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A Hall-Effect sensor based Z-Source inverter fed PMBLDC motor

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***Abstract*— The simulation and operation of PMBLDC Motor drive system with Z-Source Inverter is discussed in this paper. The z-source inverter employs a unique impedance network coupled with inverter and rectifier. It overcomes the conceptual barriers and limitations of the traditional VSI and CSI. By controlling the shoot-through duty cycle, the z-source inverter system provides ride-through capability. Simulation results are presented to demonstrate the features. The result shows that the Z-source inverter is very promising for BLDC motor drive.**

***Index Terms*—** Z-Source Inverter, Shoot through state, Motor Drive, PMBLDC Motor.

I. INTRODUCTION

There exist two traditional converters: voltage-source (or voltage-fed) and current-source (or current-fed) converters (or inverters depending on power flow directions). the VSI and CSI based system suffers from the common limitations and problems. To overcome these problems of the traditional VSI and CSI this paper presents an impedance-source power inverter (which is abbreviated as Z-source inverter) for implementing DC-to-AC, AC-to-DC, AC-to-AC, and DC-to-DC power conversion. In summary, the Z-source inverter has several unique features:

The inverter can boost and buck the output voltage with a single stage structure. The shoot through caused by EMI can no longer destroy the inverter, which increase the reliability of the inverter greatly because of no dead time is required, perfect sinusoidal output waveform is obtainable.

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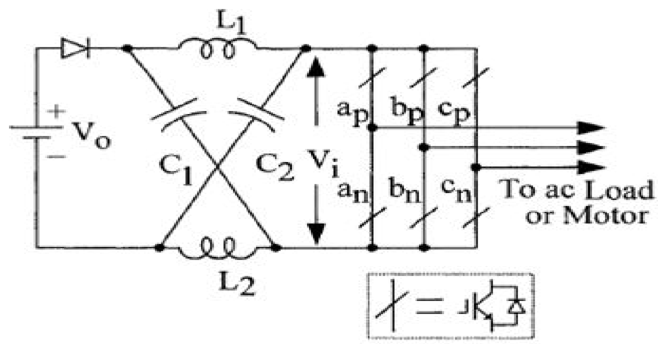

Fig.1. Z-Source inverter

Fig.1. show the topologies of voltage type three phase Z-source inverter, where a dc voltage source and a conventional VSI with three phase legs are 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. 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 turn ON simultaneously (shoot-through state) without damaging the inverter.

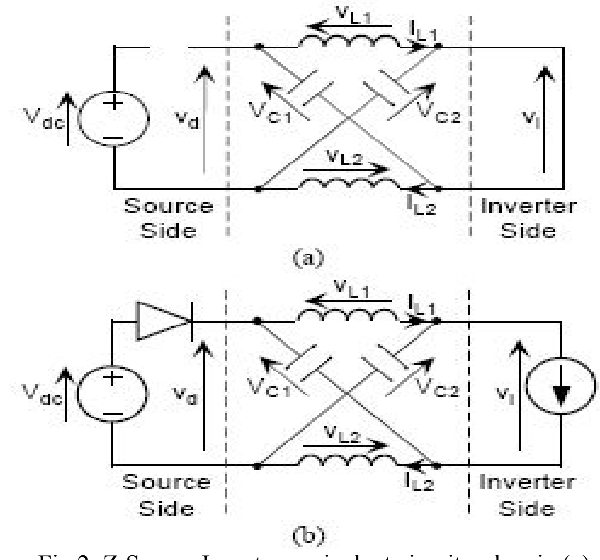

Fig.2. Z-Source Inverter equivalent circuits when in (a) shoot-through state and (b) non-shoot-through state.

The impact of the phase leg shoot-through on the inverter performance can be analyzed by considering the equivalent circuits shown in Figure .When in a shoot-through state during time interval T_0, the inverter side of the Z-source network is shorted as in Fig.2 (a). Therefore (assuming $L_1 = L_2 = L$ and $C_1 = C_2 = C$):

$V_{L1} = V_{L2} = V_L = V_{C1} = V_{C2} = V_C$
$V_d = V_L + V_c = 2V_c$
$V_i = 0$ (1)

Alternatively, when in a non-shoot-through active or null state during time interval T_1, current flows from the Z-source network through the inverter topology to the connected ac load. The inverter side of the Z-source network can now be represented by an equivalent current source, as shown in Fig.2 (b). This current source sinks a finite current when in a non-shoot-through active state and sinks zero current when in a non-shoot-through null state. From Fig. 2 (b), the
following equations can be written:
$V_L = V_{dc} - V_c$
$V_d = V_{dc}$
$V_i = Vc = VL = Vc = Vdc$ (2)

Averaging the voltage V across a Z-source inductor over a switching period (0 to T=T) then gives:
$V_c = T_1/(T_1 - T_0) * V_{dc}$ (3)

Using 2 & 3 the peak dc voltage Vi across the inverter phase-legs and peak ac output voltage Vx can be written as:
$V_i = 2V_c - V_{dc} = 1/(1-2T_0/T) * V_{dc} = BV_{dc}$ (4)
$V_x = M(V_1/2) = B\{M*V_{dc}/2\}$
Where *B* is the boost factor introduced by the shoot-through state, *M* is the modulation ratio commonly used for Conventional VSI modulation and the term within { } gives the ac output of a conventional VSI. Obviously, equation (4) shows that the ac output voltage of a Z-source inverter is boosted by a factor of *B* (always =1), which cannot be achieved with a conventional VSI.

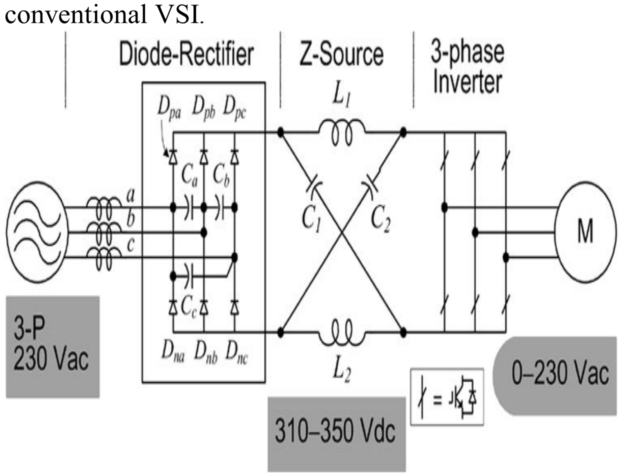

Fig.3. Main circuit configuration of proposed Z-source inverter ASD system

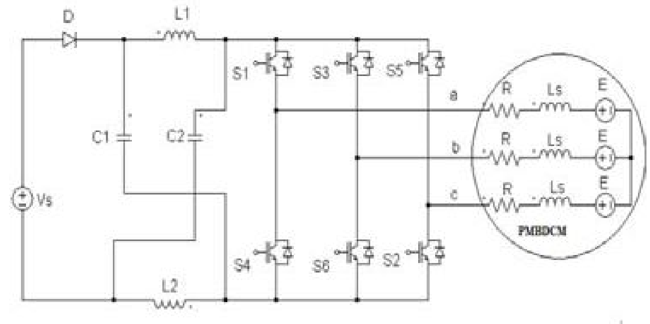

Fig.4. Main circuit of Z-source inverter fed BLDC motor drive.

Fig.3. shows the main circuit of the proposed Z-source inverter based permanent magnet BLDC motor drive system. A Z-source inverter is utilized, instead of the traditional VSI or CSI, to feed electric energy from the dc source to the BLDC motor. To gain the buck/boost ability, the PWM method is used to control the Z-source inverter to generate shoot through states. Unlike the Z-source inverter based ASD system with induction machines, the output currents of the Z-source inverter in the proposed BLDC motor drive system are composed of square waveforms of 120° electrical degree.
Consequently, the operation principle, the modelling method and the control are all different from the Z-source inverter based ASD system with induction machines. According to the operation principle of BLDC motor, two phases are conducted in the non-commutation stages. The shoot through states can be generated by shorting either any one arm or both arms in the bridge. During non-shoot-through states two switches in different legs are conducting. Four devices are conducting when shoot-through occurs in one phase leg. And six switches conduct if shoot-through occurs in two phase legs. ZSI fed BLDC motor drive is shown in the following Fig.4.

II. Simulation of Z-Source fed PMBLDC Motor

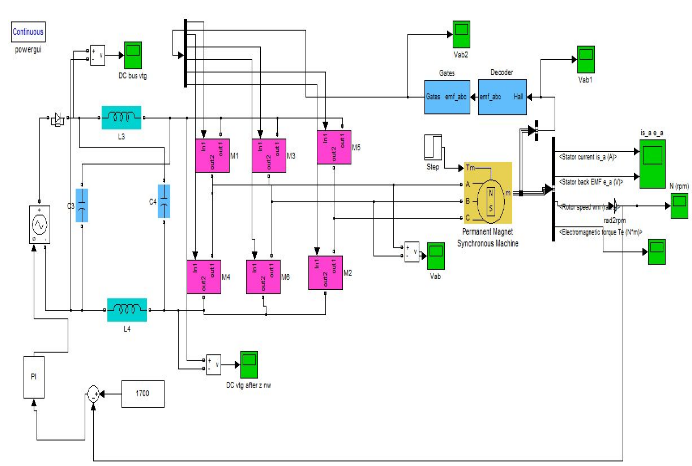

Fig.4.1 Simulation model of ZSI fed BLDC motor with three phase AC source

Results of the proposed work shown for two different operating periods. First during the starting period of the machine and during the load change of the machine is analyzed here.

1. During the starting period

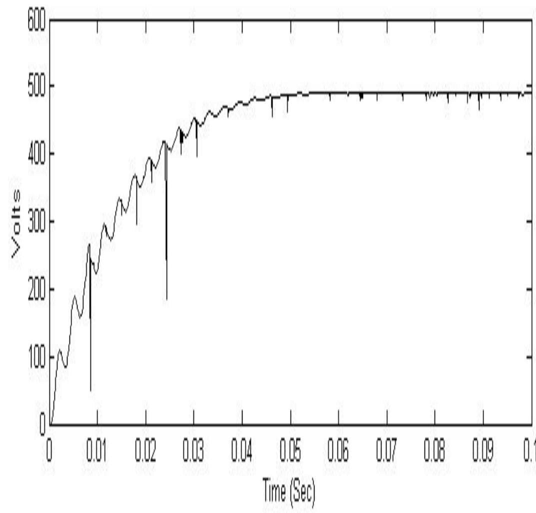

Fig 4.3 DC Voltage after lattice (Z-Source) network

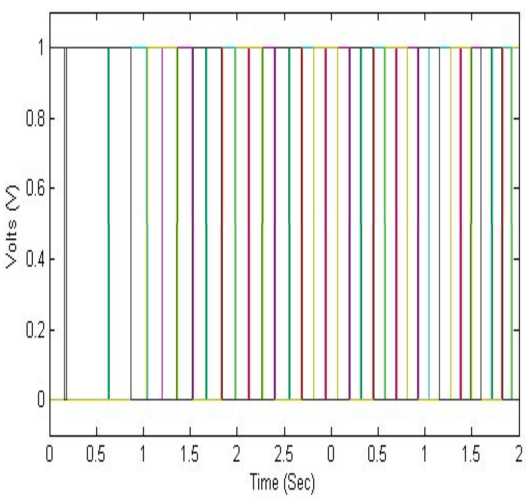

Fig 4.4 Pulses Given to the inverter obtained from Hall sensor

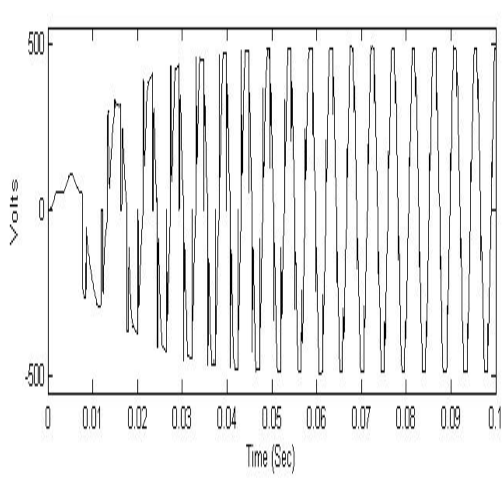

Fig 4.5 Line to Line Voltage of the inverter

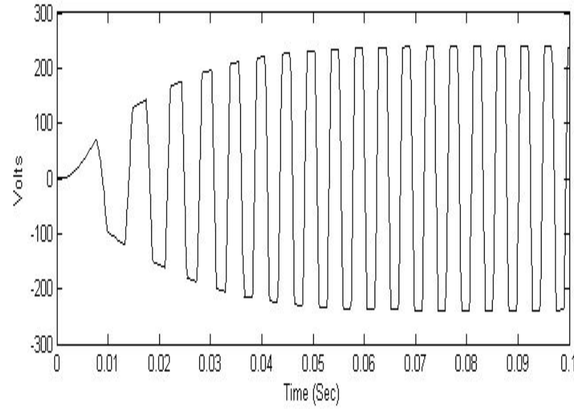

Fig 4.6 Back Emf of the motor

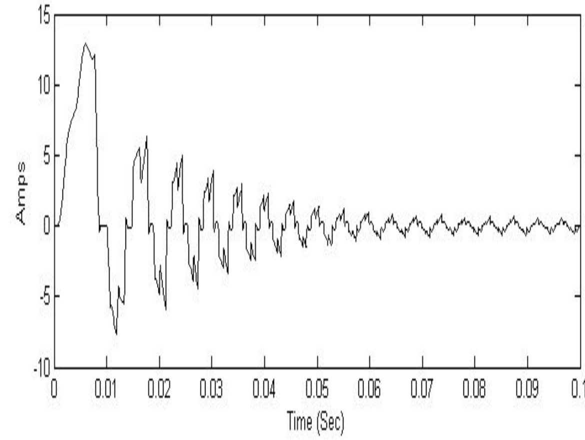

Fig 4.7 Motor Line Current

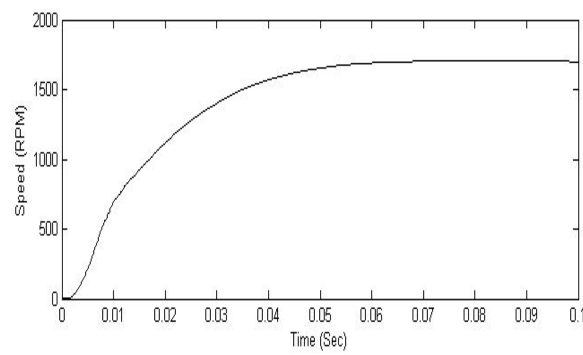

Fig 4.8 Speed of the motor

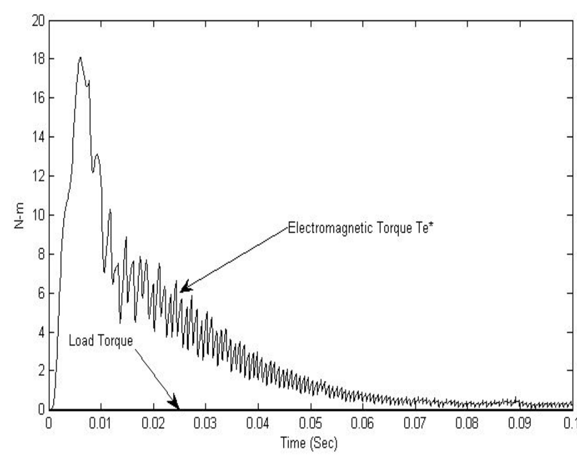

Fig 4.9 Torque of the motor

2. During the Load change

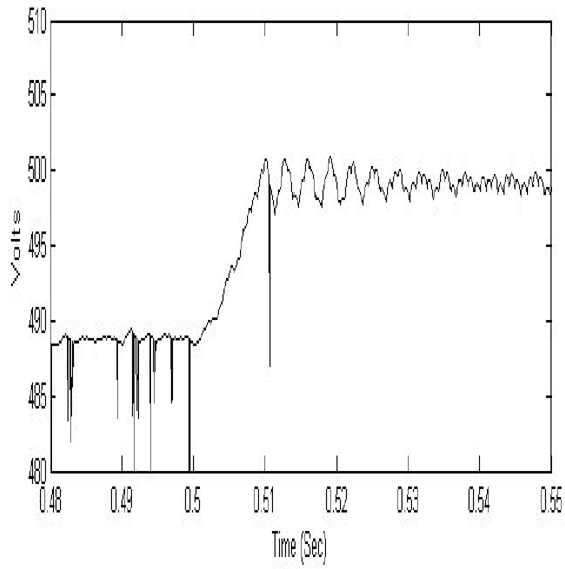

Fig 4.10 DC Voltage after lattice (Z-Source) network

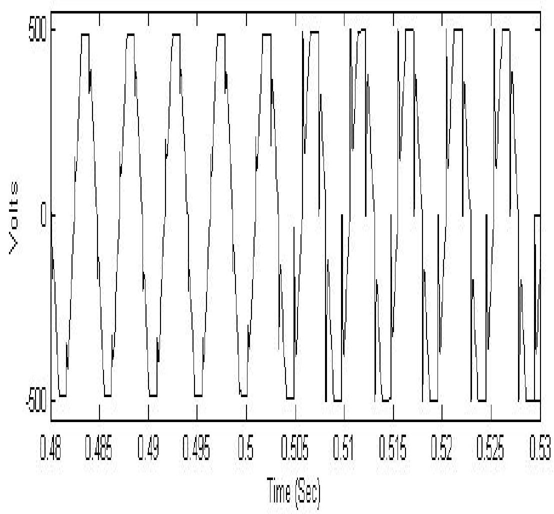

Fig 4.11 Line to Line Voltage of the inverter

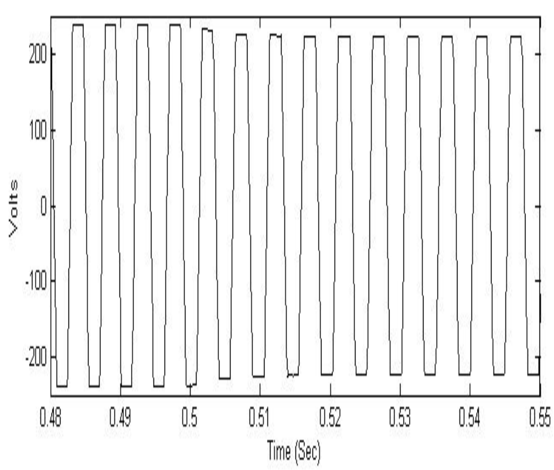

Fig 4.12 Back EMF of the motor

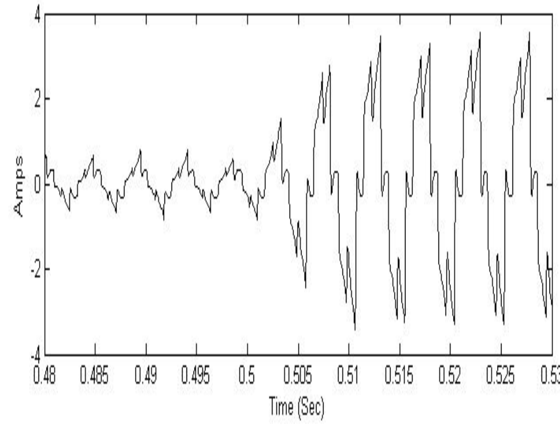

Fig 4.13 Motor Line Current

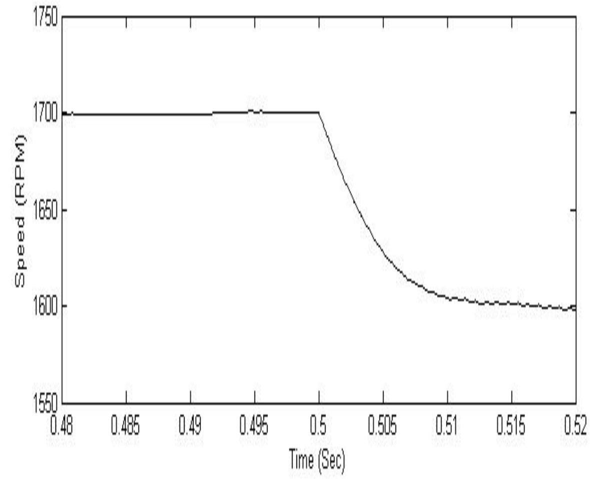

Fig 4.14 Speed of the motor

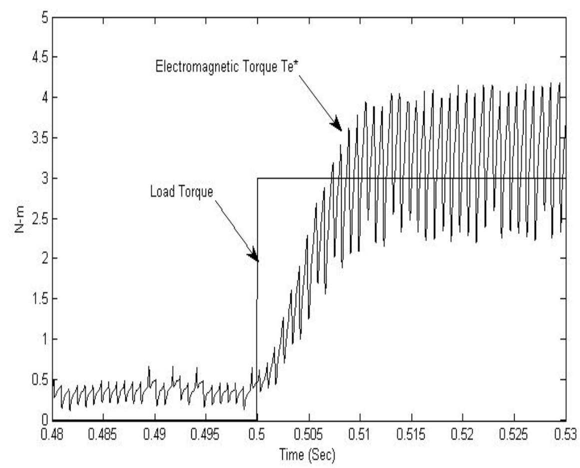

Fig 4.15 Torque of the motor

The simulation model is shown in Fig 4.1. Based on the rotor position the hall sensor makes the signals for the inverter. The normal conventional inverter is employed for this system. The DC link voltage which is boosted for the inverter from the z-source is shown in Fig 4.3. The generated pulses for the inverter from the Hall –Sensor is shown in Fig 4.4.

The line to line voltage which is shown in Fig 4.5 is applied to the terminals of the BLDC motor. The computed back EMF voltage and the currents are shown in Fig4.6 and 4.7 respectively. The speed and torque wave forms are shown in Fig 4.8 and 4.9 respectively. The variations during the loading conditions are shown. The set speed of the system is 1700 and load is applied at the time period of 0.5 sec. A set of results showing the variation in the speed, current, voltage and torque during the load change are shown form Fig.4.10 to 4.15.

Conclusions

In this thesis, a new electric drive system with permanent magnet BLDC motor fed by Z-source inverter is proposed. The drive offers the advantages of both Z-source inverter and BLDC motor. The existing inverter scheme suffers from shoot-through reliability problem. This topology provides better performance than the traditional inverter topology for an identical load and speed conditions. The feasibility of Zsource inverter fed BLDC motor drive is proved by the simulation results. From the results obtained, it is clear that the Z-source inverter fed PMBLDC motor drive is very promising for various industrial applications. The drive response can be improved by using space vector PWM technique.

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