Performance Analysis of Z-Source Inverter Fed Single Phase Induction Motor Drive

Rafat Bano[1], Vijay Anand Bharti[2]

[1]M.Tech, [2]Assistant Professor

Department of EE, Mittal Institute of Technology, Bhopal, India

Abstract*—Many research works are focusing in the development of the efficient control algorithms for high performance variable speed induction motor drives. Traditionally, three phase inverters with six switches have been commonly utilized for variable speed induction motor drives. This involves the losses of the six switches as well as the complexity of the system. Thus the main issue of this work is to develop a cost effective, simple and efficient high performance induction motor drive. In this research work a split phase single phase induction motor is used in which splitting is done by means of linear and high frequency transformer. In this Z-source inverter technique is used to boost the voltage which makes motor drive more efficient. The advantage of this method is that the single conversion from dc to ac takes place. Simulations have been done in MATLAB/ SIMULINK environment to explore the system response. The response obtained for the rotor speed (which shows soft starting of motor), main winding current, auxiliary winding current and electromagnetic torque. Result comparison has done which shows the better performance of the system.

***Keywords*— SPIM, IM, VSI, ZSI, DC/AC, VS.**

I. INTRODUCTION

Many analysis works are focusing within the development of the economical management algorithms for top performance variable speed induction motor (IM) drives. Induction motor has been operated as a work horse in the industry because of its simple build, high robustness and customarily satisfactory potency. Recent development of high speed power semi conductor devices, 3 phase inverters participate in the key role for variable speed AC motor drives. Historically, 3 phase inverters with six switches (SSTP) are ordinarily utilized for variable speed IM drives; this involves the losses of the six switches still because the complexness of the management algorithms and interface circuits to get six PWM logic signals. Up to now researchers primarily focused on the development of new management algorithms. However, the cost, simplicity and adaptability of the general drive system that are a number of the foremost necessary factors didn't get that abundant attention from the researchers. That’s why, despite tremendous analysis during this area, most of the developed system didn't attract the industry. Thus, the most issue of this work is to develop a value effective, easy and economical high performance IM drive.

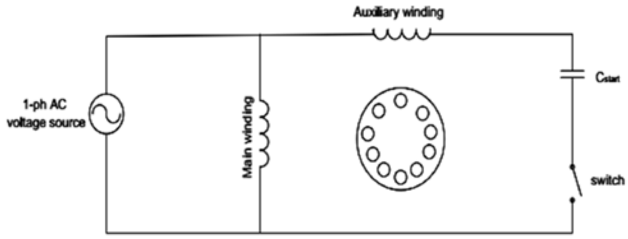

Figure 1.1: Schematic diagram of Capacitor Start Motor

The basic inverter topologies are Voltage source inverter (VSI) and Current source inverter (CSI), which incorporates diode rectifier face, DC link and Inverter Bridge. So as to boost power issue, either an AC inductor or DC inductor is generally used. The DC link voltage is roughly adequate to 1.35 times the road voltage and therefore the Voltage source inverter could be a buck converter that may solely turn out an AC voltage restricted by the dc link voltage. Due to this nature, the Voltage source inverter primarily based PWM VSI and CSI are characterized by comparatively low potency due to switching losses and wide electromagnetic Interference (EMI) generation.

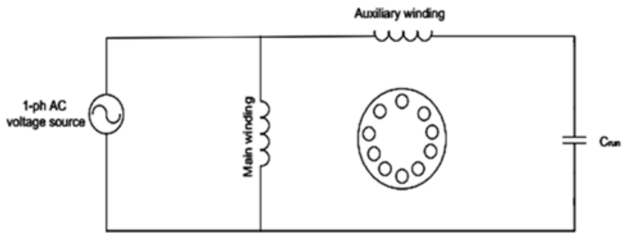

Figure 1.2: Schematic Diagram of Permanent Split capacitor Motor

The drives industry provides choices using fly back convertor or boost convertor with energy storage or diode rectifier to attain ride- through. But these choices include penalties of value, size, weight and complexness. Influx and harmonic current from the diode rectifier will contaminate the road. Low power issue is another issue of the normal drives. Performance and responsibility are compromised by the voltage source inverter structure, as a result of misgating from EMI will cause shoot- through that results in destruction of the inverter, the dead time that's required to avoid shoot through creates distortion and unstable operation at low speeds, and common mode voltage (CMV) causes shaft current and premature failures of the motor. During a traditional voltage source inverter, the two switches of the identical section leg will never be gated on, at the same time, because, such activity would cause a short circuit (shoot-through) and would destroy the inverter. Additionally, the maximum output voltage available will never exceed the dc bus voltage.

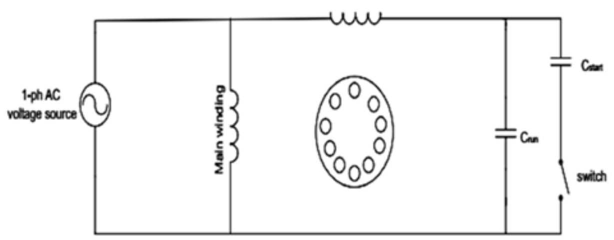

Figure 1.3: Schematic Diagram of Capacitor start/ Capacitor run Motor

1.2 Single Phase Induction Motor

Single phase induction motors today form a large percentage of the connected load attributed to electrical motors. Most of the small, fractional horsepower induction motors used in the US is single phase induction motors. Their rugged construction and single phase operation makes them an ideal choice for usage in household devices such as refrigerators, air conditioners and heat pumps.

Single phase induction motors generally have squirrel cage rotors similar to their polyphase counterparts. However, unlike polyphase induction motors that are capable of self-starting, true single phase induction motors do not produce any starting torque. However, if a single phase induction motor is started in one direction by some external means, it will develop torque in that particular direction. Due to the presence of a single main winding, the single phase induction motor does not produce a rotating magnetic field at standstill. Rather, it produces a pulsating magnetic field which is incapable of producing angular torque when the motor is at standstill. Various methods are used to start a single phase induction motor. Usually, the motor is named after the method used to start it. Based upon the method used for starting, many single phase induction motors can be classified as:

- Split phase motor
- Capacitor motor
- Shaded-pole motor

For the purpose of this study, shaded-pole motors are not considered as they are generally used in comparatively lower power applications and the harmonic filtering phenomenon outlined previously has not been observed with motors other than the capacitor start capacitor run motor. Capacitor motors are one of the most widely used category of single phase induction machines because of their use in household devices and their peculiar construction produces phenomena like harmonic ‘amplification’ as pointed out previously and in [4] and hence form the basis of this study. The sections to follow discuss the construction and principle of working of this class of machines.

II. LITERATURE REVIEW

2.1 Review based On ZSI

Van der Broeck HW et al. [1], prompt the four switch electrical converter using four switches and 4 diodes as a sensible various to the six switch electrical converter with six switches and 6 diodes. In the meantime in four switch inverters, since one in all the motor section windings is connected onto the neutral purpose of the DC- link capacitors, the one section current flowing into the DC-bus can directly charge one in all the capacitors and discharge the opposite. This will cause vital fluctuations of the DC-bus voltage and afterward unbalance 3 section currents at the electrical converter output, thus, needs a lot of larger DC-link capacitors.

Miaosen Shen et al. [2], have investigated and compared 3 completely different inverters, ancient PWM inverters, DC-DC boosted PWM electrical converter and Z□source electrical converter.

Hossein Madadi Kojabadi et al. [3], have created a comparative analysis of various pulse dimension modulation strategies for low-value induction motor drives, they according to the unbalance 3 section output currents as a result of it the dynamic unbalance between the 2 capacitors by completely different pulse dimension modulation strategies.

K.Ravichandrudu et al. [4], work on a chip implementation of Z-source electrical converter fed induction motor drive. This methodology presents associate degree impedance-source electrical converter fed induction motor and its characteristics and compared with alternative ancient inverters.

G.Pandian et al. [5], work on Implementation of construction Inverter-Fed Induction motor Drive. This methodology presents the simulation and implementation of construction electrical converter fed Induction motor Drive.

K. Srinivasan et al. [6], work on Performance Analysis of a Reduced Switch Z Source electrical converter fed IM Drives. This methodology investigates the performance of a 4-switch, 3- section Z-source electrical converter (4S3P) fed value effective induction motor (IM) drive system. Within the planned approach, rather than a traditional 6-switch, 3-phase electrical converter (6S3P) a 4-switch, 3-

phase Z□source electrical converter is employed. This reduces the price of the electrical converter, the shift losses, and therefore the complexness of the management algorithms and interface circuits to come up with half-dozen PWM logic signals. Moreover, the planned Z-source electrical converter system employs a novel LC network within the dc link and a tiny low condenser on the AC facet of the diode side. By dominant the shoot-through duty cycle, the Z-source will turn out any desired output ac voltage, even larger than the road voltage. As a result, the new Z-source electrical converter system provides ride-through capability throughout voltage sags, reduces line harmonics, improves power issue and irresponsibleness, and extends output voltage vary.

Lekhchine Salima et al. [7], work on Comparative Performances Study of a Variable Speed Electrical Drive. This methodology presents the comparative performances of a variable speed electrical drive. We have a tendency to think of 2 cases: 1st, the induction motor is fed by a matrix device and once this; it's fed by three-phase voltage electrical converter. The management ways of every configuration are bestowed and simulation results are analyzed and taken. The simulation results are disbursed mistreatment the package MATLAB/Simulink.

Preeti Soni et al. [8], work on Analysis of Voltage supply Inverters mistreatment area Vector PWM for Induction Motor Drive. Developments in power natural philosophy and semiconductor technology ought to cause enhancements in power electronic systems. Completely different circuit configurations specifically construction inverters became fashionable and appreciable analysis interest is generated in them. Variable voltage and frequency provide to AC drives are invariably obtained from a three-phase voltage supply electrical converter. Variety of Pulse dimension modulation (PWM) schemes are accustomed get variable voltage and frequency provide. The foremost wide used PWM schemes for three-phase voltage supply inverters are carrier-based sinusoidal PWM and area vector PWM (SVPWM). There's an increasing trend of mistreatment SVPWM as a result of their easier digital realization and higher DC bus utilization. This methodology proposes SVPWM implementation of Associate in Nursing Induction motor. The model of a three-phase voltage supply electrical converter is mentioned supported area vector theory. Simulation results are obtained mistreatment MATLAB/Simulink setting.

S. Shiva prasad et al. [9] work on Performance analysis of novel area vector PWM for twin 2 level and 3 level electrical converter fed six-phase induction motor (SPIM). during this methodology, a standard MATLAB/ Simulink implementation of Six section Induction motor model management by area Vector PWM theme is adopted to twin 2 level and twin 3 level electrical converter fed six-phase induction motor. During this standard system, every block solves one in every of the model equations; it's to produce management and access of the machine parameters. The SVPWM methodology provides high safety voltages with less harmonic parts. The principle of SVPWM methodology with voltage vector choice procedure for 2 level and 3 Level fed six-phase induction motor with a comparative study of those two are investigated. Within the planned methodology, the area vector diagram of every three-level electrical converter is rotten into six area vector diagrams of two-level inverters. Once decomposition, all the remaining necessary procedures for the two and three-level SVPWM are done like standard dual two-level electrical converter. This planned methodology reduces the algorithmic rule complexness and also the execution time. The theoretical study was numerically simulated and high power and high voltage 2 level electrical converter were applied to induction motors drives.

S.Sankar et al. [10], work on Simulation of Six Switch 3 section electrical converter Fed Induction Motor Drive System. This methodology presents a complete implementation of Induction Motor mistreatment Six-Switch Three-Phase electrical converter (SSTPI) for superior industrial drive systems. The microcontroller is enforced in real time operation system. This reduces the worth of the electrical converter, the change losses, and also the complication of the control panel for generating six PWM logic signals. The entire microcontroller primarily based SSTPI for the induction drive system is verified by simulation mistreatment PSpice / MATLAB and additionally through an experiment by mistreatment microcontroller – 89C2051. The FSTPI fed drive with a traditional SSTP electrical converter fed drive is additionally created in terms of speed response and total harmonic distortion (THD) of the mechanical device current. Theoretical and experimental results of the planned drive verify the lustiness of the drive.

R. Linga Swamy et al. [11], work on Speed management of area Vector Modulated electrical converter Driven Induction Motor. This methodology proposes, v/f management of Induction motor is simulated for each open loop and control system systems. The induction motor (IM) is fed from 3 section bridge electrical converter that is operated with area vector modulation (SVM) Technique. Among the assorted modulation ways, area Vector Modulation Technique is that the economical one as a result of its higher spectral performance and also the output voltage is a lot of near sin curve . The performance of SVM technique and trigonometric function triangle pulse dimension modulation (SPWM) technique are compared for harmonics, THD, dc bus utilization and Output voltage and determined that SVM has higher performance. These techniques once applied for speed management of

Induction motor by v/f methodology for each open loop and control system systems it's determined that the induction motor performance is improved with SVM.

S. M. Tripathi et al. [12], work on Dynamic Performance Analysis of Self□commutating PWM CSI-fed Induction Motor Drive below MATLAB setting. This methodology proposes an endeavor that has been created to research analytically the dynamic performance of the self-commutating current supply inverter-fed induction motor drive with volts/Hz management strategy. Speed and current PI regulators ar employed in the conclusion of closed-loop management structure of the drive system. The control system mathematical modeling of the entire drive system is bestowed within the synchronously rotating d-q organization. The dynamic performance curves of the drive are obtained through MATLAB simulation and ar mentioned intimately.

Amol R. Sutar et al. [13], work on Performance Analysis of Z-source electrical converter Fed Induction Motor Drive. This methodology proposes performance analysis and simulation of most constant boost management with third harmonic injection strategies for the Z source electrical converter, which might get most voltage boost for a set modulation index. The Z-source electrical converter could be a recently unreal a replacement power conversion conception principally developed for electric cell conveyance applications. The Z-source electrical converter has advantageous over ancient inverters and it are often utilized all told AC and DC power conversion applications. All ancient PWM strategies are often accustomed management Z source electrical converter. Most constant boost management strategies eliminate the low□frequency ripples within the electrical device current and electrical condenser voltage by maintaining the shoot-through duty cycle constant and minimize the voltage stresses of change devices at identical time. The utmost boost management methodology is appropriate for comparatively high output frequency solely, however within the most constant boost management methodology the Z-source network style is freelance of the output frequency and determined solely by the change frequency. during this methodology Z-source electrical converter parameters like boost issue, output DC link voltage, electrical condenser voltage, output AC voltage, voltage gain etc. are determined for max constant boost management methodology for a set modulation index and these results are verified by simulation and experiments.

Liss Mariya Baby et al [14] proposed a closed loop speed control of z source converter fed induction motor drive with peak dc link voltage control. Induction motor control is based on closed loop scalar control strategy. It can overcome the limitations of voltage source inverter and can offer better speed control and drive operation during voltage sags and normal working conditions. The peak dc link voltage employed in order to achieve excellent transient performance which enhances rejection of disturbance, including thee input voltage ripple and load current variation, and have good ride through for voltage sags. A maximum boost control PWM is used in switching algorithm.

Slavomir Kascak et al [15] deals with conventional control of a single-leg voltage source inverter loaded by a single-phase induction motor and its improvement by current control loop applied at reduced speed operation. Current control brings a major improvement of current quality and better behavior of motor as well.

III. PROBLEM STATEMENT

Several strategies exist for variable speed operation of a single-phase induction motor. Considering simplicity and low cost, most typical kind is that the management of applied voltage to the motor. Typical torque-speed characteristics of an induction motor with variable voltage together with the fan load curve are shown in Figure 1.5 indicating the adjustable speed operation. The voltage applied to the motor may be varied by an autotransformer or a tapped winding arrangement. Since tap changing is performed by a mechanical switch and considering size and weight of the electrical device, this kind of voltage management might not be favorable. Another approach is to use an AC chopper based TRIAC semiconductor switches.Generally the number of levels, N within the output is odd rather than even. This is often owing to inclusion of zero voltage level that makes the stepped output wave shape curved and improves its harmonic profile.

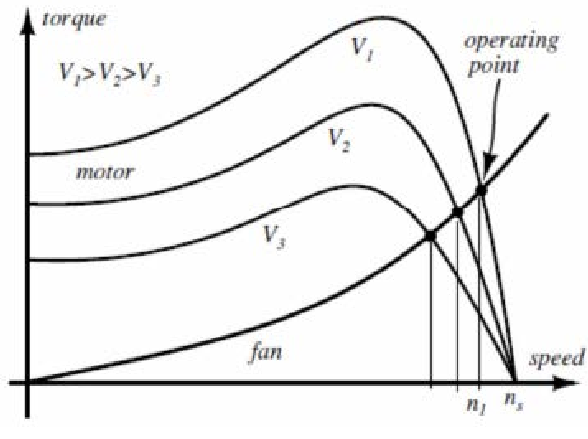

Figure 1.4: Torque-speed characteristics of an induction motor and fan load with variable voltage.

The TRIAC is turned on at a desired phase permitting some parts of the provision voltage be applied to the most and auxiliary windings of the motor. In another methodology, solely main winding voltage is varied by a TRIAC AC chopper whereas keeping the auxiliary winding voltage constant at rated worth. Phase control methodology leads to discontinuous input current wave shape that consists of upper order odd harmonics of provide frequency. Multi-speed operation at 2/3 and three□thirds of the available frequency is employing a TRIAC bridge wherever this waveform contains odd and even harmonics also as sub-harmonics of supply frequency that exceeds the harmonic limit standards. AC choppers using integral cycle control methodology uses bound variety of complete cycles be applied to load followed by bound variety of zero voltage periods. Sub-harmonics of the provision frequency additionally occur during this kind of management that is extremely tough to eliminate by the system.

IV. PROPOSED WORK

4.1 Introduction

Voltage sags may disrupt an ASD system and stop working the crucial loads and processes. Most of the power quality connected issues in ASDs are because of the temporary (typically 0.1–2 s) voltage dips or sags of 10–50% below the nominal voltage. The DC link capacitance in an ASD couldn't hold DC voltage higher than the operable level under such voltage sags because of it's a comparatively small energy storage component. It ends up in a scarcity of ride through capability for sensitive loads driven by ASDs, and additionally for Z-source inverter fed induction motor drives; the stator coil current ought to be restricted to the operable range.

The magnitude of the output line voltage of Z-source inverter is only supported the quantity of boost achieved within the DC link of the inverter. The DC link voltage boost or boost issue depends on the shoot-through duty period that is inserted within the six switching waveforms of the ability devices. The shoot-through duty period is accumulated from the standard zero vector time periods. The voltage boost is reciprocally associated with the shoot-through duty ratio; thus the ripple in shoot□through duty ratio would result ripple within the current through the Z-source inductance further because the voltage across the Z-source capacitance. Once the output frequency is low, the Z-source inductance current ripple becomes important. What is more, the standard management techniques couldn't change use of the input DC link voltage, which ends up in low management voltage margin of the drive system. The switching stress across the ability IGBT's is raised whereas altering the switching waveforms either by adding or removing certain periods to insert the shoot□through state. The output line voltage/current wave forms have important harmonics because of the modification of conventional modulating strategies. The time harmonics exist in the terminal voltage waveform (output of Z-source inverter) turn out various rotor harmonics, which successively act with the basic air-gap flux, generating undesirable harmonic torque ripples and ensuing torque pulsations within the rotor of the induction motor drive. In the conventional management techniques, the DC link voltage and also the motor terminal voltage are controlled by independent controllers and also the presence of a lot of number of controllers affects the stability of the drive system.

4.2 Operation Blocks of Z-Source Full Bridge DC/DC Converter

Z-source full bridge dc/dc converter is designed for boosting the input voltage to higher output voltage level. The main circuit diagram of the full-bridge Z-source dc/dc converter is shown in Fig.4.1.

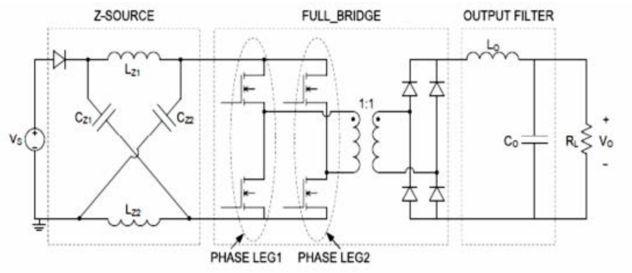

Figure 4.1: Circuit diagram of the Z-source full bridge dc/dc converter

The Z-source part of the converter, shown with dashed part, is used to boost the voltage across the full bridge MOSFETs. Boosting of input voltage is achieved by switching the MOSFETs, in the same line, at the same time. By this way, shoot□through operation is used to energize the Z-source inductors, L_{Z1} and L_{Z2}.

4.3 Analysis of Z-Source DC/DC Converter

The analysis of the input voltage to output voltage equation in terms of the duty factor, D, and other circuit components (inductors, capacitors, load resistance) is made for both in CCM and in DCM operations. Additionally, for both operation modes, the transfer functions and small signal models are derived. To use the symmetrical behavior of Z-source structure, the Z-source capacitors (CZ1 and CZ2) are set equal to each other and Z-source inductors, (LZ1 and LZ2) are chosen such as their sizes are same. Then, by the symmetry, voltage waveforms on Z-source inductors come out identical. The current waveforms through Z-source capacitors are also identical over a period. Dc component and small signal components in Z-source capacitor currents are same.

V. SIMULATION & RESULTS

5.1 Simulink

Single phase impedance source inverter fed split phase induction motor drive is simulated in this proposed work. For simulation of the proposed system here MATLAB software is used. The whole simulation is modeled in

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Simpower Sim tools. Figure 5.1 shows the Simulink model of the proposed system.

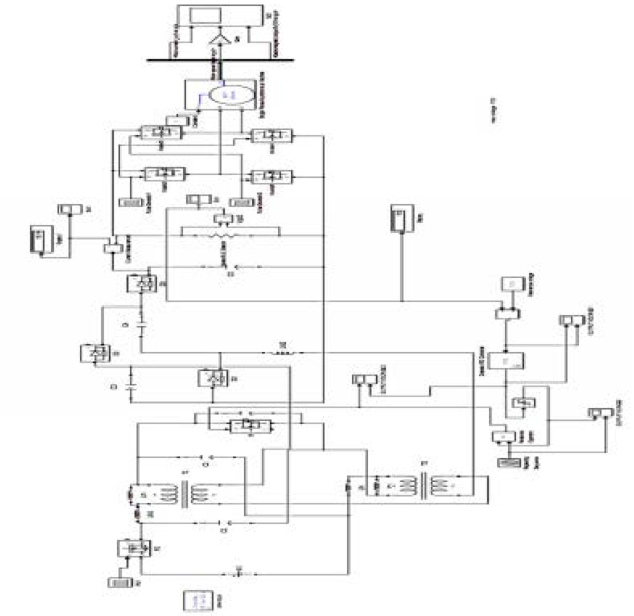

Figure 5.1: SIMULINK model of proposed Single Phase NPC-MLI

Table 5.1 shows the parameter used in this simulation. Here in this simulation impedance source inverter is used for conversion of dc power to ac. The transformer is used for phase splitting of the output voltage for operation of single phase split based induction motor.

Table 5.1: Parameter used in the SIMULATION

Parameter	Value
DC source Value	24 V
Z-Source converter Parameter	
Linear High Frequency Transformer	5000VA, 50kHz 24/100 V
L_1=L_2	1μH
C_1=C_2	300μF
C_o	5mF
R	700Ω
DC link Capacitor C_s	100nF
Coupling Capacitor C_3=C_4	1μF
Carrier Frequency	5kHz
SPIM Parameter	
Motor Rating	¼ HP, 170 V, 50 Hz
Main Winding Stator	Rs=2.02Ω, L= 7.4mH
Main Winding Rotor	R_r'=4.12 Ω, L_l'= 5.6 mH
Auxiliary Winding Stator	R_{sa}=7.14 Ω, L_{sa}= 8.5 mH
Number of Pole	2
Disconnection Speed	75%

Table 5.2 shows the Operation of the ZSI in this simulation

Switching States	S_1	S_2	S_3	S_4	Output Voltage
Active States	1	0	0	1	Finite Voltage
	0	1	1	0	
Zero State	1	0	1	0	Zero
	0	1	0	1	
Shoot Through State	S_1	S_2	1	1	Zero
	1	1	1	1	

5.2 Result & Discussion

The proposed system is simulated in MATLAB/ SIMULINK software for checking performance of the proposed system. In this section the application of proposed system in split phase induction motor drive. Figure 5.2 shows the speed of the proposed system applied on the single phase split phase induction motor. The result shows the soft starting of the drive. Here it is clearly seen that the motor start to runs smoothly from zero to 1500 rpm from zero to 2 sec. then it keep constant till end of simulation.

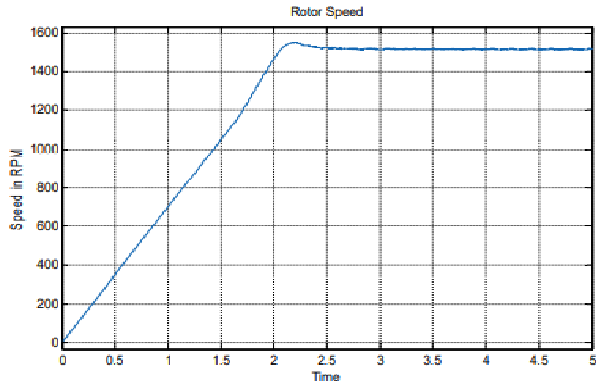

Figure 5.2: Rotor Speed of the Single phase Split Phase Induction Motor with proposed System

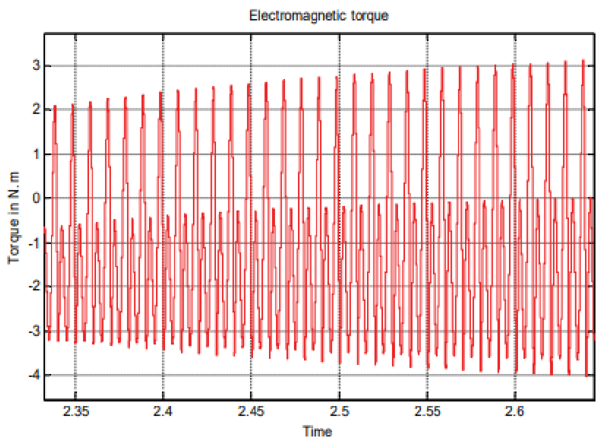

Figure 5.3: Electromagnetic Torque response of Proposed ZSI based SPIM drive Main Winding Current

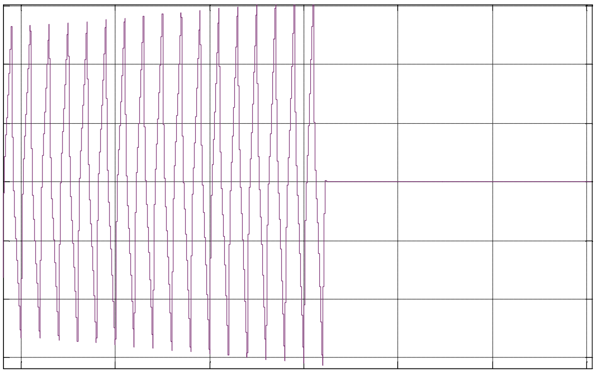

Figure 5.4: Main winding Current response of Proposed ZSI based SPIM

Figure 5.4 shows the main winding current response of the proposed ZSI based Split phase induction motor drive. The split phase induction motor have two winding one is responsible for running of the motor and secondary winding which is called Auxiliary winding is used only for starting the motor. Figure 5.5 show the response of Auxiliary winding of the proposed inverter based SPIM.

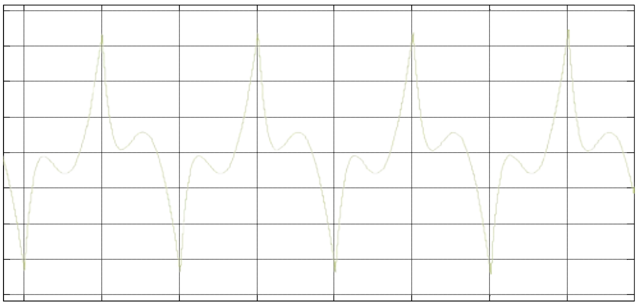

Figure 5.5: Auxiliary Winding Response of the proposed ZSI based SPIM

From the figure the cutoff of the auxiliary is taken when the speed reached 75% of the maximum speed. This time is at 1.625 s. at this time auxiliary winding is cutout. The operation of the split phase is produce by the using the transformer T1 and T2.

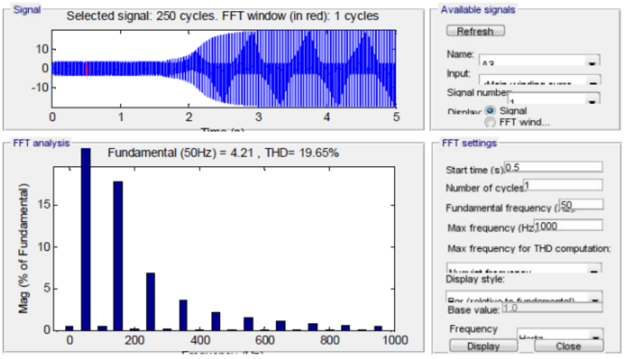

Figure 5.6: FFT analysis of the main winding current of the proposed ZSI fed SPIM

These transformers are used for phase shifting of the output voltage of the proposed ZSI inverter. The main function of the auxiliary winding is produce the phase difference for startup the induction motor.

Figure 5.6 shows the FFT analysis of the main winding of the split phase induction motor. Here it is seen that the total harmonics distortion of the main winding is 19.65% found.

Figure 5.7 shows the output voltage of the boost mode operation of the proposed inverter.

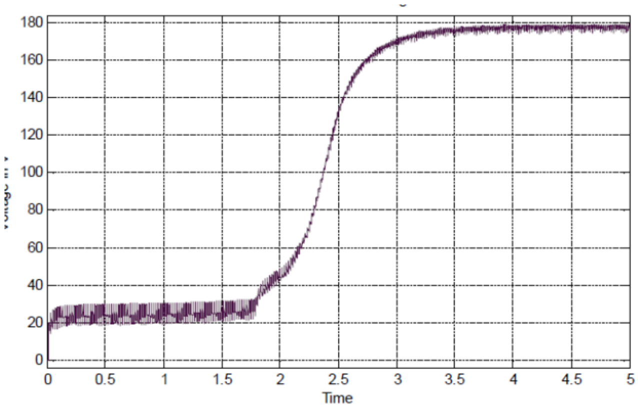

Figure 5.7: Boost Mode operation of the Proposed Impedance Source inverter

5.3 Result Comparison

In this section here discuss with the previous work with proposed work. Table 5.3 shows the comparison between previous work and present work.

Table 5.3: Comparison between previous work and present work

Parameter	Previous work	Present work
Inverter used	Half Bridge	Full Bridge is more efficient then half bridge
Phase splitting Technique	Capacitor produce 90^0 phase split for main and auxiliary winding	Linear Transformer is used for splitting phase
Methos involved for conversion	Voltage source conversion	Impedance source Conversion which is more efficient than voltage source conversion
Motor Running Status	Fluctuated start due to this jerk on the rotor present	Soft start due to this jerk on the rotor is very small
For low voltage operation	No	Yes due to ZSI

VI. CONCLUSION & FUTURE WORK

6.1 Conclusion

Induction motors are major motor works in the field of industries. There are many methods implemented for controlling of them. Single phase induction motor now a day applied in domestic as well as industrial area. Due to presence of single winding it cannot start because of not producing of rotational torque. Generally capacitors are used for starting of the motor. Due to increasing application of non-conventional energy the application of single phase induction motor increased. So here it is requirement of the inverter for converting of DC Power to

AC. The output of the non-conventional energy is very less so for starting of the induction motor required two stage of converter technology one for boosting the voltage and other is used for conversion from dc to ac. Due to this the complexity of the converter is more. This proposed work proposed impedance source inverter as a single stage conversion of the DC power to AC power. For so in this proposed work firstly reviewed the literature related to the inverters and induction motor. The new topology is discussed in this proposed work in which transformer is used for splitting the phase and impedance source inverter is used for boosting the DC voltage. The whole work is simulated in MATLAB software for validation of the proposed work. The THD of the main winding is found is 19.65% which less than the existing system. The result also shows the soft starting of the single phase induction motor.

6.2 Future Work

Domestic application utilizes single phase induction motor so now it is a major research area in now a day. There are many things which are not considered in this proposed work. The following are the major future scope of this proposed work:

- In this proposed work there is no consideration about the reduction of the ripple in the main winding. In future ripple reduction technique is required for smoothing the current.
- The time delay is seen in the running of the SPIM. In future there is required circuit application which reduces the rising time of the rotor speed.
- This proposed work used simple PWM technique for controlling of the switch of inverter. In future advance method like SPWM, SVPWM, SHE ect type of pulse generation technique is required for controlling of the switch.
- The whole system is feasible with the help of DSP system is requite=red in the future.

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