DESIGN AND IMPLEMENTATION OF RENEWABLE ENERGY FED L-Z-SOURCE INVERTER

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***ABSTRACT**: The objective of this thesis is to use double input L-Z-Source Inverter for boosting up the output voltage by taking input from combination of two different sources such as Wind Turbine and Photo Voltaic cell. L-Z-Source Inverter is used because it provides increased voltage gain by adjusting the shoot-through duty ratio and increasing the number of inductors. The proposed topology provides inrush current suppression, and no current flows to the main circuit at startup. So, there is no voltage overshoot phenomenon causing by capacitor, and this topology can improve the transition process. The L-Z-Source topology offers great advantage when compared to the conventional PVPC systems. Power loss can be reduced by reducing the number of switching devices. The inverter uses a unique inductor and diode network for boosting its output voltage, provides a common ground for the DC source and inverter, and avoids the disadvantage causing by capacitor in the classical ZSI and SL-ZSI, especially in prohibiting the inrush current at startup and the resonance of Z-source capacitors and inductors. MATLAB7.0 environment is used to analyze different states of inputsources and provide output voltage accordingly. A prototype of the proposed system has been designed, built and tested in order to validate the system.*

I. INTRODUCTION

The renewable energy such as Photo Voltaic (PV) and Wind has created various electric energy sources with different electrical characteristics for the modern power system. In order to combine more than one energy source, such as the solar array, wind turbine, Fuel Cell (FC) and commercial ac line to get the regulated output voltage, the different topologies of Multi Input Converters (MIC) have been proposed in recent years [1]-[4]. Traditionally, two dc voltage sources are connected to two independent dc-dc power converters to obtain two stable and equivalent output voltages, which are then connected to the dc bus, to provide the electric energy demanded by the load. Another approach for the double-input dc-dc converter is to put two dc sources in series to form a single voltage source where traditional dc-dc power converters can be used to transfer power to the load. In order to transfer power individually, each dc voltage source needs a controllable switch to provide a bypass short circuit for the input current of the other dc voltage source to deliver electric energy continuously [3], [4]. Another approach is to put PWM converters in parallel with or without electrical isolation using the coupled transformer [5]. Control schemes for these MICs with paralleled dc sources are based on time sharing concept because of the Clamped Voltage. Because of the voltage amplitude differences between two dc sources, only one of them can be connected to the input terminal of the dc-dc converter and transfer power to the load at a time [3]. The objective of this paper is to propose a dc motor fed with double input dc-dc converter which has the following advantages: The dc sources can deliver power to the dc motor individually or simultaneously; the multi winding transformer is not needed; the magnitude of the input dc Voltage can be higher or lower than the one with a regulated. Output; minimum switching devices are used in this circuit. The proposed double input dc-dc converter is proper for Renewable-energy applications and combination of two different sources (such as battery and photovoltaic or fuel cell)

II. CIRCUIT CONFIGURATION AND PRINCIPLE OF OPERATION

A) L-Z-Source inverters

In recent years, various Z-source inverter (ZSI) topologies have been presented in numerous diversified studies [6-14]. Some of the studies are focused on applications, modeling, controls and modulation strategies [7-14], whereas others arefocused on the development of new topologies [13-14].On the basis of the classical ZSI (Z-source inverter), this paper presents a novel ZSI which only contains inductors and diodes in Z- source network. The inverter uses a unique inductor and diode network for boosting its output voltage, provides a common ground for the DC source and inverter, and avoids the disadvantage causing by capacitor in the classical ZSI and SL-ZSI, especially in prohibiting the inrush current at startup and the resonance of Z-source capacitors and inductors. The inverter can increase the boost factor through adjusting shoot-through duty ratio and increasing the number of inductor.

B)Circuit Configuration of Proposed inverter

The schematic circuit diagram of the proposed double-input L-Z-Source Inverter with two different voltage sources is shown in Fig. 1. It consists of two different input sources, Vdc1 and Vdc2, and four diodes, D1-D4, applied to provide current path in different states. In this paper, permanent connection of input dc sources is considered, so D1 and D2 can be replaced with active switches if it's required to connect and disconnect each of sources to input side of converter frequently.

C)Principle of Operation of Double Input DC-DC Converter

There are four different operation states with respect to active or inactive states of dc sources. As previously mentioned, both of the input sources can deliver power to the load either individually or simultaneously through the MIC. When only one of the input sources feeds the MIC, it transfers power to the load individually and the MIC will operate as does a PWM converter. Table I summarizes the operation states of the proposed double input dc-dc converter.

D)Circuit diagram

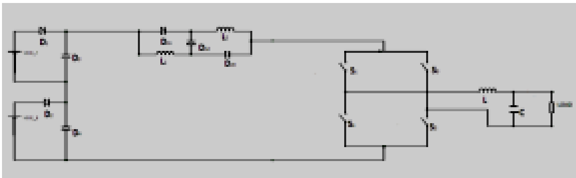

Fig.1 circuit diagram of the proposed system

State 1: Both Source 1 and Source 2 are active

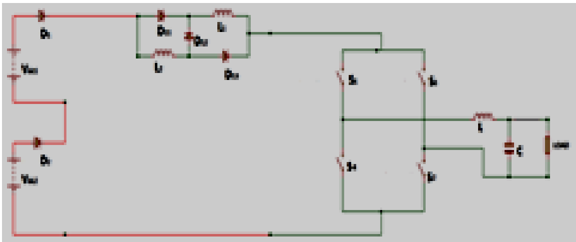

Fig.2 state 1 operating mode

When both source1 and source 2 are active, the converter input dc voltage is sum of voltage of two series dc sources, (1) illustrate.

$Vin=Vdc1+Vdc2$….(1)

In this state, because both two sources are active, D1 and D2 are forward biased and D3 and D4 are reverse biased. Thus, the sources current enters in Z-network through D1 and D2 and after passing load impedance, comes back into sources through negative polarity.

State 2: Source 1 is active and Source 2 is inactive

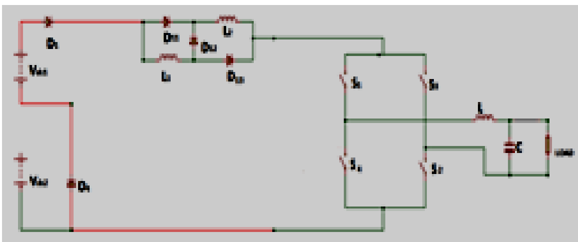

Fig.3 state 2 operating mode

The equivalent circuit of this state is source 1 is active, so only this source provides converter (consequently load) energy. Because of source 1 is active then D1 is forward biased and D3 is reverse biased, so current follows from D1 to Z-network to load. In reverse path from load to the source, current can't pass through source 2 and D2, so D4 is forcedly turned on and conduct current to source 1. In this state, converter input dc voltage is only provided by source 1, as (2) shows.

$Vin=Vdc1$ ….(2)

State 3: Source 1 is inactive and Source 2 is active

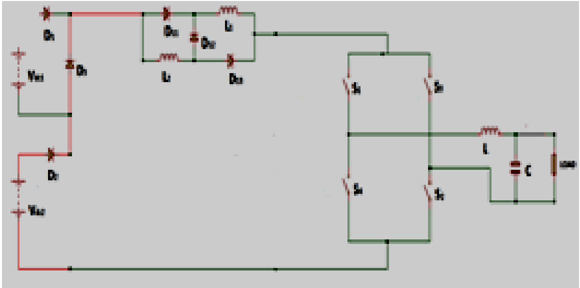

Fig.4 State 3 operating mode

If source 1 is eliminated for each reason and source 2 is active, the converter can operate normally without effect of source 1 elimination. In state 3, it's only source 2 that supplies converter and load. Source2 activation causes forward bias of D2 and reverse bias of D4. Because of source 1 disconnection, current passes through D3 and indeed, current turns it on forcedly to complete current path. In this state, converter input dc voltage is only provided by source 2, as (3) shows.

$Vin = Vdc2$….(3)

State 4: Both Source 1 and Source 2 are inactive

Basically, this state is only following of one of the previously mentioned three states. Because in this state both dc sources are inactive and disconnected from converter, D1 And D2 are forcedly turned off and consequently, the only existing path for remain current, from previous state, is provided by D3 and D4. Thereupon, in state4 D3 and D4 are turned on. Input voltage is zero in this state as shown in (4).

Vin=0 …..(4)

Obviously, because both dc sources disconnect from converter, duration of this state is very short and when current descends to zero, whole of converter will be inactive.

TABLE I. STATES OF DOUBLE INPUT SOURCES

State	**Source States**		**Switches States**				v_{in}
	V_{dc1}	V_{dc2}	D_1	D_2	D_3	D_4	
1	Active	Active	On	On	Off	Off	$V_{dc1}+V_{dc2}$
2	Active	Inactive	On	Off	Off	On	V_{dc1}
3	Inactive	Active	Off	On	On	Off	V_{dc2}
4	Inactive	Inactive	Off	Off	On	On	0

E) L- Z- SOURCE INVERTER

Different to the original ZSI, the proposed inverter has no capacitor, and is composed of two inductors (L1, L2, and L1=L2), and three diodes (D1, D2, and D3), as shown in figure 5. The combination of L2– L3– D1– D2– D3 acts as a switched inductor cell [12- 15]. The proposed topology provides inrush current suppression, unlike the traditional topologies, because no current flows to the main circuit at startup. The proposed topology also provides a common ground for the source and inverter.

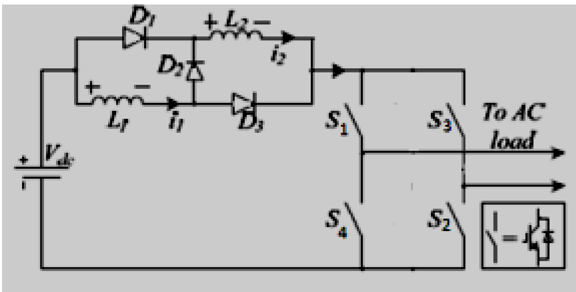

Fig.5 Circuit diagram of L-Z- Source inverter

F) OPERATING MODES OF L-Z SOURCE INVERTER

Unlike the traditional ZSIs, L- ZSI just has shoot- through zero states besides the traditional six active states. The operating principles of the proposed inverter are also similar to those of the classical ZSI. For the purpose of analysis, the operating states are simplified into shoot-through and nonshoot-through states.

NON SHOOT-THROUGH MODE:

In the nonshoot- through state, as shown in Fig 3, D2 is on, while D1 and D3 are off. *L1* and *L2* (*L1= L2= L*) are connected in series. *L1* and *L2* transfer energy from the dc voltage source to the main circuit, and the equivalent circuit is shown in Fig below. The corresponding voltages across *L1* and *L2* in this state are $V1\_non$ and $V2\_non$, respectively. Thereby, (5) and (6) can be contained.

$v1_{\_non} + v2\_non + vi = vdc$…(5)

$v1_{\_non} = v2\_non$…(6)

From (5) and (6), (7) and (8) can be concluded.

$v1_{\_non} = \frac{1}{2}vdc - \frac{1}{2}vi$….(7)

$v2_{\_non} = \frac{1}{2}vdc - \frac{1}{2}vi$…(8)

Where *Vdc*is the DC source; vi is the dc link voltage.

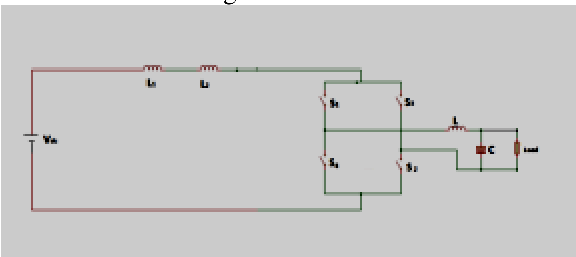

Fig.6Circuit of Non shoot-through mode of inverter

SHOOT THROUGH MODE:

In the shoot-through state, as shown in Fig, the inverter side is shorted by both the upper and lower switching devices of any phase leg. During the shoot-through state, *D2* is off, while *D1* and *D3* are on. *L1* and *L2* are connected in parallel, and inductors *L1* and *L2* store energy. The equivalent circuit is shown in Fig below. The corresponding voltages across *L1* and *L2* in this state are $V1$ and $V2$, respectively, and (9) is obtained.

$v1 = v2 = vdc$ …..(9)

Applying the volt-second balance principle to *L1* and *L2*, (10),(11), (12) and (13) can be obtained from (7), (8), and (9).

$vi = \frac{1+D}{1-D}vdc$…(10)

$B = \frac{1+D}{1-D}$….(11)

$I_L = I_1 = I_2 = (D(2L+L_l)+L(1-D))/(R_lL(1-D))v_{dc}$ ….(12)

$I_l = (1+D)V_{dc}/R_l$ ….(13)

where,

B is the boost factor; I_L is the inductor current; $I_l$is the load current; D is shoot-through duty cycle; I_1 and I_2 are current of *L1* and *L2*, respectively; R_l is load resistance;L_l is load inductance.

When L_l=0 or load is resistive, (14) is obtained.

$I_L = I_1 = I_2 = (1+D)/(R_l(1-D))$ …(14)

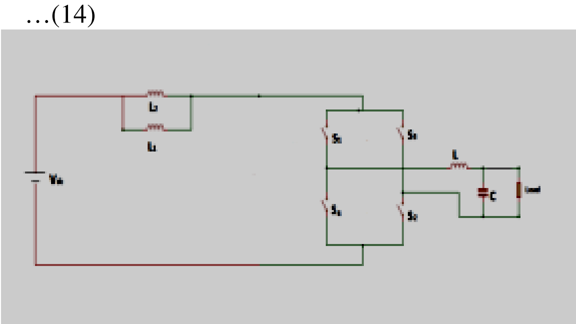

Fig.7Circuit of shoot-through mode of inverter

G) ADVANTAGES

- Voltage gain is increased with the increasing of shoot-through duty ratio and increasing the number of inductors
- The proposed topology provides inrush current suppression, and no current flows to the main circuit at startup. So, there is no voltage overshoot phenomenon causing by capacitor, and this topology can improve the transition process

III. OVERALL MODEL OF PROPOSED SYSTEM

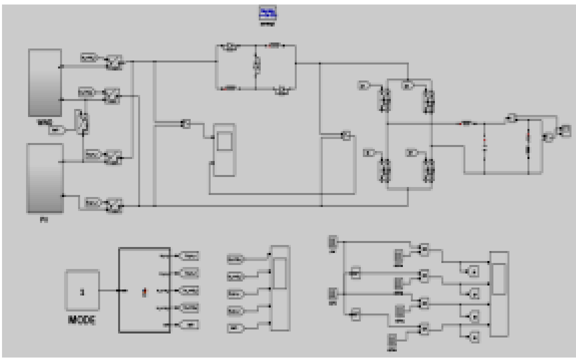

Fig.8Simulink model of overall system

State-1: Both source-1 and source-2 are Active

For state-1, both DC sources were Active. After simulation, inverter produced 190V in boosting mode.
Figure 10shows Inverter output voltage and output current. Input current passed through D1 and D2 because these switches were forward biased and turned on. D3 and D4 were reverse biased, thus their currents were zero.

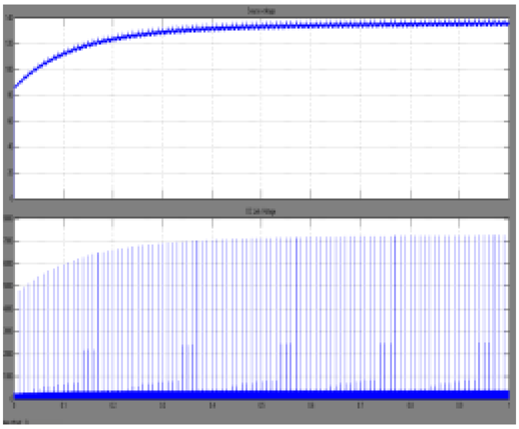

Fig.9State1 source voltage waveform

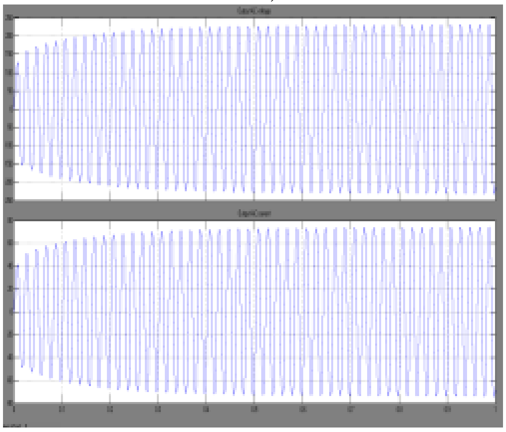

Fig.10Inverter output in state 1

When both source1(90V) and source 2(50V) are Active, the input DC voltage is sum of voltage of two series DC sources.

$Vin=Vdc1+Vdc2$

After the boosting operation of L-Z-Source network and inverter operation,it gives an output voltage of 210V.

State-2: Source-1 is active

In state 2,only source 1 supplies the inverter independent of source 2. After Simulation, inverter produced 140V in boosting mode. Figure 12shows inverter output voltage and output current. Input current passed through D1 and D4 because these switches were forward biased and turned on. D2 and D3 were reverse biased, thus their currents were zero.

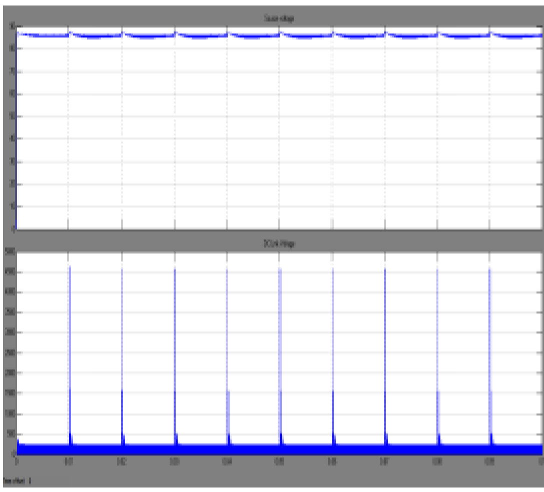

Fig.11State2 source voltage waveform

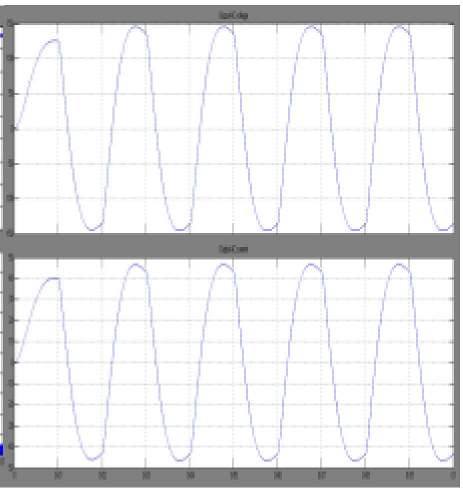

Fig.12Inverter output in state 2

When source1 active and source 2is inactive, the converter input DC voltage is equal to source1 voltage.

$V_{in}=V_{dc1}$

After the boosting operation of L-Z source network and inverter operation, it gives an output voltage of 140V.

State-3: Source-2 is active

For state 3, that source1 became inactive and disconnected from converter. Figure 14shows input voltage of the inverter for state 3. As this figure shows input voltage decreased to 50V.Which is only source 2 stepped up DC voltage. Thus only source 2 supplied to converter independent of source 1. Simulation time, converter produced 80V in boosting mode. Figure 11 shows Inverter output voltage and output current. Input current passed through D2 and D3 because these switches were forward biased and turned on. D1 and D4 were reverse biased, thus their currents were zero.

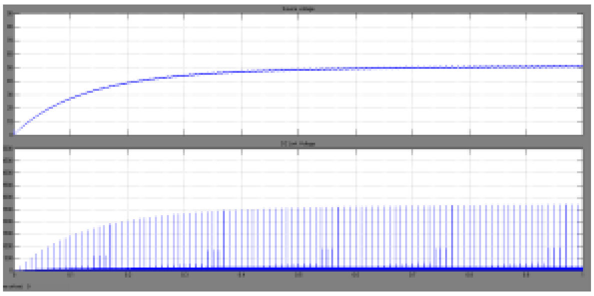

Fig.13State3 source voltage waveform.

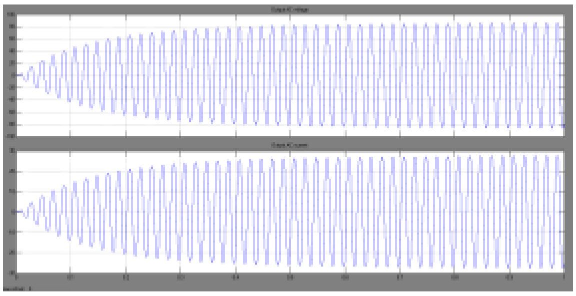

Fig.14Inverter output voltage in state 3

When source1 inactive and source 2 is active, the inverter input DC voltage is equal to source2 voltage.

$Vin=Vdc2$

After the boosting operation of L-z source network and inverter operation, it gives an output voltage of 80V

State-4: Both source-1 and source-2 are inactive

This state is not considered as an active operation state, because both DC sources become inactive and indeed, there is not any source to supply inverter and load. Figure 15 shows the input voltage. In this state D1 and D2 were turned off, thereupon inverter input current path switched to D3 and D4.Figure 16shows the output voltage and output current.

$Vin=0$

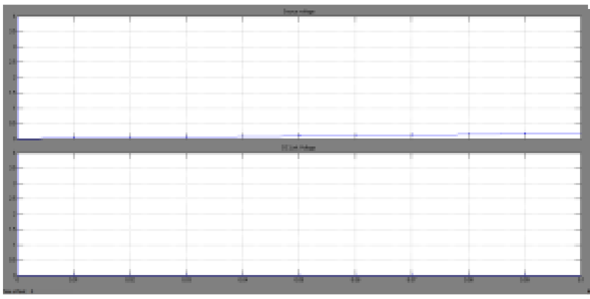

Fig.15State4 source voltage waveform

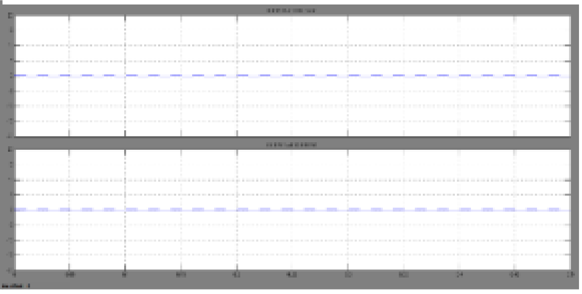

Fig.16Inverter output voltage in state 4

SIMULATIONRESULTS

STATES	CONDITION	INPUT VOLTAGE	OUTPUT VOLTAGE
1	Vdc_1 on & Vdc_2 on	140 V	200 V
2	Vdc_1 on	85 V	140 V
3	Vdc_2 on	50 V	80 V
4	Vdc_1 off & Vdc_2 off	0 V	0 V

IV.HARDWARE SETUP

In previous chapter the simulation of the proposed system was implemented in the MATLAB software .The renewable energy was fed into the L- Z-Source inverter and the desired results were obtained. In this chapter the hardware implementation of the project is explained. The simulated outputs have been produced and implemented into the hardware kit and then the desired outputs and the results are noted down.

The main components used in this system are switching state diodes, L-Z-Source Network, Inverter, Gating circuit, Microcontroller.

The Power MOSFETs (IRF840) that perform the same function as Bi-polar transistors are voltage controlled in contrast to the current controlled Bi-polar devices.MOSFETs owe their ever-increasing popularity to their high input impedance and to the fact that being a majority carrier device, they do not suffer from minority carrier storage time effects, thermal runaway, or second breakdown. The hardware setup of the overall system is given in Annexure I.

The type of circuit depends upon the application. The current sinking and sourcing capabilities of the drive circuit will determine the switching time and switching losses of the power device. As a rule, the higher the gate current at turn-on and turn-off, the lower the switching losses will be. However, fast drive circuits may produce ringing in the gate circuit and drain circuits. At turn-on, ringing in the gate circuit may produce a voltage transient in excess of the maximum VGS rating, which will puncture the gate oxide and destroy it. To prevent this occurrence, a Zenor diode of appropriate value may be added to the circuit.
The microcontroller is driven via the driver circuit so as to boost the voltage triggering signal to 9V.To avoid any damage to micro controller due to direct passing of 230V supply to it, we provide an isolator in the form of opto-coupler in the same driver circuit.A microprocessor, which is operates in 5V DC but being used to control a TRIAC that is switching 240V AC. In such situations the link between the two must be an isolated one, to protect the microprocessor from over voltage damage.
In L filter,the ripple factor isdirectly proportional to the load resistance.On the other hand,in the C filter it is inversally varying with the load resistance.Hence if we combine L filter with capacitor,the ripple factor will become almost independent of the load filter.It is also known as inductor input filter,choke input filter,L input or LC section.

HARDWARE SPECIFICATIONS
TABLE 3.SPECIFICATIONS

COMPONENT	SPECIFICATION
Diode	IN4007
Inductor(L-Z Network)	45µH
Inductor(Filter)	1Mh
Capacitor	22µf
Micro controller	PIC16F877A
MOSFET	IRF 840
MOSFET Driver IC	IR 2100
Opto-Coupler	4D817

State-1: Both Source-1 and Source-2 are Active

At state 1, both DC sources were Active and 24Vis given as input voltage. AnInverter produces an output voltage of 58V in boosting mode as shown in figure 15.

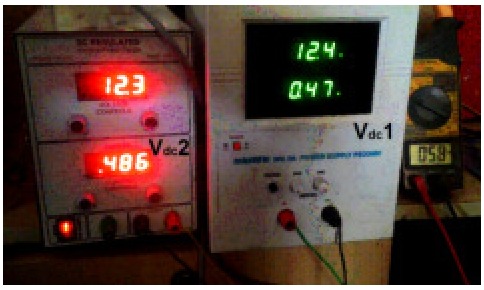

Fig.18 state 1 input and output voltage

State 2: Source-1 is active and Source-2 is inactive

In state 2 Source 2 becomes inactive and gets disconnected from the inverter. Thus only source 1 supplied inverter independent of source 2. At the time, inverter produces an output voltage of 22V in boosting mode. Figure 16 shows inverter output voltage.

Fig.19 state 2 input and output voltage

State 3: Source-1 is inactive and Source-2 is active

At state 3, source1 is inactive and is disconnected from inverter. Only source 2 supplies the inverter independent of source 1. Inverter produced 16V in boosting mode. Figure 17 shows inverter output voltage.

Fig.20 State 3 input and output voltage

State-4: Both Source-1 and Source-2 are inactive

This state is not considered as an active operation state, because both DC sources become inactive and indeed, there is no source to supply inverter and load.

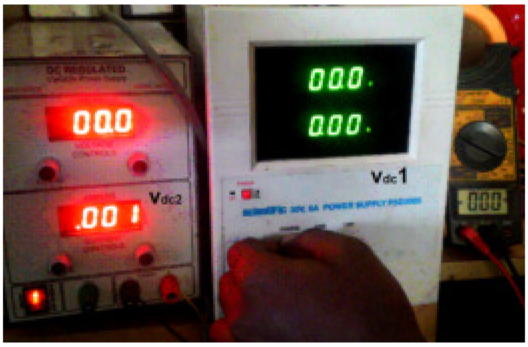

Fig.21 State 4 input and output voltage

HARDWARE RESULTS

STATES	CONDITION	INPUT VOLTAGE	OUTPUT VOLTAGE
1	Vdc_1 on & Vdc_2 on	24 V	56 V
2	Vdc_1 on	15 V	29 V
3	Vdc_2 on	11 V	17 V
4	Vdc_1 off & Vdc_2 off	0 V	0 V

V.CONCLUSION AND FUTURE SCOPE

CONCLUSION

This paper has presented a novel L-ZSI by improving the existing classical Z-source impedance network. The proposed inverter employs a unique inductor and diode network to couple the low dc voltage energy source to the main circuit of the inverter, and avoids the disadvantage causing by capacitor in the classical ZSI and SL-ZSI, especially in prohibiting the inrush current at startup and the resonance of Z-source capacitors and inductors. The inverter can increase the voltage gain through adjusting shoot-through duty ratio and increasing the number of inductor. Both the simulation and experimental results demonstrate its advantages.

FUTURE SCOPE

- This proposed system is carried out in open loop and in future it can be extended to closed loop operation.
- This can also be extended for use in multilevel inverters
- Here, single phase is used and it can be extended for three phase operation

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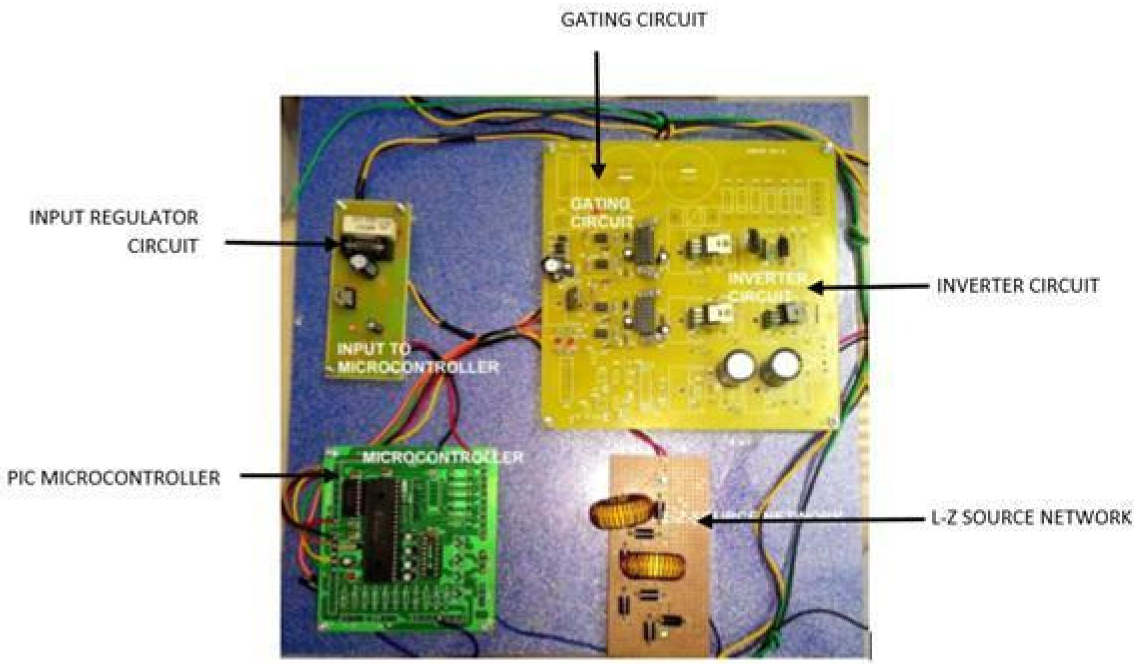
ANNEXURE I



Hardware Setup of the overall system