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Z-Source Inverter fed Three Phase Induction Motor drive with PI and PID Controlled closed loop systems

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ABSTRACT: *This* paper presents the closed loop control of Z-Source Inverter fed three phase induction motor with PI and PID controller. PI and PID controller systems are designed and simulated using MATLAB. The principle of operation and simulation results is discussed. The simulation results of PI and PID controller are compared interms of time domain parameters and comparison table have been presented.

KEYWORDS: ZSI- Z-Source Inverter, VSI-Voltage Source Inverter Z-Source Inverter fed Induction Motor.

I. INTRODUCTION

The energy demand is increasing worldwide day-by-day. The non-renewable energy sources such as coal,oil and natural gases cannot be replenished once the deposit of these fuels are depleted. So the needs for renewable energy sources are increasing across the world. Among all the renewable energy sources solar energy is expected to play on important role in future energy production [1]-[5]. The PV cells convert solar energy into electrical energy. The PV systems can be grouped into standalone systems and grid connected systems. The PV system generates low voltage and requires high step-up converters for its applications.The DC-DC converter step-up the PV voltage and VSI is used to convert DC voltage to AC voltage [6].

The traditional VSI and CSI have some limitations and problems such as two stages of power conversion are required. VSI cannot have AC output voltage higher than the DC link voltage , VSI and CSI are either buck or boost converter cannot be buck-boost converter therefore they need DC-DC converter to boost the PV panel DC voltage , shoot through will occur when the switches on same phase leg are turned ON simultaneously which destroy the devices in the circuit. These drawbacks have been overcome by the Z-Source Inverter proposed in [7]. ZSI provides single stage power conversion with voltage buck-boost ability. The X-shaped impedance network with L and C components makes shoot-through state possible for ZSI. During this shoot-through period both power switches in a same phase leg can be turned on simultaneously and thereby eliminate the dead time and provides voltage boosting capability. Simple boost control with constant boost factor was used to control the shoot through and output voltage of the inverter. Constant boost control method for ZSI was discussed in [8] to obtain maximum voltage gain under a given modulation index. F.Z.Peng et.al [9] proposed maximum boost control method to produce maximum voltage gain under a given modulation index . P.C. Loh et al [10] presented detailed analysis on various PWM technique with modifications to switch voltage type ZSI continuously or discontinuously and retaining all the unique harmonic performance .Various topologies of ZSI have been developed and discussed, pulse width modulated three level neutral point clamped inverter was demonstrated by P.C.Loh et al [11] , switched inductor quasi Z-source inverter was proposed in [12] , switched inductor quasi Z-source inverter was proposed in [13] with reduced voltage stress on capacitor , lower current stress on inductor and diodes. Anderson et al [14] developed four quasi Z-source inverters having advantages such as lower component ratings and reduced voltage stress. ZSI was proposed for residential photovoltaic system in [15], the operation principle, control method and characteristics of the system were presented in this paper. ZSI for adjustable

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speed drives (ASD) was proposed in [16] which provides ride-through capability .Z.J. Zhou et al proposed a new topology of uninterruptable power supply (UPS) using Z-source inverter , maintain the desired AC voltage with high efficiency ,low harmonics , fast response and good steady state performance[17]. Transient modeling and analysis of PWM ZSI was presented by P.C.Loh et al [18]. AC small signal modeling and analysis of ZSI in continuous conduction mode presented in [19].New family of Embedded Z-source inverter (EZSI) was proposed in [20] to maintain smooth voltage or current across the DC source without addition of LC filter. Other topologies of Asymmetric and Symmetric Embedded Z-source inverter were presented in [21]. Current mode integrated control technique for ZSI fed induction motor drives was presented in [22] by S.Thangaprakash et.al. Embedded switched-inductor Z-source inverters are presented in [23] which provide a high boost voltage inversion ability , lower voltage across the switching devices, continuous input current and a reduced voltage stress on the capacitors. The PI controller and fuzzy logic controller (FLC) are designed and implemented for H6 single phase inverter in [24].But the above literature survey does not deal with closed loop control for EZSIIM. This paper proposes closed loop control for EZSIIM using PI controller and PID controller. PI controller and PID controller circuit are designed and simulated using MATLAB/Simulink and the obtained results are compared.

II. OPERATION PRINCIPLES OF Z-SOURCE INVERTER

Fig. 2.1&2.2 shows the equivalent circuits of Z-source network in shoot-through states and non-shoot-through states. The output voltage and output current of Z-source network, respectively, and the reference directions of voltages and currents are all shown in Fig. 2.1. Due to the symmetrical Z-source network, the voltages and currents of each

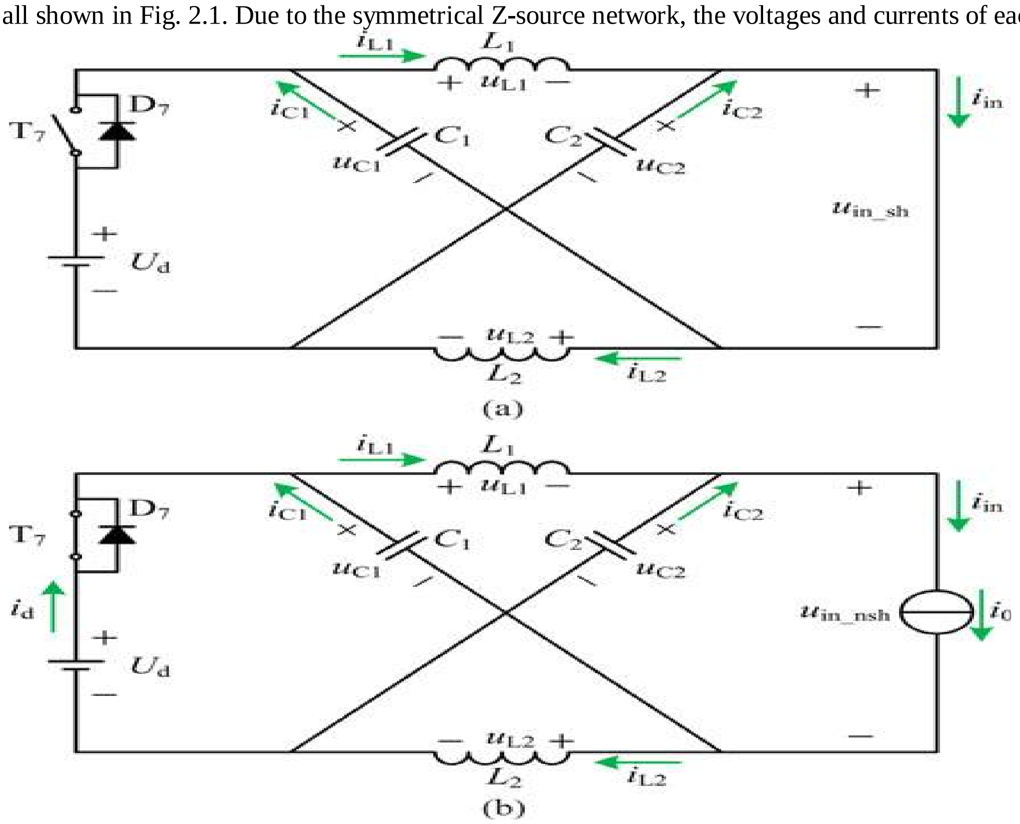

Fig. 2.1. Equivalent circuits of Z-source network. 2.2 Shoot-through state. (b) Nonshoot-through state.

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Active state: The inverter is operated in one of its six active states. The diode D is forward biased. The load and the Inverter Bridge are replaced by the current source as shown in Fig.2.1&2.2.
(The switches Sx ≠ Sx', x = A, B, or C; D = ON. For time interval T1)

$$V_L = V_{dc}/2 - V_C \qquad V_i = V_C - V_L + \frac{V_{dc}}{2} = 2V_C \qquad V_d = V_D = 0 \tag{1}$$

$$i_{dc} = i_L + i_C \qquad i_i = i_L - i_C \qquad i_{dc} \neq 0 \tag{2}$$

Nonshoot-Through zero state: Inverter Bridge is operating in any one of its two nonshoot-through zero states. The bridge can be viewed as a open circuit. The input DC voltage appears across the inductor and capacitor. But no inverter output current flows to the load.

During nonshoot-through zero state the switches Sx ≠ Sx', x = A, B, or C; D = ON.

$$V_L = V_{dc}/2 - V_C \qquad V_i = 2V_C \qquad V_d = V_D = 0 \tag{3}$$

$$i_{dc} = i_L + i_C \qquad i_i = 0 \qquad i_{dc} \neq 0 \tag{4}$$

Shoot-through zero state: Shoot through zero state is possible by seven different ways. Without disturbing the active states, shoot-through state is allocated into each phase within total zero time. The front-end diode D is reverse biased. The inverter is viewed as a short circuit from its DC link. There is no voltage across the load but the capacitor voltage is boosted based on the shoot through duty ratio.

(The switches Sx = Sx' = ON, x = A, B, or C; D = OFF. For time interval (T0)

$$V_L = V_C + V_{dc}/2 \qquad V_i = 0 \qquad V_d = V_D = -2V_C \tag{5}$$

$$i_L = -i_C \qquad i_i = i_L - i_C \qquad i_C = 0 \tag{6}$$

The DC link voltage and peak AC voltage can be expressed by performing the state space averaging results in

$$V_C = \frac{V_{dc}/2}{1 - 2T_0/T}$$

$$\hat{V}_i = \frac{V_{dc}/2}{1 - 2T_0/T} = BV_{dc}$$

$$\widehat{V_{AC}} = M\frac{\hat{V}_i}{2} = \frac{MV_{dc}}{2(1 - 2T_0/T)} = B\left(\frac{MV_{dc}}{2}\right) \tag{7}$$

The EZSI provides same voltage gain as that of ZSI with inherent filtering capacity. Embedded sources help to maintain required voltage level within impedance network with lower voltage across the capacitor [11].

This paper proposes PV based EZSIIM with closed loop system using PI controller and PID controller to operate induction motor with required speed.

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III. SIMULATION RESULTS

The simulation circuit for closed loop control with PI and PID controller is designed and simulated using MATLAB/Simulink.

3.1 Z-Source inverter fed induction motor drive closed loop system with PI controller

The simulation circuit of ZSI fed three phase induction motor with PI controller is shown in Fig.3.0.The speed of the induction motor is measured continuously and compared with the reference set speed .The difference in speeds is applied as error signal to the PI controller. The output of PI controller is given to ZSI system to run the induction motor at required speed. The speed of the induction motor with PI controller closed loop is shown in Fig.3.2. And its value is 1248 RPM. The torque of the motor is 1.2 N-m shown in Fig.6.

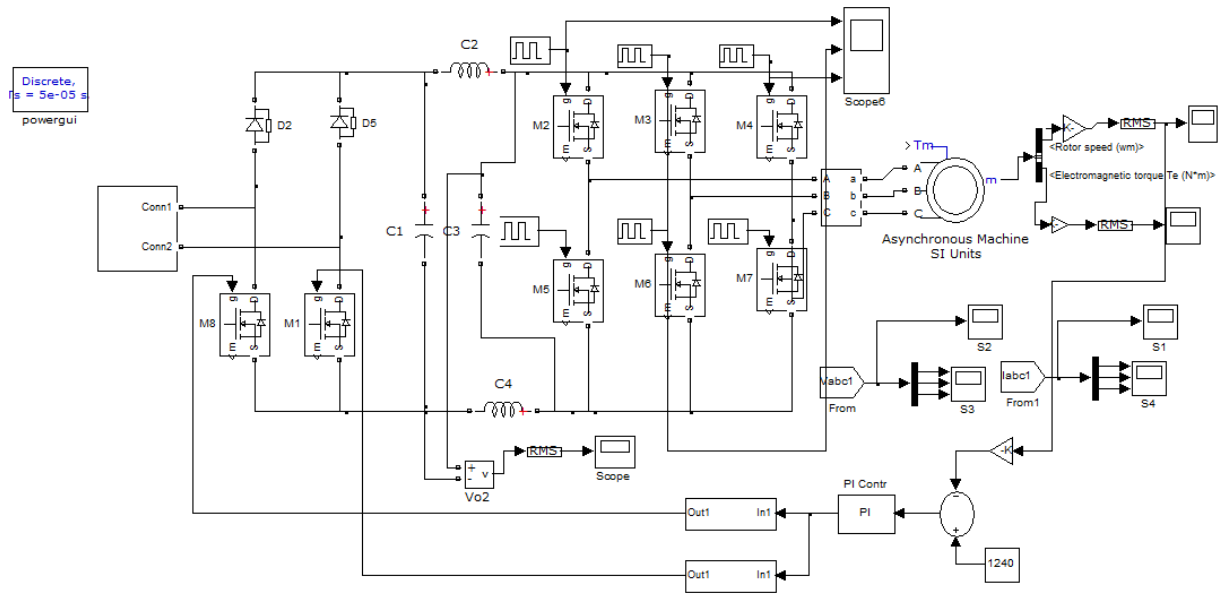

Fig.3.0. Z-Source Inverter fed three phase induction motor closed loop system with PI controller

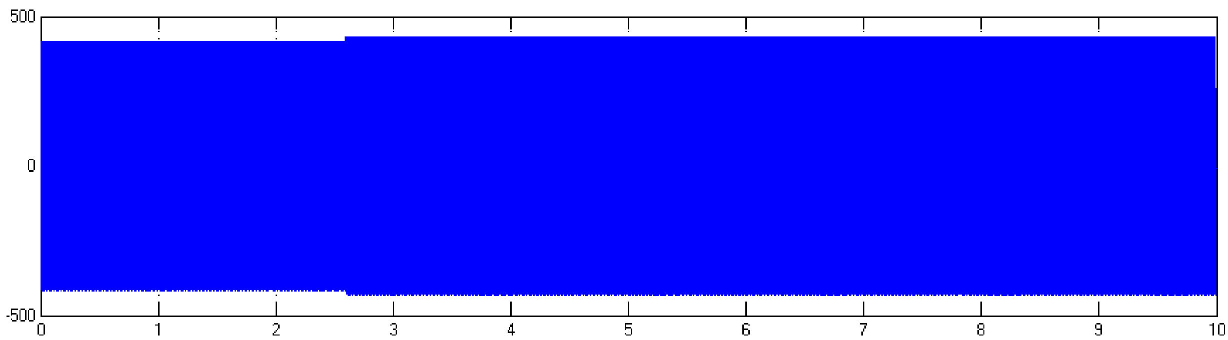

Fig.3.1. Input voltage

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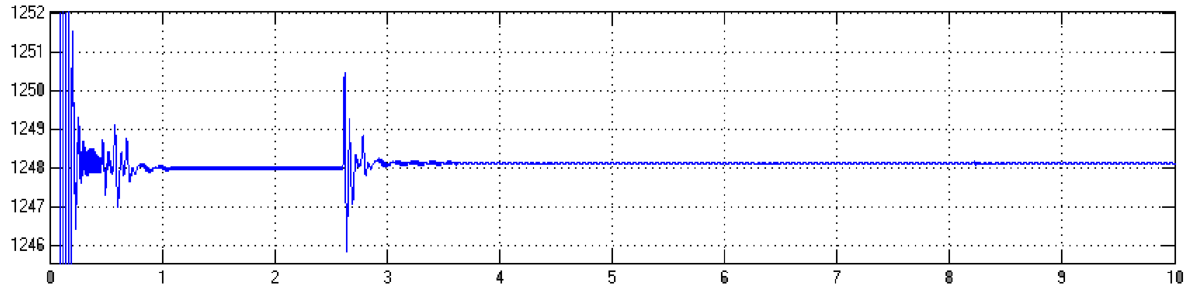

Fig.3.2. Speed of the Three phase induction motor with PI controller

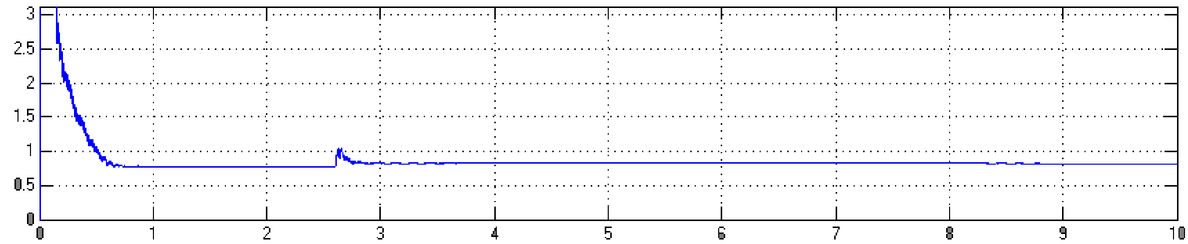

Fig.3.3. Torque of the Three phase induction motor with PI controller

3.2 Z-Source inverter fed induction motor drive closed loop system with PID controller

The simulation circuit of ZSI fed three phase induction motor with PID controller closed loop is shown in Fig.3.4.The difference in set speed and actual speed is given as error signal to PID controller. The output signal of the controller is applied to ZSI to obtain the required speed. The speed of the motor is 1248 RPM and is shown in Fig.3.6. The torque response of the system is shown in Fig3.7. And its value is 1.2 N-m.

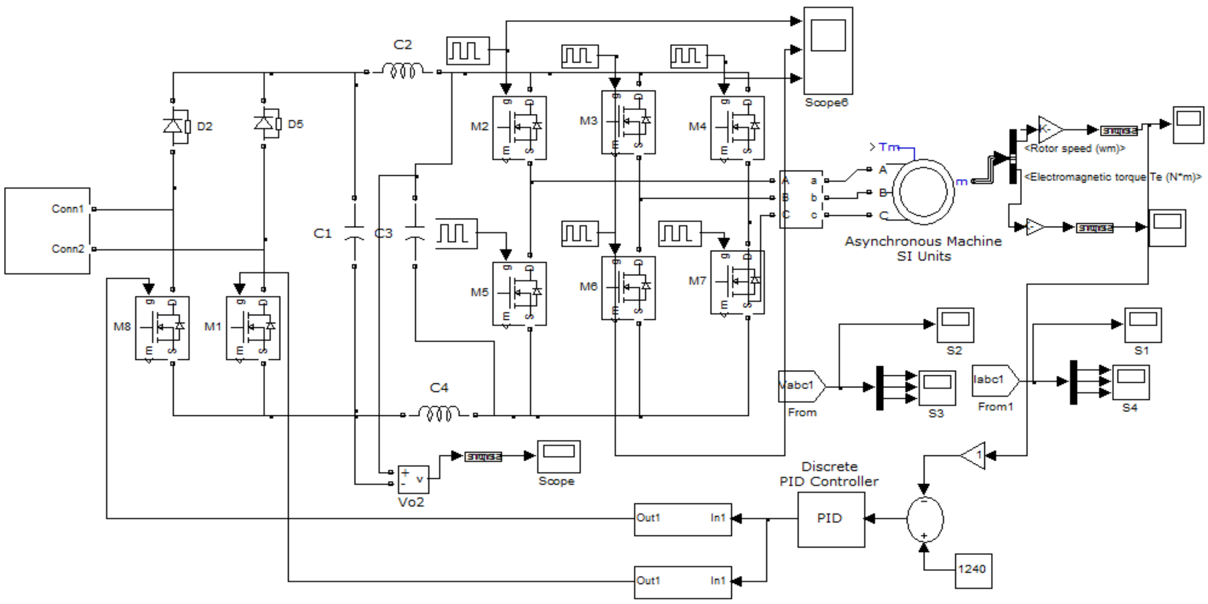

Fig.3.4 Z-Source Inverter fed three phase induction motor closed loop system with PID controller

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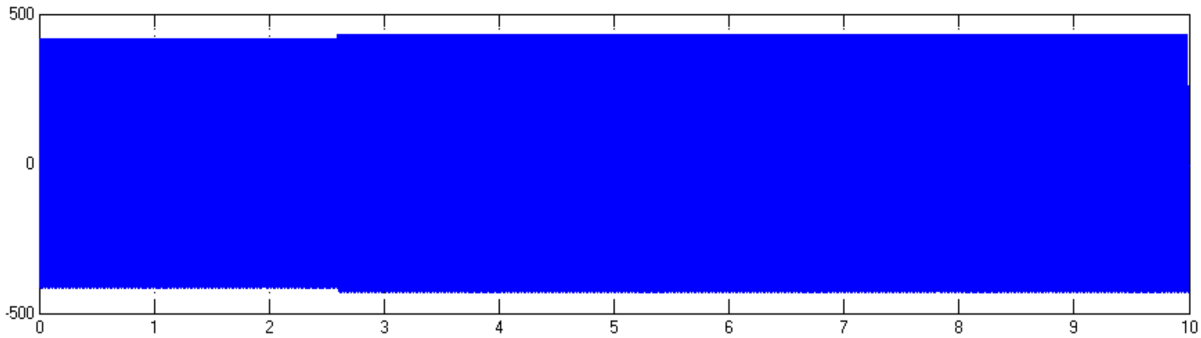

Fig.3.5. Input voltage

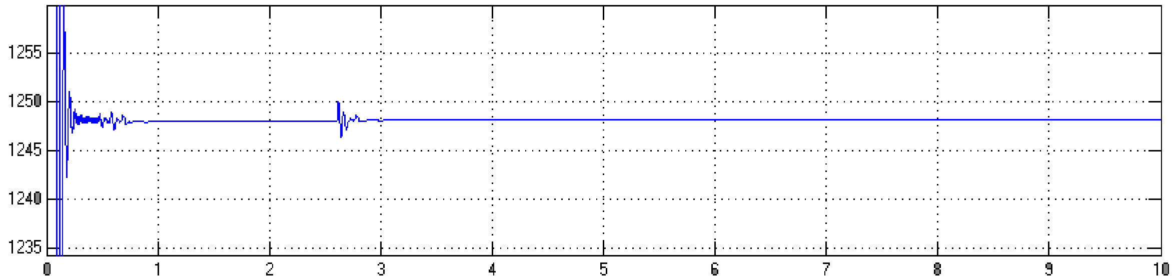

Fig.3.6. Speed of the Three phase induction motor with PID controller

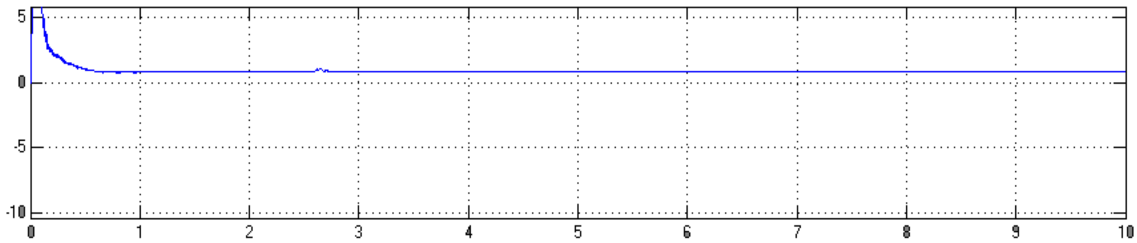

Fig.3.7. Torque of the Three phase induction motor with PI controller

The summary of the time domain parameters of Z-Source Induction motor drive closed loop system with PI controller and PID controller are given in table.1.

Table-1
Comparison of time domain parameters for PI and PID controller closed loop system

Controller	Rise time (s)	Peak time (s)	Setting time (s)	Steady state error (RPM)
PI	2.6	2.7	3.2	5.6
PID	2.5	2.6	2.7	3.2

It can be observed from the table that the rise time, settling time and steady state error are reduced with PID controller.

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IV. CONCLUSION

The closed loop control of ZSI fed three phase induction motor with PI controller and PID controller are simulated successfully. I t is observed from the simulation results that PID controlled closed loop system provides better results than PI controller, since PID controlled system reduces rise time , settling time of the closed loop system and the steady state error in speed is reduced to 3.2 RPM. Contribution of this work is to obtain the better dynamic response of the ZSIIM closed loop system. The fuzzy logic based closed loop system will be simulated in future.

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