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Analysis of Z-Source Inverter Fed Brushless Dc Motor

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Abstract – *The essential goal of this report is to minimize torque ripples and total harmonic distortions, which will enhance the performance of a BLDC motor (Brushless DC motor). Because undesirable torque pulsations of motor leads to oscillations of speed and excitation resonances at mechanical portions of the drive, Which in turn leads to visible vibrations and acoustic noise in high precision machines and there by reduction in the life time of the machine. This paper presents commutation torque ripple and Total harmonic distortion comparison analysis of a Z-source inverter fed permanent magnet brushless dc motor (PMBLDC) with voltage source inverter fed brushless dc motor.*

Index terms - Permanent magnet Brushless dc (PMBLDC) motor; Z-Source Inverter;V-Source Inverter Total harmonic distortion (THD); Commutation torque ripple.

1.INTRODUCTION

In conventional DC motors, the motor assembly contains a physical commutator which is moved by means of actual brushes in order to move the rotor. These brushes require frequent maintenance. Whereas PMBLDC motors, does not require any physical commutator. The Commutation is achieved by an electronic circuit which gives signals to stator phases. Rotor is position is sensed by a hall sensor or by using sensor less control algorithms like flux estimation, freewheeling current detection, commutation interval measurement [1],[2]. In recent past years BLDC motors are gaining attention in high power applications of industries, domestic appliances, electric traction, aerospace industry, automotive, aircrafts, military equipment, because of their high efficiency, high power factor, less noise, compact in size, reliability, low maintenance and ease of control. So, in order to use PMBLDC motors for these applications it is necessary to use inverter coupled to the voltage source (fuel cell).

BLDC Motors are a type of synchronous motors. Torque ripple generates acoustic noise and vibrations. So, it is necessary to reduce torque ripples while using these Permanent magnet BLDC motors for home appliances [2].Torque pulsations can be minimized by improving motor design and by improving motor control schemes.

Undesirable torque pulsations in the motor leads to speed oscillations and excitation resonances in mechanical portions of the drive, which in turn leads to visible vibrations and acoustic noise in high precision machines. These torque ripples are to be minimized to have better efficiency and to reduce acoustic noise and vibrations [3].

1.1. PM BLDC CONTROL DRIVE

The permanent magnet BLDC motor control drive system is based on feedback of rotor position. This position is obtained at every instant of 60^{0}, by hall sensors to controller circuit.

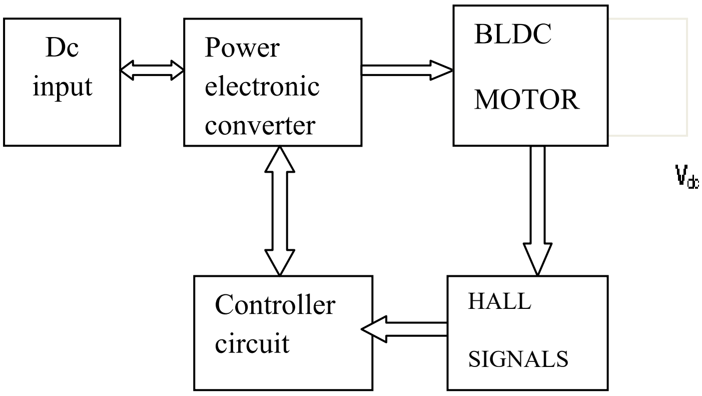

Fig.1.PMBLDC components

The stator coils are switched in correct sequence, at current time if the position of rotor is known. The rotor exact position is obtained by hall sensors. The controller circuit switches, appropriate currents using information from hall sensor.

The permanent magnet BLDC motors with 120° conduction mode, commutates at every 60°[4].so the switching at every 60° produce the commutation torque ripples at every instant. This causes the rotor to oscillate at every 60°.The power electronic converter can be either voltage source inverter or current source inverter.

1.2. VOLTAGE SOURCE INVERTER (VSI)

The voltage-source inverter is commonly used in traditional PMBLDC system [5]. This type of topology can results better output voltage at low harmonic levels. The main limitation of Voltage source inverter topology is its limited output voltage performance. The below figure shows three phase voltage source inverter fed to an adjustable speed drive.

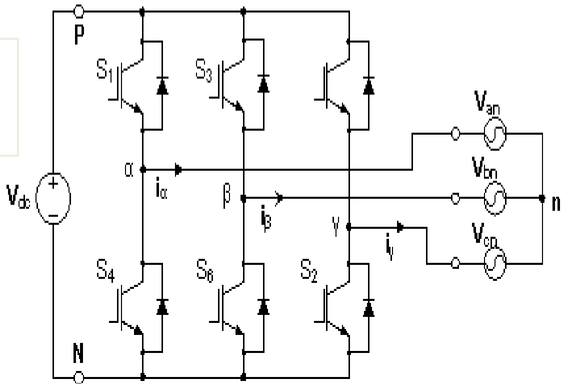

Fig.2.Three phase voltage source inverter

1.4. Z- SOURCE INVERTER (ZSI)

A Z-source power converter overcomes the limitations of the traditional Voltage source and I-source converters. Fig. 3 shows Z-source inverter structure [6].The architecture of Z-source inverter is the combination of diode and a switch in series. It employs a unique impedance circuit to couple the main converter circuit to the source, load, or another converter. Converter and provides a novel power conversion concept. In Fig. 3, network consists of a split-inductor and capacitors and connected in X shape. Which becomes an impedance source (Z-source) coupling the converter (or inverter) to the dc source, load, or another converter. The dc source can be either a voltage or a current source. Fig. 3 and 4 shows two different three-phase Z-source inverters types.

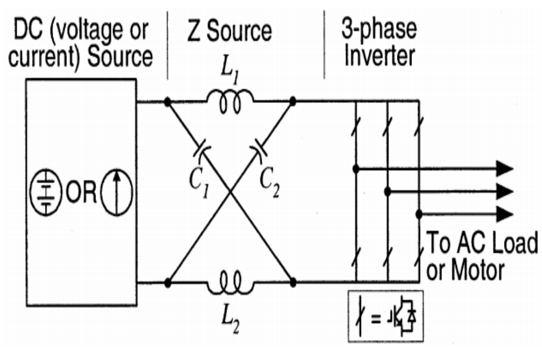

Fig.3. Z-source converter with anti parallel combination of switching device and diode.

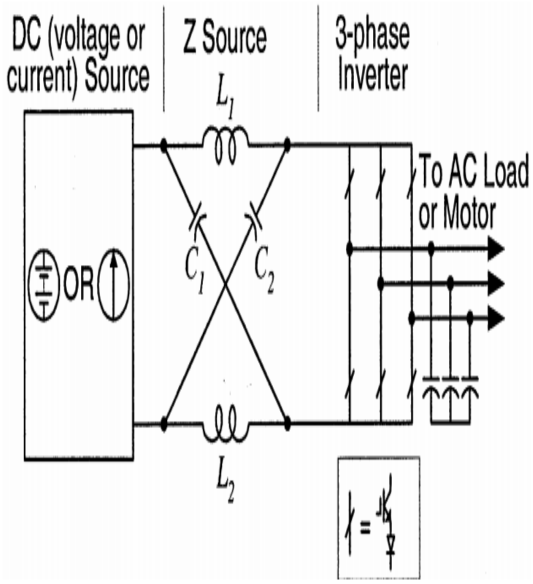

Fig.4. impedance-source converter with combination of switching device and diode in series

1.4.1 DESIGN OF Z-SOURCE INVERTER

The passive components are designed based switching frequency and their ripple requirements of current and voltage ripple. The Z-source network provides a second-order filter and is more effective to suppress voltage and current ripples than capacitor or inductor used alone in the traditional inverters.

When the two inductors (L_1 and L_2) are small and approach zero, the Z-source network reduces to two capacitors (C_1 and C_2) in parallel and becomes a traditional V-source. Therefore, a traditional V-source inverter's capacitor requirements and physical size is the worst case requirement for the Z-source network. Considering additional filtering and energy storage provided by the inductors, the Z-source network should require less capacitance and smaller size compared with the traditional V-source inverter.

Similarly, when the two capacitors (C_1 and C_2) are small and approach zero, the Z-source network reduces to two inductors (L_1 and L_2) in series and becomes a traditional I-source. Therefore, a traditional I-source inverter's inductor requirements and physical size is the worst case requirement for the Z-source network. Considering additional filtering and energy storage by the capacitors, the Z-source network should require less inductance and smaller size compared with the traditional I-source inverter

2. SIMULATION MODEL OF V-SOURCE INVERTER FED BLDC MOTOR

Fig.5 to Fig.8 shows simulink model of VSI fed BLDC motor and performance of a permanent magnet BLDC motor supplied by a voltage source inverter. Fig.8 shows speed and electromagnetic torque of voltage source inverter fed Brush less DC motor .And also t is evident that it takes more transient time of 4.4msec and the ripples occurs at every 60^{o} commutation instant.

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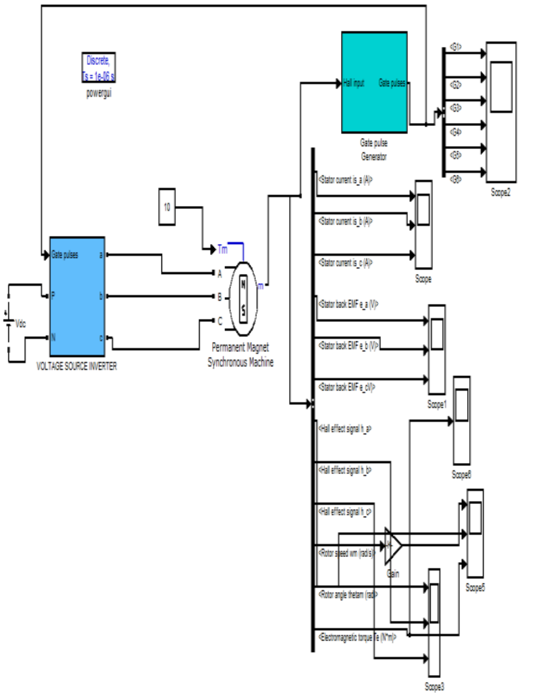

Fig.5.Simulation model of VSI fed BLDC motor

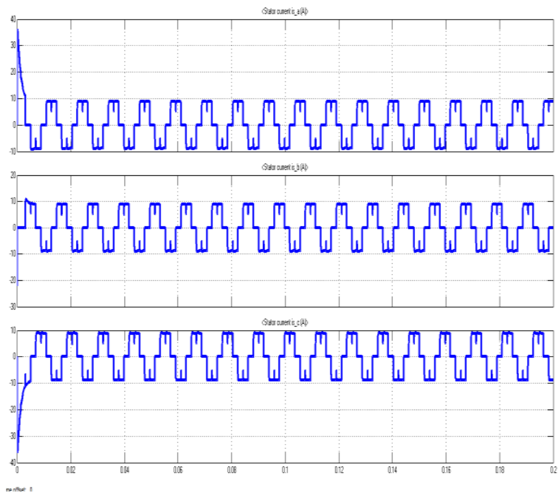

Fig.6. Stator currents speed of VSI fed BLDC Motor

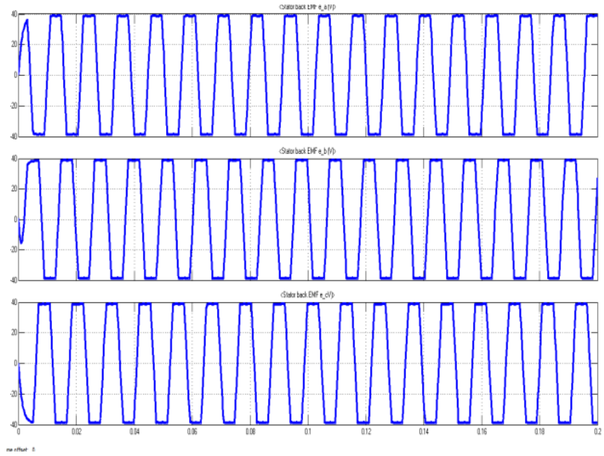

Fig.7.Stator voltages of VSI fed BLDC Motor

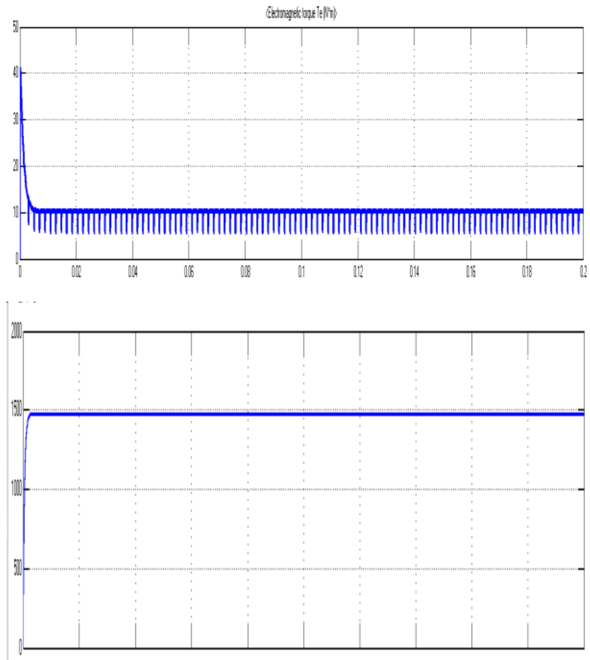

Fig.8. Electromagnetic torque and speed of VSI fed BLDC Motor

3. SIMULATION MODEL OF Z-SOURCE INVERTER FED BLDC MOTOR

Fig.9 to Fig.12 shows simulink model of Z-Source Inverter fed BLDC motor and performance of a permanent magnet BLDC motor supplied by a Z-sourcesource inverter.

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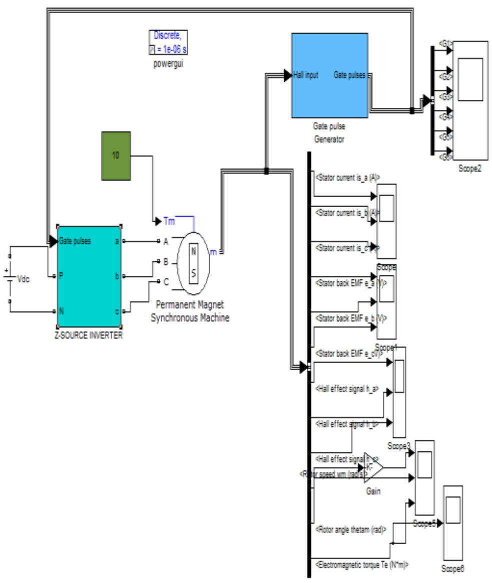

Fig.9.Simulation model of z-source inverter fed BLDC motor

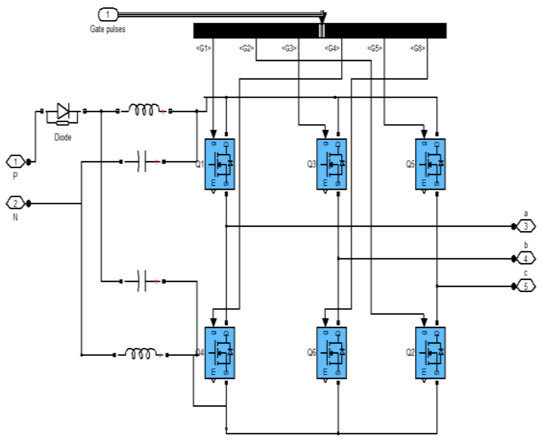

Fig.9.Simulation model of z-source inverter

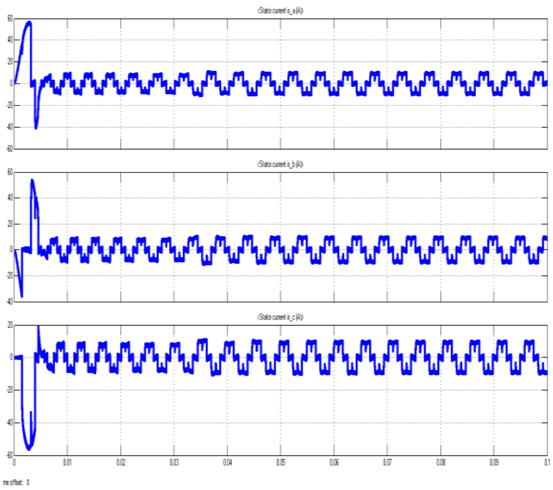

Fig.10. Stator currents speed of ZSI fed BLDC Motor

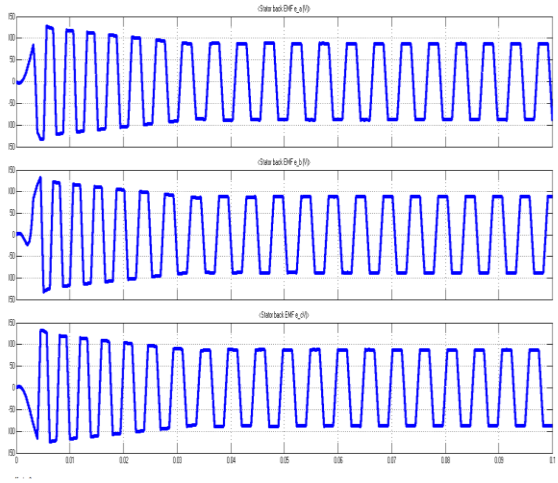

Fig.11.Stator voltages of ZSI fed BLDC Motor

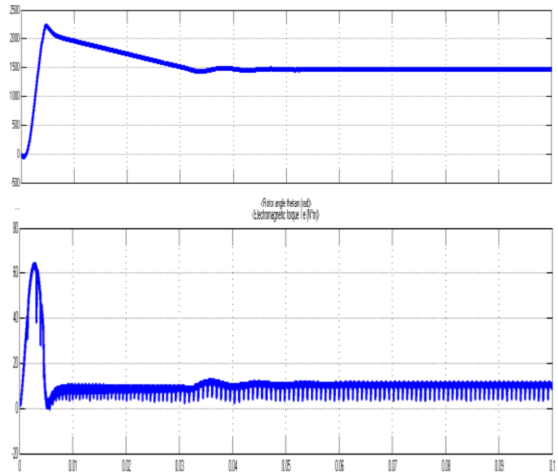

Fig.12. Electromagnetic torque and speed of ZSI fed BLDC Motor.

4. CONCLUSION

This paper presents Matlab simulation models performance of voltage source inverter fed BLDC motor and Z-source inverter fed BLDC motors. As the z-source inverter acts as a filter in addition to voltage source and current source inverter voltage and current ripples are suppressed to great extent,which can be obtained by choosing proper capacitance and inductance values.which in turn reduces production of torque ripples.

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