Proceedings of
INTERNATIONAL CONFERENCE ON COMPUTING, COMMUNICATION AND ENERGY SYSTEMS (ICCCES-16)
In Association with IET, UK & Sponsored by TEQIP-II
29th -30th, Jan. 2016

Paper ID: EE29

A MODIFIED Z-SOURCE HALF BRIDGE CONVERTER FOR PHOTOVOLTAIC APPLICATIONS

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Abstract—: Now a day's the rate of energy generated by the renewable energy sources are increasing rapidly. More popular source form these sources is the photovoltaic system source, but this photovoltaic system is now also most costly and a research work is going on to reduce the cost and increase efficiency of photovoltaic system. Half bridge converter system is developed for to convert dc power in to the ac and also boost dc output. Due to less no of switches, complicity of converter has been reduced. But this Half bridge converter has some disadvantages like it imbalance occurs at the midpoint of the capacitors, limited voltage problems also occurs and not but the least problem is it cannot generate broader range of output. And also shoot through phenomenon occurs due to the duty ratio increases beyond one. So to reduce this kind of problem a Z-source network is developed. By adding this Z-source network in between the half bridge converter then this half bridge converter can be also able to operate if duty ratio goes beyond the unity. Conventional half bridge Z-source converter can be used for resistive load. Now proposed Z-source designed for photovoltaic and able to operate resistive as well as inductive load. Simulation of Z-source half bridge converter with photovoltaic cell is done using MATLAB/SIMULINK.

Index term— Half Bridge Converter, Shoot through, Z-source, and Photovoltaic System.

I. INTRODUCTION

The traditional power converters are basically of two types: voltage-source converters and current source converters. These can be used in single phase as well as three-phase power converters. This paper mainly focuses on a single-phase power conversion. The traditional voltage-source converters and current-source converters have certain disadvantages associated with them. In case of voltage-source (V-source) converters, it acts as a buck (step-down) converter for DC to AC power conversion and as a boost (step-up) converter for AC to DC power conversion. In case of current source (I-source) power converter, it acts as a boost converter for DC to AC power conversion and as a buck converter for AC to DC power conversion. Thus, V-source and I-source power converter can be used as either as a boost or a buck converter and not as a buck-boost converter. Moreover, in case of a three-phase power conversion, if both the upper and lower switches of the same leg are simultaneously turned ON either by purpose or by electromagnetic interference, a shoot-through occurs and the converter is damaged.

Guidong Zanget al.has proposed new concept of A Z-Source half-bridge converter. LC (Z) network is connected between the split capacitors and the half bridge converter [1]. And also the author discussed about design concept of Z-source half-bridge converter. At the past conventional half bridge converter has lots of problem like it cannot produce a broader range of the output voltages and also the shoot-through problem occurs[2]. Fig.1: Conventional Half Bridge Converter

In conventional half-bridge converter has two switches and they are in one leg as shown in fig. 1.If both switches are turn-on at same time the shoot-through problem can occur. Due to this shoot-through problem, large current can flows through these switches, and this makes to short circuits and the switches are getting damage.

The half-bridge inverter output voltage is lower than its source voltage. Furthermore in the conventional half-bridge converter, unbalanced midpoint of split capacitors are makes the system unbalance due to the large ripple [3]. Eloy arcia et al. developed algorithm which is based on the extended direct power control for to balance the midpoint voltage in the multilevel inverter. Although this method is applicable for the single phase half-bridge converter, and this is also designed for the multilevel NPC and three-phase[4].And also the Win et al. and Tanaka et al. solve these problems regarding with the voltage balance of two DC split capacitors by proposing a half-bridge converter based active power quality compensator[5]-[6]. Author Mokhtar Kamli et al. has proposes a half-bridge converter to solve the problem related with limited voltage by adding the boost circuit instead of the source and also instead of the adding step-up transformer with the output [7]. So, output voltage of the transformer is fixed due to fixed turn's ratio.

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Author Rixin Lai et al. proposed a protective scheme for converters to solve the problems related with the shoot-through phenomenon. But this topology is applicable only for the specially designed switches [8]. For the solving of shoot-through phenomenon and limited voltage problem, Peng was proposed the LC network, which is named as the Z-source network as shown in the fig. 2. This topology was proposed in the year of 2003[9]. The Z-source inverter topology has been significantly modified later. For example, Author Peng et al. has been developed the Z-source network [10], [11] and the also equivalent control approaches made [12], [13].Modified Z-source converter and the control methods have been proposed in [14]-[15].New algorithms are proposed to controlling of both AC output voltages and boost DC source of the Z-source converters [14], and dual input and dual output Z-source inverter [15]. Z-source topology is used for lots of applications like a fuel cell system which is proposed by the M.S.Shen et al. in [16], and also for the motor drive application, is developed by the F.Z.Peng et al.in [17]. For distributed power generations, proposed by author D. Vinnikov et al. in [18], and also developed for the battery hybrid vehicles [19].

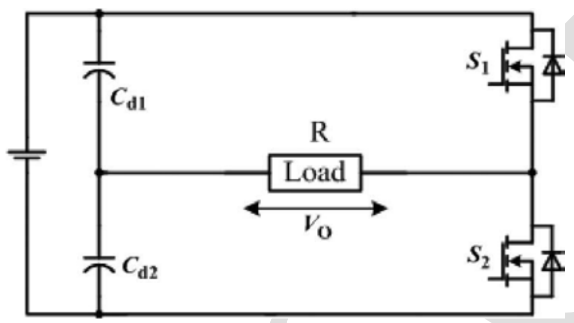

Fig. 1 Conventional half bridge.

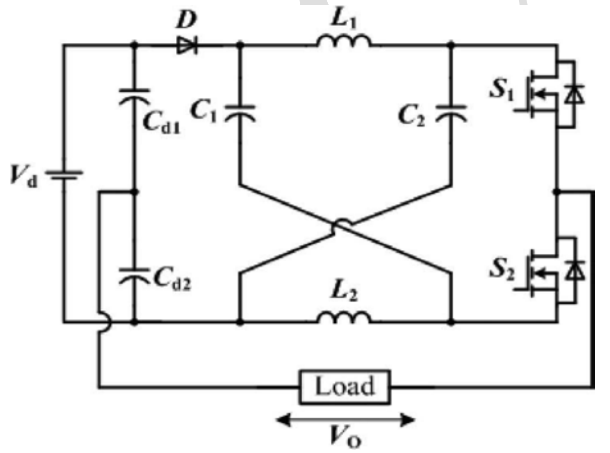

Fig. 2: Z-Source half-bridge converter

The Z-source converter has ability to work in the shoot-through phenomenon, and the output voltage of the Z-source converter has broader ranges than that of conventional half-bridge converter. Many topologies were developed for the PV applications like a half-bridge converter and full-bridge converter.

Conventional half-bridge converters have their switches in series, as shown in Fig. 1, with which the shoot-through can occur, which means that the strong current flowing through the switches makes them break down. Moreover, the ac output voltage is limited below the dc voltage, which is named the limited voltage problem, because, in practice, ac output voltage is sometimes desirable to be higher than the dc voltage. Furthermore, an unbalanced midpoint of input capacitors in conventional half-bridge converters leads to large ripples making the system unstable.

II. SYSTEM ANALYSIS

Photovoltaic model is presented using the output and input equations of general mathematical mode. In this current source is in the parallel with diode and the resistor and series with another resistor [3]. The equivalent circuit of the photovoltaic (PV) cell is depict in the following figure 2.

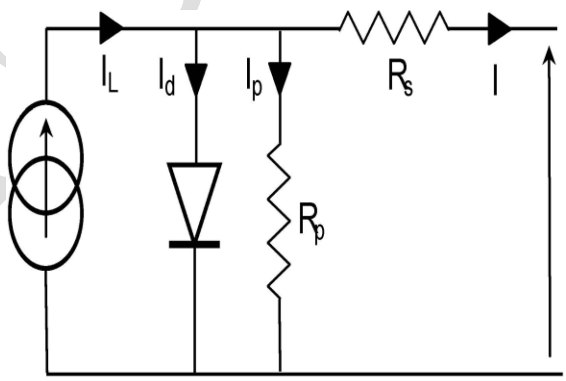

Fig. 3 Equivalent PV cell model

This model is describing the basic equations and C-I characteristics of the photovoltaic cell module are shows in the fig 3. The PV model equations are presented in mathematical model by using the PV output and input. The current source value depends upon the value of diode and it is parallel with current source .the resistor are in parallel with diode and series with its further resistor. The numbers of the resistors in parallel or in series gives the position of the cell is in series or in parallel. I.e. the objective that we are interested in current or voltage.

Mathematical formulae for the photovoltaic system. From the above fig, we are applying KCL then we get total current as given as

$$I=IL-Id-Ip \qquad (A)$$

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Id equation can be given by using the semiconductor diode theory, the above equation can written as,

$$I = I_L - I_0\left(\exp\left(\frac{V + R_s I}{a\,k\,T/q}\right) - 1\right) - \frac{V + R_s I}{R_p} \qquad \text{(B)}$$

Where, IL is the light generated current (A), I0 the PV cell saturation current (A), q the electron charge (q = 1,602 10^19 C), k the Boltzman constant (k = 1, 38 10^23 J/OK), a the cell ideality factor, T the cell temperature. Rp and Rs are pure parasitic resistances characterizing respectively parallel current leakage and series connecting circuit. A typical PV cell of 10x10 cm peak power, under standard conditions (a solar radiation of 1000 W/m 2 and a temperature of 25°C) being of the order of 2 W, a more powerful PVG involves several cells connected in a specific series-parallel configuration.

$$I = N_p I_L - N_p I_0\left(\exp\left(\frac{\left(V + \frac{N_s}{N_p} R_s I\right)}{akT\frac{N_s}{q}}\right) - 1\right) - \frac{V + \frac{N_s}{N_p} R_s I}{\frac{N_s}{N_p} R_p} \qquad \text{(C)}$$

A standard and basic commercial PVG is the module constituted by 36 cells connected in series and placed in an array of 9 by 4. In general, for a PVG involving an array of Ns cells connected in series and Np in parallel, its output voltage current relation may be deduced from the basic cell equation (B) as follows

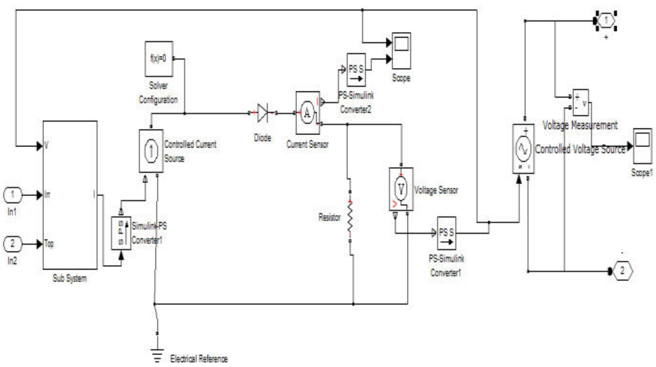

Fig. 4 Matlab model of PV system

In the above fig by using the mathematical equatios photovoltaic model is developed in the matlab Simulink model is as shown in fig, the PV and IV graph is as shown in the below fig.

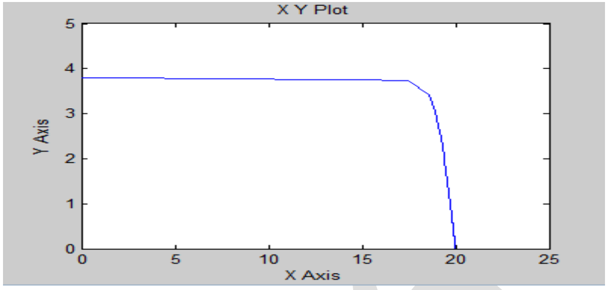

Fig. 5 IV characteristics of the photovoltaic system

In the above graph, Y-axis shows the output of the photovoltaic system. And X-axis shows the output voltage of the photovoltaic system. In this after the 18 voltage the current is decreases is as shown in the fig. this occurs because of the when voltage is increases then the current is reduces in the photovoltaic system.

In below fig, it shows the PV characteristics of the photovoltaic system. In this fig the X-axis shows the voltage of the photovoltaic system and Y-axis shows the power of the photovoltaic system. In this graph voltage and power are linear in nature till the 60 w power after that the voltage of the system is decreases as shown in the fig.

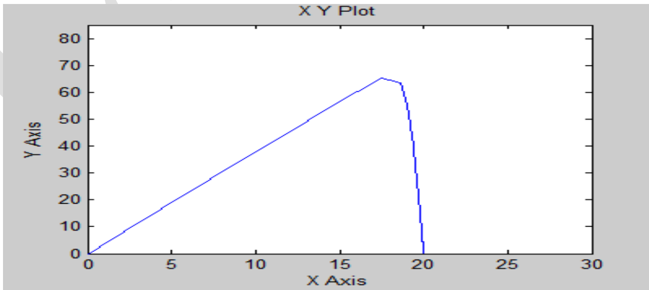

Fig.6 PV characteristics of photovoltaic system.

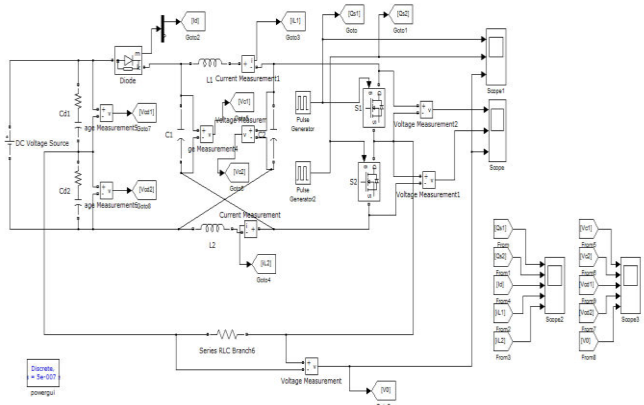

Fig. 7 Existing Z-source half bridge converter matlab simulation.

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In the above simulation, DC voltage is connected to the split capacitors the two switches are connected as shown in fig. in the existing system LC that is Z network, which consist of the capacitor C1 and capacitor C2 and thte inductor L1 and inductor L2. This Z-network is adding in between the split capacitors Cd1, Cd2 and the switches S1 and S2. And there is diode D is also connected to prevent flowing of reverse current.

For the simplicity following conditions are assumed.1 all components are assumed that these are ideal. 2. Z-network consist of inductor L1, L2. And capacitor C1 and capacitor C2, 3. Dead time in the driven pulses is ignored, 4. Capacitors C1, C2, Cd1, and Cd2 are large.

Duty ratio of switch S1 is D1 and duty ratio of switch S2 is D2. So there is shoot through phenomenon occur if the duty ratio both switches is increases the unity. Modes of operation is as shown in fig.

I Case 1: D 1 + D 2 ≤ 1

In this case, switches cannot be operated at same time. Then this circuit is not shoot through state. There are three modes of operation.in the mode 1 switch S1 is on and switch S2 is in the off state. So the current is flowing through the Diode D1 then Z network then switch S1 through load. After that in the mode 2 there is both of these switches are in the off mode, that time current flowing through the only Z network. That time Z network is charging mode. In the mode 3 switch S2 is closed and S1 open sate, that time voltage of Z network is greater than the source voltage. And the conduction path of the current is as shown in the fig. 8(c)

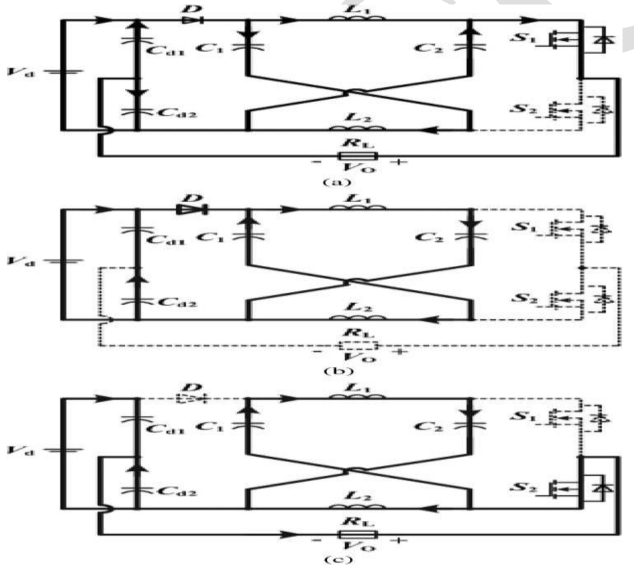

Fig. 8. Equivalent circuits in case 1. (a) S 1 on and S 2 off. (b) S 1 off and S 2 off. (c) S 1 off and S 2 on.

Above fig shows the mode of operation of the non-shoot through phenomenon.

II Case 2: D 1 + D 2 > 1

In this case the shoot through phenomenon is occurs. In this phenomenon, three is condition occurs that both of this switches are operated at same time. In the mode 1shoot through phenomenon occurs in this phenomenon both switches are in the on state that time the flow of current path of is shown in the fig.9 (a) at that time the voltage of the Z network is in greater than the source voltage. In the mode 2, switch S1 is on and S2 is off at that time the current flows from source to Z network to the load as shown in the fig. In the next mode 3. Switch S1 is off and switch S2 is on and the current path is as shown in the below fig.9 (c)

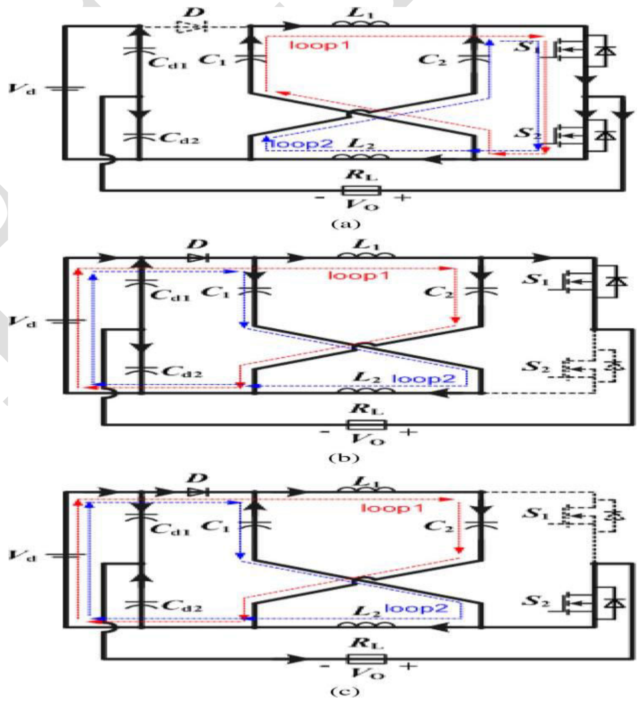

Fig.9. Equivalent circuits in case 2. (a)Mode1:S1 on and S2 on. (b) Mode2: S1 on and S2 off. (c) Mode 3: S 1 off and S2 on.

III. PROPOSED INVERTER TOPOLOGY

Proposed topology of the Z-source half bridge converter is with the photovoltaic system, consist of the two switches (S1 and S2), one diode D1, two split capacitors Cd1 and Cd2, Z network and the resistive R and the inductive L load.is as shown in the fig. in this proposed topology the output of the solar cell is given to the split capacitors and then the diode through Z network is connected. Exact

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location of Z network is between the split capacitors and the two switches of the converter.

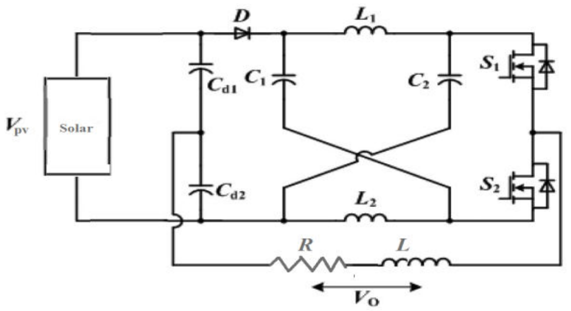

Fig.10 Proposed topology of PV connected Z-source half bridge converter

IV. FORMULAE FOR THE Z-SOURCE NETWORK

A Parameter formulae for the Capacitor in the Z-Network. Generally, the capacitor of design of the capacitor is to determine the rated voltage and capacitance with a permitted fluctuation range x C % (x C is preassigned), a given output voltage V o , a given output current I o , and a given switching period T.

$$v_{C_2} = \frac{2 - D_1 - D_2}{D_1} V_o, \quad \text{when } (S_1) = (\text{on}) \qquad (1)$$

$$v_{C_2} = \frac{2 - D_1 - D_2}{1 - D_1} V_o, \quad \text{when } (S_1, S_2) = (\text{off, on}). \qquad (2)$$

In terms of KCL, the equations of the connected nodes of L2−C1−S2 in Fig. 6(a), L1−C2−S1 in Fig. 9(b), and L2−C1−S 2 in Fig. 9(c) can be derived as

i L 2 = i C 1 + i o , when (S1 ,S2) = (on, on)
i L 1 = i C 2 + i o , when (S1 ,S2) = (on, off) (3)
i L 2 = i o − i C 1 , when (S1 ,S2) = (off, on).

And this denote the rms currents of L 2 and C 2 by I L 2 and I C 2, respectively. Then, from the above curretns, one has

I C 2 ≈ I L 2 =Io2 (4)

1. Determination of the Rated Voltage: The range of v C2 is determined by (1) and (2). Thereby, the rated voltage of C2 can be determined by the maximal V C 2 M. considering the safety margin, the rated voltage of C 2 is normally set between1.5V C 2 M and 2V C 2 M .

2. Determination of the Rated Capacitance: The ripples of the capacitors have great influence on the stability of the converter, whose permitted fluctuation range can be used to design the capacitance. Then, the capacitors in the Z-network can be designed according to the differential equation of capacitors

C2=i C2 dt/dv C2 (5)

The high harmonic frequency of the capacitance is nearly equal to the switching frequency of the converter,

dt ≈ (D1+D 2−1)T (6)

Denote the permitted error of VC2M by dvC2, according to the permitted fluctuation range xC%; dvC2 is expressed as

dv C 2 =xC%V C2M (7)

Substituting (4), (5), and (7) into (25) leads to

$$C_2 = \frac{I_o(D_1 + D_2 - 1)T}{2x_C\% V_{C_2M}}. \qquad (8)$$

Therein, the range of the capacitance can be calculated, and the maximum is taken as the rated capacitance.

B Parameter Formulae of the Inductor in the Z-Network
This is also similar with the capacitor with the capacitor formulae. The parameter design of the inductor is to determine the rated current and capacitance with a permitted fluctuation range xL % (xL is preassigned), a given output voltage Vo, a given output current Io, and a given switching period T.

1) Determination of the Rated Current: IL2 can be determined by (4). Considering the safety margin, the rated current of L2 is normally taken as 2IL2.

2) Determination of the Rated Inductance: The ripples of the inductors also have great influence on the stability of the converter; therefore, the inductance can be designed in terms of the permitted ripples.

The inductances in the Z-network can be designed according to the differential equation of inductances

L2 =vL2 dt L/di L2. (9)

In the L1−C2−L2−C1 loop, the KVL equation can be expressed as v L 2 + v C 1 = v L 1 + v C 2. In the Z-network, the rms voltages of C1, C2, L1, and L2 are denoted by VC1, VC2, VL1, and VL2, respectively, and one has v C 1 ≈ V C 2 and V L 2 ≈ V L1. Thereby, the maximum of vL2 is derived as

V L 2 M ≈ V C 2 M (10)

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The high harmonic frequency of the inductance is nearly equal to the switching frequency of the converter, as in the conventional half bridge, so the time interval dtL in (9) can be obtained as

$$dtL \approx (D1+D2-1)T \qquad (11)$$

Denote the permitted error of IL2 by di L2. According to the permitted fluctuation range xL%, diL2 is expressed as

$$di\,L\,2 = x\,L\,\%I\,L2 \qquad (12)$$

Substituting (24), (25), (27), and (33)–(35) into (32) leads to the inductance of L2

$$L_2 = \frac{2V_{C_2M}(D_1 + D_2 - 1)T}{x_L\%I_o}. \qquad (13)$$

V. MATLAB SIMULATION OF PROPOSED TOPOLOGY

Simulation of proposed topology is as shown in the following fig. In this topology output of the photovoltaic system is connected to the split capacitors and then the Z network is connected after that two switches are connected with the snubber capacitor.

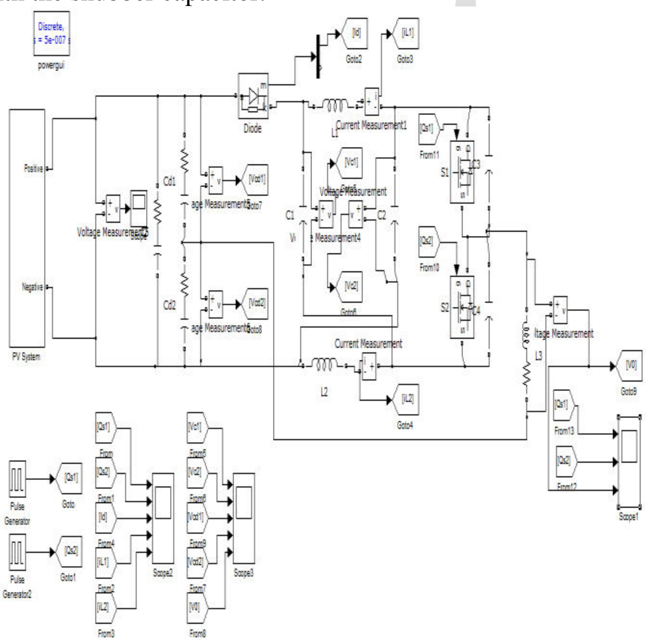
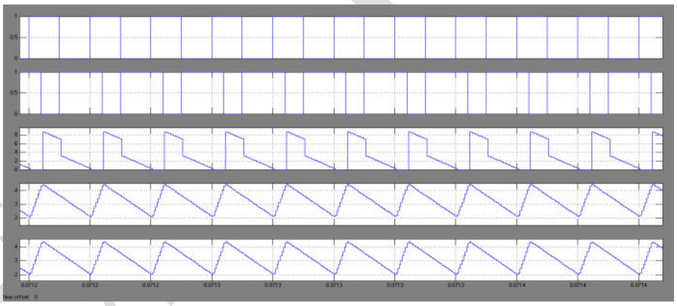


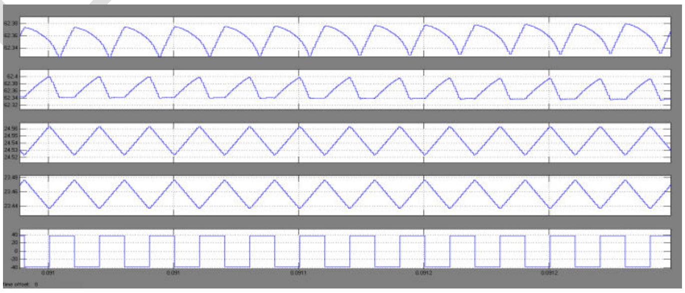
Fig.8 MATLAB model of H6 type IGBT inverter and PWM scheme.

VI. RESULT ANALYSIS

This simulation results are carried out by using the matlab Simulink software for to compare the operation and analyze and to check overall performance of the existing Z-source half bridge converter and the proposed haf bridge converter. The parameters used for the both two topologies are same. But the extra parameter is the snubber capacitor which is connected across the switches of the converter. The parameters is taken as follows: Vp=48V, Vo=100V, Io=10 A, and T=20µs. According to the design, the parameters of the converter can be calculated: C1=C2=482.5µF and L1=L2 =105.5 µH. However, in practice, the parameters can be chosen as follows: C1=C2=470µF and L1=L2=100µH.

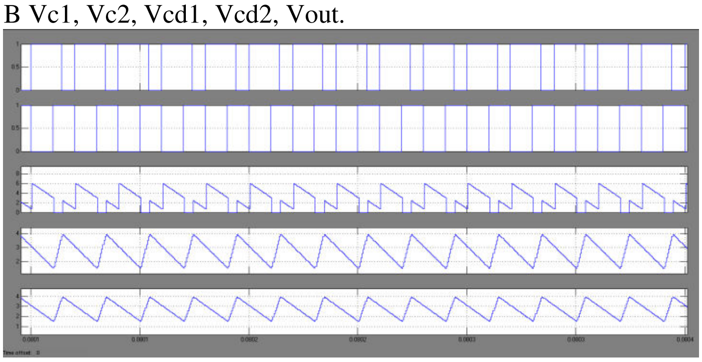


A



B

Fig. Waveform of Z-source half bridge converter.(D1=0.5, D2=0.7) without inductive load.
A Q1, Q2, Id, IL1, IL2.
B Vc1, Vc2, Vcd1, Vcd2, Vout.



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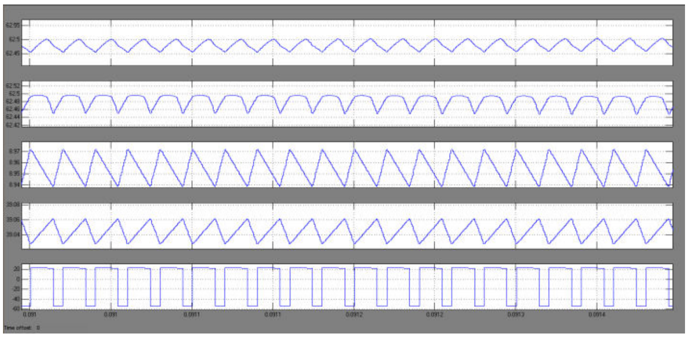
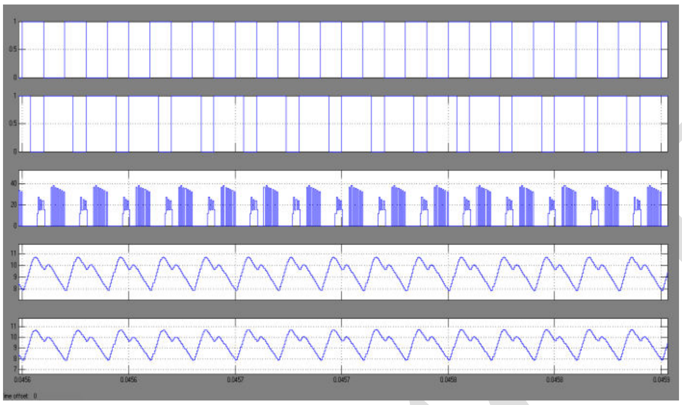


B

Fig. Waveform of Z-source half bridge converter.(D1=0.7, D2=0.5) without inductive load
A Q1, Q2, Id, IL1, IL2.
B Vc1, Vc2, Vcd1, Vcd2, Vout.



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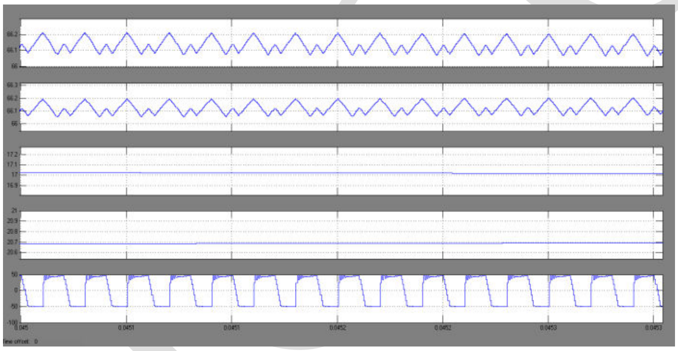
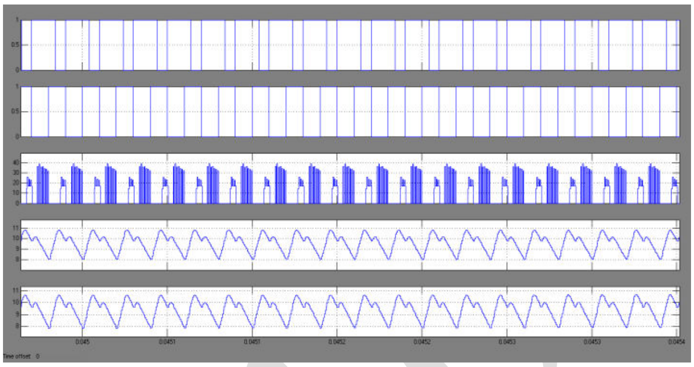


B

Fig. Waveform of proposed Z-source half bridge converter.(D1=0.5, D2=0.7) with inductive load
A Q1, Q2, Id, IL1, IL2.
B Vc1, Vc2, Vcd1, Vcd2, Vout.



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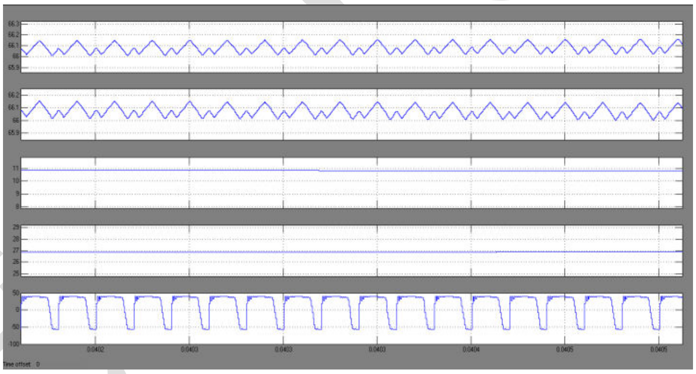

B

Fig. Waveform of proposed Z-source half bridge converter.(D1=0.7, D2=0.5) with inductive load
A Q1, Q2, Id, IL1, IL2.
B Vc1, Vc2, Vcd1, Vcd2, Vout.

VII. CONCLUSION

This paper proposes a Z-source half bridge converter for a photovoltaic application. This paper presents the improved performance of the Z-source half bridge converter under the inductive and resistive. Existing converter and proposed topology has been developed in the matlab simulink model and results are compared in this paper. These are the following advantages of existing half bridge converter over the proposed Z-source half bridge converter.

1 Proposed topology can be able to operate for the resistive and the inductive load.
2 Proposed topology also capable for the photovoltaic application.
3 This system does not required any buck or boost converter.

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