Z-SOURCE INVERTER FED INDUCTION MOTOR DRIVE PERFORMANCE ANALYSIS

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ABSTRACT

For the Z-source inverter, which can achieve maximum voltage boost for a fixed modulation index, performance analysis and simulation of maximum constant boost-control using third harmonic injection techniques are presented in this work. Recently, a novel power conversion idea known as the Z-source inverter was created, primarily for fuel cell vehicle applications. The Z-source inverter may be used in all ac and dc power conversion applications and has several advantages over regular inverters. Z-source inverters are controllable using all conventional PWM techniques. Maximum constant boost control techniques reduce the voltage strains on switching devices while eliminating low-frequency ripples in the inductor current and capacitor voltage by keeping the shoot-through duty cycle constant. While the Z-source network design in the maximum constant boost control technique is solely reliant on the switching frequency and is independent of the output frequency, the maximum boost control method is only appropriate for output frequencies that are reasonably high. This study determines Z-source inverter parameters for a maximum constant boost control technique for a fixed modulation index. Simulation and tests are used to verify the results, which include boost factor, output dc link voltage, capacitor voltage, output ac voltage, voltage gain, etc.

Keywords – *Z-source inverter, voltage boost, boost factor, PWM, third harmonic injection, voltage gain, etc.*

1. INTRODUCTION

Conventional Inverter topologies are commonly used as power electronics circuit for power conversion. These inverters having limitations like they are only used as buck inverter or boost inverter and cannot be a buck-boost inverter. Their main circuit cannot be interchangeable. In other words, the voltage-source inverter main circuit cannot be used for the current-source inverter or vice versa. The shoot-through problem for voltage source inverter and open circuit problem for current source inverter by electromagnetic interference (EMI) noises reduce the inverter's reliability. These limitations are overcome by using Z- Source Inverter. In this project two Z-Source Inverter fed induction motor drive system performance by using controller and without controller is compared with Voltage Source Inverter fed induction motor drive system. Result from this system is to be study and analyzed.

Conventional converter topologies such as voltage source inverter (VSI) and current source inverter (CSI) are commonly used as power electronics circuits for power conversion purposes. The VSI produces an ac output (after filtering it) which is limited below the dc input voltage, which means that VSI is buck type converter. The buck operation nature of the VSI limits its operation to power conversion applications and ac drive circuits. An additional dc-dc unit is connected to the dc input of the converter in order to further increase the dc input voltage, which leads to an increase in the ac output voltage.

As a result, the additional dc-dc boost converter increases the system cost, control complexity and reduces the efficiency. Further, animism-gating of the inverter bridge switches cause short circuit and destroys the power switching devices. For that, a dead-time is set between the upper and the lower switching devices of the same leg in order to avoid short circuit occurrences. The idea of impedance-source converter (ZSI) was originally developed due to the limitation in VSIs and CSIs. The conceptual and theoretical limitations in the conventional converters types reduce their application and complicate their control methods. While the ZSI great advantage can be seen as: it can operate as VSI inverter (buck type) or as CSI inverter (boost type) depending on the application. The output voltage can ideally ranges from zero to infinity. Since the invention of the ZSI inverter, there are number of research works on this interesting topology, and this project presents its basic operation and control.

The Z-source inverter mainly used the shoot-through states to boost the dc bus voltage for the turning ON two thyristors of the upper and lower phase same leg. As a result the Z-source inverter can buck and boost voltage to a wanted output voltage that is more than dc bus voltage. Therefore improve the reliability of an inverter, the shoot-through cannot occurs to burnout the circuit. The advantages of ZSI has a low-cost, reliable and highly efficient single-stage structure for boost and buck power conversion. The main structure circuit of the Z-source inverter is presented in Fig.1. The maximum constant boost control can greatly reduce the L and C requirements of the Z-source impedance network.

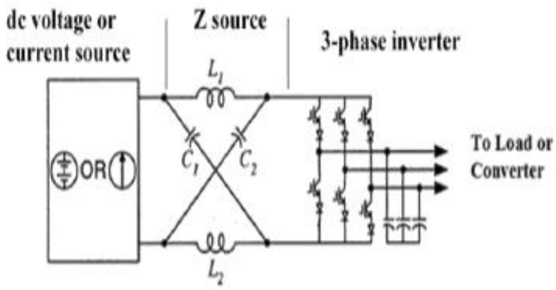


Fig. 1.1.1 Structure of ZSI

The purpose of this work is to investigate modeling and simulation of a single phase Z-source inverter and its control strategy for implementation dc-to-ac power conversion. The research motivation for this thesis also comes from the necessity of maximum power point tracking (MPPT) for the Z source inverter. The Z-source inverter and its control system should be capable of tracking individual maximum power point of the solar panels and ensures the maximum capture of energy on DC side.The ZSI impedance network has a unique LC network which is connect with dc link and controller to provide optimal output ac voltage. Also, a comparative performance analysis of a ZSI and VSI.

2. LITERATURE REVIEW

D. I. Ivanchenko, R. A. Salov and E. V. Yakovleva, "Analysis of Z-source inverter control system for asynchronous drive for gas compressor," 2018 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus), 2018, pp. 636-640, doi: 10.1109/EIConRus.2018.8317177.

The article deals with the comparison of Z-source inverter based control systems for the asynchronous drive of gas compressor that is used in oil and gas industry. The relevance of the task is highlighted by the fact that choice of control system determines the reliability and the efficiency of gas system drive. Two types of indirect DC-link voltage control techniques were examined in order to estimate operation effectiveness of control system in dynamic modes. For that purpose, simulation model of ZSI fed by induction motor, based on state space averaged modeling method, has been developed utilizing MATLAB/Simulink environment. The simulation results of dynamic performance of the ZSI with single-loop and dual-loop capacitor voltage control techniques during input voltage changes and steady state operations are presented and analyzed.

S. Rahman, K. Rahman, M. A. Ali, M. Meraj and A. Iqbal, "Quasi Z Source Inverter Fed V/f Controlled Five Phase Induction Motor Drive Powered," 2019 International Conference on Electrical, Electronics and Computer Engineering (UPCON), 2019, pp. 1-6, doi: 10.1109/UPCON47278.2019.8980073.

Impedance Source Inverters are extremely popular these days. They offer simultaneous boosting of input voltage applied as well as inversion operation. The converter achieves this by means of a specially designed impedance network along with H - Bridge. Unlike conventional H - Bridge (HB) inverters, impedance source inverters can boost the supply voltage thereby achieving boost operation. Utilizing this feature, voltage transient due to grid side disturbance, improved control and enhanced fault tolerance capability can be achieved. There are two types of impedance source-based inverters namely Z Source Inverters (ZSI) and quasi Z Source Inverters (qZSI). In this paper, five phase qZSI fed five phase induction motor drive is discussed. V/f control is implemented to induction motor in synchronism with closed loop voltage control of quasi network output voltage. Constraints in the integrated performance are discussed and taken into consideration for development of control algorithm. Simulation results are presented for the system when subjected to different load transients thereby validating the integrated control.

O. Ellabban, J.V. Mierlo, P. Lataire, "Capacitor Voltage Control Techniques of the Z-source Inverter: A Comparative Study", EPE Journal, Vol. 21, no. 4, 2011, pp. 13-24. DOI:10.1080/09398368.2011.11463806.

The Z-source inverter (ZSI) is a recently proposed single-stage power conversion topology. It adds voltage boost capability for complementing the usual voltage buck operation of a traditional voltage source inverter (VSI) with improved reliability. In this paper, a single-loop and dual-loop capacitor voltage control techniques for the ZSI are digitally designed based on a third order small signal model of the ZSI, implemented using a digital signal processor (DSP) and compared. Simulation and experimental results of a 30 kW ZSI during input voltage changes, load disturbances and steady state operations are presented and compared. The results show that the dual-loop capacitor voltage control technique achieves better steady state and transient performance and enlarge the stability margins of the ZSI compared to the single-loop capacitor voltage control technique.

3. METHODOLOGY

The proposed work is planned to be carried out in the following manner:

1. Study of basic concepts of Induction motor
2. Study of basic concepts of Z- source Inverter.
3. Finding the problems from conventional system by surveying literature.
4. Design VSI fed induction motor drive.
5. Analysis of the proposed topology.
6. Study of the control strategies of system.
7. Simulation of the model can be done in MATLAB software. Evaluation of the performance

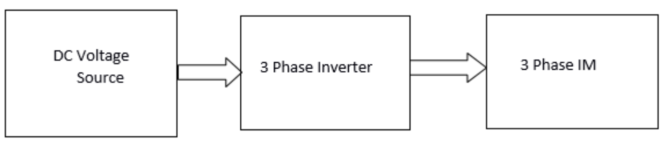


Fig. 3.1.1: Block Diagram of Voltage -Source Inverter fed Induction Motor drive

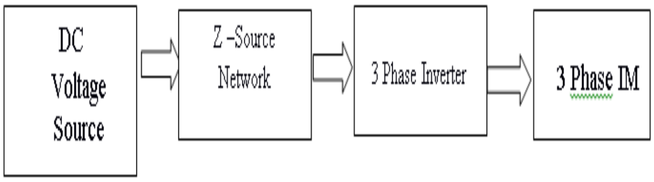


Fig. 3.1.2: Block Diagram of Z-Source Inverter fed Induction Motor drive without Controller

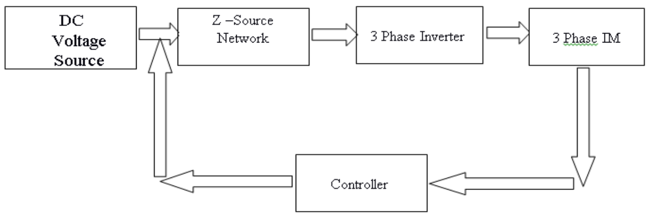


Fig. 3.1.3: Block Diagram of Z-Source Inverter fed Induction Motor drive with Controller

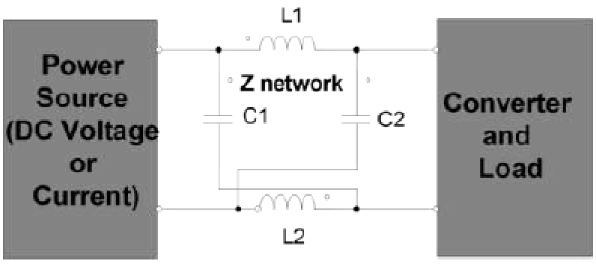


Fig. 3.1.4 The general configuration of a Z-source converter

Fig. 3.1.4 shows a simplified equivalent circuit for voltage source based ZSC. In the simplified circuit, the VSI inverter bridge is viewed as an equivalent current source or drain in parallel with an active switch S2.

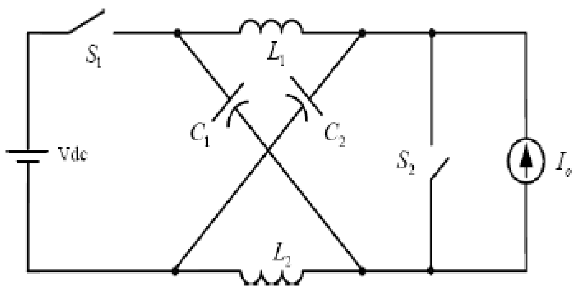


Fig. 3.1.5 Equivalent circuit of voltage source based Z-Source Converter

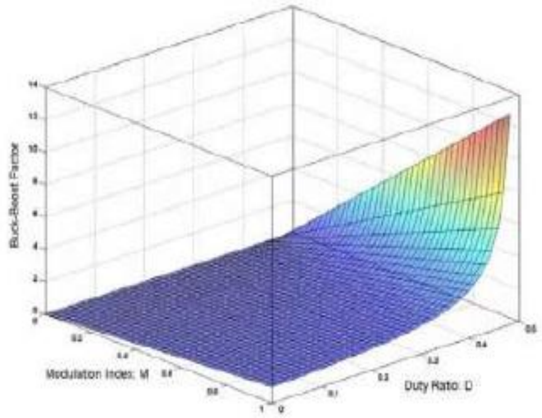


Fig. 3.1.6 Buck-boost factor of Z source inverter

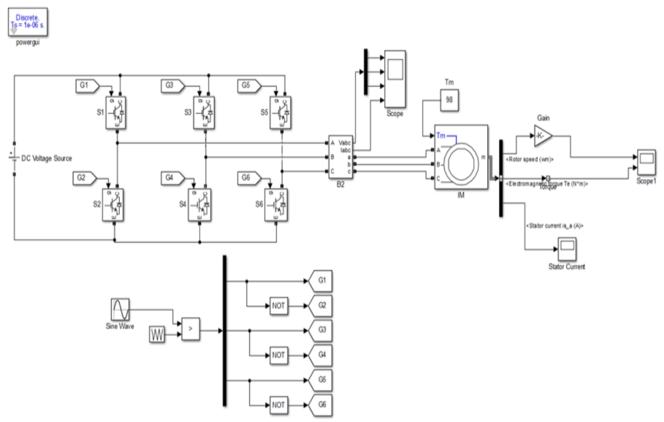
It is important to note that the process of energy transfer between DC and AC overlaps the process of energy transfer from DC source to the Z-network. The overlap process seems very demanding on Switch "S1". Therefore, for both motoring and generating operation, S is subject to substantial current stresses. In particular, for a high starting current application, the total current will impose a tremendous stress on S1 (the starting current plus the current needed to store energy in the Z- network). The ripple current through C is higher than that through the dc bus capacitor used in a conventional VSI. In terms of voltage, the boosted dc voltage is the voltage across the capacitor in ZSI. Additionally, for starting and generating operation, S1 need to handle bi-directional current and, thus, a diode with an anti- parallel transistor should be used. The selection of inductors and capacitors for Z-network is also of great importance. Firstly the reactive components selection should be guaranteed that no resonance would occur. In addition, the inductance and capacitance should be large enough to make the inductor current and capacitor voltage ripple as small as possible. With the shoot-through states evenly distributed among the pulse width modulation (PWM) cycles, the equivalent switching frequency seen by the Z-network will be several times of that used in VSI part, implying that minimization of reactive components is possible.

Current Source Inverter (CSI)	Voltage Source Inverter (VSI)	Impedance Source Inverter (ZSI)
As inductor is used in dc link , source impedance is high . It acts as constant current source	As capacitor is used in d.c link. It acts as a low impedance voltage source.	As capacitor and inductor issued in the d.c link, it acts as a constant high impedance Voltage source.
A CSI is capable of withstanding short circuit across any two of its output terminals. Hence momentary short circuit on load and misfiring of switches are acceptable.	A VSI is more dangerous situation as the parallel capacitor feeds more powering to the fault.	In ZSI mis-firing of the switches sometimes are also acceptable.
Used in only buck or boost operation of inverter.	Used in only a buck or boost operation of inverter.	Used in both buck & boost operation of inverter.
The main circuits can not Be interchangeable.	The main circuit cannot be interchangeable.	The main circuits are interchangeable
It is affected by the EMI noise.	It is affected by the EMI noise.	It is less affected by the EMI noise.
It has a considerable amount of harmonic distortion	It has a considerable amount of harmonic distortion	Harmonics Distortion in low
Power loss is high because of filter	Power loss is high	Power loss is low
Lower efficiency because of high power loss	Efficiency is low because of power loss high	High in efficiency because of less power loss

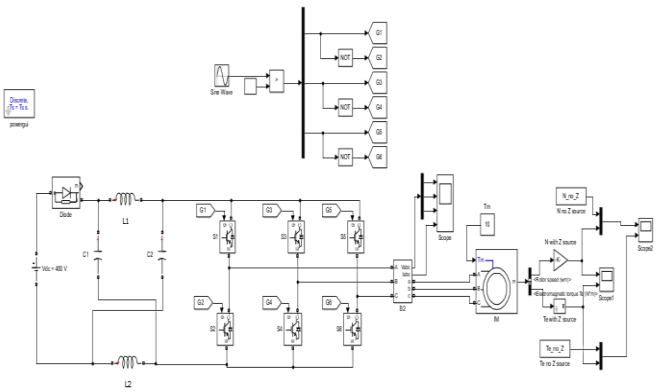
Table: 3.1.1 Comparision of CSI,VSI and ZSI

4. SIMULATION AND RESULTS

4.1 Simulation



4.1.1 Fig:Matlab Simulation Model Of Vsi Fed Im Drive



4.1.2 Fig:Matlab Simulation Model Of open loop Z source Fed Im Drive

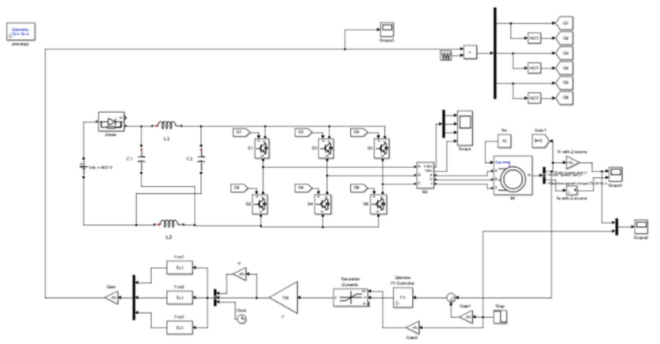


Fig: 4.1.3 Matlab Simulation Model Of closed loop Z source Fed Im Drive

4.2 Result

- Matlab Simulation Result Of Vsi Fed Im Drive

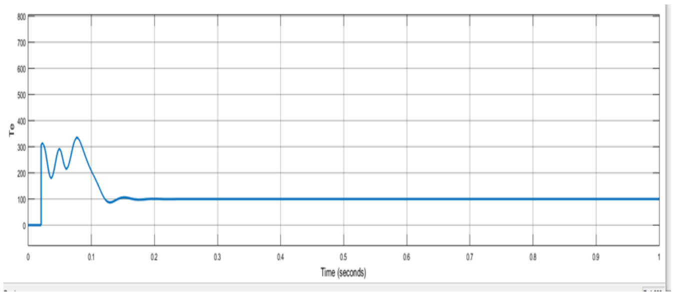


Fig 4.2.1Performance characteristics of Electromagnetic Torque

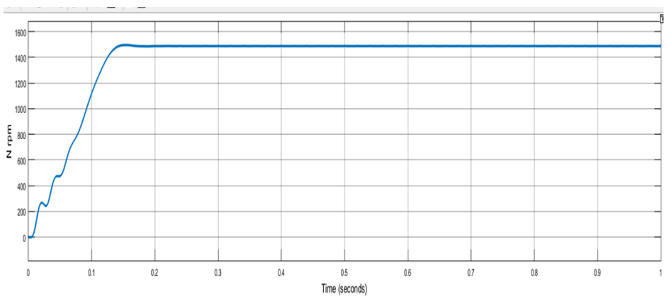


Fig 4.2.2. Performance characteristics of Rotor Speed

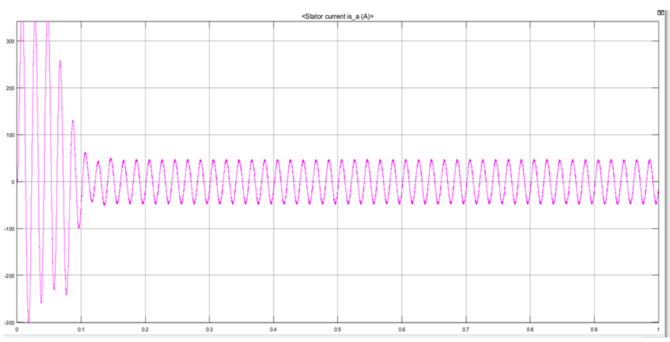


Fig 4.2.3. Performance characteristics of Stator Current

- Matlab Simulation Result of Open loopZ Source Fed Im Drive

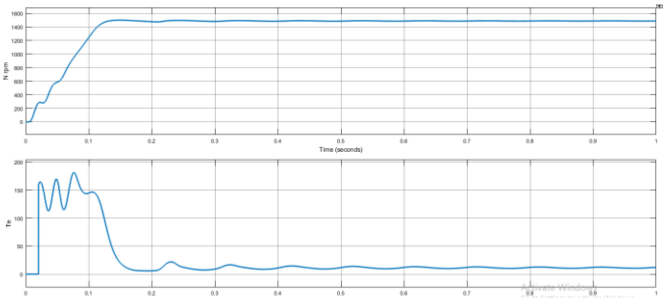


Fig 4.2.4. Performance characteristics of Rotor Speed and Torque using Open loop Z source

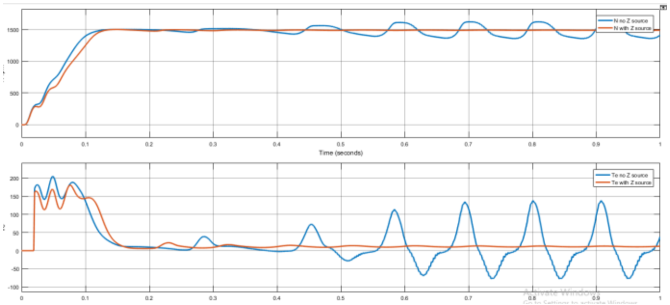


Fig 4.2.5. Performance characteristics of Rotor Speed and Torque with Z source and without Z source

- Matlab Simulation Result of Closed loop Z Source Fed Im Drive

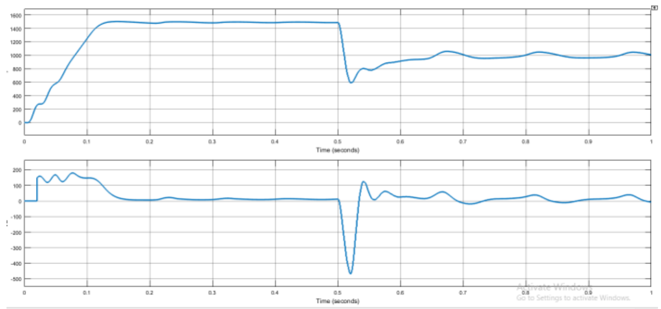


Fig 4.2.6. Closed loop Z Source Fed Im Drive

5. DISADVANTAGES

Adjustable speed or motor drives use Z-source inverter to overcome the restrictions of VSI. An inductor is normally used in voltage source inverter to enhance the power factor but still it has complications like voltage sag, line harmonics and limited obtainable output voltage. Z-source ASD system has small capacitors connected with diodes at rectifier-bridge contrary to conventional ASD scheme. In Z-source ASD systems Z-source impedance network connects rectifier with three phase inverter while an inductor is utilized as a part of traditional ASD framework for this reason. In Z-source ASD systems voltage may increase due to line inductance during shoot through state that's why capacitors are used with diodes. Only those phases that have maximum potential difference can conduct the current from AC line to DC side. Therefore, diodes of rectifier-bridge reverse biased and turned off. The remaining diodes direct and convey current in active stage, which usually discontinue conducting in traditional ASD system relying on voltage level of capacitor.

6. LIMITATION

The limitations of traditional converter are:

- The capability of traditional converter is only used as buck converter or boost converter.
- Efficiency lower down where over drive is required
- No two thyristors can be gated ON in the same leg
- Only 8 switching states are available in traditional converter.
- Either capacitor or inductor available for energy storage and suppress ripples.

7. APPLICATION

Conventional converter topologies such as voltage source inverter (VSI) and current source inverter (CSI) are commonly used as power electronics circuits for power conversion purposes. The VSI produces an ac output (after filtering it) which is limited below the dc input voltage, which means that VSI is buck type converter. The buck operation nature of the VSI limits its operation to power conversion applications and ac drive circuits. An additional dc-dc unit is connected to the dc input of the converter in order to further increase the dc input voltage, which leads to an increase in the ac output voltage. As a result, the additional dc-dc boost converter increases the system cost, control complexity and reduces the efficiency.

Further, animism-gating of the inverter bridge switches cause short circuit and destroys the power switching devices. For that, a dead-time is set between the upper and the lower switching devices of the same leg in order to avoid short circuit occurrences. The idea of impedance source converter (ZSI) was originally developed due to the limitation in VSIs and CSIs. The output voltage can ideally ranges from zero to infinity. Since the invention of the ZSI inverter, there are number of research works on this interesting topology, and this project presents its basic operation and control.

8. CONCLUSION

The Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage source converter and current-source converter and provides an advanced power conversion concept. The Z-source inverter system can produce an output voltage greater than the dc input voltage by controlling the shoot-through duty ratio, which is impossible for the traditional ASD systems. In this work, described the operating principle, analysed the circuit characteristics, and demonstrated its concept and superiority. Different PWM techniques and their comparison are presented. Maximum constant boost control method is more advantageous PWM control method among the other PWM control methods. Maximum constant boost with third harmonic injection PWM control method increases output voltage boost while minimizing voltage stresses across switching devices. It allows over-modulation where modulation index can be varied from 0.57 to 1.154. Z-Source inverter fed IM drive system is simulated using Simulink software using above described PWM method. Results of simulation are compared with traditional PWM inverter.

9. FUTURE SCOPE

For the future research, the following improvement can be implemented. With optimization the inductor and the capacitor value of the Z-source network, the sizing of these electrical components could be minimized to the proper value, which could reduce the total cost of the proposed experiment research. The modified PWM control strategies may improve the performance of the inverter up to certain extent. Also by using double switching frequency the component will result better performance.

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