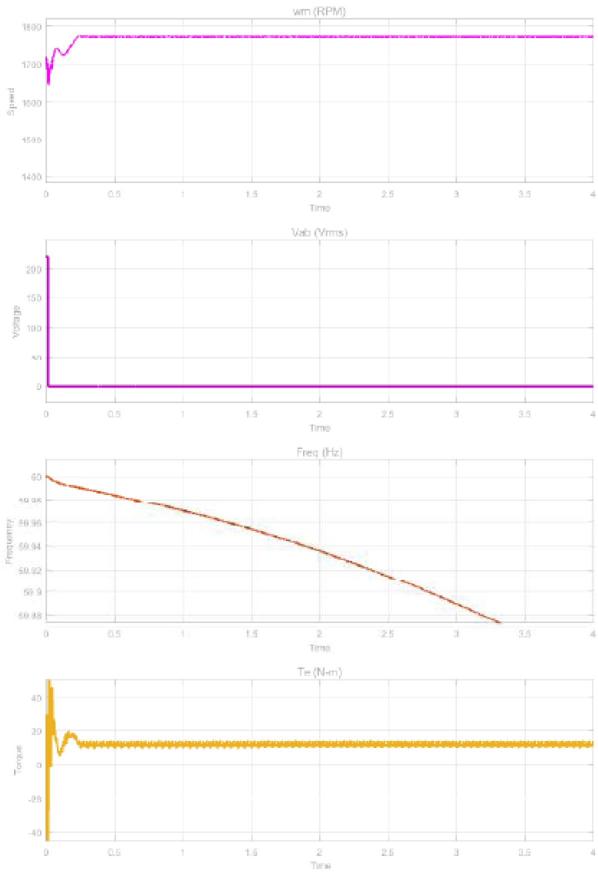

Figure 19 Speed Acceleration (1400rpm to 1725 rpm)

Case–5: Speed Deceleration (1725 rpm to 1400rpm)

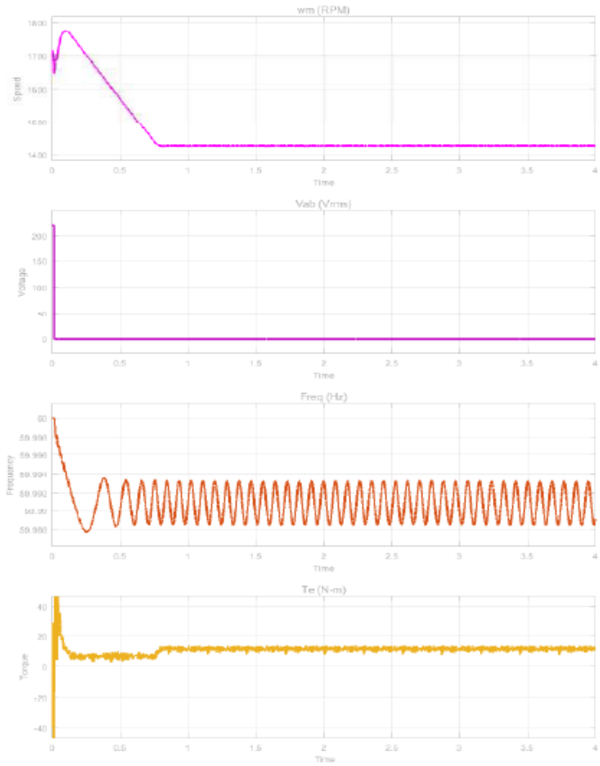

Figure 20 Speed Deceleration (1725 rpm to 1400rpm)

Case–6: Speed Deceleration (1400 rpm to 1000 rpm)

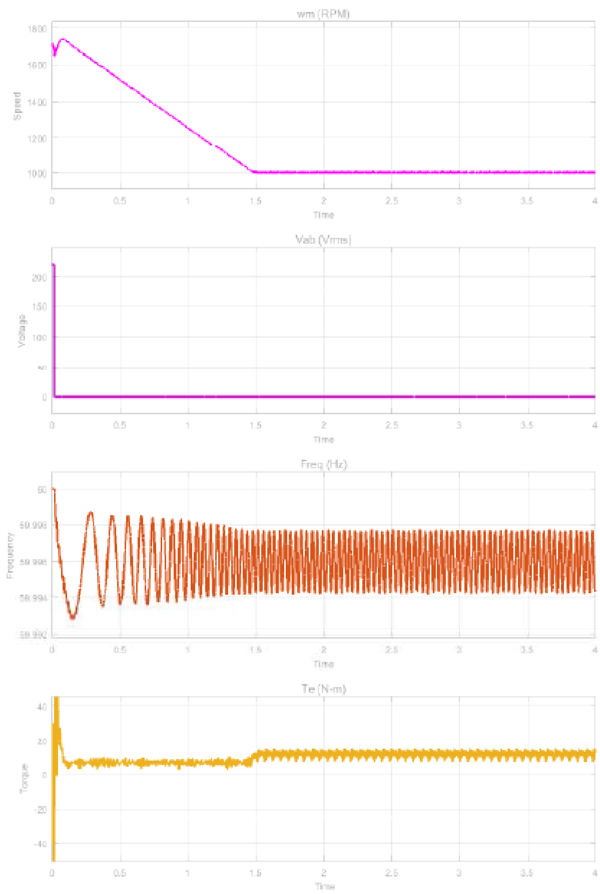

Figure 21 Speed Deceleration (1400 rpm to 1000 rpm)

Case–7: Speed deceleration (1000 rpm to 500 rpm)

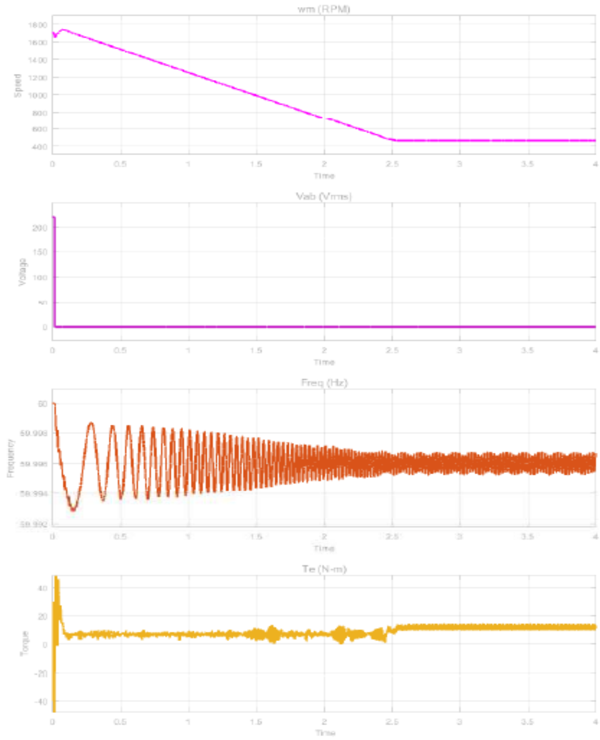

Figure 22 Speed Deceleration (1000 rpm to 500 rpm)

Case–8: Decrease in load torque (11.9 N-m to 0 N-m)

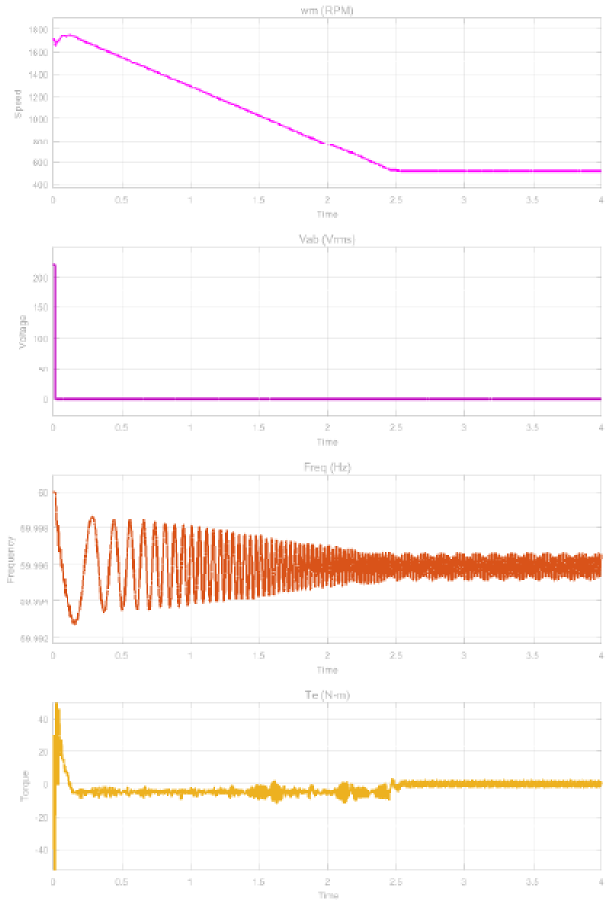

Figure 23 Decrease in load torque (11.9 N-m to 0 N-m)

Case–9: Increase in load torque (0 N-m to 18 N-m)

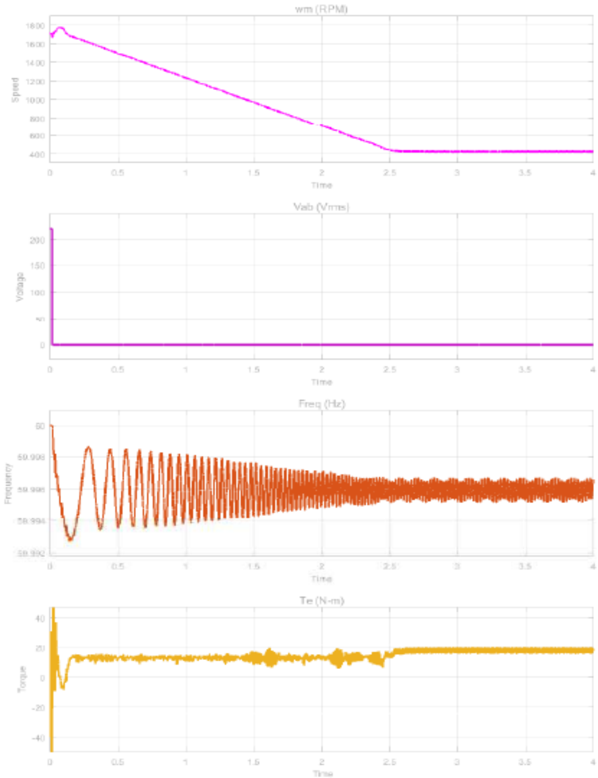

Figure 24 Increase in load torque (0 N-m to 18 N-m)

Case–10: Decrease in Load Torque (18 N-m to 8 N-m)

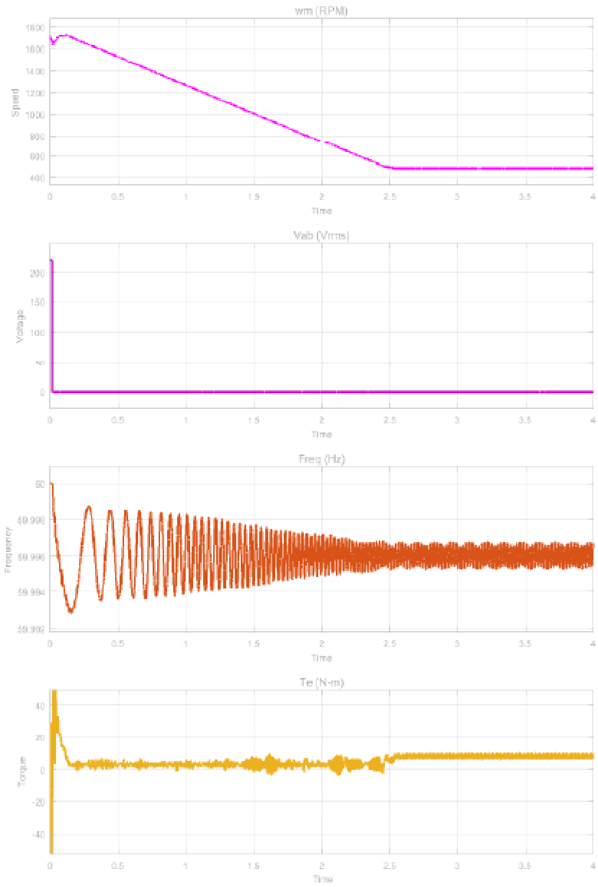

Figure 25 Decrease in load torque (18 N-m to 8 N-m)

Case–11: Increase in Load Torque (8 N-m to 11.9 N-m)

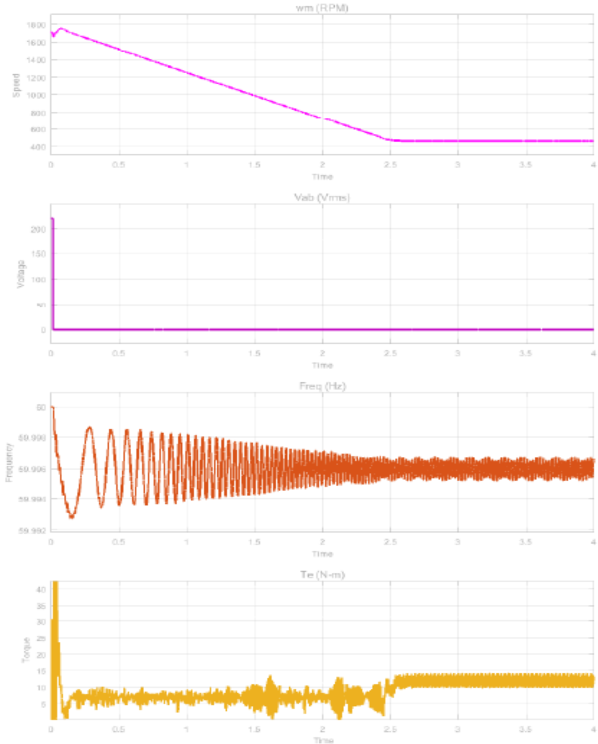

Figure 26 Increase in load torque (8 N-m to 11.9 N-m)

DC WAVEFORM

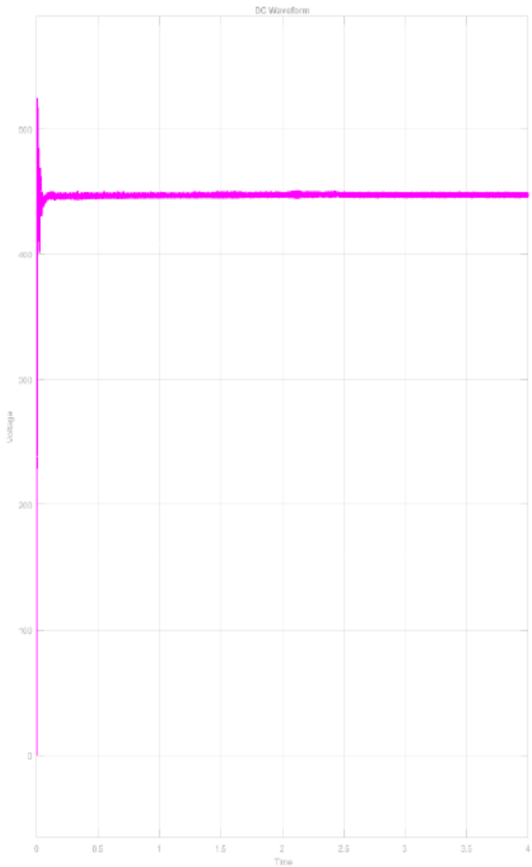

Figure 27 DC Waveform

LCI CONTROL VOLTAGE

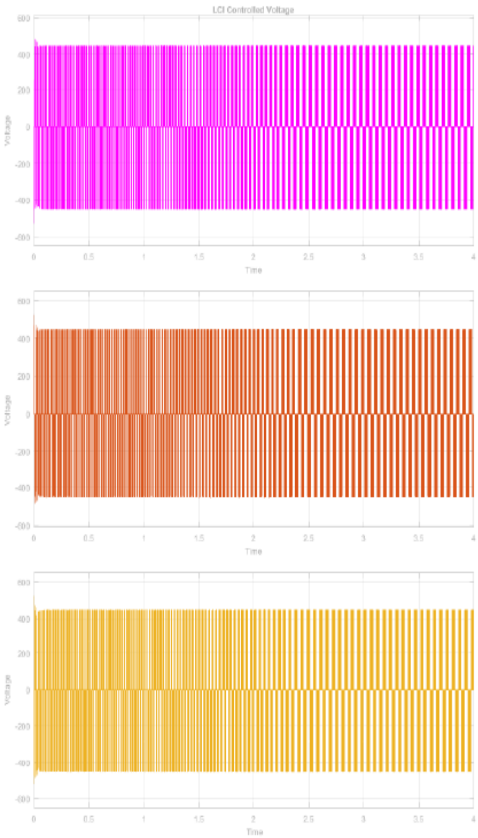

Figure 28 LCI Voltage

VI. Conclusion

In this paper, describes LCI and VSI fed three-phase induction motor drive is simulated, fabricated and tested. The reliability is increased by using microcontroller as the on chip intelligent controller. The experimental results closely agree with the simulation results. Modified Sine PWM is used to reduce switching losses. The contribution of this work is the development of modified Sine PWM model using the blocks of simulink. Modified Sine PWM inverter fed induction motor drive is a viable alternative to the VSI fed induction motor drive due to the reduced switching losses. The present work indicates that SVM inverter fed induction motor drive is an economical drive with reduced harmonics Sine PWM and SVM inverter fed induction motor drives are compared. The performance of the Load Commutated Inverter fed induction motor drive has been investigated through the MATLAB/Simulation for the different alteration in reference speed and load torque. Simulation results shows that the presented drive system provides the more satisfactory results than the conventional CSI and VSI.

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