# Analysis of Impedance fed Induction motor drive

M.Thangamarimuthu[1], S.Govindaraj[2], V.Damin doori[3]

[1] Assistant Professor

*Department of Electrical and Electronics Engineering,*
*VSB College of Engineering Technical Campus, Kinthukadavu*

[1]thangamarimuthum@gmail.com

[2] *Assistant Professor*

*Department of Electronics and Communication Engineering*

*Selvam College of Technology, Namakkal*

[2]govind1990raj@gmail.com

[3] *Assistant Professor*

*Department of Electrical and Electronics Engineering,*
*VSB College of Engineering Technical Campus, Kinthukadavu*

***Abstract*— This paper represents an impedance source (impedance-fed) based power converter (Z-source converter) and its control method by implementing both combination of current and voltage source inverter power conversion. It has both buck and boost capabilities of output voltage, as they allows inverter to be operated in shoot through the state. The Z-source converter employs a unique impedance network (or circuit) to couple the converter main circuit to the power source The Simple Boost control with independence relation between modulation index and shoot-through duty ratio is to be minimized, in order to reduce the line harmonics, to improve the power factor, by increased reliability and extended output voltage range. Simulations were carried out in MATLAB/Simulink for VSI (Voltage Source Inverter) and CSI (Current Source Inverter) fed Induction motors and it is being compared with the Z-Source Inverter fed Induction motor drive and also their performances were compared.**

***Keywords* - *Induction motor drive, pulse width modulation (PWM), shoot-through state, Z-source inverter.***

## I. INTRODUCTION

Traditional voltage-source inverters (VSIs) and current-source inverters (CSIs) have similar limitations and problems. For VSIs: 1) the obtainable ac output voltage does not exceeded in dc source voltage. So a dc–dc boost converter is needed in the applications, for instance, with limited available dc voltage or with the demand of higher output voltage. 2) Dead time which is required to prevent the shoot-through of the upper, lower switching activity of each phase leg. However, it induces waveform distortion. For CSIs: 1) their output voltage cannot be lower than the dc input voltage; and. 2) overlap time between phase legs is required to avoid the open circuit of all the upper switching devices or all the lower devices. The Z-source inverter (ZSI) [1], as well as the derived Z-source inverters (ZSI) [2], [3], can overcome the aforementioned problems. They advantageously utilize the shoot-through of the inverter bridge to boost voltage in the VSIs (or open circuit in the CSIs to buck voltage). Thus, buck–boost functionality is achieved with a single-stage power conversion. They also increase the immunity of the inverters to the EMI noise , which may cause misgating and shoot-through (or open circuit) to destroy the conventional VSI's and CSI's. Z-source inverters is the presence of a Z-source impedance network connected between the input dc source and inverter circuitry, as shown in Fig. 1 for a VS-type Z-source inverter. This unique X-shaped impedance network is implemented using two inductors and capacitors with the inductors effectively appearing in series between the capacitors and inverter circuitry when any two switches from the same phase leg are turned ON to boost the ac output voltage in a defined shoot-through state (allowing phase-leg shoot-through also means that the Z-source inverter does not require dead time protection)

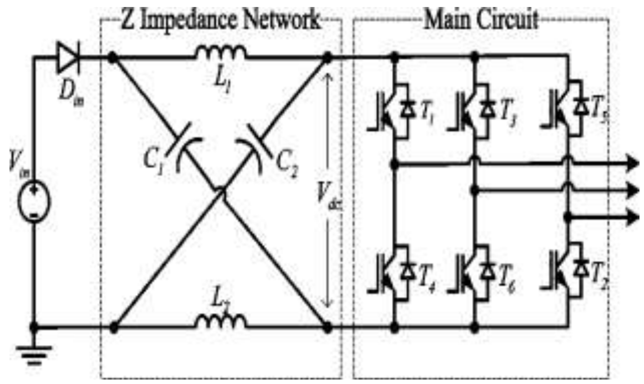


Fig.1.1 Z-source inverter

Depends on the voltage boosting, the Z-source inverter should be controlled by using a modified pulse width modulation (PWM) scheme with which shoot-through states are inserted in between active and null state.

In general-purpose motor drive (adjustable speed drive-ASD) system is based up on the voltage-source inverter (V-source inverter), consisting of diode rectifier front end, the dc link capacitor and an inverter bridge. Improving the power factor, either an ac inductor or a dc inductor which is used. The dc link voltage is roughly equal to 1.35 times of a line voltage and Voltage source inverter is a buck (step-down) converter that can produces an ac voltage limited by the dc link voltage. Main circuit consists of three parts: a diode rectifier, dc-link circuit, with inverter Bridge .The differences are that the dc link circuit is implemented by the Z-source network and small input capacitors are connected to the diode rectifier. These changes can be easily retrofitted and implemented from the traditional ASD systems. Since the Z-source inverter bridge can boost the dc capacitor and voltage to any value that is above the average dc value of the rectifier, a desired output voltage can be obtained regardless of the line voltage. Various methods can be used to control Z-source inverter. These can be classified into two categories according to the different shoot-through (ST) states insertion methods. The first method has the principle that ST states are generated by properly level shifting the modulation signals of voltage source inverter. ST states then will be inserted at every states transition, six ST state insertions are done by one switching cycle.

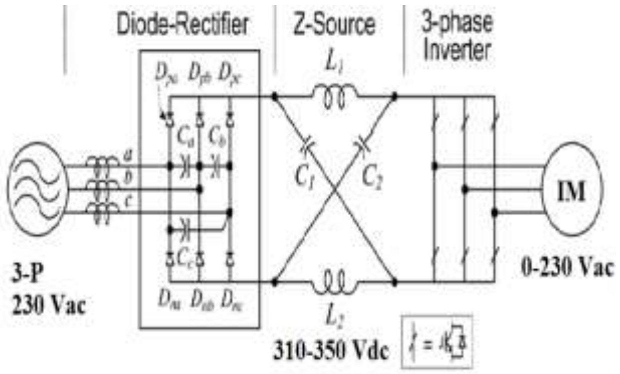


Fig. 1.2 Main Circuit Configuration o Proposed Z Source Adjustable Speed Drive System.

The second category, in the other hand, directly replaces the null states (111 and 000) by ST states. The two ST states insertion are done by one switching cycle of the second category. The comparison between those two categories shows that the second category has higher efficiency than the first category [2]. In this paper, two different ways of Z-Source inverter control with two ST states insertion in one switching cycle (second category).

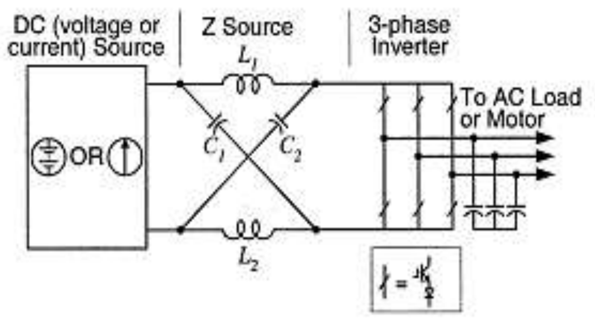


Fig. 1.3 Z-source converter structure using the series combination device and diode.

The configuration of 3-phase Z-source inverter. It consists of 2 identical inductors and 2 identical capacitors which are composed to form a unique impedance network to avoid short circuit when the devices are in shoot through mode, a diode is used to block the reverse current, and a three phase bridge act as traditional inverter. One additional control parameter is introduced In 3-phase Z-source inverter, namely the Boost Factor (B), which modifies the AC output voltage equation of traditional 3-phase PWM inverter as give in equation 1.

## 1.1. FORMULA USED

Output voltage can be expressed as,

$$\mathbf{V_{out} = B.M .V_0/2} \quad .....(1)$$

where:

$V_{out}$=Maximum sinusoidal inverter output voltage
B = Boost factor
M = Modulation Index
$V_O$ = DC Input voltage

## 1.2. VOLTAGE SOURCE INVERTER

The V-source inverter is a buck converter that can only produce an ac voltage limited by the dc link voltage. The voltage source inverter requires an output LC filter to provide sinusoidal voltage compared with current source inverter. The LC filter makes additional power loss and control complexity.

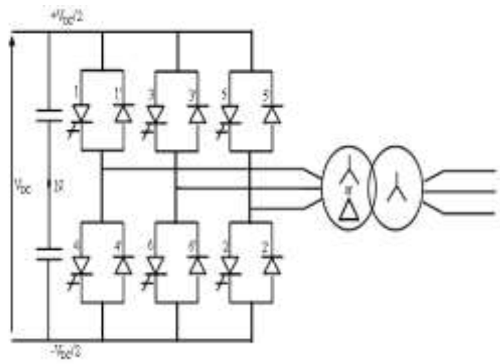

Fig . 1.4 Voltage source inverter

### 1.2.1. LIMITATIONS

1) The obtainable ac output voltage cannot exceed the dc source voltage. So a dc–dc boost converter is requiring the applications, for instance, to provide the limited dc voltage or with the demand of higher output voltage.
2) Dead time is required to prevent the shoot-through of the upper and lower switching devices of each phase leg. However, it result in waveform distortion.

## 1.3. CURRENT SOURCE INVERTER

The Current Source Inverter is a boost inverter for dc to-ac power conversion and the Current source converter is a buck rectifier for ac-to-dc power conversion. Current source inverters could be employed with boost control. A dc current source is used in the main converter circuit and three-phase bridge. The dc current source a large dc inductor fed by a voltage source such as a battery or diode rectifier. Six switches can be used in the main circuit; each is composed traditionally by a semiconductor switching device with reverse block capability.

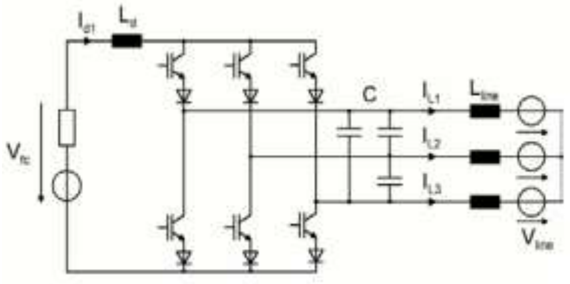

Fig. 1.5 Traditional Current source inverter

1.3.1. LIMITATIONS

The Current source converter having the following conceptual, theoretical barriers and also their limitations. The original dc voltage that feds dc inductor has to be lesser than the ac output voltage or the dc voltage produced is always smaller than the ac input voltage. An application where wide voltage ranges which are desirable and an additional dc-dc buck converter is to be needed.

At least one of the upper device and one of the lower devices has to be gated on and to maintain at any time. An open circuit of the dc inductor will occur and destroy the device. Overlapping time for the safe current commutation is needed in the current source converter, which causes waveform distortion.

## 2. SIMULATION OF Z-SOURCE INVERTER FED INDUCTION MOTOR

The simulation diagram of Z Source Inverter fed induction motor using Harmonic Injection Pulse Width Modulation is done through MATLAB/SIMULINK toolbox. Here, rectifier fed dc voltage to Z source inverter where the ac voltage at desired level is produced as the output .The desired voltage is produced by comparing with ac reference voltage signal using pulse width modulation.

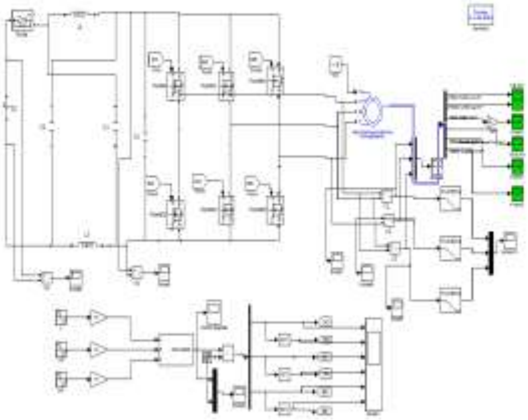

Fig 2.1 Simulation circuit of z source inverter fed Induction motor

SIMULATION RESULTS

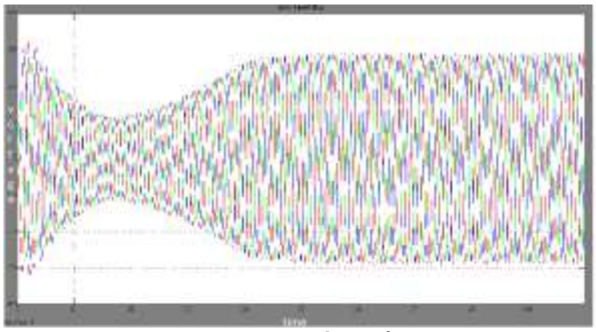

Fig 2.2 Output voltage of ZSI

Let now the input voltage is 120 V DC and is given to the Z-source network. Here the output got is around 280 V AC. The output voltage will vary depending upon the modulation index used to generate the PWM signals. The output is greater than the input voltage.

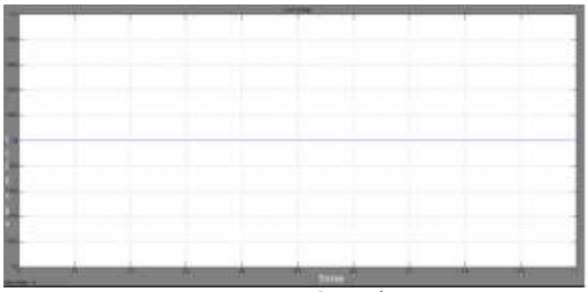

Fig 2.3 Input voltage of ZSI

The inverter is operating as boost inverter. Thus the voltage can be boosted up to any level by introducing the shoot-through mode. As a result the inverter can be operated as both buck and boost inverter. During the shoot-through mode the two switches S1 and S4, the shoot-through will occur and during this period the capacitor will supply the inductor. The average voltage across the inductor for one complete one cycle is zero. So the DC voltage will get boosted up and the boosted DC voltage will be implied across the inverter. Finally the output of the inverter will be higher than the input DC voltage.

2.1.A. Rotor and Stator current

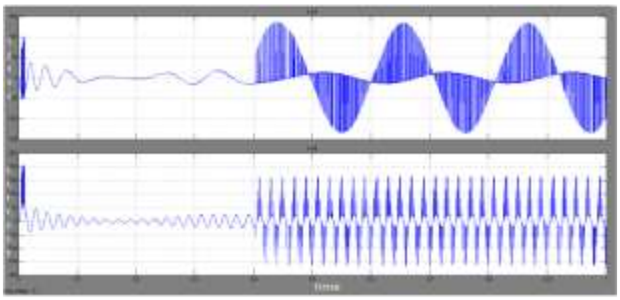

Fig 2.4 Rotor speed and rotor current of induction motor

The Rotor and Stator current response of three -phase induction motor is shown in. Initially the rotor current fluctuates between and 0.4 s and then it reach a steady state.

2.1.B. Rotor Speed and Electromagnetic torque

The rotor speed is gradually increases to the rated speed. The rated speed is 1650 rpm and it is reached at nearly 0.4 second. Similarly the time response of electromagnetic torque of three - phase induction motor is variable between 0 to 0.4 second then at last the rated torque is reached.

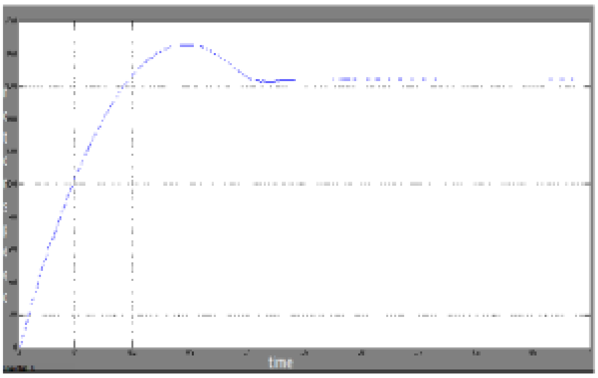


Fig 2.5 Rotor Speed

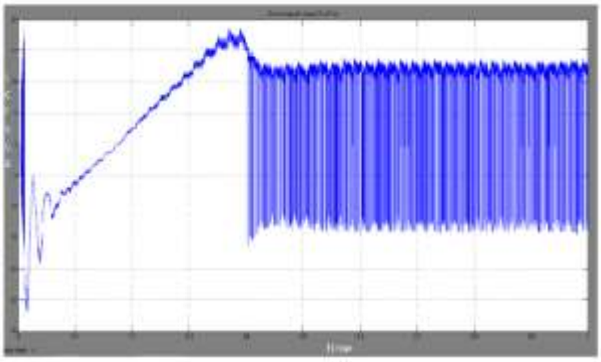

Fig.2.6 Electromagnetic torque

2.1.C. Rotor and Stator flux

It is observed that the flux of rotor is greater than the stator. Both the values attain the steady state at 0.4 second. The values 0.5wb and 0.4wb are the steady state value of rotor and stator flux respectively

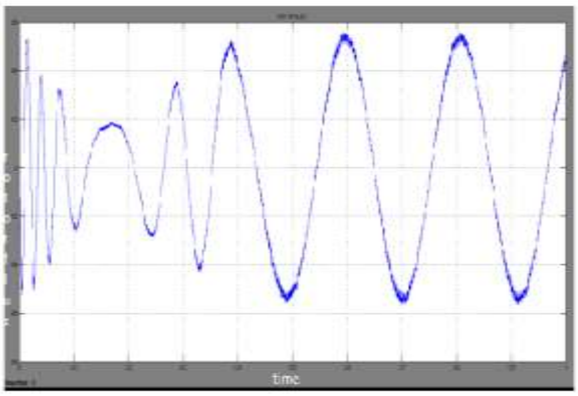


Fig.2.7 Rotor flux waveform

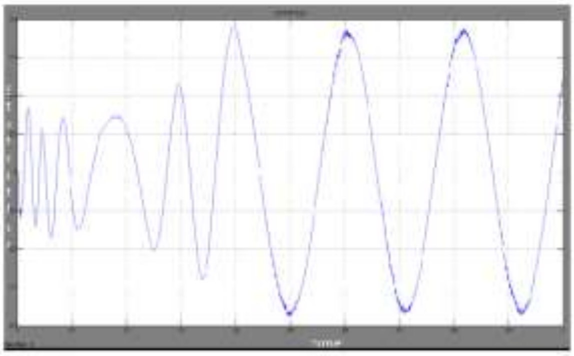

Fig. 2.8 Stator flux waveform

## 3. SIMULATION OF CURRENT SOURCE INVERTER FED INDUCTION MOTOR

The simulation diagram of Current Source Inverter fed induction motor is shown in fig 3.1. Gate pulse is given to inverter circuit by pulse width modulation .Three phase output is taken through second order filter to reduce the harmonics.

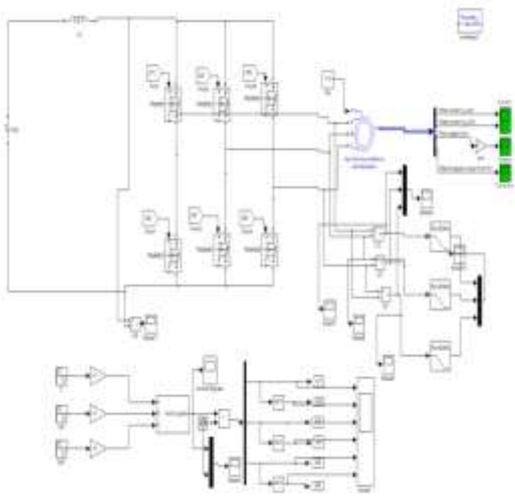

Fig 3.1 Simulation circuit of current source inverter fed Induction motor

SIMULATION RESULTS

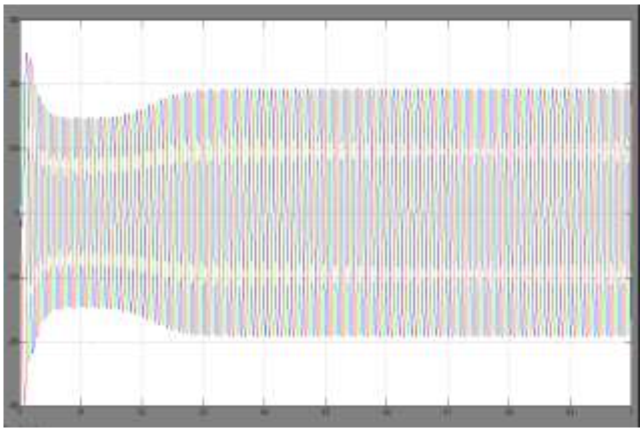

Fig 3.2 Output voltage of CSI

Output voltage and input voltage is shown in fig 3.2 and 3.3. It is inferred that output voltage magnitude (280v) is dependent on input voltage magnitude (280v).

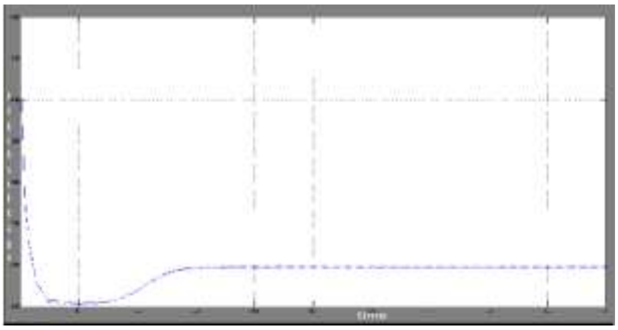

Fig 3.3 Input voltage of CSI

3.1. A. Rotor and Stator Current

Stator and rotor current obtain steady state at amplitude of 20A.

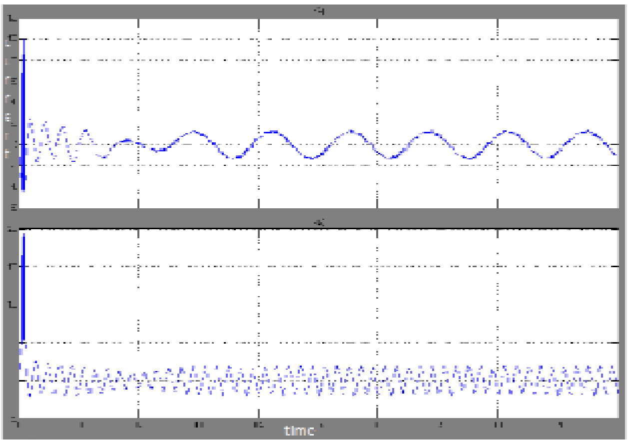

Fig. 3.4 Rotor and stator current waveforms

3.2. B. Rotor speed and Electromagnetic torque

Speed of the rotor reaches a rated speed at 0.25s of 1720rpm. Torque fluctuates till 0.25s and reach the rated torque of 10N-m.

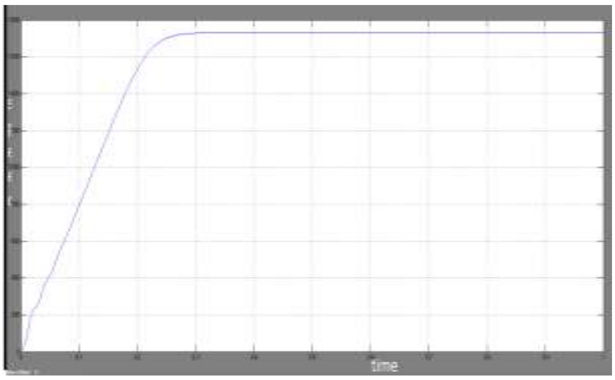

Fig. 3.5 Rotor speed

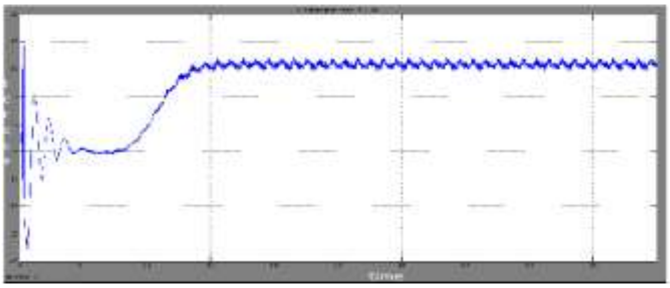

Fig. 3.6 Electromagnetic torque

## 4. SIMULATION OF VOLTAGE SOURCE INVERTER FED INDUCTION MOTOR

The simulation diagram of Voltage Source Inverter fed induction motor using MATLAB/SIMULINK toolbox is shown in fig 2.15.The speed, current, torque of the induction motor is measured by connecting motor with bus selector.

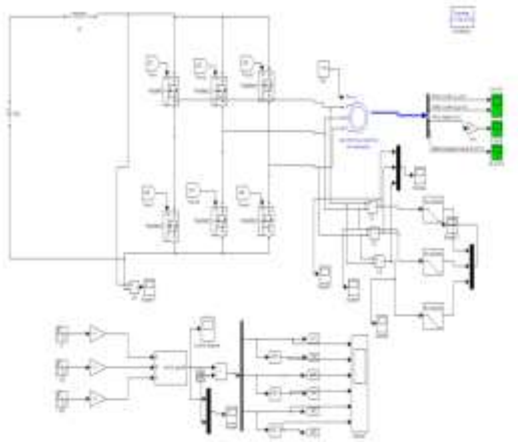

Fig .4.1. Simulation circuit of voltage source inverter fed Induction motor

## SIMULATION RESULTS

4.1.A. Rotor and Stator Current

Rotor and stator current reaches steady state at 0.3s with 15A.

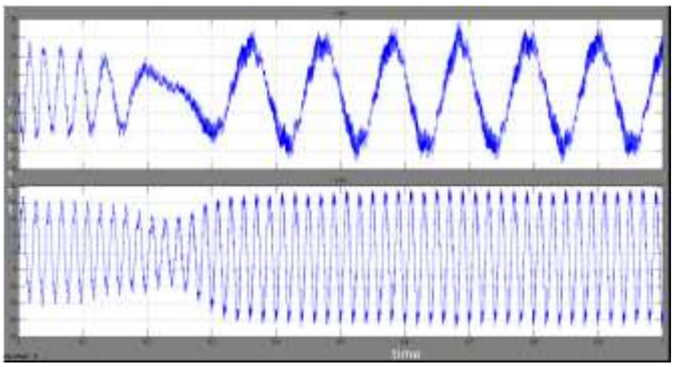

Fig 4.2. Rotor and Stator current waveform

4.2.B. Output voltage and Input voltage

Given input voltage is about 3000v.The output is taken through the filter which removes second order harmonics

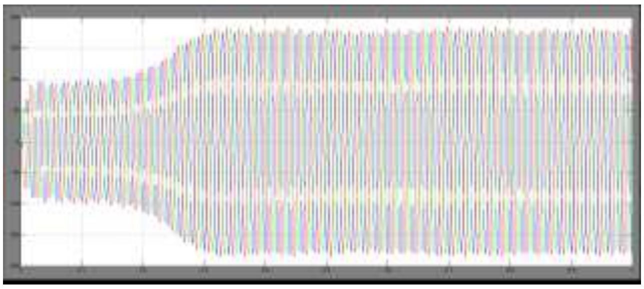

Fig.4.3. Output Voltage of VSI

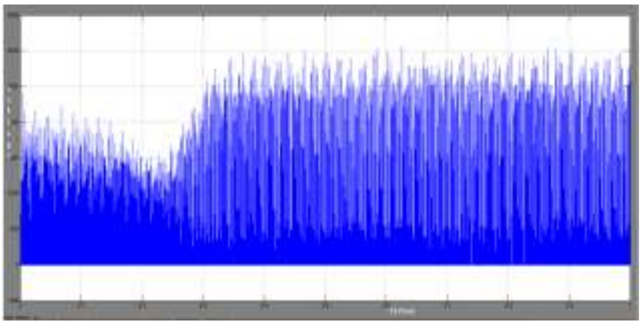

Fig.4.4. Input Voltage of VSI

4.2.C. Rotor speed and Electromagnetic torque

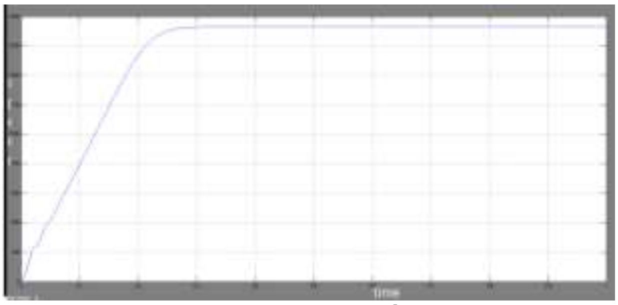

Fig.4.5. Rotor speed

Speed of the rotor reaches a rated speed at 0.25s of 1720rpm. Torque fluctuates till 0.25s and reach the rated torque of 10N-m.

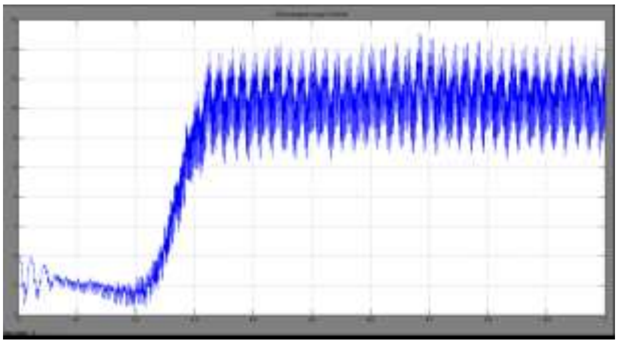

Fig.4.6. Electromagnetic torque

## 5. CONCLUSION

This paper has presented the simulation model of Z-source inverter based Induction motor drives using pulse width modulation technique. From simulation waveforms compare to voltage and current source inverter fed motor and verifies the output z source inverter is better than current and voltage source inverter, it is clear that Z-Source inverter will produce the desired output voltage even when input voltage level is reduced. Z-source inverter provides output voltage without voltage sags with reduced line harmonic current and also improves the power factor.

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