Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 6 April-June (2015) pp. 26-30

http://www.krishisanskriti.org/areee.html

Speed Control of 3Phase IM using Z-Source Inverter

Arun Kumar V[1] and Keshavamurthy V[2]

[1]*IV SEM M.tech Power Electronics, Dr.Ambedkar Institute of Technology, Bangalore*
[2]*Department of Electrical and Electronics, Dr Ambedkar Institute of Technology Bengaluru-560056*
E-mail: [1]arunk0064@gmail.com

Abstract—*This paper proposes speed control of a 3 phase induction motor fed by a high performance Z-source inverter (ZSI), the speed control is based on PWM control. The proposed speed control methods, with reduced DC input voltage compared with the standard adjustable speed drives (ASD), are able to change the motor speed from zero to the rated speed with the rated load torque. The performance of the proposed speed control methods is verified by MATLAB simulation of induction motor fed by a high performance ZSI. The simulation results during start up, load disturbance and input voltage change are presented. The simulation results have verified the validity of the proposed open loop speed control methods. Also it indicates that, the performance of PWM control for speed control of the induction motor fed by the high-performance ZSI is more efficient.*

1. INTRODUCTION

The Z source inverter [1] is a single stage converter that can either buck or boost the ac output voltage from a dc supply. This topology overcomes the shortcomings of the traditional voltage source and current source inverters, where the output ac voltage is either respectively less or more than the input dc voltage. This combined operation of the z source inverter eliminates the need of a separate dc-dc converter, thus reducing the cost and increasing the efficiency of the circuit. Induction motors have many advantages compared to DC motors and synchronous motors in many aspects, such as size, efficiency, cost, life span and maintainability. Low cost and ease of manufacturing have made the induction motors a good choice for electric and hybrid vehicles. However, one must be able to achieve energy regenerative braking and be able to control the torque and the speed of an induction motor in traction drives such as hybrid electric vehicles

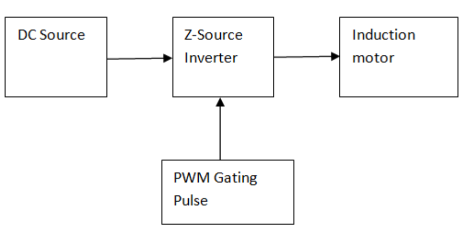


Fig. 1: Block diagram of the proposed system

An Induction motor is a AC motor where the rotor current needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding, This eliminates the requirement of mechanical excitation or self excitation for all part of energy transferred from stator to rotor.

Most recent publications have focused on modified

Pulse width modulation (PWM) switching algorithms for source inverter (ZSI). In order to produce flexible ac output voltage, a modified PWM strategy must be applied with proper shoot-through duty ratio. By controlling the shoot through duty cycle, ZSI can produce any desired ac output voltage. A detailed analysis, showing how various conventional carrier-based PWM strategies could be modified for ZSI, is presented in. Authors in propose two methods of maximum constant boost control for ZSI, which can achieve maximum voltage gain at any given modulation index without low-frequency ripple. This paper presents PWM based open loop speed control of three phase induction motor fed by high performance ZSI, There are different types of ways to control the speed of an Induction motor most efficient way is V/F control. The high performance ZSI with controlled peak dc link voltage is used to drive the three phase IM. The peak dc link voltage is estimated by measuring the input and the capacitor voltages. MATLAB simulations results are verified that Z source inverter has proved able to solve many conversion problems.

2. II Z – SOURCE INVERTER

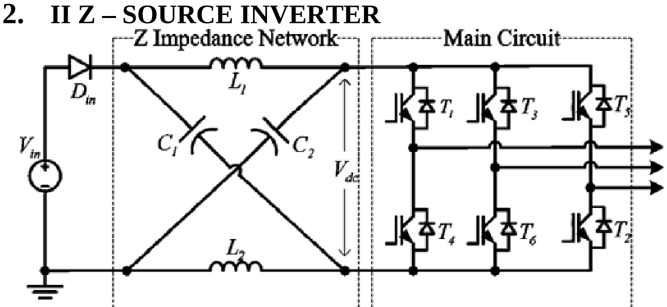


Fig. 2: Prototype of the classical Z-source inverter

Fig. 2 shows the main circuit configuration of the proposed Z-source inverter ASD system. Similar to that of the traditional ASD[1] system, the Z-source ASD system's main circuit consists of three parts: a diode rectifier, dc-link circuit, and an inverter bridge. The differences are that the dc link circuit is implemented by the Z-source network (C_1, C2, L1, and L2), Since the Z-source inverter bridge can boost the dc capacitor (C_1 and C_2) voltage to any value that is above the average dc value of the rectifier, a desired output voltage is always obtainable regardless of the line voltage.

3. OPERATING PRINCIPLE AND CONTROL

The basic operating principle [2] and control of the Z-source inverter fed by a dc source such as fuel cell stack. In the proposed ASD system a diode rectifier bridge with input capacitors serves as the dc source feeding the Z-source network. The input capacitors

Are used to suppress voltage surge that may occur due to the line inductance during diode commutation and shoot-through mode of the inverter. Thus requiring a small value of capacitance. At any instant of time, only two phases that have largest potential difference may conduct, carrying current from ac line to the dc line,

The proposed modelling and analysis begins with the following assumptions[3].

1) ZSC is operating in continuous conduction mode CCM.
2) The passive components, and, in the network are lossless.
3) The input voltage is an independent voltage source. The forward voltage drop of switch is modelled by a fixed voltage drop.
4) Because the on-resistance of switch is much smaller than the load impedance, the effect is neglected

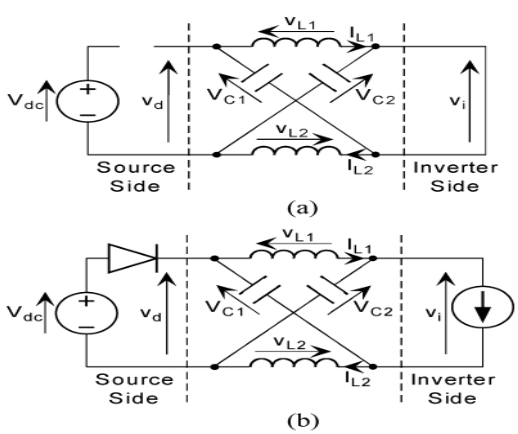


Fig. 3: Equivalent circuit of a Z-source inverter in (a) shoot-through state (b) Non shoot-through state.

Two operation modes involving two different circuit topologies can be identified in ZSC operation as shown in Fig. 3(a)and (b). In Mode 1, energy transferred from the source to load is zero because the load side and source side are essentially decoupled by the shoot-through states and the open status of .The duty ratio of switch is defined as the shoot-through duty ratio. In Mode 2, real energy transfer between source and load occurs, as shown in Fig. 3(b).

Table I: ZSI Parameters

In put voltage VIN	400V
Inductances(L=L1=L2)	300µH
Capacitances(C=C1=C2)	360µF
Switching frequency Fs	20KHZ

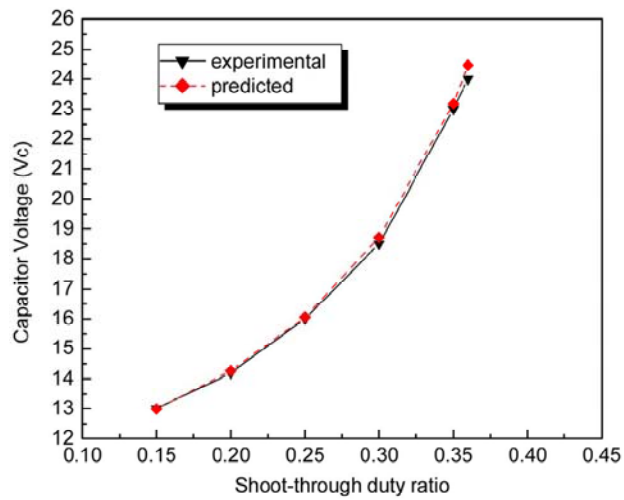
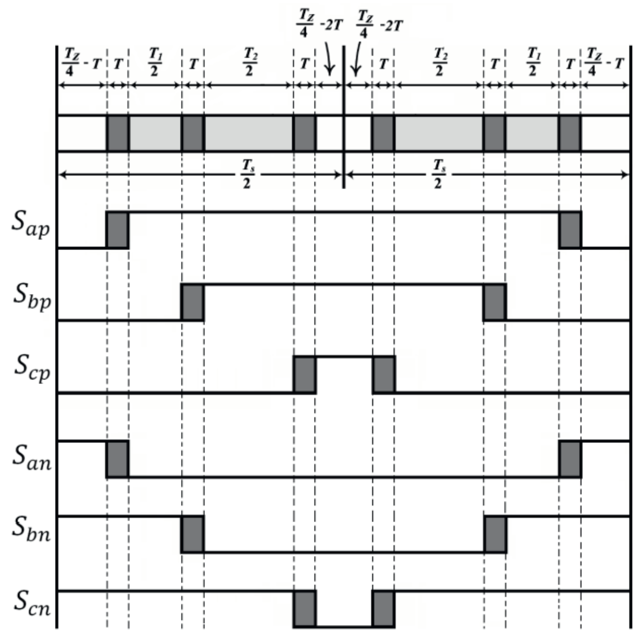


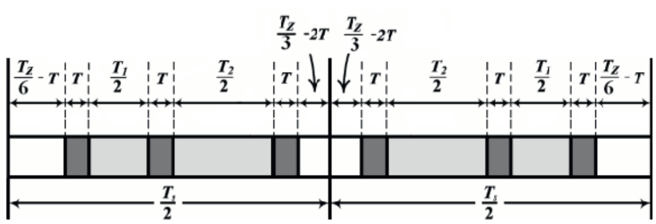
Fig. 4: Experimental results for input-to-capacitor-voltage dc gain with different shoot-through duty ratios.

4. PWM CONTROL METHOD FOR ZSI

Many PWM control methods have been developed and used for voltage source inverter (VSI). The VSI has six active states, when the dc voltage is impressed across the load, and two zero states when the load terminal are shorted through the lower or upper switches. The ZSI has an additional zero state, the shoot-through state. How to insert this shoot-through state becomes the key point of the PWM control methods for the ZSI. The space vector PWM (SVPWM) techniques have widely used at industrial applications of PWM inverter because of lower current harmonics and a higher modulation index. The SVPWM is suitable to control the ZSI. Unlike the traditional SVPWM, the modified space vector PWM (MSVPWM) has an additional shoot-through time T_O for boosting the dc link voltage of the inverter beside time intervals T_1 T_2 and T_Z. The shoot-through states are evenly assigned to each phase with $T_O/6$ within zero voltage period T_Z. The zero voltage period should be diminished for generating a shoot through time, and the active states T_1 and T_2 are unchanged. So, the shoot-through time does not affect the PWM control of the inverter, and it is limited to the zero state time T_Z. The modified space vector PWM (MSVPWM) can be applied using two patterns. The MSVPWM1 as shown in Fig. 5 (a), at this switch pattern, the shoot-through time T_O is limited to (3/4) T_Z, because the period should be greater than zero. The MSVPWM2 as shown in Fig. 5 (b), where the distribution of zero state time is changed into (T_Z/4-2T) and (T_Z/6) and (T_Z/3). The maximum shoot-through time is increased to the zero state time T_Z.



(a)



(b)
Fig. 5: PWM control methods for basic ZSI: (a) MSVPWM1; (b) MSVPWM2

5. THREE PHASE INDUCTION MOTOR

Three phase induction motors are the most widely used in various industrial applications because of the following properties-self starting property; elimination of a starting device; robust construction; higher power factor and good speed regulation. But the induction motor is a constant speed machine which makes its applications pretty much limited. To increase the areas of application of the induction motor, its speed has to be controlled by varying the supply frequency. The advantage of speed control of the induction machine is that it can save the energy spent by the machine. For example, a speed reduction of about 20% can improve the energy savings up to 50% in a centrifugal pump. This means that the energy inefficient motor can be replaced by a variable speed machine given an efficient control system. The base speed of an induction motor is directly proportional to the supply frequency and the number of poles. Now since the number of poles is fixed in the motor design, the best way to control the speed of the motor is to vary the supply frequency. The torque developed by the motor is directly proportional to the ratio of the applied voltage and the supply frequency. The torque is kept constant by varying the applied voltage and the supply frequency and by keeping their ratio to a constant value.

The torque speed characteristics also denote that:

1. The starting current requirement is lower.

2. The stable operating point of the motor is increased. The motor can be run at 5% of the synchronous speed up to base speed instead of running the motor from the base speed itself.

3. The acceleration and deceleration of the motor can be controlled by controlling the change of the supply frequency of the motor with respect to time.

The open loop PWM control of an induction motor is far the most popular method of speed control because of its simplicity and these types of motors are widely used in industry. Traditionally, induction motors have been used with open loop 60Hz power supplies for constant speed applications. For adjustable speed applications, Frequency control is natural. However, voltage is required to be proportional to frequency so that the stator flux remains constant if the stator resistance is neglected. Where V_{pn} is the peak value of the output phase voltage.

6. PROPOSED CIRCUIT DIAGRAM DISCRIPTION

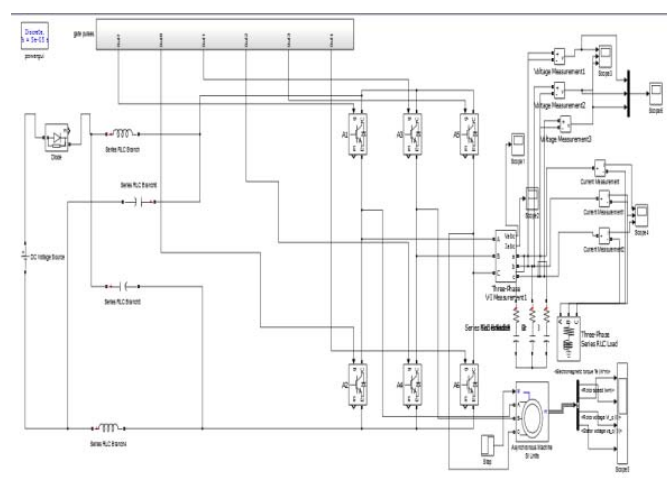


Fig. 6: Proposed circuit diagram

Fig. 6 gives simulation circuit for proposed system.The three phase induction motor is connected to the three inverter bridge whose 6 switches are controlled in order three phase ac output from the dc bus. PWM signals generated from a microcontroller are used to control the 6 switches. The DC bus voltage in this case is increased or decreased to the required value by the improved version of the z source inverter. The higher value of the dc voltage is obtained when the value of the inductance in the circuit is increased. Likewise, the dc voltage is decreased by increasing the value of the capacitance in the circuit, thereby providing buck/boost functionality to the circuit. And also the Z source inverter allows both the switches in the same phase leg to be gated at the same time without producing any damage to the switches. This negates the presence of any dead time in the circuit, and actually helps in the buck/boost performance of the improved ZSI by controlling the duty cycle of the shoot through state.

The amplitude of the phase voltage is dependent on the duty cycle of the PWM signals given to the inverter switches. At any instant of time, 3 switches (2 upper and1 lower or 1 upper and 2 lower) are gated and the remaining 3 are turned OFF. The switching produces a rectangular shaped output waveform that is rich in harmonics. The supplied current with harmonics is made to produce 3-phase sine wave with negligible harmonics by the inductive nature of the motor's stator windings. The inductive nature of the windings oppose any sudden change in the reverse direction of flow of current until all of the energy stored in the windings are dissipated, when the switches are turned off. This is accomplished using fast recovery diodes, known as freewheeling diodes across every Insulated-Gate Bipolar Transistor (IGBT) switch. Figure 5(a) show the simulation of the open loop operation of the induction motor using MATLAB program. The simulation results prove that the motor has a high starting torque and does not require any separate starting circuit unlike a few other motors. The motor block used in the simulation is the squirrel cage induction motor block which is commonly used induction motor type. The rotor bars are permanently shorted in this motor, thus negating the addition of any external resistance to the motor circuit. Thus the rotor copper losses are reduced, thus providing higher efficiency. Figure 5(b) shows the simulation of the closed loop operation of the induction motor in which the motor's actual running speed is compared with a base speed, in this case 1200 rpm.

7. SIMULATION RESULTS

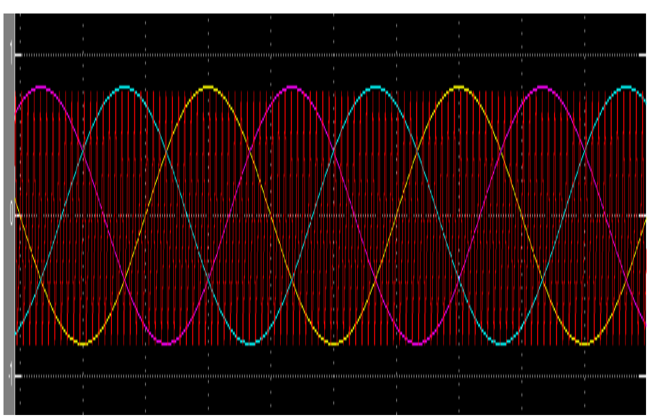


Fig. 7: Gate pulse generation using PWM control

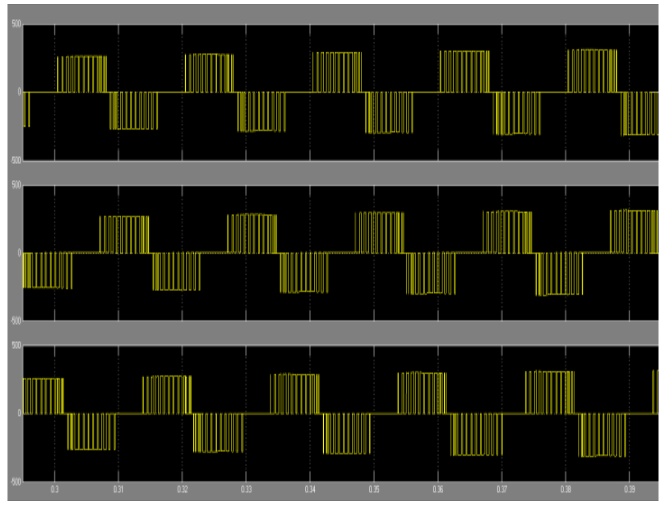


Fig. 8: Stator voltage (Va,Vb,Vc)

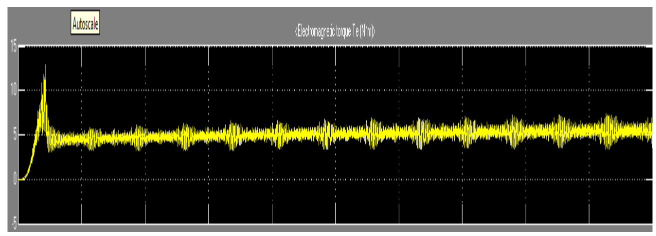


Fig. 9: Torqe

Simulation results are obtained from MATLAB Simulinlk .Fig. 7,8,9 gives Gate pulse generation using PWM control, Stator voltage (Va,Vb,Vc),Torqe

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