Modeling of Magnetically Coupled Embedded Z Source Inverter

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Abstract **This Project deals with an Embedded Z source inverter to control the three phase induction motor. The Z source inverters are recent topological options for buck boost energy conversion with a number of possible voltage and current type circuitries. Embedded Z Source inverter is a single stage converter which performs both buck boost energy conversions using the LC impedance network. The proposed inverters provide high boost voltage inversion ability, a lower voltage stress across the active switching devices, a continuous input current and a reduced voltage stress on the capacitors. In addition, they can suppress the startup inrush current, which otherwise might destroy the devices. The microcontroller is used to generate PWM pulses and to control operation of Z Source inverter. The complete hardware is designed to drive the three phase induction motor. This paper presents the operating principles, analysis, and simulation results, and compares them to the conventional switched inductor Z source inverter. The desired three phase PWM signals are generated by using control circuit and detailed hardware results are presented.**

KEYWORD *Embedded Z source, PWM, voltage boost, Z Source Inverter, Boost inversion ability, motor drives, buck boost.*

1. INTRODUCTION

Now-a-days, PV energy has attracted interest as a next generation energy source capable of solving the problems of global warming and energy exhaustion caused by increasing energy consumption. So, solar energy is considered as input source and this energy is given to the Z-Source. As we know solar module can give constant energy so to satisfy load conditions i.e. buck boost operations can be achieved by using Z Source inverter. As we know, we have voltage source inverter where voltage buck operation is achieved and in current source inverter, boost operation is achieved. So, to overcome these effects and to achieve buck boost operation in a single stage converter, a new technique is implemented i.e. z

source inverter, by using Z source voltage buck boost operation is achieved in single stage conversion. In recent years, a lot of work has been done in power quality improvement using variable generators and power electronic devices. Small-scale stand-alone wind energy systems are an important alternative source of electrical energy, finding applications in locations where conventional generation is not practical. Unfortunately, most of these systems do not capture power at every wind speed especially low wind speeds which are low in power but can be very common, but modern permanent magnet synchronous generator technology offers high efficiency power conversion from mechanical into electrical power. Moreover, it allows for special machine design with very low speed e.g. in gearless wind and hydro application and at very high speed for micro-gas turbines, which is of interest for several regenerative or co-generative power conversion technologies. A survey of already realized prototypes or in use PM generator systems is presented for that purpose. Impedance source inverter also referred as Z-Source Inverter is an advanced PWM inverter topology. Z Source Inverter is more advantageous over traditional inverters with high efficiency, improved power factor and THD, EMI immunity and so on. Nowadays PWM control method is mostly used in power converter applications.

These PWM signals can be generated using analog circuit as well as digital circuit. PWM generation using analog circuit requires large number of discrete circuits such as triangular carrier wave generator circuit, sine wave generator circuit; comparator, adder circuits and phase shifters etc. Each of these circuits is formed by connecting many discrete components together such as transistors, resistors, capacitors, inductors, op-amps and so on. In addition analog method of three phase PWM generation requires accurately designed phase shifter circuits and other circuit. Also the response of analog circuit may get affected by environmental conditions, noise, changes in the voltages and currents in the circuit and so on. Thus analog method is critical and increases complexity and cost of the circuit. Digital method of PWM generation requires only microcontroller and its minimum configuration. With the advent in the technology now many microcontrollers has in built feature of PWM generation. While some special controller ICs are also available that are designed and fabricated for three phase PWM generation and control purpose. PWM generation digitally require only knowledge of internal architecture of controller and good programming skill.

II .RELATED RESEARCH

Some of the recent researches related to power quality improvement for wind energy conversion systems and solar PV using z source inverter are discussed Fang Zheng Peng et al. [1] have proposed control methods for the Z-source inverter and their relationships of voltage boost versus modulation index. A maximum boost control is presented to produce the maximum voltage boost (or voltage gain) under a given modulation index. The control method, relationships of voltage gain versus modulation index and voltage stress versus voltage gain are analyzed in detail and verified by simulation. Shahrokh FARHANGI [2] have presented the design procedure of the Z-source converter as a single phase PV grid connected transformer-less inverter has been presented in this paper. An optimal switching pattern for the modulation of the converter has been proposed, which reduces the switching loss and common mode EMI. In single phase application, the output power is not constant and leads to a low frequency ripple in the converter elements. An approximate analysis has been proposed, which considers this effect. The validity of the design method has been verified by simulation.

III SYSTEM CONFIGURATION

An impedance network abbreviated as Z-Source is couples the inverter main circuit and input power source. Z-Source circuit consists of two capacitors and two inductors connected in such a way as to form second order filter, smoothens dc link voltage and current. Z-source inverter circuit provides both voltage buck and boost properties, which cannot be achieved with conventional voltage source and current source inverters. Three phase inverter circuit consists of six switches connected in three legs, converts input dc link voltage in to corresponding three phase ac voltage. Microcontroller and driver circuit is used to control on/off time of switching devices in a proper sequence in a particular time used in the main inverter circuit. Microcontroller PIC used to generate modified maximum constant boost PWM signal. These PWM signal is applied to the gate terminals of MOSFETs through gate. Z-Source is the X –Shaped structure consists of L1, L2, C1, and C2 in which we can obtain both buck-boost operations in single stage conversion. In this DC Source is placed at far-left in series with diode. So, by this, chopping is occurred in the source current which is caused by the commutation of diode D. So, in this condition to smoothen the source current an additional LC filter is required which would rise over all cost of the system and construction of the system by this additional LC filter is complex. So, to overcome the above drawbacks, a new technique is proposed i.e. embedded source inverter. In this EZ-Source inverter, source is placed in series with the inductor L1 andL2 and chopping current i.e. Obtained in the previous section is filtered. EZ-Source inverter, smoothens the source current without any additional LC filter but the gain of the Z-Source and Ez Source is same but only source filtering is achieved without any additional LC filter. The voltage stress experienced by C1 and C2 is lower than the original network but in this EZ-Source inverter requires two PV panels which are cost effective. So to reduce stress across the capacitor and its rating, to achieve lower harmonics, to obtain low switching losses and to make system compact in size, a new technique is implemented i.e. partially parallel EZ-Source inverter with reduced switches.

The Z-source network makes the shoot-through zero state possible. This shoot-through zero state provides the unique buck-boost feature to the inverter. The Z-source inverter can be operated in three modes.

Mode 1

In this mode, the inverter bridge is operating in one of the six traditional active vectors; the equivalent circuit. The inverter bridge acts as a current source viewed from the DC link. Both the inductors have an identical current value because of the circuit symmetry. This unique feature widens the line current conducting intervals, thus reducing harmonic current.

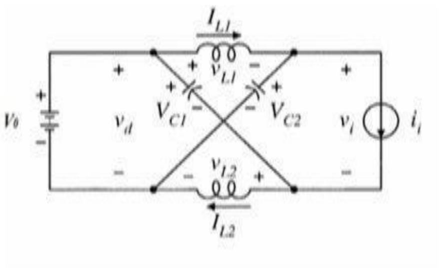


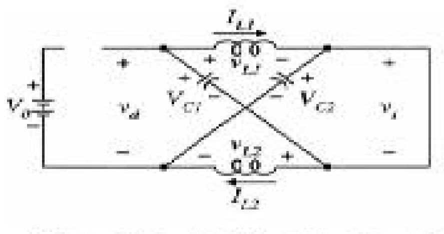
Fig.4: Equivalent Circuit of the ZSI in one of the Six Active States

Non-shoot-Through (Sx≠Sx_, x = A, B, or C; D = ON) VL=Vdc /2− VCVi= 2VC

Vd=VD= 0

Idc=IL+IC Ii= IL− IC

Idc≠0 Mode III:



Equivalent Circuit of the ZSI in the Shoot-Through State.

Shoot-Through(Sx= Sx_ON, x = A, B, or C; D = OFF)
VL=VC +V dc /2 Vi= 0
Vd= VD= The−2VCinverter bridge is operating in one of the seven shoot-through states. The equivalent circuit of the inverter bridge in this mode is as shown. This mode separates the dc link from the ac line. This shoot-through mode is to be used in every switching cycle during the traditional zero vector period generated by the PWM control. Depending on how much a voltage boost is needed, the shoot-through interval (T0) or its duty cycle (T0/T) is determined. It can be seen that the shoot-through interval is only a fraction of the switching cycle.

IV TYPES OF EZ-SOURCE

In this embedded Z-Source inverter, we have

A) Shunt embedded Z-Source inverter

B) Parallel embedded Z-Source inverter

A) Shunt embedded z-source inverter:

In general we have jumping currents which flow

in the input DC source which will induce the power Interruption in the input. By this jumping currents, the complexity to control maximum power and designing of system increases. To overcome the traditional network, Shunt EZ-Source is proposed,

Shunt EZ-Source consist two types

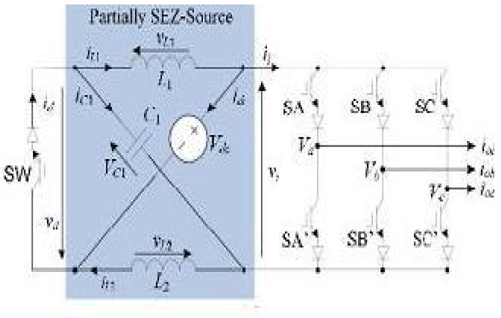
1. Partially shunt EZ-Source

2. Fully shunt EZ-source

Partially shunt embedded Z (PSEZ)-Source inverter:

In this PSEZ-Source inverter, VSI operates as current source inverter during shoot-through conditions. A switch

SW is used for removing the unwanted conditions of the diode during voltage boost operations and it should be turned off during traditional CSI

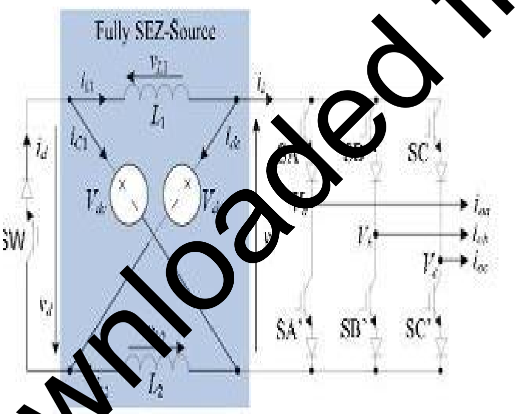


partially shunt embedded Z-Source inverter

In this, Vdc and inductor L are used for inverter boost operation and this voltage boost is equal to traditional CSI. Alternatively for buck operation open circuit tate should be connected in the switching sequence referring to SX and SX' (X=A, meanwhile SW turns ON toset the effective dc-link voltage. The voltage-buck (current-boost) ratio equals to the traditional current type Z-Source inverter.

<u>Fully shunt embedded Z</u>

<u>(FSEZ)- Source inverter:</u> In FSEZ-Source inverter,an equal voltage dc source is placed instead of a capacitor C 1 in the shunt leg. Voltage boost and buck capability are same in both FSEZ and PSEZ.The current ratio of L 1 and L 2 are reduced due toequal DC-link currents of L1 and L 2. But huge circulating currents between inductor and source are occurred and reduce output voltage amplitude due to unequal input of two dc voltage sources are considered. So to avoid this, small rated capacitor is placed in series with one dc source to share the voltage difference. This current type SEZSource inverter is not an ideal choice for substituting traditional Z-Source inverter but easily smoothen source current.



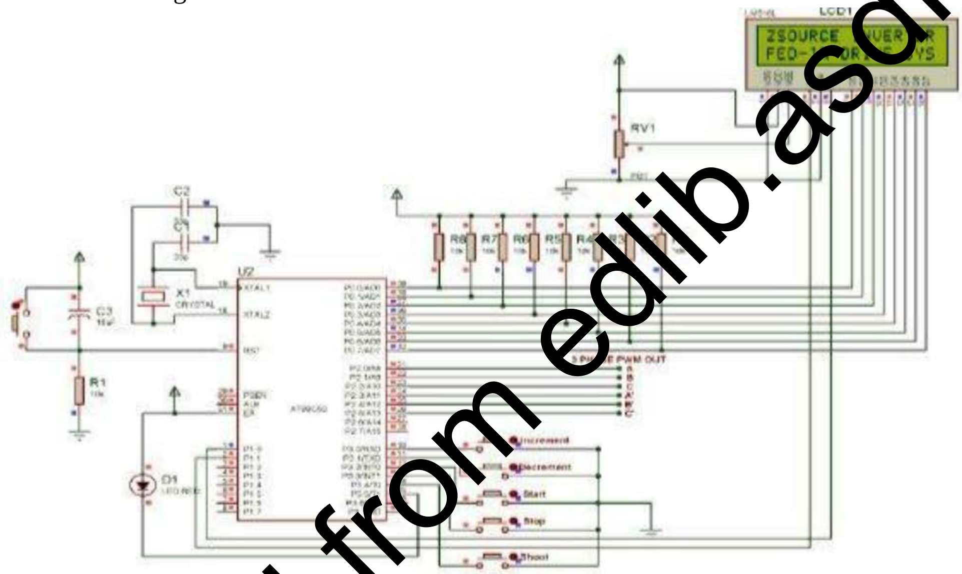
fully shunt embedded Z- Source inverter

V.SIMULATION RESULTS

For PWM generation microcontroller is used. The control circuit diagram is shown in the following in fig, drawn using Proteus software.

The six PWM signals are send at port P2 pins P2.0 through P2.5. The control circuit simulation is performed using Proteus software. Five switches are provided for special purposes, to interrupt microcontroller, increment, decrement shoot-through time and input voltage values and to change the mode of operation two types of edge aligned PWM waveforms are generated using microcontroller.

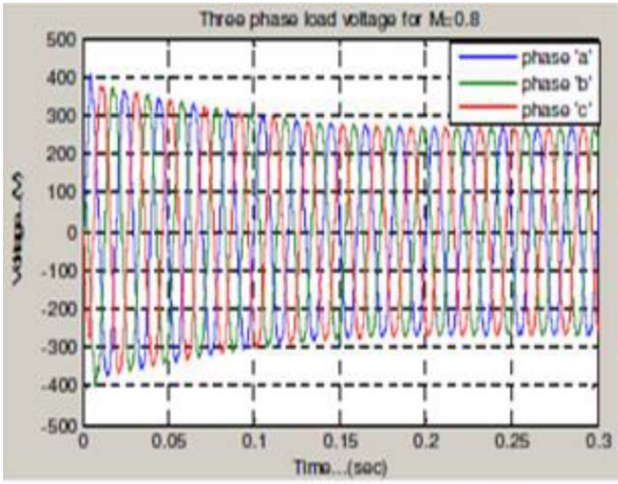
This circuit includes LCD interface at port0 of microcontroller, five push button switches and one led interfaced to port3 pins, gate driver circuit not shown interfaced to PWM output port2 pins and microcontroller minimum circuit. LCD display is used to display starting message regarding project title, welcome message and provides user interface. It also displays theoretical values of output voltage for given input voltage. For this two modes of operation are provided: one is traditional mode of operation and other is boost mode. In traditional mode of operation traditional PWM is generated, while in boost mode of operation some part of traditional zero state is converted into shoot-through state.



The E Z-source inverter can be operated in both boosts and buck operations depending on values of ‘M’. If M is greater than 0.5 it acts as boost inverter, if M is less than 0.5 then it acts as buck inverter. Here a 3-phase RLC parallel load is connected to ZSI.

Table 1 Load Voltage Profile for Different values of ‘M’

S.NO	Modulation Index (M)	Inverter Output Peak Voltage (volts)
1	0.8	1150
2	0.6	1050.3
3	0.4	142.6
4	0.2	30



Three Phase Load Voltage across Load for M=0.8.

The 3-phase output voltage across load is shown

CONCLUSION

The partially parallel embedded Z-Source inverter with reduced switches reduces number of PV panels and wind power; Capacitor rating smoothens source current and also reduces total harmonic distortion. PPEZ-Source inverter makes system compact which reduces cost and switching losses, lower voltage stresses and line harmonics. The two main objectives for WECSs are extracting maximum power from wind and feeding the grid with high-quality electricity. Compared to conventional WECS with simple boost converter based Z-Source inverter method, the voltage profile is improved 35% by using maximum constant boost with third harmonic injection based Z-source inverter method.

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