

# Performance Analysis of Z-Source Inverter with Switched Reluctance Motor Drive

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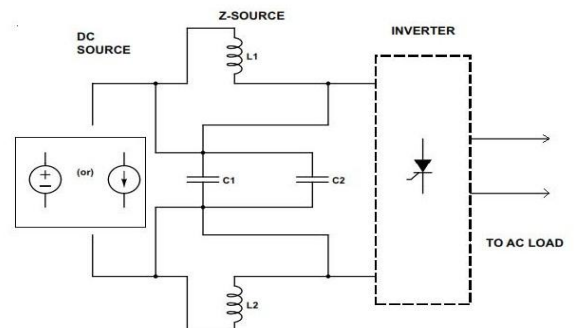
**ABSTRACT:** The performance analysis is made on switched reluctance motor with a Z-source inverter. The proposed systems provide uninterrupted operation of SRM by using the six leg inverter topology incorporated with a simple Embedded C program. Six leg inverter topology comprises of dual IGBT switch in each phase leg and IGBT switches are controlled in such a way that is when current exceed the prescribed limit the flow of current is shared between IGBT of the adjacent leg. The current pulses given to inverter leg which is provided by the PWM controller through the PI controller error signal and also from position sensor. By providing the Z-source inverter it improves the DC-link voltage to the inverter i.e. extends output voltage range and also improves the reliability due to special Z-source network structure. The operating principle and analysis has been carried out and proposed model is simulated. The simulation result verifies the validity of the performance analysis on SRM with Z-source inverter.

**KEYWORDS:** Z source network, Three phase inverter, Switched reluctance motor, PWM controller.

## I. INTRODUCTION

Switched reluctance motor is a single excited and double salient pole electric motor. This means that it has salient pole on both rotor and the stator, but only one member carries winding. The rotor has no windings, magnets or cage winding. It is electromagnetic and electro-dynamics equipment. SRM operating principle is similar to a single-stack variable-reluctance stepping motor. All these machines operate on the principle of faraday's law of electromagnetic induction and faraday's law of electromagnetic interaction

The optimum performance of SRM depends upon the appropriate positioning of the currents relative to rotor position. At controlling the motor; as the current passes through one phase, the torque is generated by the tendency of the rotor to align with the excited stator pole. The direction of the torque generated is a function of the rotor position with respect to the energized phase, and is independent of the direction of current flowing through the phase winding. Continuous torque can be produced by synchronizing each phase's excitation with the rotor position. The amount of current flowing through motor windings is controlled by switching on and off by the power electronic switches. The power converter is the heart of the motor drive. The performance, size, and the cost of the motor drive are mainly depends upon the selected converter type of the power converter circuit.



The major aspect related to the performance analysis of SRM in mostly depends upon the inverter. The main to design of the inverter topology is to provide an uninterrupted operation of the SRM drive. A newly designed six leg inverter topology with increased number of power electronic components along with an embedded program is proposed in this project. Thus the proposed converter is designed and performance analysis is made on different parameters of the SRM motor by using MATLAB Simulink.

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## II. PROPOSED SYSTEM

SRM are now finding increasing use in adjustable-speed drives because of the following features,

- A. This motor is simple in construction with no winding on rotor and simple concentrated coils on stator.
- B. It can run successful at high speeds (about  $2 \times 10^5$  rpm) because of no winding on rotor and rugged rotor construction.
- C. Stator windings can be cooled easily and efficiently.
- D. Because of effective stator cooling, the motor dimensions decrease for a given machine rating.

Fig. 1 Z-source network

However it has many advantages it has several drawback such as high torque ripple, acoustic noise and difficult to analysis the model due to its non-linear characteristics.

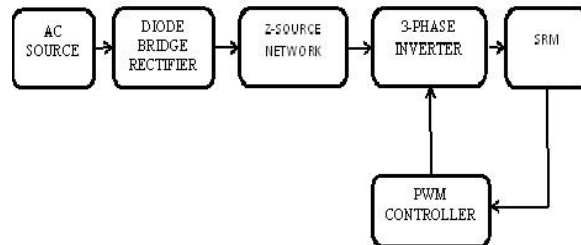


Fig. 1 Block diagram of the proposed system

Z-source network topology is provided which has a unique LC network. The Z-source inverter is shown in the figure 3, where the converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage-source converter (abbreviated as V-source converter) and current-source converter (abbreviated as I-source converter) and provides a novel power conversion concept. The Z-source concept can be applied to all dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. The Z-source inverter provides eight switching states with six active states and two zero states but these switching configuration does not match with SRM switching pattern, so here it is proposed for boost up of the DC-link voltage.

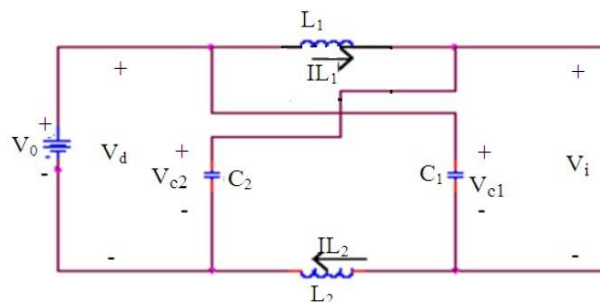


Fig. 3 Equivalent circuit for the z-source inverter

, SR machine utilize power converter switching circuits for the commutation of phase excitation. In general, a switching circuit for an SR machine is simple because of unipolar characteristics of flux-linkage and phase current. Since the direction of rotation does not depends on the signs of flux-linkage and a phase current, a switching circuit for an SR machine is designed so that the current in the excitation coil flow only in one direction. SR machines cannot operate directly from AC or DC mains voltage supplies because inputs to their phase winding must be current pulse. A power converter must supply unipolar current pulses from a DC voltage source, precisely at desired rotor positions. It must also regulate the magnitude and even waveform of the current in order to satisfy the requirements of the torque and speed control and ensure safe operation of the motor and power transistor. The proposed three phase inverter comprises of IGBT (insulated gate bi-polar transistor) switch in each leg which is provided with an appropriate input supply through the gate. Each phase leg are implemented with an average current estimator to detect the amount of

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current flow across the phase, if phase current exceed the desired limit of 150A then the current is shared between the adjacent IGBT switched provided with help of embedded C program. Thus the embedded program provides an uninterrupted operation of the SRM drive. When phase A, phase B and phase C current pulses are below the average current limit of 150A then there will no use of the adjacent phase leg in the inverter topology. If anyone of the phase current exceeds the limit of 150A then there will be the sharing current pulses. The excess current is provided by using a circuit breaker which operates at different switching times so that current is shared in each phase at particular time basis. Circuit breakers switching times are predefined for each phase leg in the inverter, so that is appropriate to provide gate signal to the corresponding phase leg. Thus the proposed system block diagram I shown in the figure 2.

### III. SRM SYSTEM DRIVE

The proposed control scheme has been applied on a three-phase 6/4 SRM. The closed loop operation of SRM gives ripple less torque waveforms. This review focus on the torque and speed controller of the SRM by using a PI controller. Generally torque ripple on high speed motor generally decreases with increase in the pole, that is stator/rotor pole of 6/4 combination have larger torque ripple comparing to 8/6 combination.

#### A. Z-source Network

Z-source network is shown in the figure 1, topology is provided which has an unique LC network. The Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage-source converter (abbreviated as V-source converter) and current-source converter (abbreviated as I-source converter) and provides a novel power conversion concept. The Z-source concept can be applied to all dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. The Z-source inverter provides eight switching states with six active states and two zero states but these switching configuration does not match with SRM switching pattern, so here it is proposed for boost up of the DC-link voltage.

#### B. Design Of PI Controller

Initially the proportional-Integral (PI) algorithm computes and transmits a controller output signal every sample time, T, to the final control element. The computed output from the PI algorithm is influenced by the controller tuning parameters and the controller error ( $\Delta$ ) and the error output prediction is given the following equation:

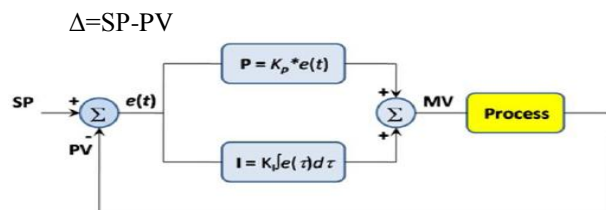


Fig. 4 Basic block of the PI controller

The basic block diagram of the PI controller is shown in the figure 4, SP refers to the set value and PV refers to the preserved value whereas the set the value is 1500rpm and the preserved value changes with respect to change in rotational speed of the SRM. Integral action enables PI controllers to eliminate offset, a major weakness of a P-only controller. Its function is to integrate or continually sum the controller error. The proportional term of the PI controller adds or subtracts based on the size of controller error. Thus PI controller increases the speed of the response and also to eliminate the steady state error. And thus PI controller enable to provided fast response time by validating the proportional and integral values according and thus provide a fast response time to attain the prescribed value. And the various controller characteristics are shown in the figure table I.

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TABLE I  
VARIOUS CONTROLLER CHARACTERISTICS

controller	Respose time	overshoot	error
On-off	smallest	highest	large
Proportional	small	large	small
Integral	decreases	increases	zero
Derivative	increases	decreases	Small change

### C. PWM Converter

A PWM technique is used in Z-source inverter to control the current pulse provided to the SRM. All three legs of an inverter are supplied by a DC voltage source. A large capacitor is connected at the input terminals tends to make the input DC voltage constant and suppresses the harmonic fed back to source. A control signal is provided through the gate of each transistor. PWM controller collects the parameters, such as PI controller output and the output current of the SRM and comparing these two parameters the PWM controller generates a current pulse through the relay which is given as DC input to gate for the each power electronic switch.

TABLE II  
ANGLE VALUES FOR 6/4 POLE

Description	For 3 phase
Turn on angle	45 <sup>0</sup>
Turn off angle	75 <sup>0</sup>
Modulus input angle	90 <sup>0</sup>

The angle values of the SRM for 6/4 pole combination is shown in the table II. Thus the width of the current pulse and on-time and off-time of the pulses is depends upon the combination of PI controller output, position sensor output and the output current of the SRM. Finally, the relay offers pulse to inverter.

### D. Overall system

In the proposed system overall performance analysis is made each and individual parameter for the SRM such as voltage, current, speed and torque. In the overall performance of the proposed system enables the improvement in the reliability of the power electronic switches and reduction in the torque ripple for 6/4 poles combination of the SRM. The proportional and integral helps in reducing the steady state error and there by have the effect of reducing the rise time by proper setting the proportional and integral values Proportional gain( $K_p$ ) = 0.1 and Integral gain( $K_i$ ) = 0.1.

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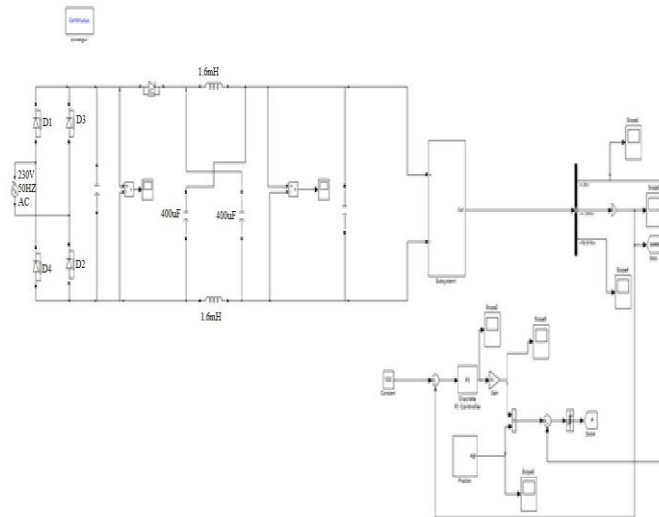


Fig. 5 Simulation diagram for the proposed system

The above figure shows that the performance analysis is made on certain circuit for the improvement of certain parameters comparing the existing system. The simulation diagram for the proposed system is shown in the figure 5. Thus proposed system comprises of the z-source inverter which is used to boost up the output voltage which is slightly greater than the input voltage whereas the z-source inverter switching pattern does not match with the SRM switching pattern. SR machine utilize power converter switching circuits for the commutation of phase excitation. In general, a switching circuit for an SR machine is simple because of unipolar characteristics of flux-linkage and phase current. Since the direction of rotation does not depends on the signs of flux-linkage and a phase current, a switching circuit for an SR machine is designed so that the current in the excitation coil flow only in one direction. SR machines cannot operate directly from AC or DC mains voltage supply because inputs to their phase winding must be current pulse. A power converter must supply unipolar current pulses from a DC voltage source, precisely at desired rotor position.

TABLE III  
SRM SPECIFICATION

Description	Specification
Number of rotor poles	4
Number of stator poles	6
Aligned Inductance	23.6e-3 H
Unaligned Inductance	0.67e-3 H
Saturated Inductance	0.15e-3 H
Stator resistance	0.05 Ohms
Inertia	0.05 Kg.mm
Friction	0.02 Nm /s
Maximum Current	450 A
Maximum Flux Linkage	0.486 V.s

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## IV. SIMULATION RESULTS AND DISCUSSION

The proposed system improves the performance on certain parameters of 6/4 pole combination of the SRM comparing with existing system which are follows. The torque of the SRM for the proposed system is shown in the figure 6, which has reduced torque ripple comparing to the existing system due to the change in the SRM ratings.

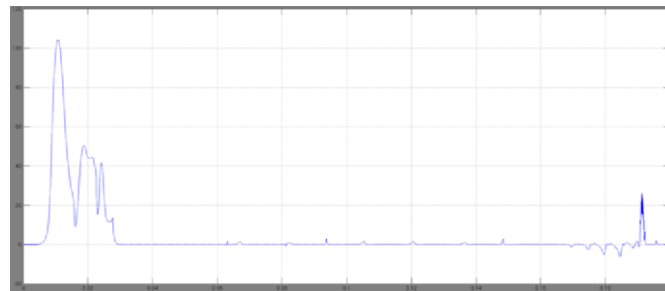


Fig. 6 Output torque

Torque ripple is high at the starting due to the more inrush current at the starting of the motor and linearly it reduced to a negligible value and later increase is due to the fault created by the circuit breaker at different switching times. The input current pulses at the output of the SRM is shown in the figure 7, which is obtained by the proper excitation of the switched aligned by the proper power electronic control. The output current pulses is obtained with large number of spikes which is because of the circuit breaker switching on the different switching times for the each phase A, phase B and phase C. The output speed of the proposed system is shown in the figure 10, for the 6/4 pole combination of the SRM. The output current for a proposed system for the 6/4 pole combination of the SRM.

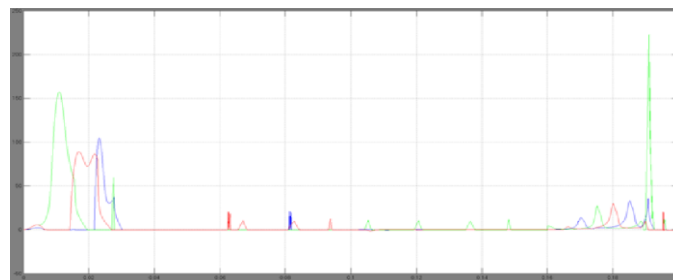


Fig. 7 Output current

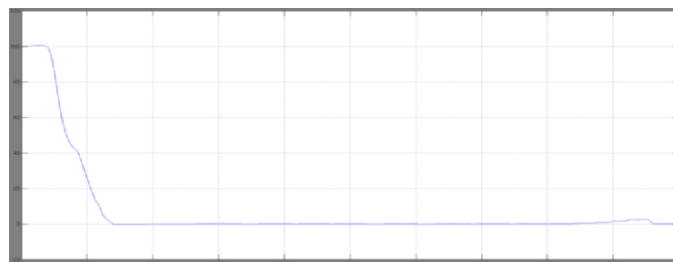


Fig. 8 PI controller output

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The set speed of 1000rpm is attained in short interval by proper set values of the proportional-integral controller. The PI controller output is shown in the figure 8, the set speed value is attained around 0.03seconds, which is obtained for the simulation period 2seconds. The PI controller output is shown in the figure 8.

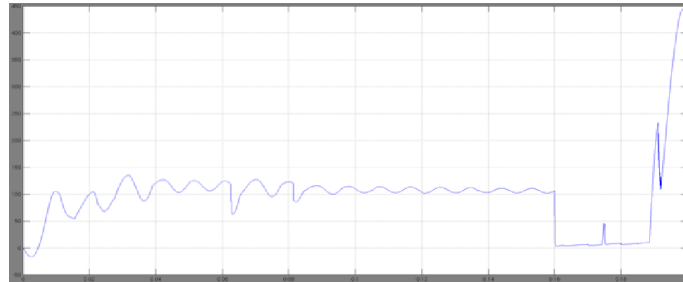


Fig. 9 Z-source output voltage

The PI controller output for the proposed system the PI controller integrates the error between the feedback current and reference current, which makes the PI controller to reach settling time in small duration of 0.03seconds by properly setting the values of the proportional and integral gain. The output voltage for the Z-source network is shown in the figure 9, which is that output of impedance network which boost up the output DC voltage greater value than the input applied voltage depends upon the ratings of the inductors and capacitors. The input source of the impedance network is a constant DC which is applied by diode bridge rectifier and impedance network is provided to the proposed inverter topology.

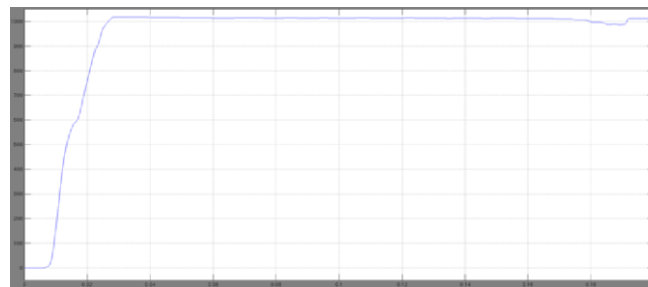


Fig. 20 Output speed

The output speed for the proposed system is shown in the figure 10, which is obtained speed of the SRM where obtained speed is the set speed of the system. The the set speed obtained as soon as which is the short duration and the duration of the time is determined by the proportional and integral values of the PI controller.

The current pulses provided by the PWM controller to phase A is shown in the fig.6.10, which is corresponds to fault created by the circuit breakers and thus them embedded C program helps in sharing the current pulse between the adjacent leg and there is sharing between the gate pulses provided to G1 and G4. The current pulses provided by the PWM controller to phase B is shown in the fig.6.11, which is corresponds to fault created by the circuit breakers and thus them embedded C program helps in sharing the current pulse between the adjacent leg and there is sharing between the gate pulses provided to G2 and G5. The current pulses provided by the PWM controller to phase A is shown in the fig.6.12, which is corresponds to fault created by the circuit breakers and thus them embedded C program helps in sharing the current pulse between the adjacent leg and there is sharing gate pulses provided to G3 and G6.

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