A Comparative Analysis among PWM Control Z-source Inverter with Conventional PWM Inverter for Induction Motor Drive

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***Abstract*-The uses of induction motor is ever-growing day by day because of its superiority and high efficiency over dc machine. So for wide range of use in the industry, this machine requires an efficient driver circuitry arrangement. Currently conventional Voltage Source Inverter (VSI) or Current Source Inverter (CSI) is dealing as key part in the field of induction motor driver circuit. These converters fail to perform at our desire level due to some crucial drawbacks like they can perform as either buck or boost operation and they contain considerable amount of harmonics as well as EMI noise. So we are trying to replace these traditional inverters by PWM control Z-Source Inverter (ZSI) which offers buck-boost operation capability by utilizing shoot through state and provides less EMI noise. This paper presents a comparative study among these three inverters. Firstly three MATLAB simulation model of Induction motor driver by using VSI, CSI and ZSI (having almost same environment) have arranged. Then some important motor characteristics such as rotor speed, electromagnetic torque, rotor current and stator current have observed for three system models at various loading conditions. The model using Z-source inverter exhibits efficient performance in all cases compared to the other models.**

Keywords- PWM, Z-Source Inverter, Conventional Inverter, Shoot Through, Buck-boost.

I. INTRODUCTION

In the previous decades the dc motors were extensively used for the industrial purposes due to the decupled torque and flux that can be obtained by controlling field and armature current respectively [1]. Though the dc motor provides high starting torque, it has a number of drawbacks such as it requires high maintenance and not suitable for hazardous environment [2].

But in this decade the induction motor has taken the place of work horse in industry instead of dc motors because its robustness, less maintenance, high efficiency and low cost [3]. At past induction motors were mainly used for essentially constant speed applications as there was unavailability of variable frequency voltage supply. But with the advancement of the power electronics, it has made possible to supply variable frequency voltage, thus increase the use of induction motor in variable speed drive applications.

There are basically two ways to get voltage at variable frequency for the induction motor drives. One is cycloconverter and another is three phase inverter. The cycloconverter is widely used in very large power application such as locomotives and cement mills where the frequency requirement is one half or one third of line frequency. On the other hand, three phase inverters are very suitable for small and medium application [4]. The pulse width modulation (PWM) is the most efficient method used to varying both the voltage and frequency within a three phase inverter. In this method, a fixed dc input voltage is applied to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components [5].

II. CONVETIONAL PWM INVERTERS FOR MOTOR DRIVE

There are basically two types of conventional inverter for the motor drive on the basis of input power supply. Those are a) Current source inverter (CSI) and b) Voltage source inverter (VSI).

a. Conventional Current Source Inverter:

The current source inverter is that one, in which the source and therefore the load current is predetermined and the load impedance decide the output voltage [6]. The supply current cannot change rapidly and the magnitude of the load current is controlled by varying input dc voltage to the large inductance, hence inverter response to the changing load is slow.

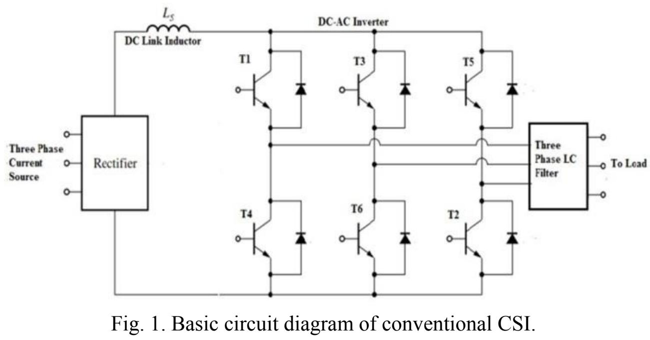

Fig. 1. Basic circuit diagram of conventional CSI.

Figure 1 shows the basic circuit diagram of conventional current source inverter. A three phase ac current source is fed to the rectifier circuit in order to converter three phase ac current into dc current. Then the rectified dc current is fed to the three phase semiconductor switch based inverter through a dc link inductor. After that the output voltage form inverter is fed to a three phase LC filter in order to obtain sinusoidal three phase output voltage.

The current source inverter for motor drives have some conceptual limitations such as, they usually perform as a buck converter so additional power conversion stage is required to maintain required power, which increases the system cost, their output response is very slow and output voltage contains more harmonics and EMI noise[7].

b.*Conventional Voltage Source Inverter:*

A voltage source inverter is an arrangement where input voltage is constant and output voltage is independent of nature of the load.

But the output current waveform as well as magnitude depends upon nature of load impedance [8]. Three phase voltage source inverters are more common for providing adjustable frequency power to industrial application as compared to single phase inverters. The voltage source inverter takes dc supply from a battery or more usually from a 3-ϕ bridge rectifier [9].

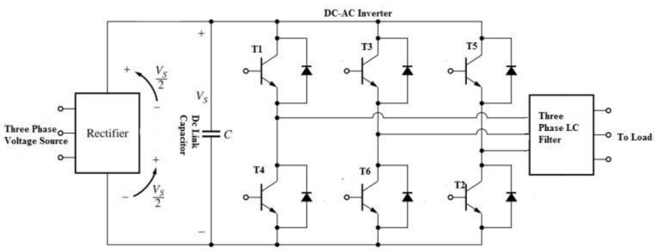

Fig. 2. Basic Circuit Diagram of Conventional VSI.

Figure 2 shows a basic circuit diagram of conventional voltage source inverter. The rectified dc voltage from the rectifier section is fed to the three phase bridge inverter through a dc link capacitor. Then the output voltage from the three phase inverter is fed to the three phase LC filter in order to obtain sinusoidal output voltage,

The voltage source inverter drives also have some crucial drawback such as, they worked as a buck converter and required additional circuitry to get desired output voltage which further introduce a considerable amount of harmonics and EMI noise [10].

III. Z-SOURCE INVERTER:

In order to overcome the limitations of conventional inverter, researchers have concentrated to an efficient inverter system called Z-source inverter. The input power of the Z-source either be current or voltage source [11].

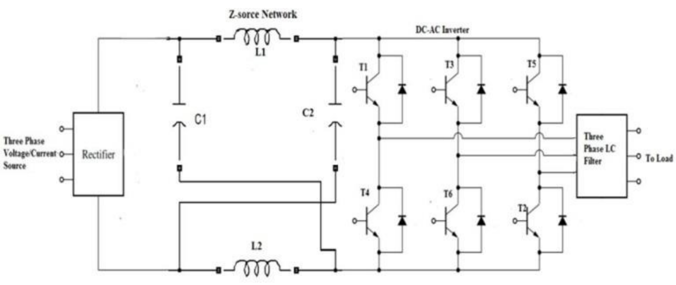

Fig.3. Basic Circuit Diagram of Z-source Inverter

Figure 3 shows the basic circuit diagram of Z-source inverter. Form the circuit, it has been seen that the Z-source inverter utilizes an impedance network consists of two inductors and two capacitors of same values between the dc source and three phase inverter [12].

The impedance network also known as Z-source network, utilizes shoot through state to boost the dc voltage by gating on both the upper and lower switches of the same phase leg [13]. The shoot through state does not affect the PWM control of the inverter as it equivalently produce the same zero voltage to the load terminal but to achieve the high output voltage, it is required to increase the shoot through duty ratio[14]. The Z-source inverter offers some efficient feature such as it can operate by voltage source or current source, it contains fewer amounts of harmonics and EMI noise as compared to the conventional inverters and it provides buck-boost capability by utilizing shoot through state [15].

III. Simulation and results

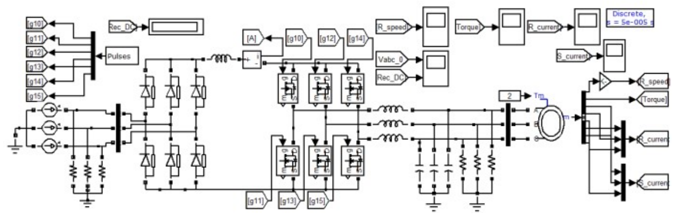

Fig. 4. Simulation circuit arrangement of CSI for Motor Drive.

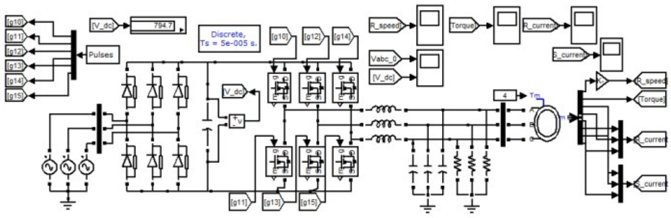

Fig.5. Simulation circuit arrangement of VSI for Motor Drive.

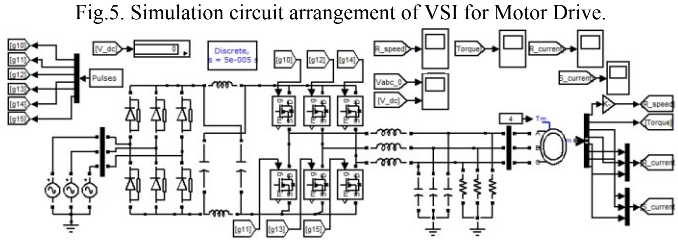

Fig. 6. Simulation circuit arrangement of ZSI for Motor Drive.

a. Comparison of Rotor Speed:

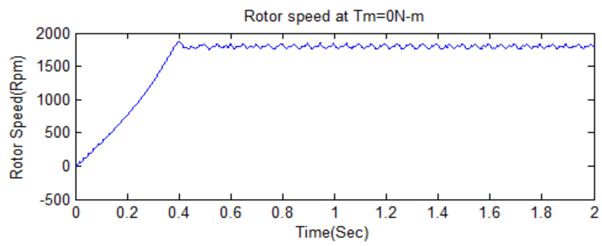

Fig. 7. Rotor Speed of CSI Fed IM at Tm=0N-m.

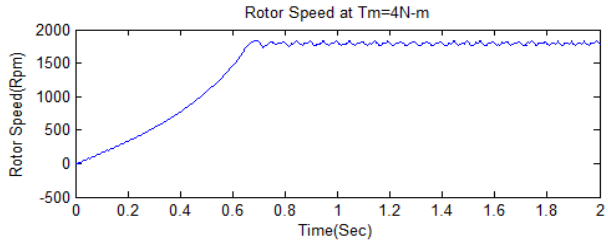

Fig. 8. Rotor Speed of CSI Fed IM at Tm=4N-m.

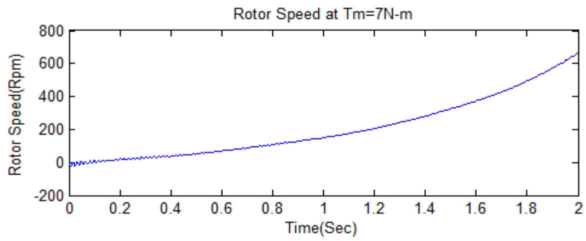

Fig. 9. Rotor Speed of CSI Fed IM at Tm=7N-m.

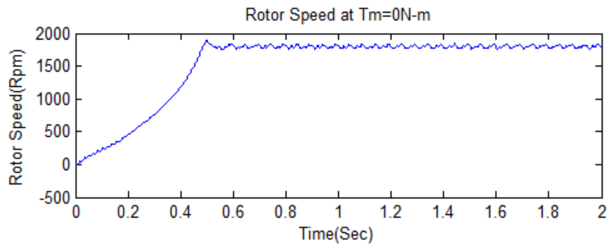

Fig. 10. Rotor Speed of VSI Fed IM at Tm=0N-m.

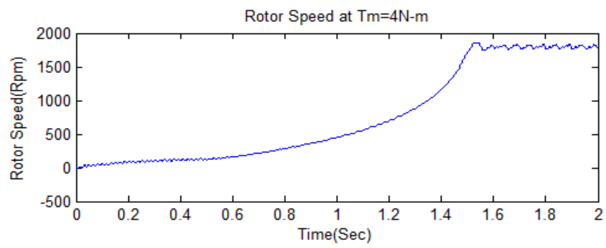

Fig. 11.Rotor Speed of VSI Fed IM at Tm=4N-m.

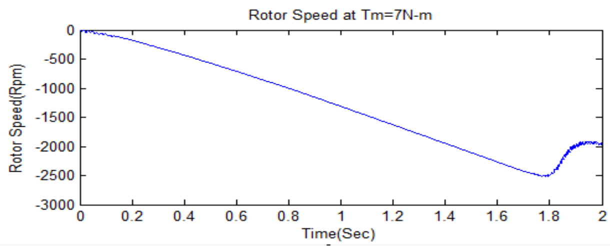

Fig. 12. Rotor Speed of VSI Fed IM at Tm=7N-m.

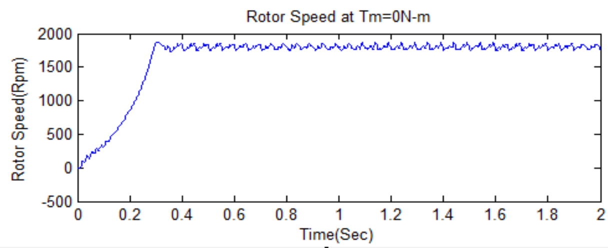

Fig. 13.Rotor Speed of ZSI Fed IM at Tm=0N-m.

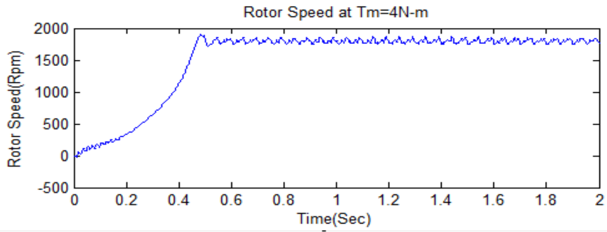

Fig. 14. Rotor Speed of ZSI Fed IM at Tm=4N-m.

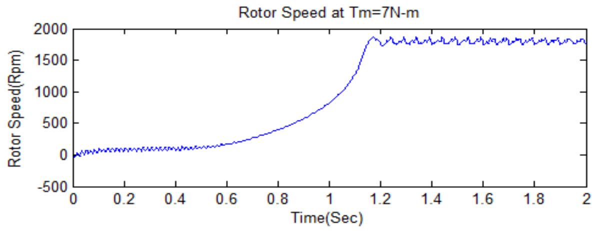

Fig. 15. Rotor Speed of ZSI Fed IM at Tm=7N-m.

Table. I: Comparison of rotor speed settling time at different torque

Drive	Settling time(Sec) at Tm=0N-m	Settling time(Sec) at Tm=4N-m	Settling time(Sec) at Tm=7N-m
CSI	0.4	0.68	t>2
VSI	0.48	1.57	failed
ZSI	0.29	0.47	1.18

Table-I shows that, the ZSI fed IM attains steady state speed condition earlier than CSI and VSI fed induction motor. It has also shown that, ZSI fed IM can run at higher load condition than the CSI and VSI fed IM.

b. Comparison of Electromagnetic Torque:

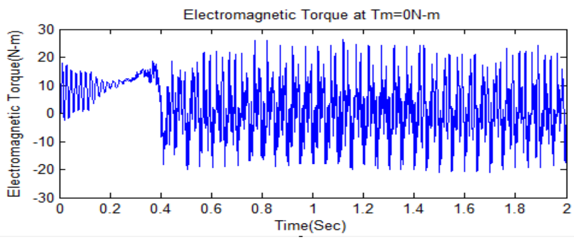

Fig.16. Electromagnetic Torque of CSI Fed IM at Tm=0N-m.

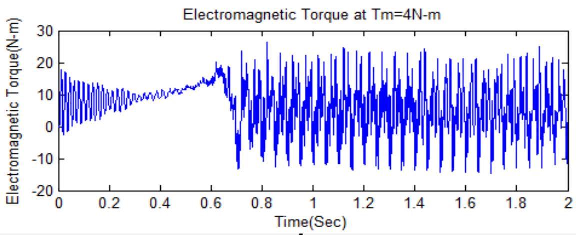

Fig. 17. Electromagnetic Torque of CSI Fed IM at Tm=4N-m.

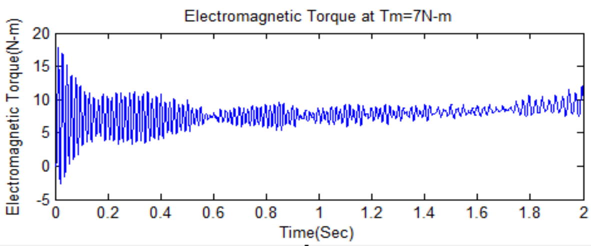

Fig. 18. Electromagnetic Torque of CSI Fed IM at Tm=7N-m.

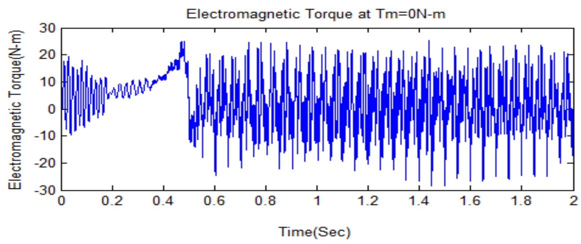

Fig. 19. Electromagnetic Torque of VSI Fed IM at Tm=0N-m.

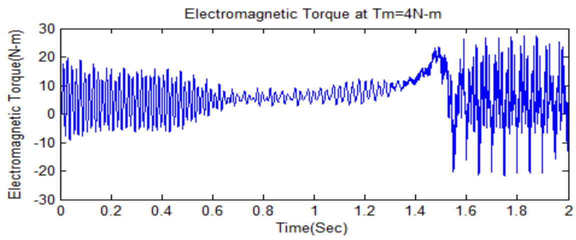

Fig. 20. Electromagnetic Torque of VSI Fed IM at Tm=4N-m.

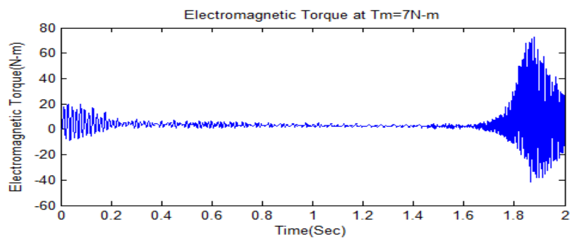

Fig. 21. Electromagnetic Torque of VSI Fed IM at Tm=7N-m.

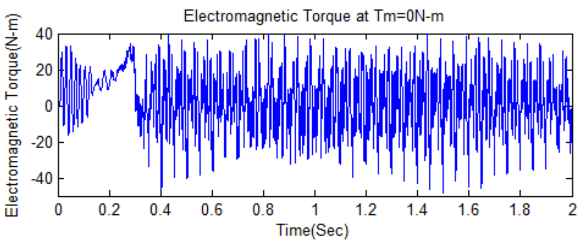

Fig. 22. Electromagnetic Torque of ZSI Fed IM at Tm=0N-m.

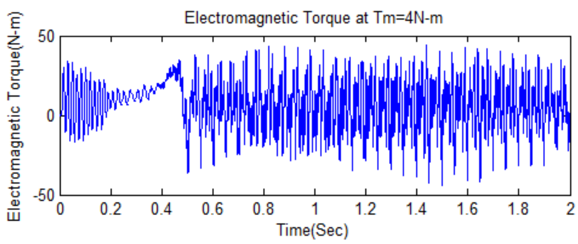

Fig. 23. Electromagnetic Torque of ZSI Fed IM at Tm=4N-m.

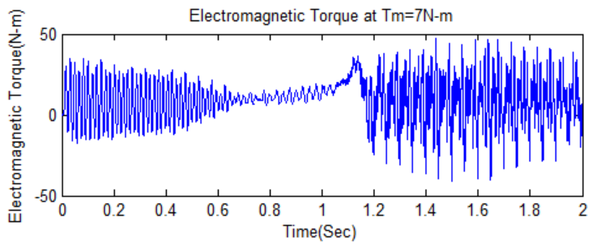

Fig. 24. Electromagnetic Torque of ZSI Fed IM at Tm=7N-m.

The Figures 16 to 24 shows the electromagnetic torque of CSI, VSI and ZSI fed IM respectively. From those figures it has been clear that ZSI fed IM attains load torque quicker than CSI and VSI fed.

c. Comparison of Rotor Current:

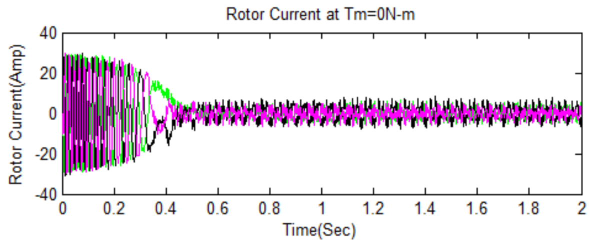

Fig. 25.Rotor Current of CSI Fed IM at Tm=0N-m.

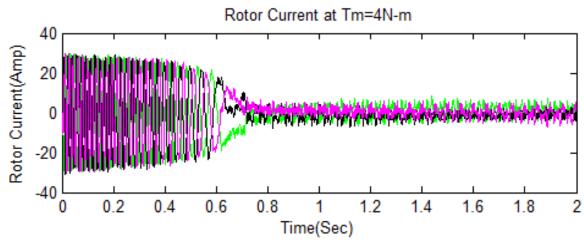

Fig. 26. Rotor Current of CSI Fed IM at Tm=4N-m.

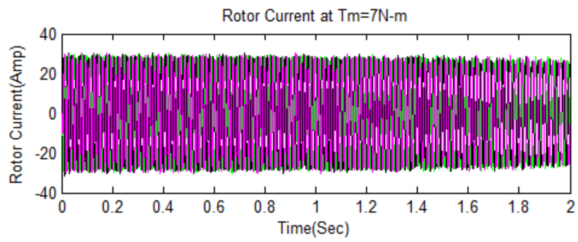

Fig. 27. Rotor Current of CSI Fed IM at Tm=7N-m.

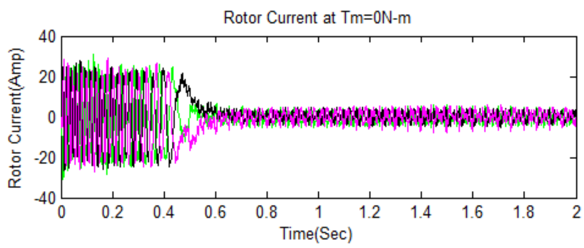

Fig. 28. Rotor Current of VSI Fed IM at Tm=0N-m.

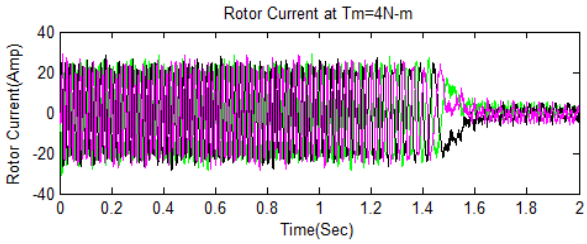

Fig. 29. Rotor Current of VSI Fed IM at Tm=4N-m.

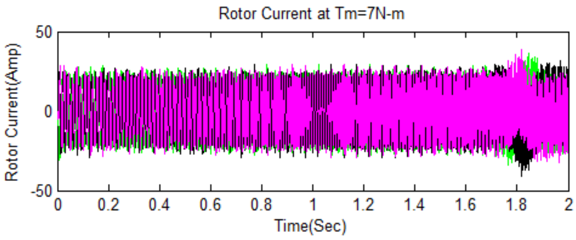

Fig. 30.Rotor Current of VSI Fed IM at Tm=7N-m.

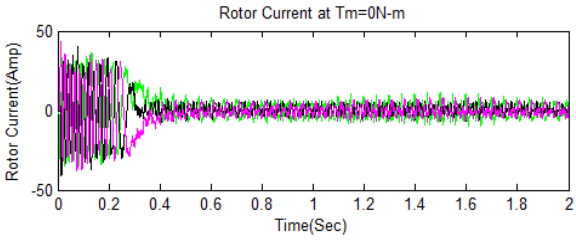

Fig. 31. Rotor Current of ZSI Fed IM at Tm=0N-m.

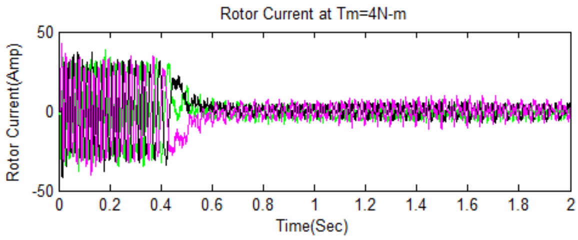

Fig. 32.Rotor Current of ZSI Fed IM at Tm=4N-m.

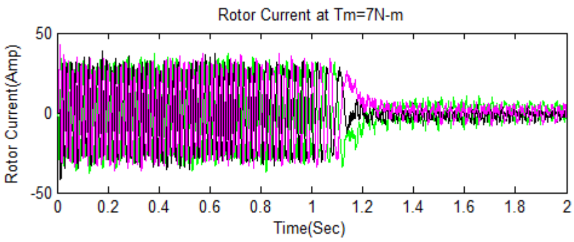

Fig. 33. Rotor Current of ZSI Fed IM at Tm=7N-m.

The Figures 25 to 33 show the rotor current of CSI, VSI and ZSI fed IM at different torque condition respectively. From those figures it has been seen that the settling time of ZSI fed IM rotor current is quicker than the CSI and VSI fed IM rotor currents. The rotor current of ZSI fed IM also contains fewer ripples than the rotor currents of CSI and VSI fed IM.

d. Comparison of Stator Current

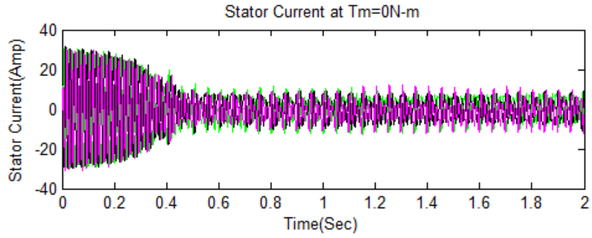

Fig. 34. Stator Current of CSI Fed IM at Tm=0N-m.

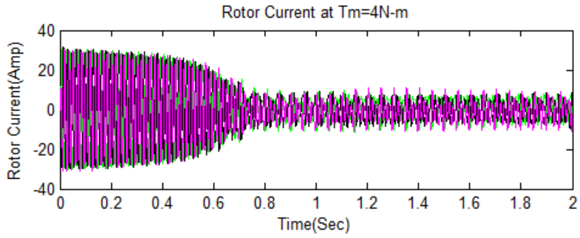

Fig. 35. Stator Current of CSI Fed IM at Tm=4N-m.

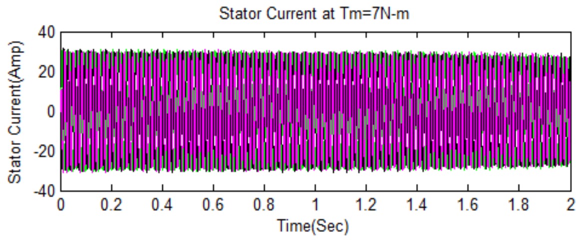

Fig. 36. Stator Current of CSI Fed IM at Tm=7N-m.

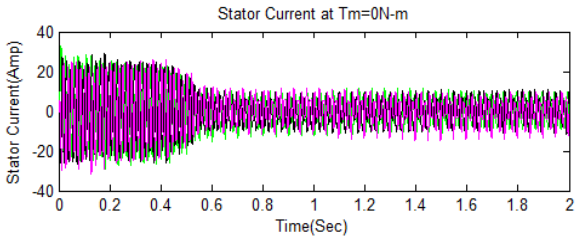

Fig. 37. Stator Current of VSI Fed IM at Tm=0N-m.

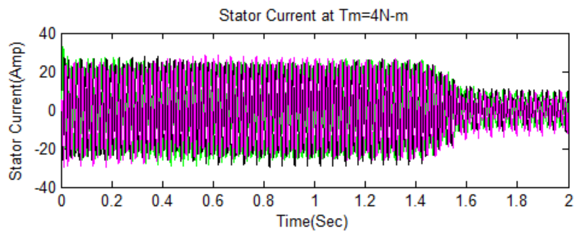

Fig. 38.Stator Current of VSI Fed IM at Tm=4N-m.

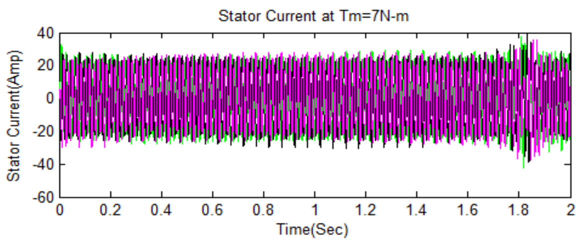

Fig. 39. Stator Current of VSI Fed IM at Tm=7N-m.

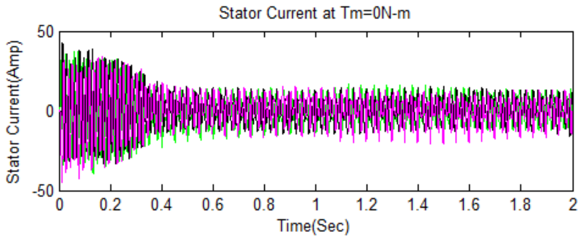

Fig. 40. Stator Current of ZSI Fed IM at Tm=0N-m.

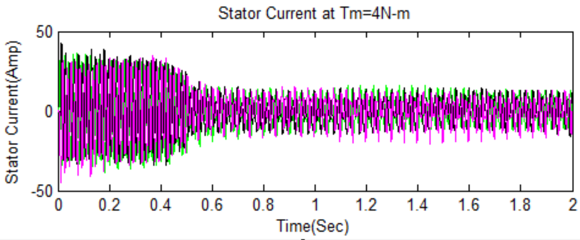

Fig. 41. Stator Current of ZSI Fed IM at Tm=4N-m.

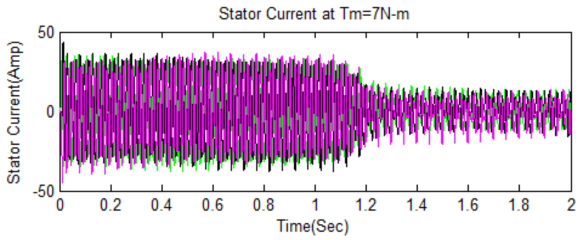

Fig. 42. Stator Current of ZSI Fed IM at Tm=7N-m.

The Figures 34 to 42 shows the stator currents of CSI, VSI and ZSI fed IM at different torque respectively. The settling time of stator current of ZSI fed IM decreases as compared to the stator currents of CSI and VSI fed IM.

CONCULATION

This paper presents the comparative study of PWM control Z-source inverter for motor drive with conventional inverters for motor drive by using MATLAB Simulink simulation. Various performance of induction motor such as rotor speed, electromagnetic torque, rotor current and stator current has been analyzed at different torque conditions. It has been prove that the induction motor fed with Z-source inverter provides quick operation, fewer harmonic, reduces the settling time of rotor and stator currents as compared to CSI and VSI fed IM.

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