Academic Science

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 7
July 2017

Design and Simulation of Single Phase Z-Source Inverter Using Variable Resistive Load

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Abstract- *This paper discusses the latest development in the field of Z-source inverters. Z-source inverters are a new breed of inverters specially designed to be used in domestic and household applications. It is basically designed to overcome the limitations of traditional voltage source inverter (VSI) and Current source inverter (CSI). Various topologies designed so far are discussed on the basis of size, cost, no. of passive elements, THD of output voltage etc. This Impedance-source inverter can provide a single stage power conversion concept where as the traditional inverter requires two stage power conversion for renewable energy applications. A new low cost Z-source inverter system is simulated and the results are compared with the hardware results of Z-source inverter system. Performance analysis, simulation and comparison have been confirmed that the Z-source inverter system is more appropriate for. Hardware implementation is done to validate the proposed system. The proposed drive system is simulated using Matlab/Simulink. The simulation results were compared with the experimental results.*

Keywords- Microcontroller, Single Phase Z-Source Inverter, Variable Load, Matlab/Simulink Simulation, modulation index

1. INTRODUCTION

Z-SOURCE inverters have been proposed as an alternative power conversion concept as they have both voltage buck and boost capabilities unlike the traditional voltage source inverter. Modified topologies of ZSI include quasi ZSI and improved trans ZSI. In order to overcome the inconvenience of inrush current suppression at start up, quasi ZSI has been proposed which provides continuous input current, reduced voltage stress on capacitors and lower current stress on inductors and diodes[2]. This paper presents a novel high step up inverter based on the transformer to improve the input current profile and the boost inversion ability of the traditional inverter. Like the traditional ZSI, it also allows two switches of the same leg to be gated in the circuit, thus eliminating the shoot through fault. The buck and boost capabilities of inverters are operated in the shoot through state. In this paper, design of ZSI and improved VSI is proposed. Simulation is carried out to compare the buck and boost operation of both inverters to determine it's quality.

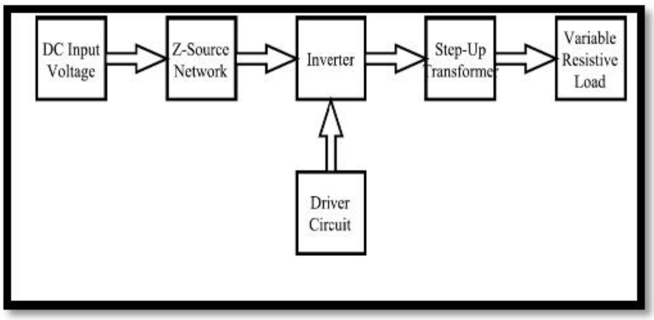

Fig 1. Block Diagram of Single Phase Z Source Inverter

Fig.1 represents the block diagram of the z source network. Here the dc voltage source As per the discussion we give input to the implemented system by using SMPS which is 24 volt, 10 A DC given to the Z network. The Z network is made of the combination of the capacitor and inductor which are connected in X- shape. Then the impedance network is connected to the inverter. Inverter converts the DC input into AC output. Then the converted AC input fed to the step up transformer. The step up transformer transforms the low voltage into high i.e. it will increase the voltage level of primary side and given to the secondary which is a 230 volt AC. The secondary of transformer connected to the load. The load is a resistive type of load and we increase the load as 15 watt, 60watt, 100watt, 200watt respectively.. The transformer is connected to the load. The rectifier circuit is used for the +5 volt DC which is fed to the microcontroller. By using microcontroller we implement the PWM technique for that we use the MOSFETS which are connected in H bridge form. DC-AC converters are known as inverter. The function of an inverter is to change a dc input voltage to a symmetrical ac output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output voltage can be obtained by giving the input dc voltage and maintaining the gain of the inverter constant, on the other hand if the dc input voltage is fixed and it is not controllable a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse width modulation (PWM) control within the inverter. The inverter gain may be defined as the ratio of the ac output voltage to dc input voltage.

2. SYSTEM DESCRIPTION

ZSI is a buck boost inverter that has a wide range of voltage. The shoot through period is the time period when two switches of the same leg are gated; this allows the voltage to be boosted to the required level when the input DC voltage is not up to the required level. The diode D is used to prevent the reverse flow of current in the circuit. The pulse width modulation of the Z-source inverters produces the AC voltage boost by controlling the duty cycle of the switches used on the circuit.

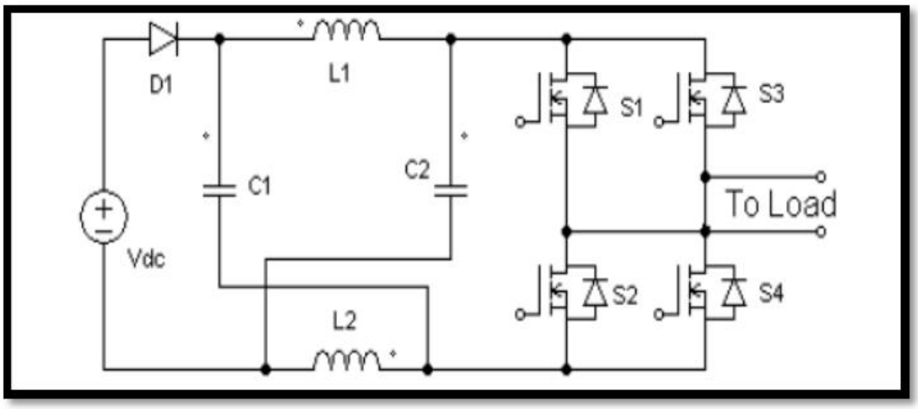

Fig 2. Generalized structure of the Z-source Inverter.

The pulse width modulation of the Z-source inverters produces the AC voltage boost by controlling the duty cycle of the switches used on the circuit Sinusoidal PWM is employed to turn on the switches. The extent to which the dc voltage is boosted is decided by the modulation index of the PWM used. The switches 1, 4 are simultaneously gated to provide the shoot through condition for the inverter. This enables the voltage to be increased to the required value without the additional need of switches. The shoot through condition is also used to buck the voltage given to the load side through proper gating signals thus providing a dual buck/ boost function using the same ZSI.

3. HARDWARE ANALYSIS

According to the project and the arrangement we connect the all three stages which are first is SMPS then second is inverter and third is the load which is nothing but our output. As per the circuit diagram and our connection we switch ON the mains 230 Volts, 50H_Z which are connected to the SMPS. The dc energy comes

International Journal of Electronics, Electrical and Computational System
IJEECS
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From the SMPS source inverter is buck-boost type of inverter it converts the DC energy into AC and given to the load over there by varying the load we obtain the resultant output on CRO and by using digital multi meter (DMM) .

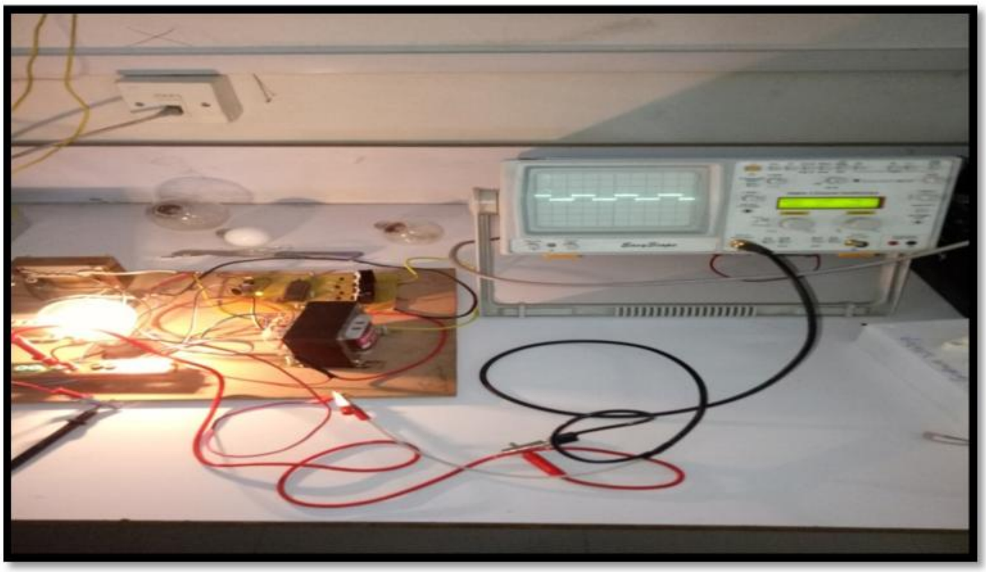

Fig 3. Live Set Up Of Single Phase Z Source Inverter

TABLE 1. Design Parameters used

SR.NO.	PARAMETER/ COMPONENTS	VALUES
1	L_1=L_2	160 µH
2	$C_1 = C_1$	1000 µF
3	Switching frequency	10 kHz
4	Input DC voltage	24V
5	Load	Up to 200watt
6	Modulation Index	0.642

TABLE 2. Hardware Results for Modulation Index (m) =0.6

Sr.no	Input voltage (V)	Input current (I)A	Input Power (P)w	Output voltage (V_U) V	Output current (I_U)A	Output Power (P)w	Efficiency (%η)	Load (W)	Inverter output voltage
1	24	97mA	2.32	191.11	∞	-	−	No load	20
2	24	0.52	12.48	181.39	82.69m	14.99	120.19	15	20
3	24	1.82	43.68	150.79	0.39	58.80	137.36	60	20
4	24	2.71	65.04	129.53	0.77	99.73	153.75	100	20
5	24	4.05	97.2	100.38	1.99	199.75	205.76	200	20

Academic Science

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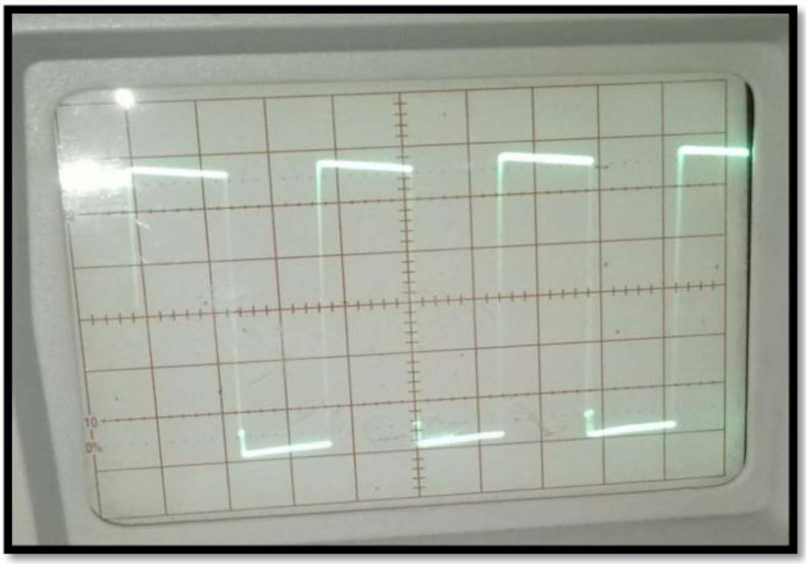
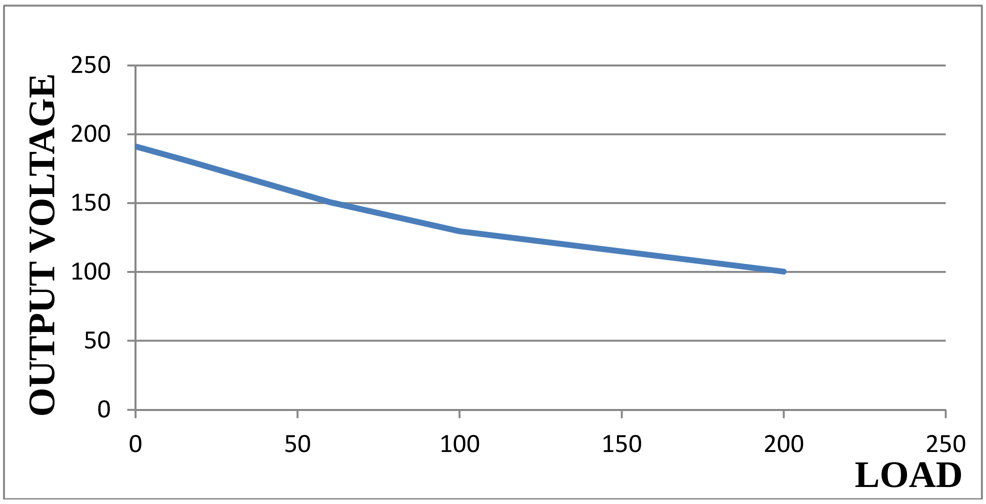
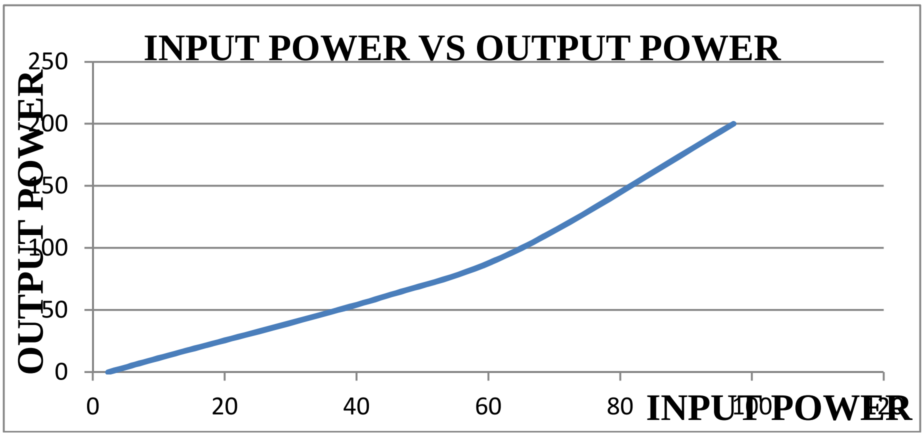


Fig 4. Output Voltage Waveform across the Secondary of Transformer



Graph 1: - Graph of Load Vs Output Voltage



Graph 2:- Input Power Vs Output Power

4. MODEL AND SIMULATION OF THE SYSTEM

In this paper, MATLAB/SIMULINK (version 15) software has been used to design and develop the Z-Source Inverter using resistive load and analyze simulation in MATLAB environment along with SIMULINK and power system block set (PSB) toolboxes and also the design of Z-source network for simple boost control technique is described. The circuit diagram of Z-Source inverter based test system feeding load is depicted in Figure 5. Here, Z-Source Inverter is triggered by techniques PWM control technique. The rectified DC pulsating signal is applied to the Z-source inverter then the output of the inverter is fed to the primary of Step-up transformer winding and the secondary winding is directly connected to the load. The reference value of the magnitude and phase of voltage applied to the auxiliary winding are computed by the reference voltage block. The Matlab/ Simulink model is tested under input voltage *Vin = 24 Vrms,* shoot through duty ratio *D0 = 0.218*, and modulation index *m = 0.6 to m=1.1 upto Vo = 170V*. The main and auxiliary winding voltages simulation and implementation response of single -phase Z-Source Inverter using variable load is described in table 3 to 8.

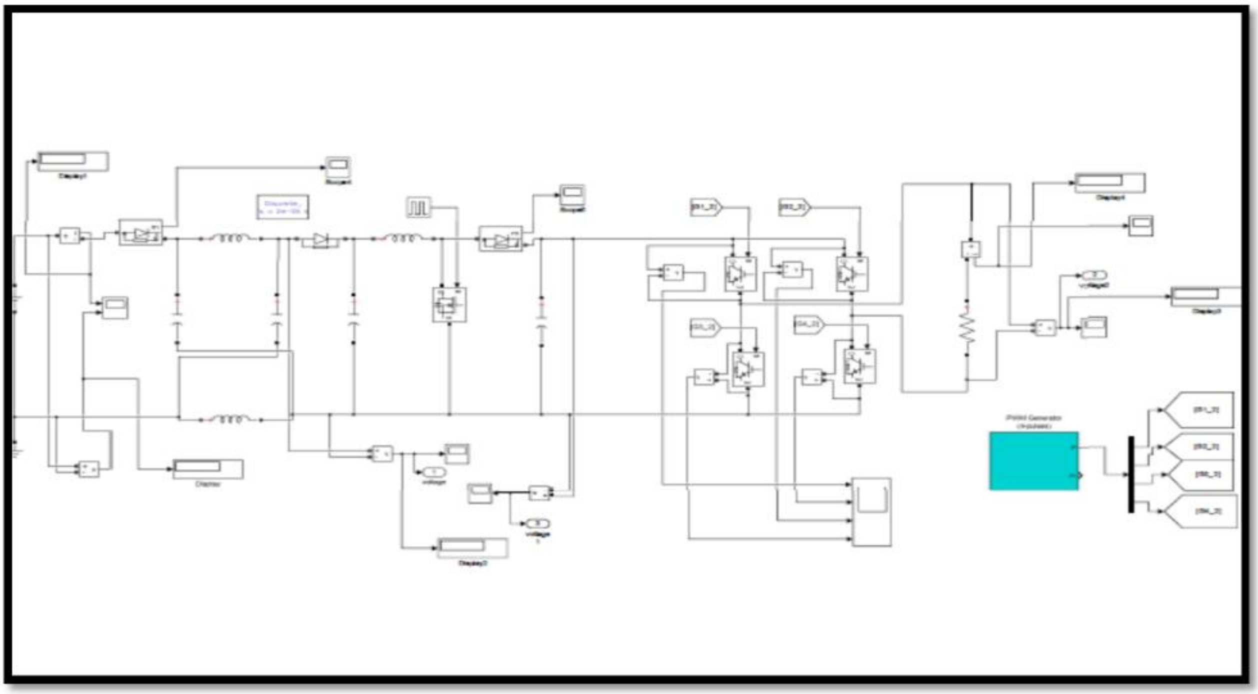


Fig 5.Single Phase Z-Source Inverter MATLAB-Simulink Model

Table 3 Simulated Input Output Values of Single Phase Z Source Inverter Using Resistive Load for Modulation Index (m) =0.6

Sr.no	Input voltage (V)	Input current (I)A	Input Power (P)w	Output voltage (V_O) V	Output current (I_O)A	Output Power (P)w	Efficiency (%η)	Load (W)	Inverter output voltage
1	24	89	2.13k	190.2	90	17.11k	−	No load	35
2	24	2.5	60	170.2	80.2m	13.65	25	15	35
3	24	2.7	64.8	140.8	0.34	47.87	92.59	60	35
4	24	2.9	69.6	115.2	0.7	80.64	143.67	100	35
5	24	4.05	97.2	110	2.18	239.8	205.76	200	35

Table 4 Simulated Input Output Values of Single Phase Z Source Inverter Using Resistive Load for Modulation Index (m) =0.7

Sr.no	Input voltage (V)	Input current (I)A	Input Power (P)w	Output voltage (V_O) V	Output current (I_O)A	Output Power (P)w	Efficiency (%η)	Load (W)	Inverter output voltage
1	24	84	2.01k	100	90	9k	–	No load	35
2	24	2.8	67.2	166.9	60m	10.01	22.32	15	35
3	24	2.9	69.6	123	0.3	36.9	86.20	60	35
4	24	3.0	72	111.7	0.6	70.62	138.88	100	35
5	24	3.5	84	109	2.2	239.8	238.09	200	35

Table 5 Simulated Input Output Values of Single Phase Z Source Inverter Using Resistive Load for Modulation Index (m) =0.8

Sr.no	Input voltage (V)	Input current (I)A	Input Power (P)w	Output voltage (V_G) V	Output current (I_G)A	Output Power (P)w	Efficiency (%η)	Load (W)	Inverter output voltage
1	24	89.8	2.15k	97.2	90	1.74k	–	No load	35
2	24	3.28	78.72	154.6	69m	10.66	19.05	15	35
3	24	3.45	82.8	115.5	0.3	34.65	72.46	60	35
4	24	3.5	84	112.5	0.66	74.25	119.09	100	35
5	24	3.60	86.4	100.2	2.15	215.43	231.32	200	35

Table 6 Simulated Input Output Values of Single Phase Z Source Inverter Using Resistive Load for Modulation Index (m) =0.9

Sr.no	Input voltage (V)	Input current (I)A	Input Power (P)w	Output voltage (V_O) V	Output current (I_O)A	Output Power (P)w	Efficiency (%η)	Load (W)	Inverter output voltage
1	24	96.9	2.32k	100.2	93.2	10.27k	–	No load	35
2	24	3.7	88.8	170.02	59m	10.13	16.89	15	35
3	24	3.8	91.2	115	0.3	34.5	71.42	60	35
4	24	3.10	74.4	108.9	0.66	71.87	134.4	100	35
5	24	3.24	77.74	99.9	2.15	214.78	260.41	200	35

Table 7 Simulated Input Output Values of Single Phase Z Source Inverter Using Resistive Load for Modulation Index (m) =1.0

Sr.no	Input voltage (V)	Input current (I)A	Input Power (P)w	Output voltage (V_O) V	Output current (I_O)A	Output Power (P)w	Efficiency (%η)	Load (W)	Inverter output voltage
1	24	101.5	2.43k	102.25	94.5	9.6k	–	No load	35
2	24	2.8	67.2	167.40	70m	11.17	22.32	15	35
3	24	2.72	65.28	115.5	0.29	33.49	92.59	60	35
4	24	3.58	85.92	111.4	0.66	73.52	119.04	100	35
5	24	3.67	88.08	100.5	2.15	216.07	227.06	200	35

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Table 8 Simulated Input Output Values of Single Phase Z Source Inverter Using Resistive Load for Modulation Index (m) =1.1

Sr.no	Input voltage (V)	Input current (I)A	Input Power (P)w	Output voltage (V_O) V	Output current (I_O)A	Output Power (P)w	Efficiency (%η)	Load (W)	Inverter output voltage
1	24	103.9	2.49k	105	104.5	10.9k	−	No load	35
2	24	3.13	75.12	154.2	69m	10.63	19.96	15	35
3	24	3.55	85.2	114.15	0.29	33.10	104.2	60	35
4	24	3.7	88.8	111.2	0.66	73.39	112.67	100	35
5	24	4.02	96.48	108.2	2.15	232.63	225.73	200	35

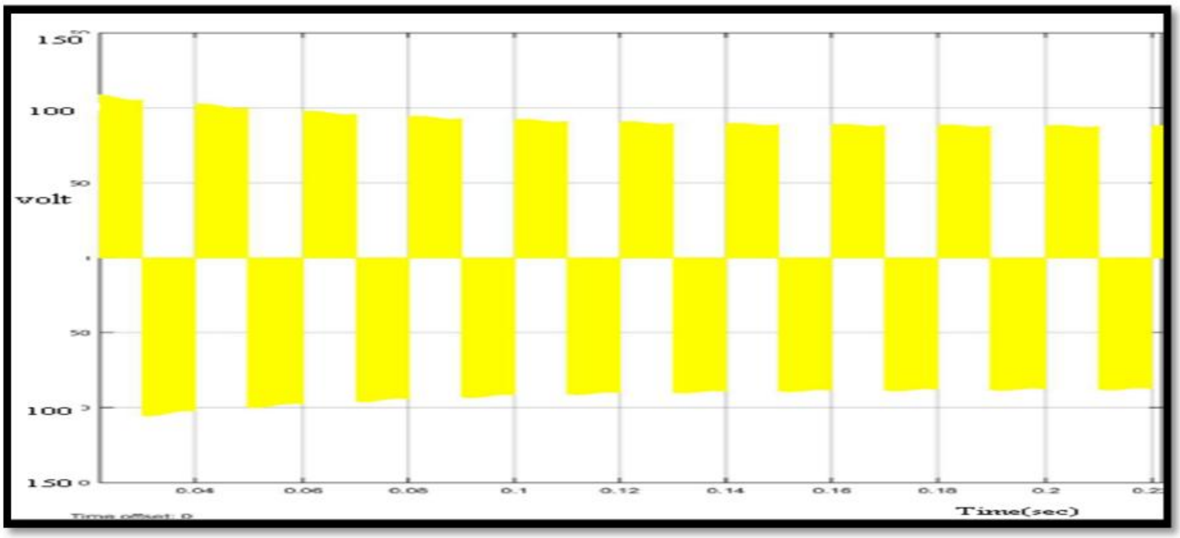


Fig 6:-Output Voltage across the 100 Watt Load

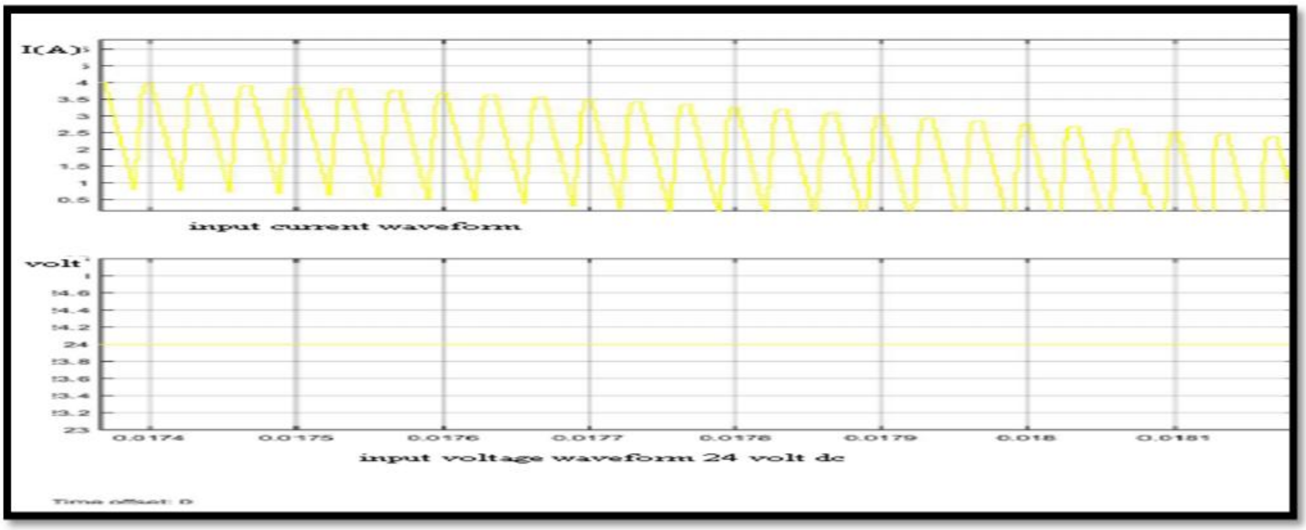


Fig 7:-Input Current and Voltage Waveform

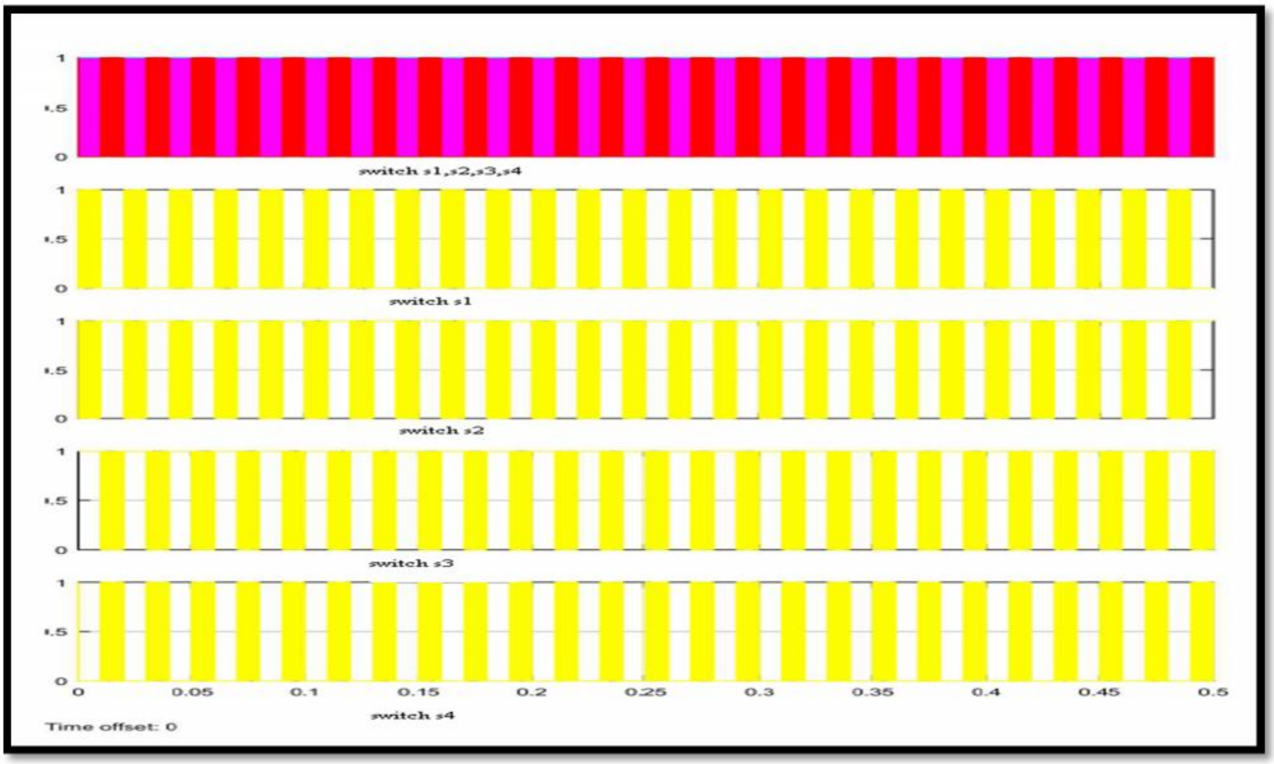
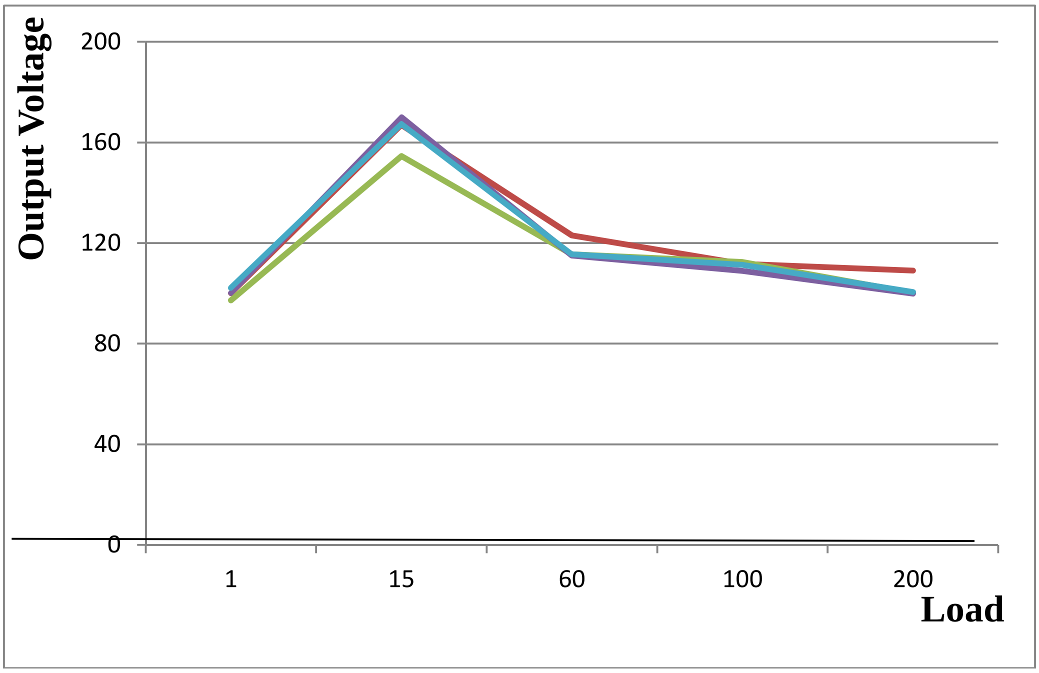
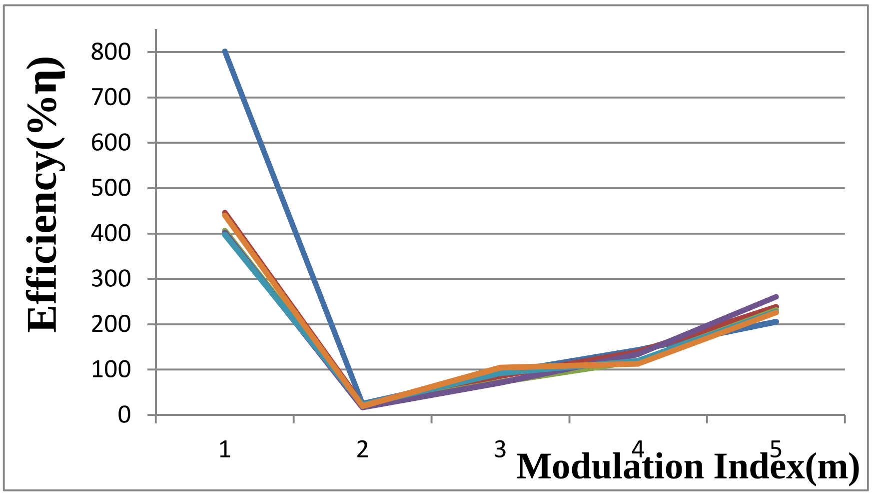


Fig 8:-Gate Pulses Of Switches S1,S2,S3,S4

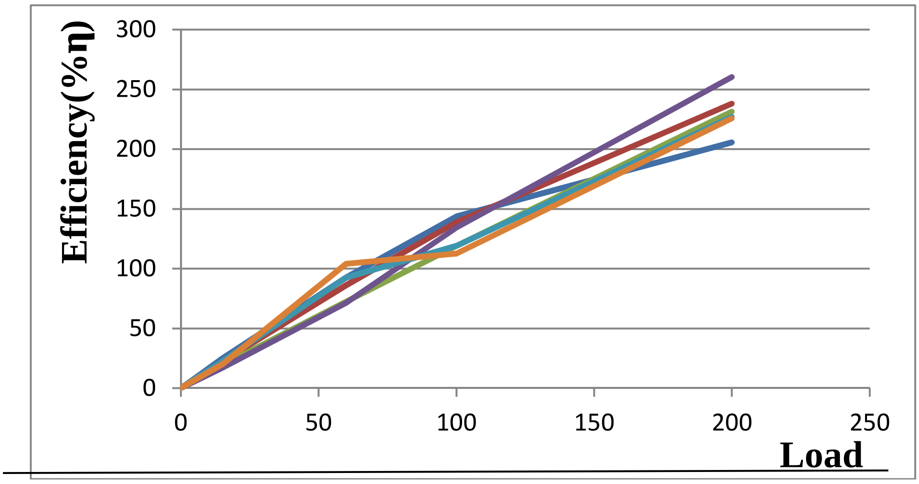
5. STASTICAL ANALYSIS OF Z SOURCE INVERTER



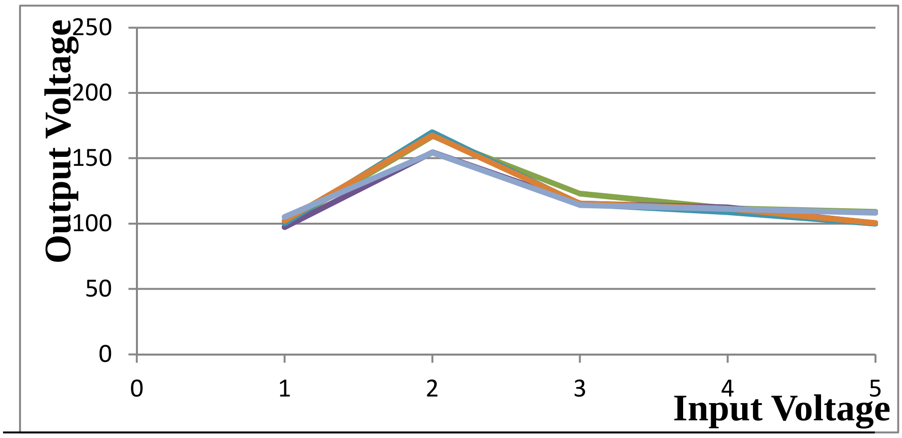
Graph 3 Load Vs Output Voltage



Graph 4 Modulation Index (m) Vs Efficiency (%η)



Graph 5 Load Vs Efficiency (%η)



Graph 6 Input Voltage Vs Output Voltage

6. CONCLUSION

A new topology was designed to improve the conventional voltage source inverter with the Z-source network. The simulation results for input voltage 24V DC, we obtain upto 191V AC, with improve efficiency output voltage for single phase Z-Source inverter using variable resistive load. This paper can be concluded the modeling and simulation of Z-source network with single phase full bridge Z-Source inverter with variable load is of 15 watt to 200 watt, also it is presented in MATLAB-Simulink environment varying the modulation index 0.6 to 1.1 for the verification of the design parameters. The ZSI is better inverter topology because of following reasons

1) Improve efficiency

2) To increase the voltage gain

3) To reduce the number and size of both active and passive devices

4) To reduce the voltage stress on the active and passive devices

5) Optimal utilization of input voltage to maximize the output voltage

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