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Research Article

Photovoltaic Simplified Boost Z Source Inverter for Ac Module Applications

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Abstract: This study mainly proposed PV z source boost inverter used to boundary grid or ac module applications. Separate types of converter used for solar system due to its current lagging, here capacitor multiplier based boost converter introduced for maintain the current lagging and voltage gain. Here, the switched inductor z source inverter implemented for grid interface. Proposed z source inverter is controlled by pulse width modulation. A simplified capacitor multiplier controlled by continuous conduction mode, A detailed topology analysis and a generalized discussion are given. The multiplier boost converter has the merits of maintain voltage level and reducing cost and current lagging. Simulation results are implemented and analysis MATLAB software.

Keywords: Capacitor multiplier, CCM, MPPT, PWM, switched z source inverter

INTRODUCTION

The world's Renewable sources growing up recently and Photovoltaic (PV) market will grow up to 30 GW by 2014, due to the following policy-driven scenario (Xue *et al*., 2004). The role of grid-connected PV systems in distribution energy systems will become important and the PV inverter will also play a unique role in this growing market. To obtain higher dc-link a String-type inverters use series connections with numerous modules to the main electricity through a dc-ac inverter (Shimizu *et al*., 2006; Li and Hi, 2011).

Figure 1 shows that the Single-Ended Primary Inductance Converter (SEPIC) having non- inverting output voltage (Adar *et al*., 1997; Chiang *et al*., 2009). Although the boost converter usually has higher efficiency than the SEPIC, nonetheless, it is only applicable for cases where the battery voltage is higher than the PV module voltage (Kim *et al*., 2010). The SEPIC's buck boost features extends the applicable PV voltage and thus increases the adopted PV module flexibility.

The comparison of various buck-boost converters from voltage gain and efficiency and cost. It is shown in Table 1. Among these converters, although the SEPIC is not the best from the views of efficiency and cost, it still has the merits of no inverting polarity, user free-to-drive switch and low input-current expand for high-accuracy Maximum power point tracking that makes its integral point suitable for the low-power PV charger method. This study will investigate the SEPIC with the PV module input and zeta converter with PV module input. Switched z source inverter interface with SEPIC and Zeta converters.

Table 1: Parameters of simulation

Output power P_0	1500 W
Input voltage V_{in}	11 V
Output voltage V_0	600 V
Switching frequency f_s	1080 Hz

Zeta converter provides either a step-up or a step-down function to the output, in a manner similar to that of the buck-boost or SEPIC converter topologies. The conventional Zeta converter is configured of two inductors, a series capacitor and a diode. Previous research work developed diverse Zeta converter applications, as follows. A coupled inductor can be employed to reduce power supply dimensions (Falin, 2010).

The features of the proposed zeta converter replaced inductor to the leakage-inductor. Leakage inductor energy of the coupled inductor can be recycled, increasing the efficiency and the voltage spike on the active switch has been restrained. The switched-capacitor and coupled-capacitor techniques are introduced for high boost conversion range. During non operating condition active switch isolates the PV panel's energy to humans or facilities (Chen *et al*., 2013).

In Conventional System Inverters (VSI and CSI) (Yang and Smedley, 2008; Kerekes *et al*., 2009) are widely required in various industrial applications such as Induction drives, distributed power systems and hybrid electric vehicles. However, the normal VSI and CSI have been seriously restricted due to their stabilized output voltage range, shoot-through problems caused by misgating and some other theoretical difficulties due to their bridge-type structures.

The topology of the Z-source inverter (Peng, 2002) was used to limits the problems in the traditional

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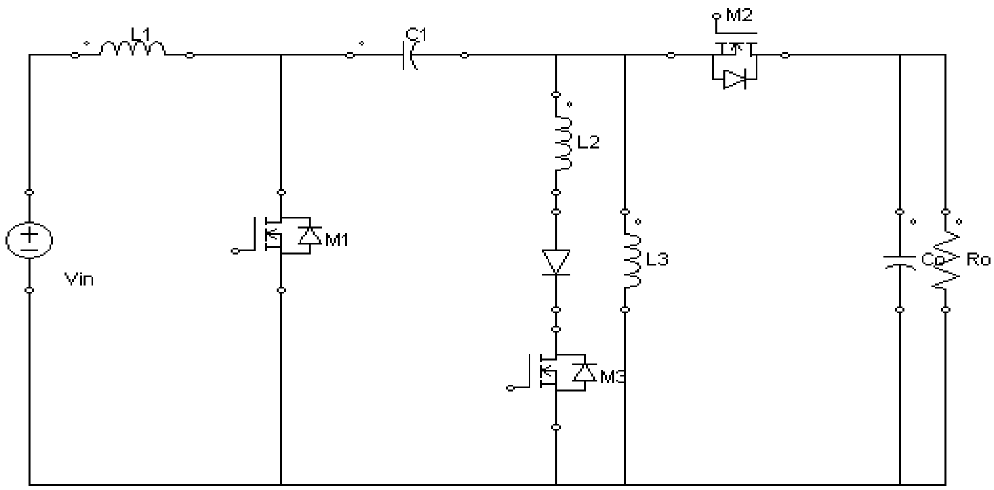

Fig. 1: Sepic converter

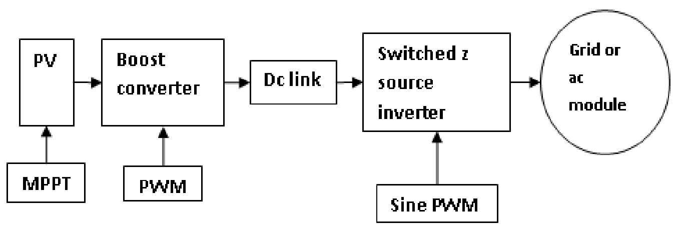

Fig. 2: System block diagram

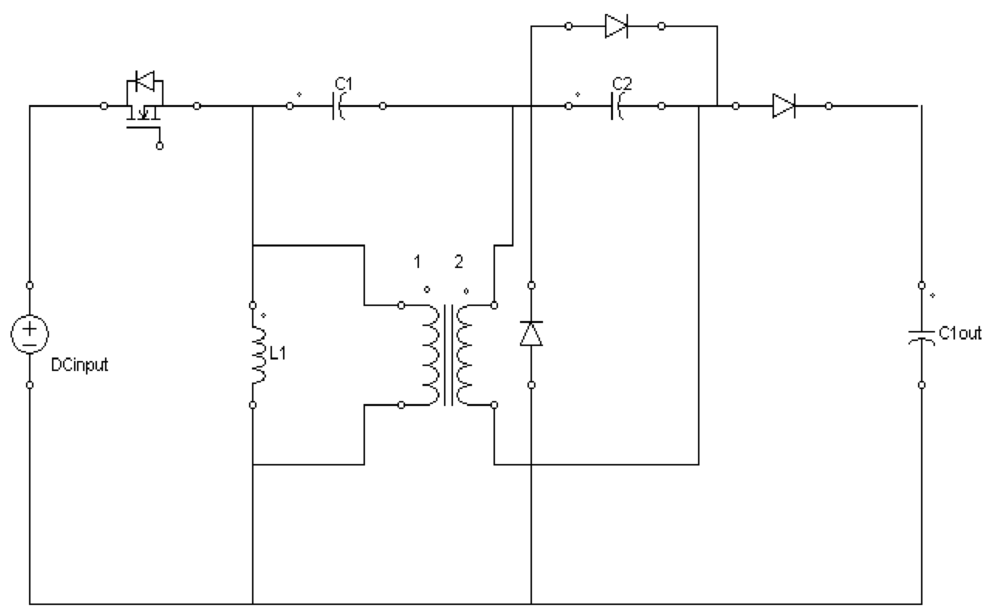

Fig. 3: Proposed zeta converter

inverters (Yang and Smedley, 2008; Kerekes *et al*., 2009). In which the functions of the traditional dc-dc boost converter and the bridge-type inverter have been successfully combined. As a research troublespot in power electronics the Z-source.

In this study the Switched inductor z source inverter having the boost factor has been increased from 1/ (1-2D) to (1+D) / (1-3D) over normal z source inverter. Proposed converter is applied to ac module applications (Rodriguez and Amaratunga, 2008) in

Fig. 2 shows that block diagram of PV simplified boost z source inverter.

PROPOSED CONVERTER METHOD

Even though SEPIC converter having some merits, the proposed converter is shown in Fig. 3; its basic configuration came from a Zeta converter, but the input inductor has been replaced by a coupled inductor. Employing the turn's ratio of the coupled inductor increases the voltage gain and the secondary winding of the coupled inductor series with a switched capacitor for further increasing the voltage. The coupled-inductor Zeta converter is configured from a coupled inductor T_1 with the floating active switch S_1. The primary winding N_1 of a similar inductor T_1 is similar to the input inductor of the existing boost converter, except that capacitor C_1 and diode D_1 are recycling leakage-inductor energy from N_1. The secondary winding N_2 is connected with another pair of capacitors C_2 and with diode D_2, all three of which are in series with N_1. The rectifier diode D_3 connects to its output capacitor C_3 and load R. The features of the proposed converter are:

- The leakage-inductor energy of the coupled inductor can be recycled, increasing the efficiency; and the voltage spike on the active switch has been restrained.
- The voltage-conversion ratio is efficiently increased by the switched-capacitor and coupled-capacitor techniques.
- The floating active switch isolates the PV panel's energy during non-operating conditions, thus preventing any potential electric hazard to humans or facilities. The operating principles and steady-state analysis are presented in the following sections.

Proposed system suitable simplified boost converter operations based on low range of capacitor and suitable for PV generation (Chen *et al*., 2013). Key waveform of voltage multiplier boost converter shown in Fig. 4.

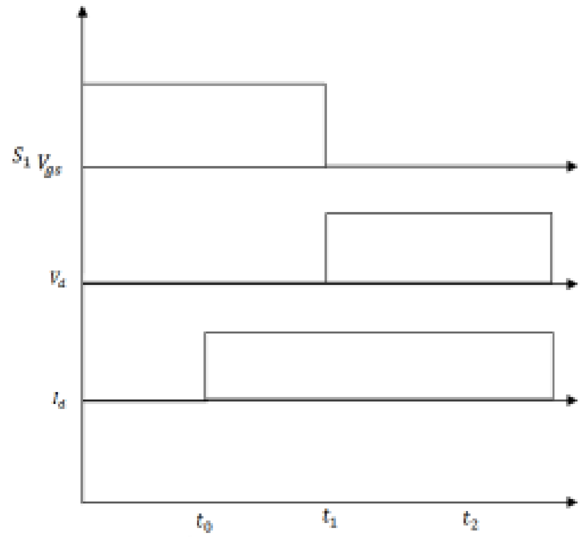

Fig. 4: Key wave form voltage multiplier boost converter

Interface of grid we used switched z source inverter, proposed synchronized PWM topology used to produce high voltage gain in dc link side than conventional inverter (Zhu *et al*., 2010) topology has been greatly explored from various aspects (Peng *et al*., 2004).

Switched Z source network: To provide a stabilized output power in inverter is a challeging issue and also z source converter performance is improved by addition of capacitor and inductor bank recently.

Purely based on high step up without non-isolation circuit, Switched z source is a suitable medium for AC module or grid interface even though if we have low DC source in our primary side.

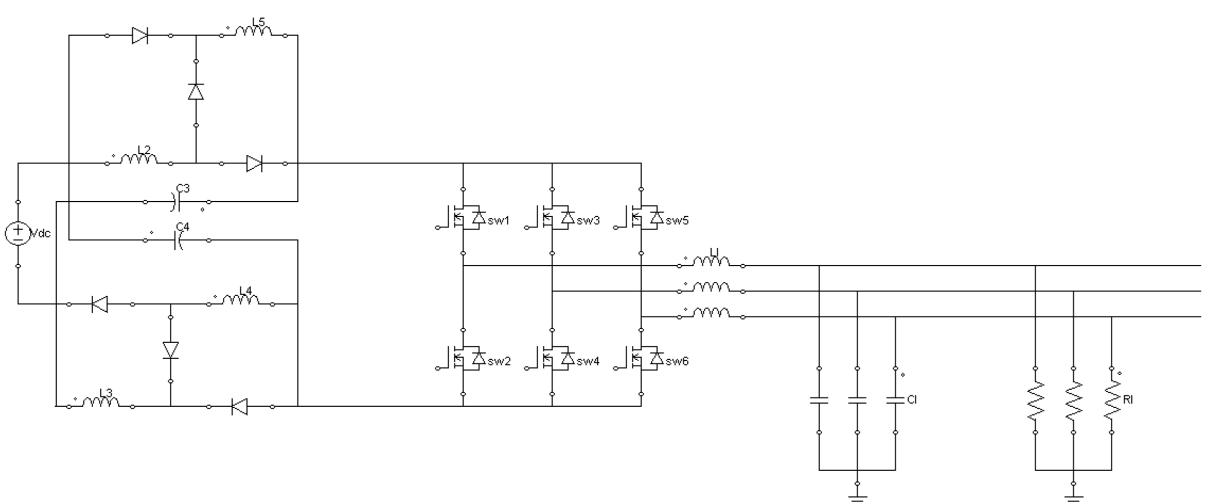

Fig. 5: Proposed switched z source inverter

An newest dc-dc conversion enhancement techniques such as Switched Capacitor (SC), Switched inductor (SL), hybrid SC/SL, voltage multiplier cells and voltage lift techniques have been greatly explored (Ioinovici, 2001; Zhu and Luo, 2009).

In this, the concept of the SL techniques has been integrated into the classical Z-source impedance network. Additionally three diodes, the introduced topology is termed the SL Z-source inverter and is shown in Fig. 5. This topology is totally different from any other existing Z-source inverters based on structure and operation principles.
The main features are sum up in the following:

- Low range of inductors and capacitors
- Simplified and synchronized PWM topology for z source inverter
- Additional boost factor over normal Z source inverter circuit with less duty cycle:

  M≥1-D

OPERATING PRINCIPLES OF THE PROPOSED CONVERTERS

The Simplified circuit model of the proposed (Chen *et al*., 2013) converter is shown in Fig. 3. The coupled inductor T1 includes a magnetizing inductor Lm, both leakage inductors L_{k1} and L_{k2} and an ideal transformer primary winding N_1 and secondary winding N_2. To simplify the circuit analysis of the proposed converter, the following assumptions are made:

- All components are important, except for the leakage inductance of coupled inductor T_1. The ON-state resistance RDS (ON) and all parasitic capacitances of the main switch S_1 are neglected, as are the forward voltage drops of the diodes $D_1 \sim D_3$.
- The capacitors $C_1 \sim C_3$ are sufficiently large that the voltages across them are considered to be constant.
- The ESR of capacitors $C_1 \sim C_3$ and the parasitic resistance of coupled-inductor T_1 are neglected.
- The turn's ratio n of the coupled inductor T_1 winding is equal to N_2/N_1.

The operating principles for Continuous-Conduction Mode (CCM) are now presented in detail. The typical waveform of several major components during one switching period. The five operating modes are described as follows.

Modes of operations:
Mode I (t_0, t_1): During these modes, energy transferred from the secondary leakage inductor L_{k2} to capacitor C_2. switch S_1 and diodes D_2 are conducting. The current i_{Lm} is descending because source voltage V_{in} is applied on magnetizing inductor L_m and primary leakage inductor L_{k1}; same time, L_m is also releasing its energy to the secondary winding, as well as charging capacitor C_2 along with the decrease in energy, no conduction from V_{in} to load (Kerekes *et al*., 2009):

$$I^{I}_{in}(t) = i^{I}_{DS(t)} = i^{I}_{LK1}(t) \quad (1)$$

$$\frac{diILm(t)}{dt} = \frac{VLm}{Lm} \quad (2)$$

$$\frac{DiILk1(t)}{dt} = \frac{Vin - VLm}{Lk1} \quad (3)$$

$$i^{I}_{Lk2}(t) = \frac{iILm(t) - iILk1(t)}{n} \quad (4)$$

Mode II (t_1, t_2): During this modes interval s_1 and V_{DS}, D_3 is conducted. Primary and secondary inductor I_{Lm} and I_{lk1} gets energized charging and discharging of C_1, C_2 and C_3. From C_3 to Load flow is taken:

$$i^{II}_{Lm}(t) = i^{II}_{Lk1}(t) - ni^{II}_{Lk2}(t) \quad (5)$$

$$\frac{diIILm(t)}{dt} = \frac{Vin}{Lm} \quad (6)$$

$$i^{II}_{in}(t) = {}_{i}{}^{II}{}_{DS}(t) = {}_{i}{}^{II}{}_{Lm}(t) + (1+n)\, i^{II}_{Lk2}(t) \quad (7)$$

$$\frac{diIILk2(t)}{dt} = \frac{diIId3(t)}{dt} = \frac{(1+n)\,Vin + Vc1 + Vc2}{Lk2} \quad (8)$$

Mode III (t_2, t_3): During this transition interval, secondary leakage inductor L_{k2} keeps charging C_3 when switch S_1 is off. D_1 D_3 is conducting alone. IL_{k1} stored energy transferred through D_1 C_1, C_2 gets charging. Through D_3 C_3 charging and discharge from it to load:

$$i_{in}{}^{III}(t) = 0 \quad (9)$$

$$i_{Lm}{}^{III}(t) = i^{III}_{Lk1}(t) - ni^{III}_{Lk2(t)} \quad (10)$$

$$\frac{diIIILk1(t)}{dt} = \frac{-Vc1 - V\,Lm}{Lk1} \quad (11)$$

$$\frac{diIIILk2(t)}{dt} = \frac{diIIID3(t)}{dt} = \frac{nVLm + Vc2 - V0}{Lk2} \quad (12)$$

Mode IV (t_3, t_4): During this interval, the energy stored in magnetizing inductor (L_m) releases simultaneously to C_1 and C_2. Only diodes D_1 and D_2 are conducting. IL_{k1} and ID_1 current decreases based on leakage energy still flows through D_1 and continue charging capacitor C_1. L_m is delivering its energy through T_1 and D_2 to charge capacitor C_2. The energy stored in capacitors C_3 is constantly discharged to the load R:

$$i^{IV}_{Lm}(t) = i^{IV}_{Lk}(t) - ni^{IV}_{Lk2(t)} \quad (13)$$

$$\frac{diIVLk1(t)}{dt} = \frac{-Vc1 - VLm}{Lk1} \quad (14)$$

$$\frac{diIVLk2(t)}{dt} = \frac{Vc2 + nvLm}{Lk2} \quad (15)$$

Mode V (t_4, t_5): During this interval, magnetizing inductor Lm is constantly transferring energy to C_2. Diode D_2 is conducting based on current flow on it. Transferring from Stored energy (C_3) to load R:

$$\frac{diVLm(t)}{dt} = \frac{VLm}{Lm} \quad (16)$$

$$i^{V}_{Lk1}(t) = 0 \quad (17)$$

$$\frac{diVLk2(t)}{dt} = \frac{nVLm + Vc2}{Lk2} \quad (18)$$

Simple boost PWM topology of proposed Z source inverter: The switching pulse generation, peak value of three phase reference with modulation index compared with high frequency triangular signal (V_{sin}>V_{tri} is ON) and (V_{sin}<V_{tri} is OFF).
Voltage gain derived by:

$$n\text{-}1\text{-}M \quad (19)$$

$$G = MB = \frac{M}{1-2D} \quad (20)$$

Where inverter voltage Gain (G) derived by Boost factor (B) and Modulation index (M):

$$G = \frac{M}{1-2D_0} = \frac{M}{1-2(1-M)} = \frac{M}{2M-1} \quad (21)$$

$$V_{out} = \frac{MBV_0}{2} \quad (22)$$

Voltage stress across inverter device is derived by:

$$V_{inv} = BV_0$$
$$B = 2G\text{-}1$$

$$V_{inv} = (2G-1)V_0 = \frac{V_0}{2M-1} \quad (23)$$

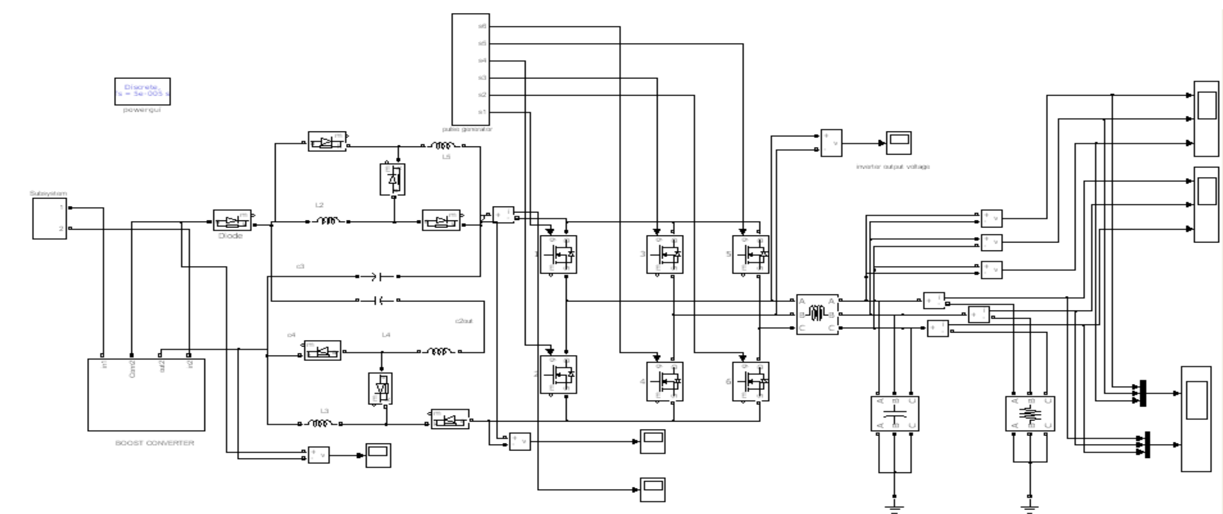

Fig. 6: Proposed simulation circuit

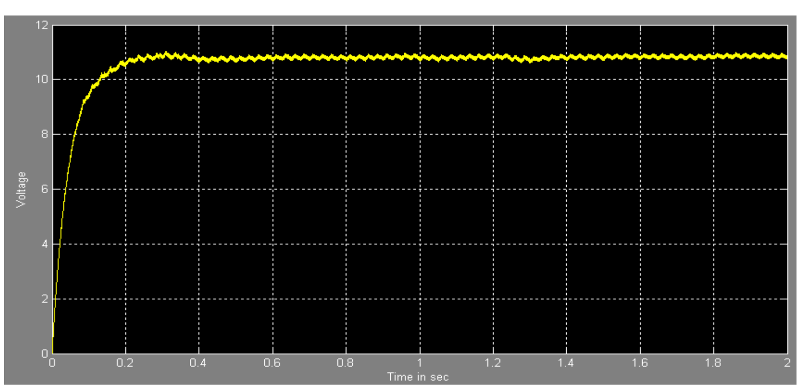

Fig. 7: Photovoltaic voltage

Simulation results: The proposed converter is simulated by MATLAB/SIMULINK. The specification and parameter of capacitor multiplier voltage boost converter as follows:

$C_1 = C_2 = 47\mu$F, $C_3 = C_4 = 800\ \mu F_1$, $L_2 = L_3 = L_4 = L_5 = 1\ \mu$H, $C_{1out} = 20\ \mu$F, Turns ratio: 1:2. Switching frequency = 1080 hz

Proposed simulation implementation circuit shown in Fig. 6. In Fig. 7 shows source voltage of Photovoltaic. Zeta converter voltage gain performance shown in Fig. 8. Boost z source DC-Link voltage for M = 0.8 shown in Fig. 9. Voltage gain across the Z source DC-Link circuit is obtained voltage before LC filter obtained equal to Z source DC-Link voltage shown in Fig. 10. In Proposed PWM scheme applied to z source inverter. Three phase V_a, V_b and V_c sine wave compared with V_P and V_N references and $V_{carrier}$. Extra gain over zeta is shown in Fig. 11.

RESULTS AND DISCUSSION

The Proposed topology simplified boost Z source inverter provided additional Power gain by presented Zeta converter. Maximum power Generation of

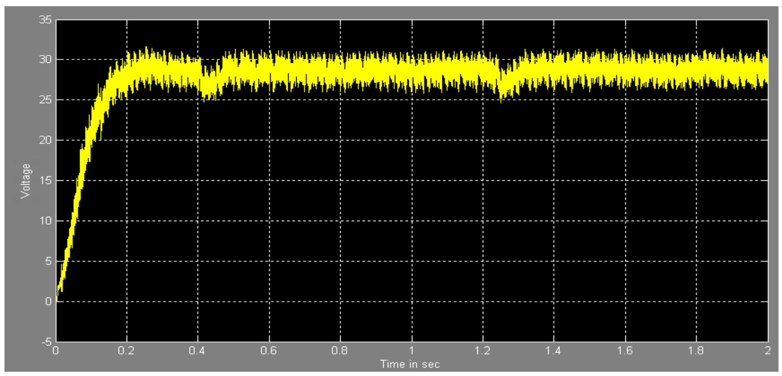

Fig. 8: ZETA boost converter output voltage and current

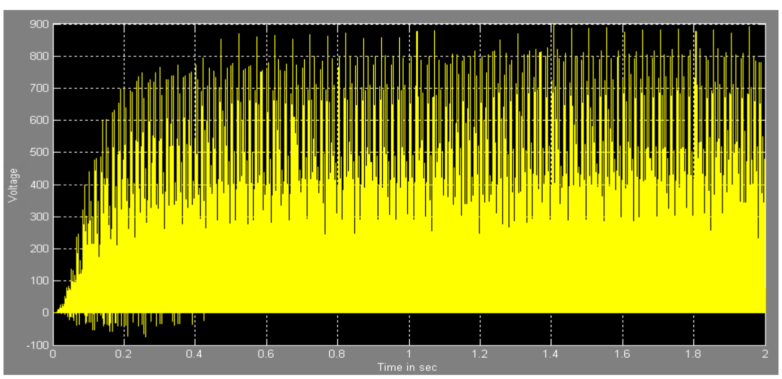

Fig. 9: Proposed boost z source DC-link voltage for M = 0.8

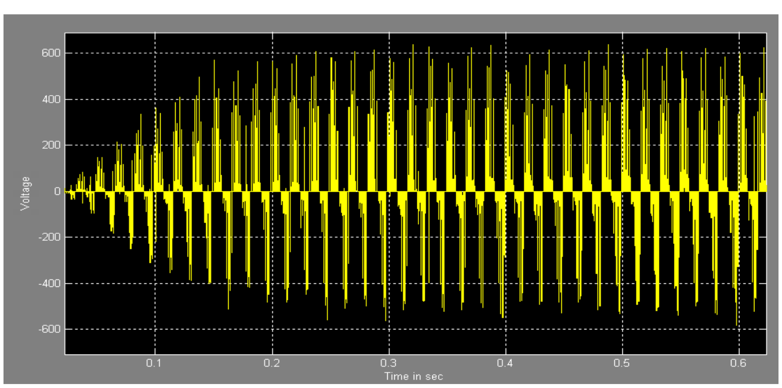

Fig. 10: Boost Z source output voltage before LC filter circuit

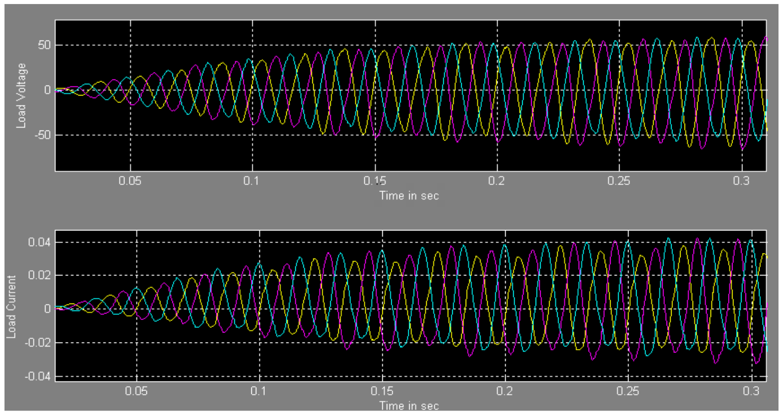

Fig. 11: Load voltage and load current for M = 0.8 (L = 20 mH, C = 150 uF)

Photovoltaic obtained by zeta. Proposed simple PWM topology carried out from the range of M = 0.2-0.8. Maximum Load gain obtained M = 0.8 in proposed circuit topology.

CONCLUSION

Proposed ZETA converter achieved a systematic Maximum PV power generation and efficient power flow. Simplified Boost Z source inverter provided satisfactory solutions for AC grid interface using simple Boost PWM topology. Simplified Boost z source inverter drawn a lossless PV power generations to grid. Result has been implemented in MATLAB (SIMULINK).

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