Comparison Study of Z-Source and V-Source Feed 3-Phase Induction Motor

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Abstract

This article presents the control of an induction motor with a Z-source inverter system. The Z-source inverter can effectively reduce the voltage stress across the capacitors in the impedance network. The Z-source inverter system employs a unique *LC* network in the dc link and a small capacitor on the ac side of the diode front-end. By controlling the shoot-through duty cycle, the Z-source can produce any desired output ac voltage, even greater than the line voltage. As a result, the Z-source inverter system provides ride-through capability during voltage sags, reduces line harmonics, improves power factor and reliability, extends output voltage range and also reduces the cost of the proposed topology, which is in turn used to control the speed of an induction motor. Old topologies like VSI produce stress over switching device. The simulation results indicate that the proposed topology is a promising technique that can be applied to improve overall efficiency.

Keywords: Voltage source inverter, Simple boost controller, Single phase induction motor, Z-source inverter.

Introduction

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. The simple boost-control PWM technique is used to simulate the single-phase Z-source inverter for induction motor control. The speed control of such motors can be achieved by controlling the applied voltage on the control operation of ZSI [1]. Inverters are the dc to ac converters. The input dc supply is either in the form of voltage or current is converted into variable output ac voltage. The output ac voltage can be controlled by varying input dc supply or by varying the gain of the inverter. There are two types of traditional inverters based on input source used in industries for variable speed drive and many other applications; those are:

a) Voltage-source inverter

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b) Current-source inverter motor by the use of power electronic devices. Z-Source inverter is used for power control of single-phase induction motor as compared to the traditional voltage source inverters (VSIs) and current source inverters (CSIs). The control strategy of Z-source inverter is simulated in MATLAB environment and implemented using a simple boost controller. It is used to sense and control the motor speed. The simple boost pulse width-modulated signal is applied to the control operation of ZSI.

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 [2]. The advantage of speed control of the induction machine is that it can save 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 an energy-inefficient motor can be replaced by a variable-speed machine given an efficient control system [1]. 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 [2]. There are two types of traditional inverters based on input source used in industries for variable speed drive and many other applications; those are (a) Voltage-source inverter and (b) Current-source inverter [5]. The gain of the inverter can be controlled by using pulse-width modulation (PWM). Different PWM techniques are devised to control these inverters. PWM control technique also reduces harmonic distortion in the output signal and improves the performance of the inverter. PWM with third-harmonic-injection method eliminates third-harmonic component from output waveform and also provides higher range of modulation index than regular PWM modulation technique [5]. These PWM waveforms can be generated using analog circuits using active and passive components or it can be generated digitally using microprocessor and microcontroller [6]. The dc voltage source is connected at the input side across a large capacitor. DC link voltage produced across this capacitor feeds the main three-phase bridge. The input dc supply can be a battery or fuel-cell stack or diode rectifier, and/or capacitor. Three-phase bridge inverter circuit consists of six switches; each is composed of a power transistor and an anti-parallel diode to provide bidirectional current flow and reverse voltage blocking capability. Shows the traditional current-source inverter (CSI). The dc current source is formed by a large dc Inductor fed by a voltage source such as a battery or fuel-cell stack or diode rectifier or converter, etc. [3]. Like VSI, a three-phase bridge inverter circuit consists of six switches;

each is composed of a switching device with reverse-block capability such as a gate-turn-off thyristor and SCR or a power transistor with a series diode to provide unidirectional current flow and bidirectional voltage blocking. For voltage source inverter and current source inverter, the on/off time the switching devices is controlled by applying control voltage (PWM) to the control terminal, i.e., gate of the device.

Z-source Inverter-fed Induction Motor Drive

Z-source Inverter

A conventional VSI with three-phase legs is connected at opposite ends of the Z-source impedance network. A diode is connected in series with the power source to block the reverse flow of current.

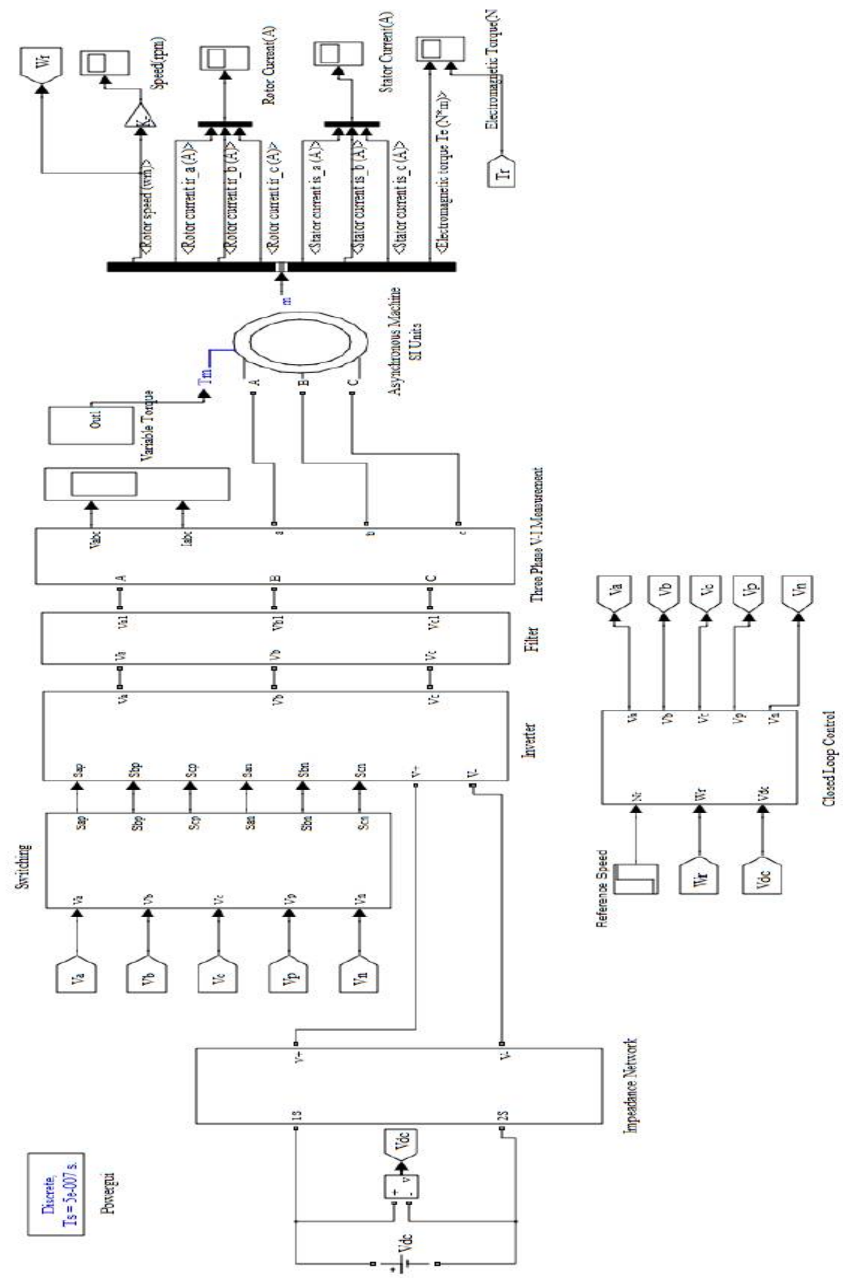

Figure 1.Equivalent circuits

A voltage type Z-source inverter can assume all active and null switching states of VSI. Unlike conventional VSI, a Z-source inverter has a unique feature of allowing both power switches of a phase leg to be turned ON simultaneously (shoot-through state) without damaging the inverter [1]. Inverter performance can be analyzed by considering the equivalent circuits shown in Fig. 1. When in a shoot-through state during time interval T0, the inverter side. Alternatively, when in a non-shoot-through Active or null state during time interval T1, network through the invertertopology to the connected ac load. The inverter side of the Z-source network can now be represented by an equivalent current source.

Simulation Result

All simulation results will be discussed in the following part. The simulated results obtained from the models of ZSI-fed IM drive and VSI fed IM drive have been given.

The different performance characteristics such as speed, torque, rotor current characteristics of ZSI-fed IM drive and VSI-fed IM drive are compared for the time period 0-0.3 sec, constant torque of value 0 N-m is applied to the motor drive of VSI and ZSI. For the time period of 0.3-0.42 sec, the variable torque of the range between 15 and 30N-m is applied in the step of 0.02 sec.

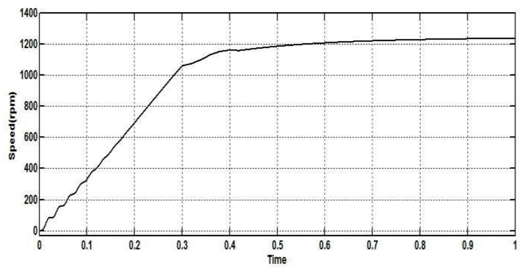

Figure 2.Speed of VSI-Fed IM Drive

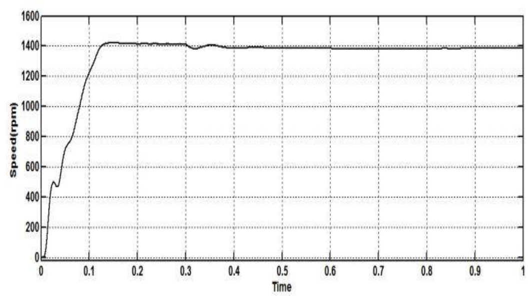

Figure 3.Speed of ZSI-Fed IM Drive

Figures 2 and 3 show the speed of VSI-fed IM drive and ZSI-fed IM drive respectively. From the results, it is clear that the ZSI gives better speed control than the VSI model [7]. ZSI also provides less jerky motion at the starting of the motor as compared to VSI. When the variable torque is applied, the change in the speed in VSI-fed IM drive is greater and sudden as compared to ZSI-fed IM drive. Figures 4 and 5 show the rotor current for VSI-fed and ZSI-fed IM drive respectively. It shows that with ZSI, settling time for rotor current is decreased as compared to VSI. It is also clearly seen that VSI has more ripple component as compared to ZSI [2].

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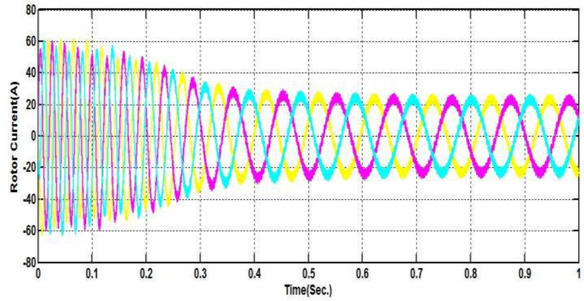

Figure 4.Rotor Current of VSI Fed IM Drive

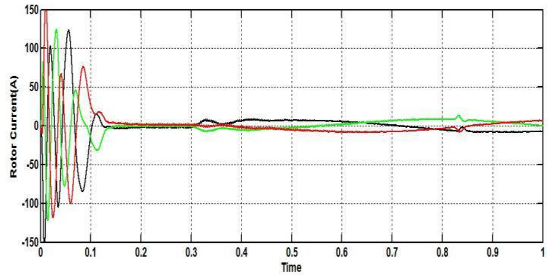

Figure 5.Rotor Current of ZSI Fed IM Drive

Conclusion

This article presents a new closed-loop speed control of an induction motor fed by ZSI based on V/F control. The peak dc link voltage is controlled by a single loop controller. The simulation results verified the validity of the proposed closed-loop speed control methods during start up and input voltage change. The ZSI can be improved by controlling linearly the capacitor voltage. The proposed method can achieve the good transient responses of variations of both the reference capacitor voltage and reference output voltage, and also during 20% dc input voltage sag.

References

[1] Peng FZ. Z-Source Inverter. *IEEE Transaction Industry Applications* Mar/Apr 2003; 39: 504-10.

[2] Peng FZ, Joseph A, Wang J et al. Z-Source inverter for motor drives. *IEEE Transactions on Power Electronics* Jul 2005; 20(4): 857-63.

[3] Kumar D, Husain Z. A comparative study of Z-source inverter fed three-phase IM Drive with CSI and VSI fed IM. *International Journal of Power Electronics and Drive System (IJPEDS)* Sep 2013; 3(3): 259-70.

[4] Antal R, Muntean N, Boldea I. Modified Z-source single-phase inverter for single-phase PM synchronous motor drives. *Proc OPTIM* 2008: 245-50.

[5] Farhangi B, Farhanghi S. Application of Z-Source converter in photovoltaic grid-connected transformer-less inverter. *Proc of PELINCEC*-2005, Warsaw, Poland, 198-203.

[6] Mohan N, Robbins WP, Underland TM. Power Electronics. *John Wiley*, 1995.

[7] Ellabban O, Mierlo JV, Lataire P. Voltage mode and current mode control for a 30 kW high-performance Z-source inverter. *IEEE Electrical Power & Energy Conference (EPEC)* Montreal, Canada. 22-23 Oct 2009.