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Design and Simulation of Developed Embedded Z-Source Inverter for Photovoltaic Interface

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Abstract. This paper presents the implementation of Embedded Switched Z Source Inverter (ES-ZSI) using photovoltaic interface. Lesser passive elements are required in ES-ZSI with reference to the conventional Z-source inverter. Buck boost operation can be simulated in ES-ZSI, and it is interfaced with PV module. The shorting of the inverter leg is resolved adding to the high output voltage gain of the inverter. Various modes of operation are evaluated and their results are simulated using MatLab. Eventually, simulation study of the complete system is presented for both buck and boost state in ES-ZSI and their results are validated experimentally.

Key words: Embedded switched Z-source inverter, PV module, MatLab.

INTRODUCTION

In conventional inverters, two-level inverter is used in order to obtain a controllable voltage. A separate boost network is required for both standard voltage source inverter (VSI) and current source inverter (CSI). VSI does buck operation whereas CSI does boost operation. Therefore, the buck-boost operation cannot be achieved by using these inverters. In order to compromise this drawback, the ZSI has been studied and implemented.

In Z-source inverter, buck-boost operation can be done at a same time by simply changing its modulation index. It is highly reliable. It can boost or buck the output voltage in absence of switching time delay. In contrast to conventional ZSI, ES-ZSI has higher number of active elements and it has high efficiency [1-3]. When same leg of inverter switch conducts, shoot through mode takes place whereas, when different leg of inverter switch conducts non-shoot through mode takes place.

In this paper, ES-ZSI is investigated for both shoot through and non-shoot conditions. Mathematical modelling for PV array is designed and their parameter values are noted. Eventually, PV array is interfaced with ES-ZSI by dc-link capacitor and their results are simulated.

COMPARISON OF VARIOUS TOPOLOGIES

The dc to ac converter, which is commonly called as inverter is capable of producing ac power at a preferred voltage and frequency level. The input dc power is obtained from existing power supply network. Here, the improvised inverter topology is observed for a single phase system.

Figure 1 shows the generalized schematic of ZSI in which the dc supply is provided by a rectifier circuit or a battery. Ac loads need non-adjustable voltage that is fed by the inverters that is compatible with the load requirements. To conquer the above problem of VSI and CSI here, impedance fed power converter is preferred and

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various control techniques for performing dc to ac, ac to dc, ac to ac, dc to dc power conversions. The generalized ZSI structure is implemented [2]. It includes a unique impedance network to connect the converter main circuit to the power source for indicating unique requirements which is not available in VSI & CSI [4].

A two port network which is composed of inductor and capacitor which is attached to X shape and it is employed to provide an impedance source coupling the converter to load or to another converter [5-10].

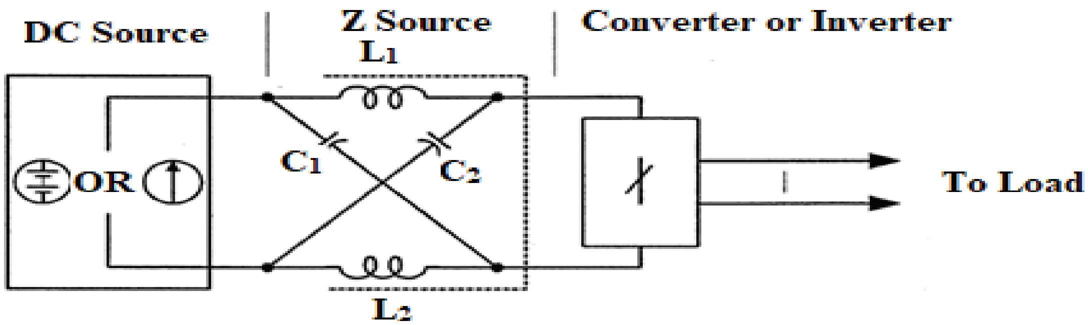

FIGURE 1. Structure of ZSI

EMBEDDED SWITCHED Z SOURCE INVERTER (ES-ZSI)

An ES-ZSI is a power inverter type, which is capable to do both shoot through and non-shoot through operation. It can act as a buck-boost inverter without depending on the dc-dc converter due to its unique network topology [3]. Schematic representation of ES-ZSI is represented in Fig.2.

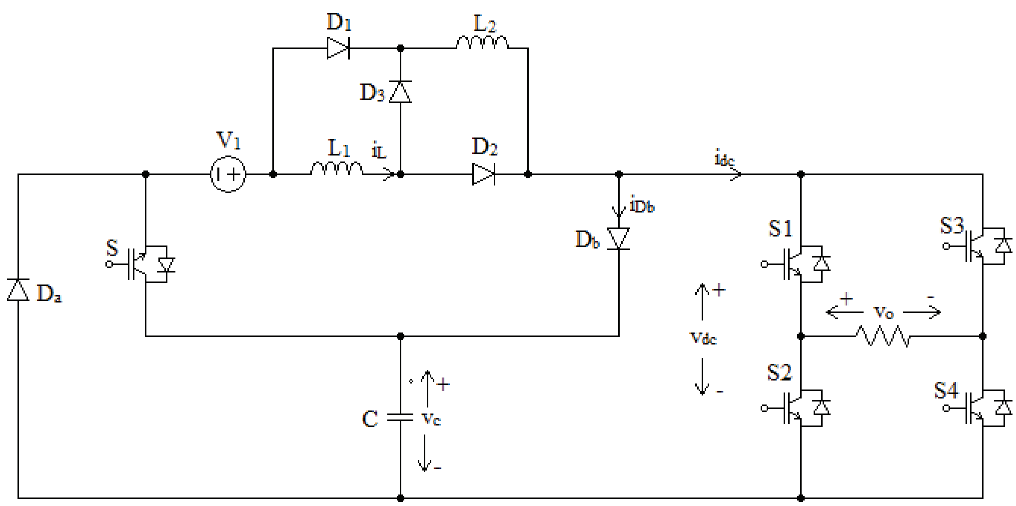

FIGURE 2. Structure of ES-ZSI

Fig. 2 represents the power network of ES-ZSI on the basis of switched inductor cell. In accordance to ES-ZSI, switched inductor cell is preferred [6-7]. This cell is made up of two inductors and three diodes. Various operating modes of ES-ZSI are listed below.

- ***Mode 1:*** In mode1, all the switches in accordance to switch S is turned on, during this stage the inverter leg is short circuited and acts in shoot through mode. Due to this, the voltage across diode D_a and D_b are negative and the diodes are turned off (Fig. 3).

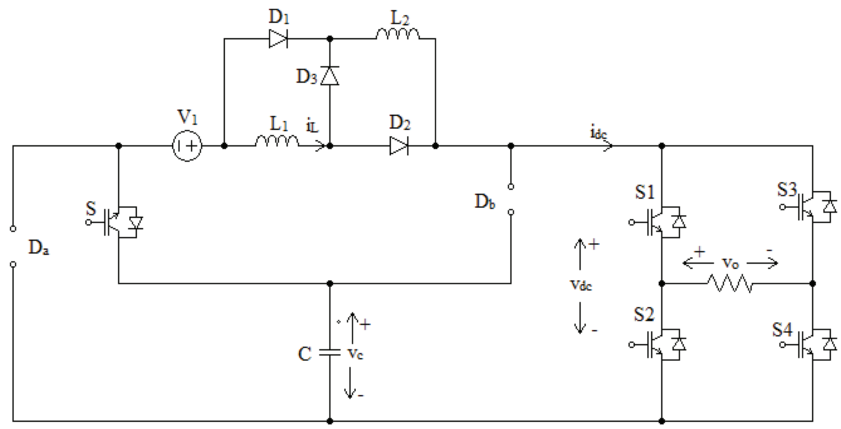

FIGURE 3. Mode l operation of ES-ZSI

- ***Mode 2:*** In mode2, positive half cycle takes place so switch S1&S4 is in on state and the other switches are turned off. The pictorial representation of mode 2 is shown in Fig.4.

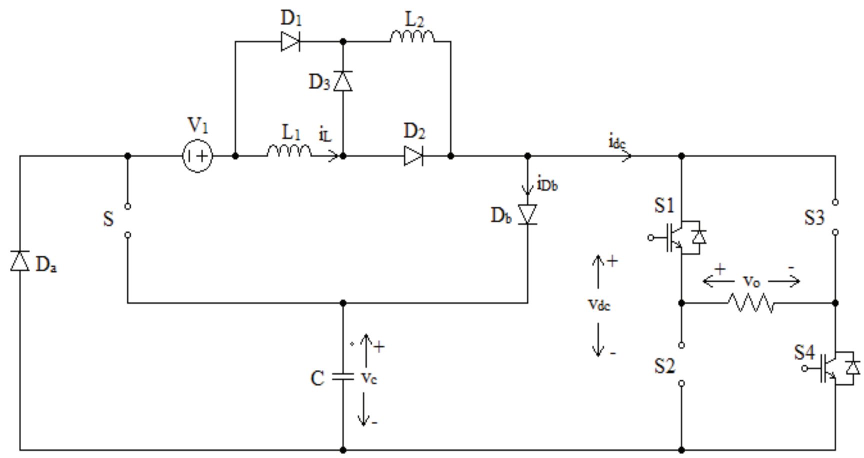

FIGURE 4. Mode 2 operation of ES-ZSI

- ***Mode 3:*** In mode3, negative half cycle takes so switch S2&S3 are turned on and the remaining switches are turned off. The pictorial representation of mode 3 is shown in Fig.5.

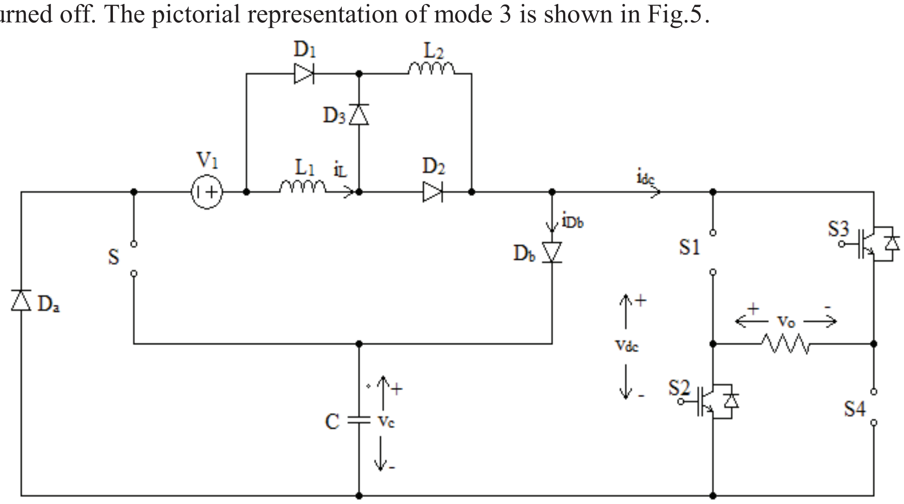

FIGURE 5. Mode 3 operation of ES-ZSI

PV SYSTEM MODELLING AND INTEGRATION

PV system includes subsystems required to convert solar energy into electrical energy for suitable load. The solar panel used in this work produces 21V (V_{oc}), 2.5A (I_{sc}) and 36W_{peak}. Figure 6 shows a simple equivalent circuit for a PV cell [1].

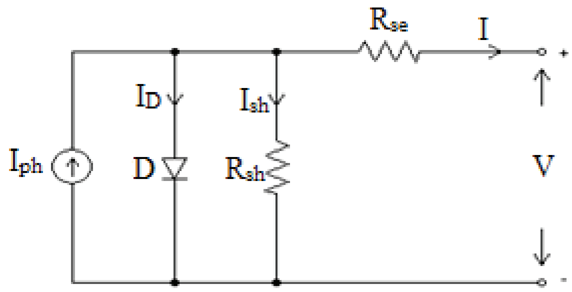

FIGURE 6. Equivalent circuit of PV cell

The output current of the PV module can be interpreted as a function of its output voltage which is obtained from [4] represented in Eq. 1.

$$I = I_{ph}(G,T) - I_D - \frac{V_D}{R_{sh}} \tag{1}$$

TABLE 1. Parameters of solar PV array

Datasheet Parameters	Speciifcations
Maximum power (P_{max})	111.24 W
Voltage at maximum power(V_{mp})	49.62 V
Current at maximum power(I_{mp})	2.55 A
Open circuit Voltage(V_{oc})	63.72 V
Short Circuit Current(I_{sc})	2.55 A
PV array sizing (series×parallel)	3×1

SIMULATION RESULTS

The proposed concept is implemented for input voltage V_{in} =48V and output voltage for buck mode is V_o = 24V and for boost mode is V_o = 96V; the output power P_o =100W at switching frequency of 15kHz. The other designed parameters of the ES-ZSI are listed in Table 2.

TABLE 2. Parameters of solar PV array

Datasheet Parameters	Speciifcations
Input voltage	48V
Load – R	55Ω
Switching frequency for S1,S2,S3,S4	15kHz
Switching frequency S	10kHz
Capacitor – C	47µF
Inductor – L	1.2µH

The simulation network of PV array module is represented in Fig.7. The characteristics obtained are presented in Fig.8.

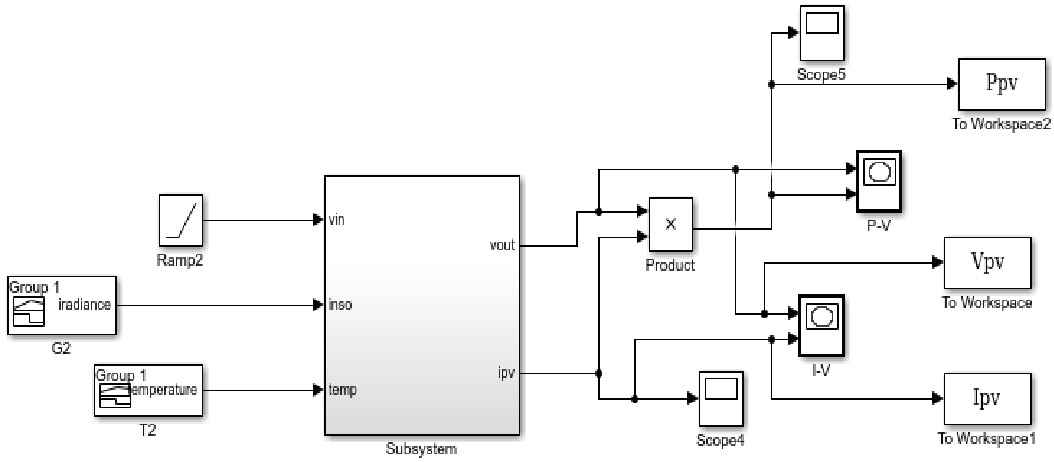

FIGURE 7. PV array model

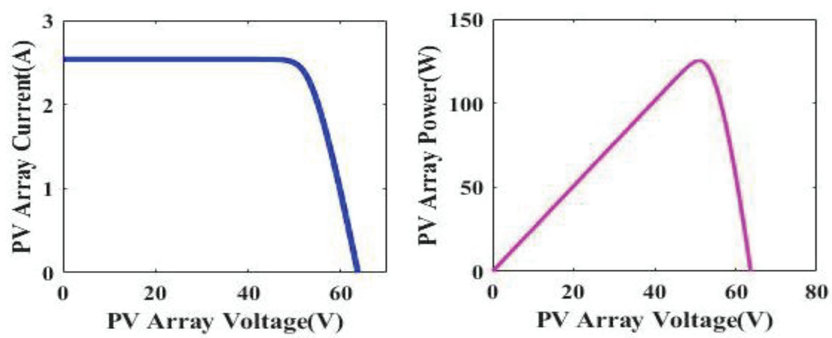

FIGURE 8. VI & VP characteristics

The simulation network of ES-ZSI is represented in Fig.9. The output obtained from ES-ZSI for input voltage of V_{in} = 48V in boost mode and buck mode are shown in Fig.10 & Fig.11. Interfacing PV and ES-ZSI by dc link capacitor is represented in Fig.12.

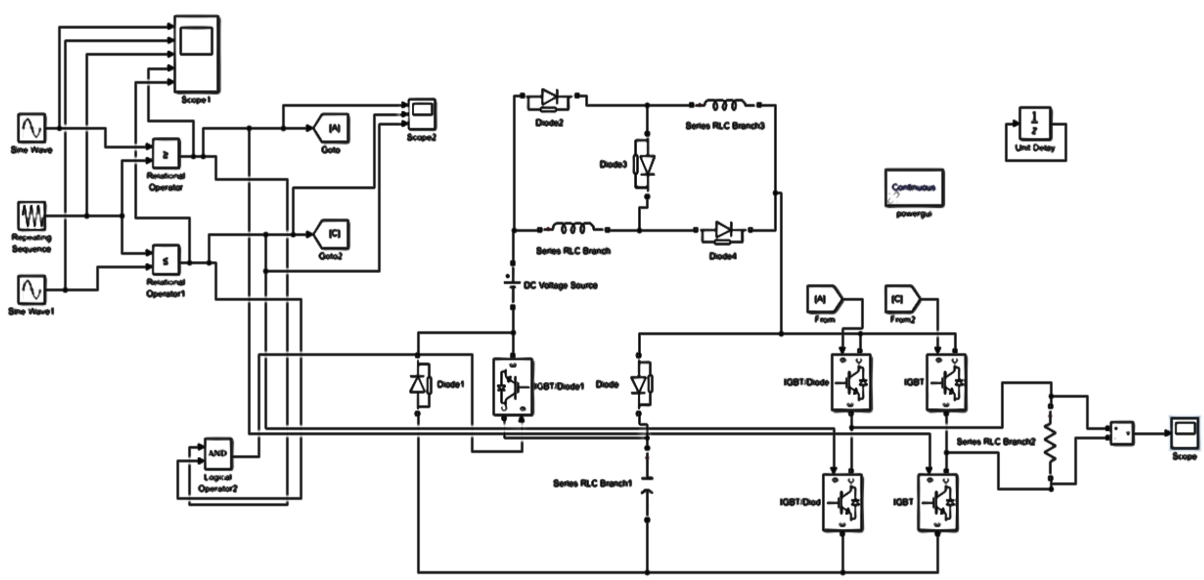

FIGURE 9. Simulation network of ES-ZSI

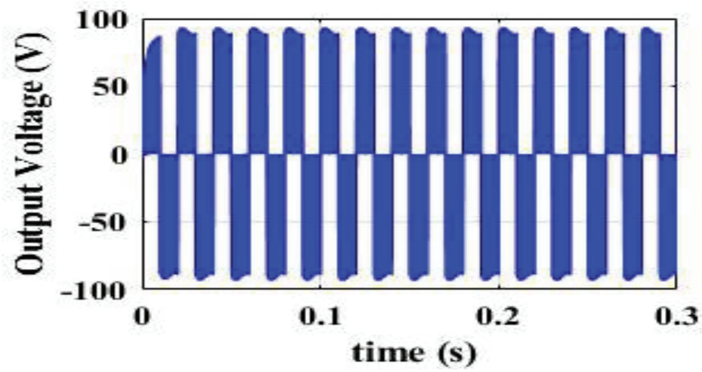

FIGURE 10. V_o in boost mode

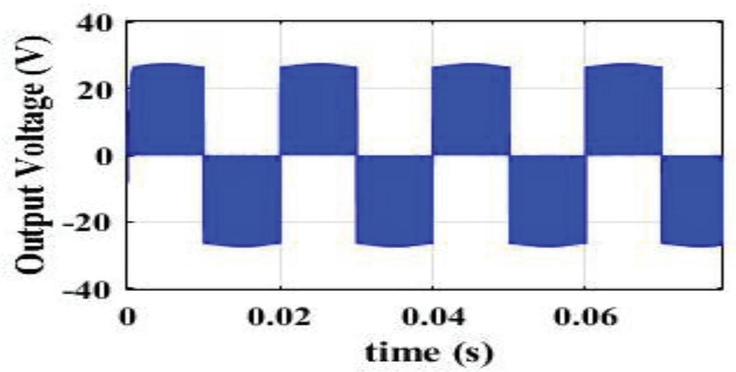

FIGURE 11. V_o in buck mode

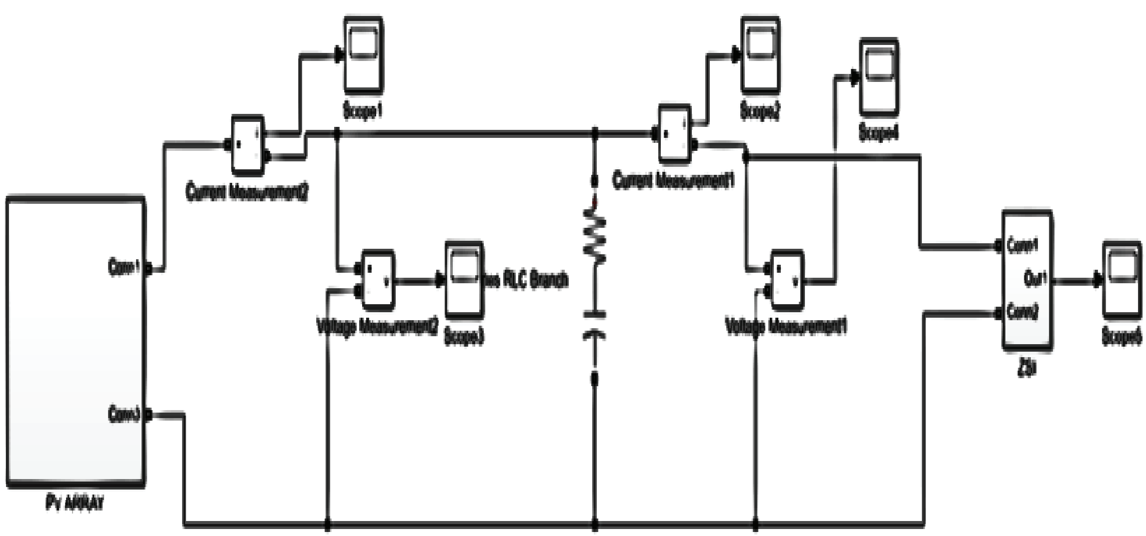

FIGURE 12. Interfacing PV and ES-ZSI

The PV side, dc link capacitor, output voltage and current waveforms obtained for both shoot through as well as non-shoot through modes for an input voltage of 48V are presented in Figs.13 and 14. The encircled portions in Fig.13 (shoot through mode) and Fig.14 (non-shoot through mode) represent the zoomed view of the waveforms, which show the less ripples in steady state.

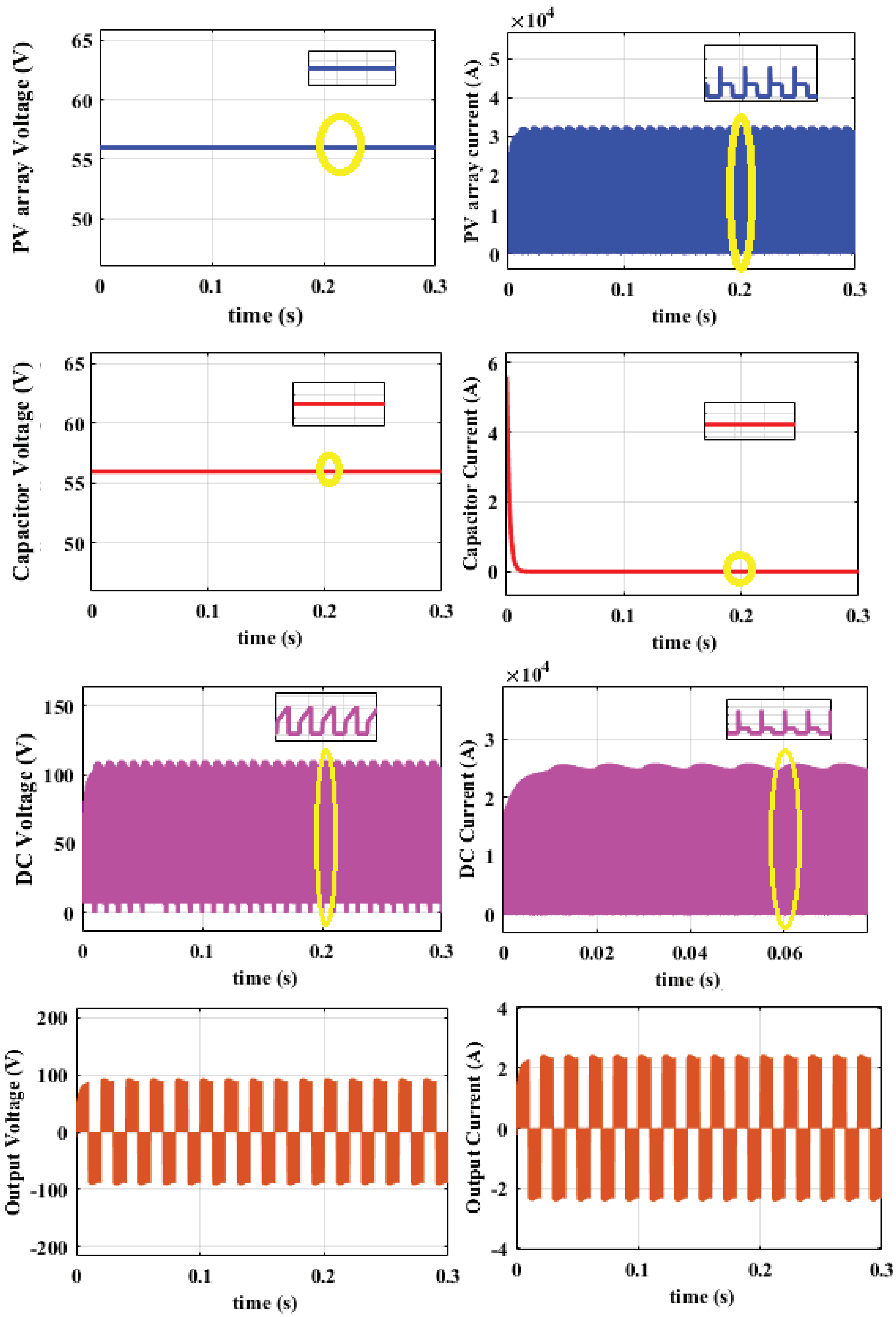

FIGURE 13. Shoot through mode waveforms

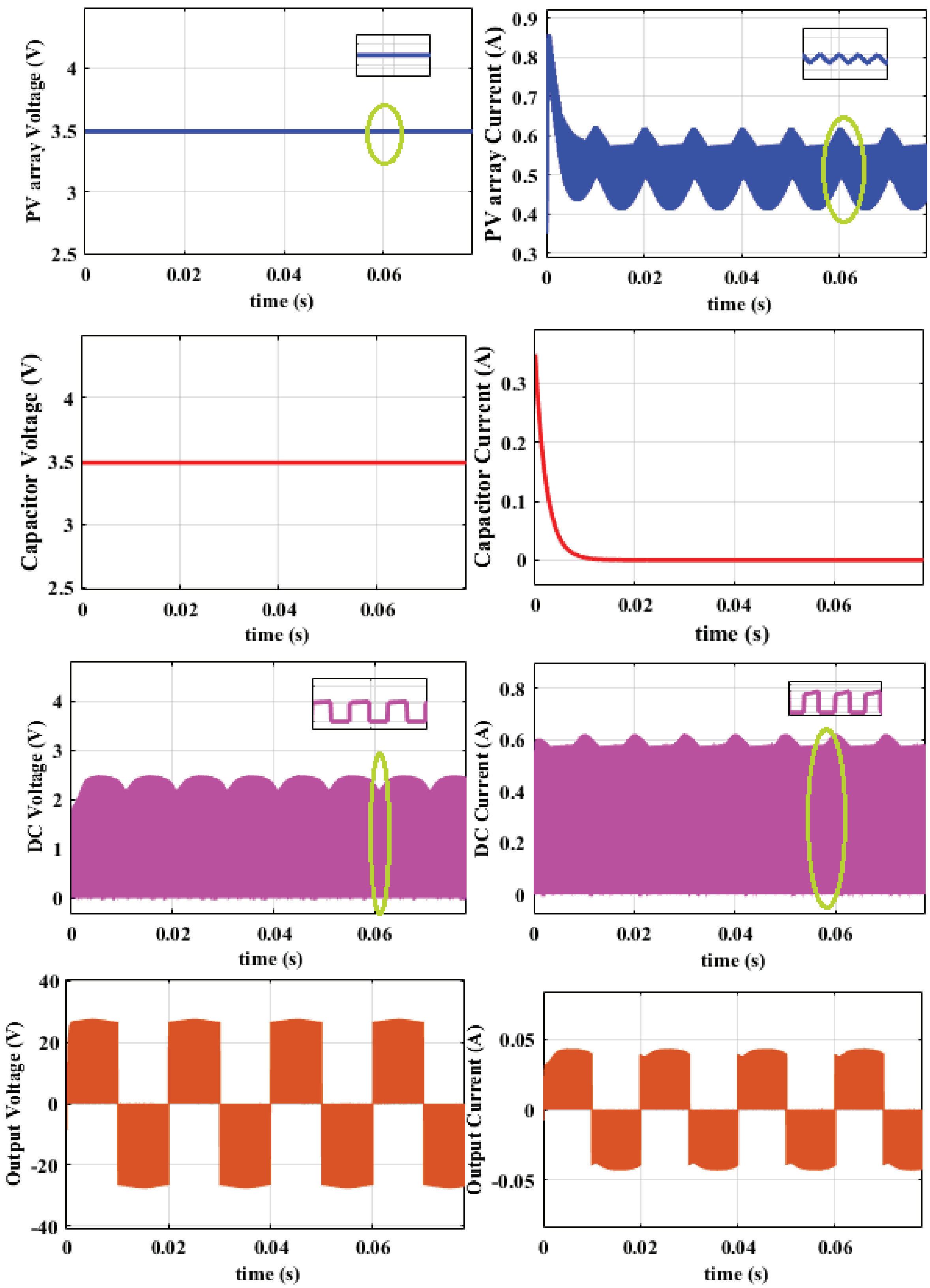

FIGURE 14. Non Shoot through mode waveforms

CONCLUSION

The implementation of developed Embedded Switched Z Source inverter using photovoltaic interface is simulated in this paper, for both buck and boost modes with the input voltage of 48V. The shorting of the inverter leg is resolved adding to the high output voltage gain of the inverter. Output voltage and current waveforms at different stages are obtained using MatLab and presented. The suitability of the proposed inverter for PV array interfacing was checked. As the inverter can capable of doing boost operation, the voltage fluctuations in the PV array side can be managed by the inverter as a single stage conversion unlike conventional PV inverters.

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