A CLOSE LOOP SPEED CONTROL FOR HIGH PERFORMANCE Z-SOURCE INVERTER FED INDUCTION MOTOR DRIVE

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Abstract
This paper presents a performance analysis of a close loop speed control of three phase an induction motor fed by a High Performance Z-source inverter (HPZSI);Speed control is based on a Closed loop V/F control strategy. A V/F control is based PWM voltage modulation and PWM technique is used for Z-source inverter. A PI dual loop controller (i.e. current and voltage controller) is used to control the shoot-through state of Z-source capacitor voltage error. The operational performance of High performance Z-source inverter and speed control is also tested using PSIM software. The performance analysis of HPZSI fed induction motor drive is based on speed response, DC link voltage control and THD analysis on current by keeping the modulation index and duty ratio constant. The performance of speed control method is verified by PSIM simulation of a 1.8KW induction motor fed by HPZSI.
Index Terms: High performance Z-source inverter, PWM, V/F control, closed loop speed control.

I. INTRODUCTION

The adjustable speed drives are mainly dependent on use of induction motors, almost 80% of drives in industry are based on use of induction motor. Which consist of front end rectifiers, dc link capacitors and Inverter bridge. Induction motors have many advantages as compared to DC drives and synchronous machines in many aspects, such as size, efficiency, cost, maintainability and control. The ASD traditionally based on voltage source inverter or current source inverter and both suffers from some limitations that they are either buck or boost converter not buck-boost converter [1][3]. The VSI is a buck converter that only produced ac output voltage limited by dc link voltage. Hence VSI based ASD system having following limitations.

1. Output voltage is below the input voltage i.e. buck output
2. Voltage sag can be occurs in ASD system and shut down critical loads and processes.
3. The effect of inrush and harmonic current of diode rectifier can cause on line as well as low power factor is another issue.
4. The shoot through can occur due to miss-gating from EMI.

The CSI converter having following limitations:

1. The current source inverter acts as boost inverter for dc-to-ac conversion. Also current source inverter is a buck converter for ac-to-dc power conversion and the I-source converter is a buck rectifier for ac-to-dc power conversion when the output dc voltage is smaller than ac input voltage.
2. The open circuit problem cause by EMI noise and also cause waveform distortion.
3. The main switches of the I-source converter are used to block the reverse voltage that requires a series diode in combination with high-speed and high performance transistors such as insulated gate bipolar transistors (IGBTs). This prevents the direct use of low cost and

high-performance IGBT modules and intelligent power modules (IPMs).

A recent development in inverters, Z-source inverter, has allows to overcome the problems of traditional converters. Z-source based ASD system can produce any output ac voltage greater than the line voltage, regardless of input voltage, provided ride-through during voltage sag [3].

This boost voltage is necessary when voltage sag occurs in DC side or the load needs higher voltage than voltage level provided by DC side. In comparison with Z-source inverter the traditional voltage source inverter has six active state and two zero state. When the upper or lower switches turn on at same time, shorting the output terminal at this condition the zero state produced.

The traditional Z-source inverter is combination of two inductors and two capacitors connected in anti-parallel combination called as impedance network. There are three different topologies for three phase two level ZSI as voltage source: the first topology is the basic ZSI; the second topology is the bidirectional ZSI; and the third topology is the high performance [1]. The traditional Z-source can be change into a high performance Z-source inverter by addition of a switch in front of Z-source inverter. The HPZS inverter can operate at wide range of load with very small value of Inductor eliminate possibility of DC link voltage drop.

The Volt per hertz (v/f) induction motor drives are widely used in several industrial applications promising not only energy saving but also improved performance and quality. This report consists of the performance comparison of a V/F close loop control of three phase induction motor drive fed with High Performance Z-source inverter.

This paper presents the basic idea of high performance Z-source inverter, v/f control block diagram, close loop speed control of induction motor and simulation and performance analysis.

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II. BASIC ELEMENTS IN PROPOSED SYSTEM

A. High performance Z-source Inverter

The proposed high performance Z-source inverter is illustrated in this section. The basic constructional and operational difference between conventional Z-source inverter and proposed inverter is as per the diagram shown in figure 1. As can be seen, the first difference is the connection way. In proposed system Z-source network is in series with the inverter bridge, where as in traditional system the ZS network is in parallel with the inverter bridge [4]. The second between these two is the control switch SW7 is added in the proposed system to control the output voltage of ZS network. The third difference is the connection of the capacitor used in Z-source. The capacitor is connected in inverse way which result in polarity of capacitor voltage in proposed inverter remains same with the polarity of input source voltage. At last, the capacitor C_{in} with the diode D8 introduced in proposed system to control the reverse current from inverters and unidirectional current from other applications. Since the Z-source network is in series with inverter, the Z-source network inductor can limit inrush current at start up. Hence, the proposed inverter has inherent inrush-current controlled capability.

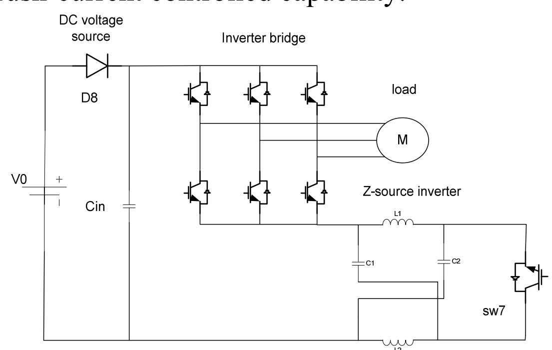

Figure 1: Basic Block Diagram of HPZSI

B. V/F control basis

A simplified diagram of the V/F controlled induction motor is shown in Fig. 2. The closed loop control by slip regulation of the combined inverter induction motor improves the dynamic performance. The speed of the induction motor is compared with the reference speed and error speed is generated. The speed loop error generates the slip command ω^{*}_{sl} through a proportional integral (PI) controller and a limiter. The slip is added to the speed feedback signal to generate the slip frequency command. Thus the frequency command ω^{*}_{e} generates the voltage command through a Volts/Hz generator. Then this voltage and frequency signals are modulate with the PWM controller to generate the pulses for the inverter.

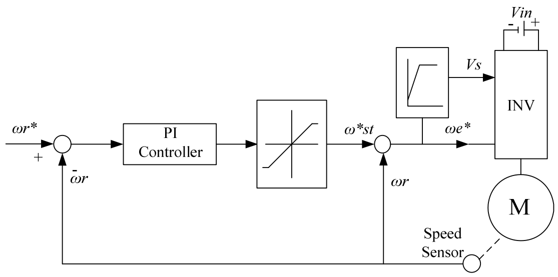

Figure 2: basic block Diagram for V/F control

III. PROPOSED SYSTEM

A. Basic block diagram of proposed drive

A closed loop V/F control for High performance Z-source inverter fed induction motor drive consists of the high performance Z-source network connected to three phase Inverter Bridge and induction motor as load. Speed control is consists of V/F control and DC link control of high performance ZSI. The V/F control is discussed in previous section, the output of V/F control is given to the PWM controller with the DC link control output as shown in figure 3.

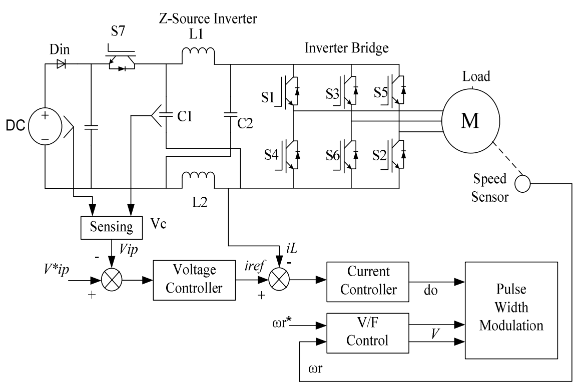

Figure 3 Block diagram of proposed system

B. DC link control of HPZSI

One PI controller was used to control the shoot-through time interval from the Z-source capacitor voltage error. The PI controller can be seen in Figure 4. The input is the error between the prescribed C capacitor voltage (fig. 3.1.1) and the measured capacitor voltage and the output is the shoot-through interval.

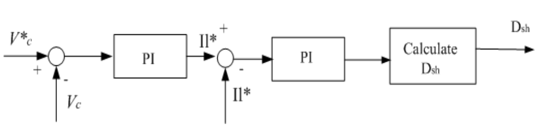

Figure.4. PI controller for peak DC link Voltage Control for Z-source

The shoot through duty ratio of the Z-source inverter can be controlled by the schematic of the external hardware needed between the PWM and driver of Inverter Bridge. The triple input AND gate for the upper switches PWM1, PWM3 and PWM5 monitors the zero voltage generated by turning on all the upper switches and outputs one if all of them are on while the other three input AND gate does the same thing for the lower switches of the inverter bridge. The two gates together cover the two zero voltage states. The OR gates multiply the two outputs and, if the two input AND gates enable is on, it sends the resulting shoot-through state signal to the output two inputs OR gates, which override the PWM input if shoot-through is on.

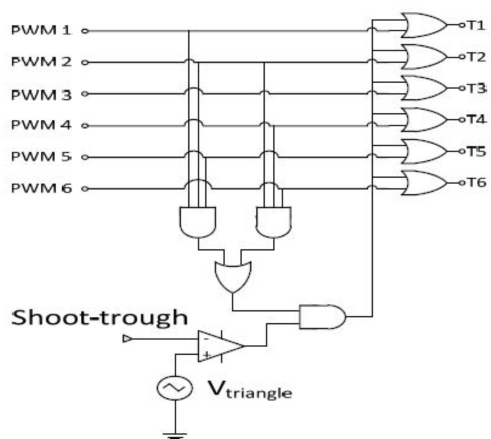

Figure.5. Shoot-through control of Z-source inverter

IV. SIMULATION AND RESULTS

In order to verify the close loop speed control and peak dc-link voltage control strategies of High performance Z- source inverter fed induction moor drive, simulations are carried out using PSIM software for a 1.8kw induction motor using parameters in table number I and for Z-source network in table number II. In simulation modulation index is calculated using reference voltage of V/F method.

To analyze performance of HPZSI fed IM drive the modulation index and duty ratio is kept same for simulation of induction motor drive i.e. 0.6 and 0.5 respectively. Results of the High performance Z-source fed induction motor drive on basis of speed response, output DC link voltage of Z-source and THD analysis of the three phase current of inverter.

Table-I: 1.8KW Induction Motor Parameter

Parameter	values
Output power	1.8KW
RMS line voltage	400V
Input frequency	50Hz
No. of pole	4
Stator resistance	2.56Ω
Rotor resistance	19.7 Ω
Stator inductance	0.01472 Ω
Rotor inductance	0.01124 Ω
Mutual inductance	0.2815 Ω
Moment of inertia	0.012024 Ω
Rated DC input voltage	500dc

Table-II Z-source network parameter

Parameter	Values
Capacitor	750uF
Inductor	450uH

The value of dc link voltage plays an important role in the motor operation, especially on speed of motor. Similarly the modulation index also cause effect on the motor iron losses and ripple current below base speed. In order to improve the performance modulation index is kept maximum as possible. Also, this modulation index does effect on the dc link voltage. In order to maintain constant dc link voltage the modulation index is kept 0.9 to maintain dc link voltage 400v as shown in figure 6. Figure 5 shows the speed response of induction motor. Three phase current waveform of HPZSI drive is shown in figure 5 and THD for current is shown in figure 9.

The output of V/F control is verified by comparing the actual speed of induction motor with the reference speed as shown in figure 7. The V/F ratio is kept constant to make speed constant as shown in figure 8. The THD for three phase current considering the phase A is comes out to be 2.89% as shown in figure 9.

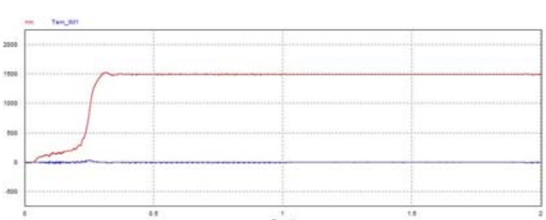

Figure: 6. Speed torque waveform of HPZSI fed IM drive

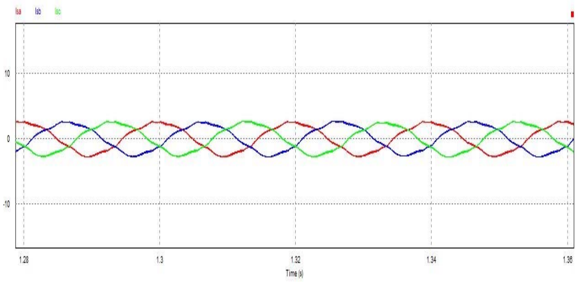

Figure: 7. Three phase current waveform of HPZSI fed IM drive

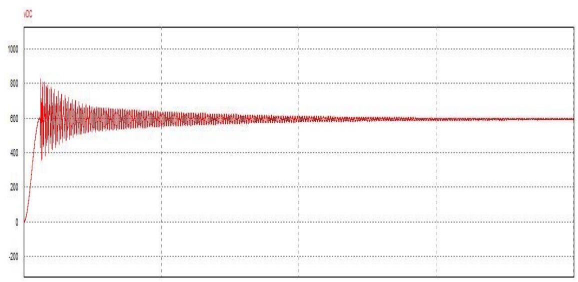

Figure.8 DC link voltage of HPZSI

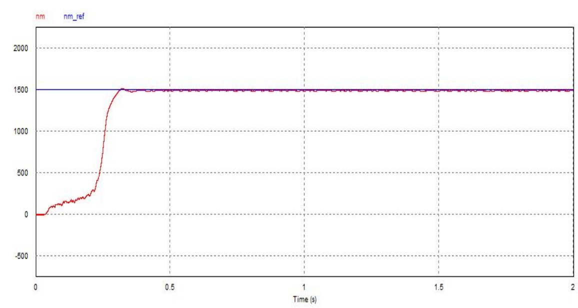

Figure: 9. Reference speed and actual speed plot of HPZSI drive

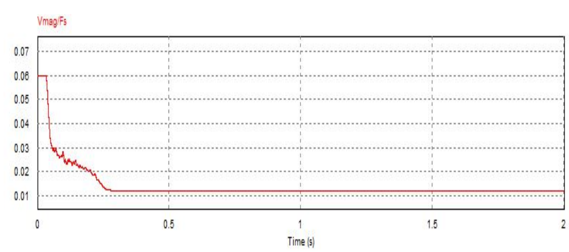

Figure: 10. V/F ratio of HPZSI drive

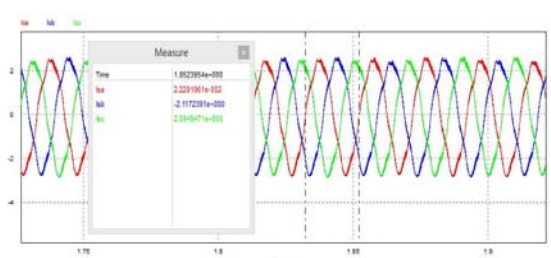

Figure: 11. THD analysis of current for HPZSI

V. CONCLUSION

This report presents a new closed loop speed control of an induction motor fed by a high performance Z-source inverter based on V/F control. The peak dc link voltage is controlled by a dual loop controller. The V/F control is applied to the motor drive keeping modulation index and duty ratio constant. The simulation results verified on basis of speed response, current waveform distortions and DC link voltage control. Results shows that, a close loop V/F control is simple and accurate method for speed control of induction motor.

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