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"A Photovoltaic Applications Using BOOST DC-DC Converter for Voltage Regulation with Zero Voltage Switching"

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Abstract

In this paper, a DC-DC boost converter is used for a Solar PV Panel for a drive application. The DC-DC boost converter is performed using a, Zero Voltage Switching (ZVS) for a smooth and effective operation. The ZVS reduces the voltage stress during the switching of DC-DC boost converters. The Solar PV Panel is considered as the source of renewable energy for producing the DC supply. The Solar PV panel is designed to produce the maximum power out from the panel. The proposed method is performed in MATLAB Simulink for the various components and the results are analysed.

Keywords: *AC/DC converter, Continuous current mode (CCM), DC-DC converter, Interleaved boost converter, Power factor correction (PFC), Zero-current switching (ZCS), Zero-voltage switching (ZVS), Solar array.*

I. INTRODUCTION

A Photovoltaic energy source is capable of solving the problems of global warming and energy exhaustion, caused by increasing energy consumption. There is no air pollution or waste, and no mechanical vibration or noise. The output power of the solar cell can be changed easily by the surrounding conditions, such as irradiation and temperature. To transmit the power

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from the PV array to the load with higher efficiency, the interleaved soft switching boost converter is introduced. The presented converter can minimize switching losses, by adopting resonant soft switching [1] - [5]. The boost converter is a popular choice for most power electronic systems to serve as a pre-regulator, due to advantages of simplicity and high performance. In high-power applications, interleaving of two boost converters is very often employed to improve performance and to reduce the size. Because interleaving effectively doubles the switching frequency and also partially cancels the input and output ripples, the size of the energy-storage inductors and differential-mode EMI filter in interleaved implementations can be reduced [6]-[12].

II. INTERLEAVED BOOST CONVERTERS:

Interleaved buck and boost converters have been studied in recent years with the goal of improving power-converter performance in terms of size, efficiency, conducted electromagnetic emission and also transient response. The gains of interleaving consist of high power potential, modularity and better reliability. Since the inductor is frequently the largest and heaviest component in a high-boost converter, the use of a coupled inductor as a substitute of multiple discrete inductors is potentially beneficial. The coupled inductors also offer additional benefits such as reduced core and winding losses as well as better input and inductor current ripple.

Generalized steady-state analysis of multiphase IBCs has been previously reported. Useful design equations for continuous inductor current mode (CICM) operation of an IBC, including the effects of inductor coupling on the key converter performance parameters (inductor ripple current, input ripple current, and minimum load current requirement for achieving CICM operation), are detailed in Reports studying specific applications for coupled inductor topologies including soft switching, active clamping, and high power utilization are becoming more prevalent in the literature as understanding of their benefits increase[13].

III. OPERATION OF THE PROPOSED CONVERTER:

The operation of the boost converter is explained as following four modes and the proposed converter has given

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1. *Boost Converter*

A Boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. Battery power systems often stack cells in series to achieve higher voltage. However, sufficient stacking of cells is not possible in many high voltage applications due to lack of space. Boost converters can increase the voltage and reduce the number of cells. Two battery-powered applications that use boost converters are hybrid electric vehicles (HEV) and lighting systems.

2. *Operating principle*

The coupled inductor T1 is represented as a magnetizing inductor Lm, primary and secondary leakage inductors Lk1 and Lk2, and an ideal transformer. In order to simplify the circuit analysis of the proposed converter, the following assumptions are made.

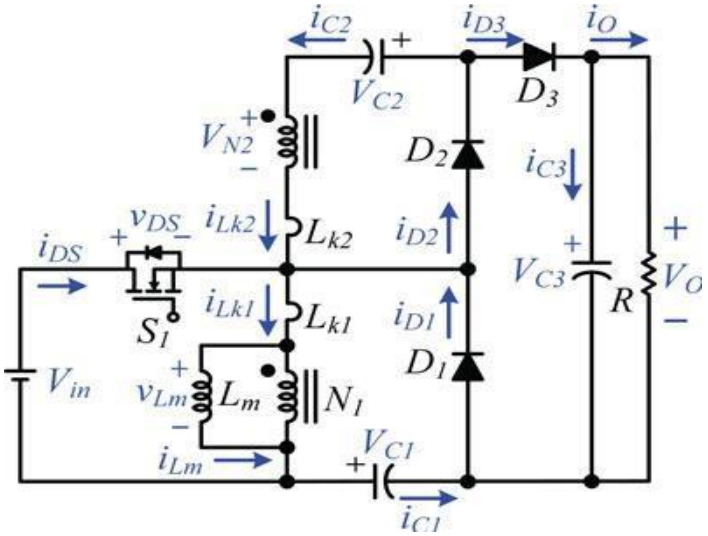


Figure: 1

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All components are ideal, except for the leakage inductance of coupled inductor T1, which is being taken under consideration. The on-state resistance RDS(ON) and all parasitic capacitances of the main switch S1 are neglected, as are the forward voltage drops of diodes D1 D3 .

1) The capacitors C1 ~ C3 are sufficiently large that the voltages across them are considered to be constant.

2) The ESRof capacitorsC1 ~C3 and the parasitic resistance of coupled inductor T1 are Neglected.

3) The turns ratio n of the coupled inductor T1 windings is equal to N2 /N1.

The operating principle of continuous conduction mode (CCM) is presented in detail. The current waveforms of major components are there. There are five operating modes in a switching period.

3. CCM Operation

Mode I [t0 , t1]: In this transition interval, the magnetizing inductor Lm continuously charges capacitor C2 through T1 when S1 is turned ON. Switch S1 and diode D2 are conducting. The current iLm is decreasing because source voltage Vin crosses magnetizing inductor Lm and primary leakage inductor Lk1 ; magnetizing inductor Lm is still transferring its energy through coupled inductor T1 to charge switched capacitor C2 , but the energy is decreasing; the charging current iD 2 and iC2 are decreasing. The secondary leakage inductor current iLK2 is declining as equal to iLm / n. Once the increasing iLk1 equals decreasing iLm at t = t1, this mode ends.

Mode II [t1, t2]: During this interval, source energy Vin is series connected with N2 , C1 , and C2 to charge output capacitor C3 and load R; meanwhile magnetizing inductor Lm is also receiving energy from Vin . The iLm, iLk1 , and iD3 are increasing because the Vin is crossing Lk1 , Lm, and primary winding N1 ; Lm and Lk1 are storing energy from Vin ; meanwhile Vin is also serially connected with secondary winding N2 of coupled inductor T1 , capacitors C1 , and C2 , and then discharges their energy to capacitor C3 and load R. The iin , iD 3 and discharging current |iC1 | and |iC2 | are increasing. This mode ends when switch S1 is turned OFF at t = t2

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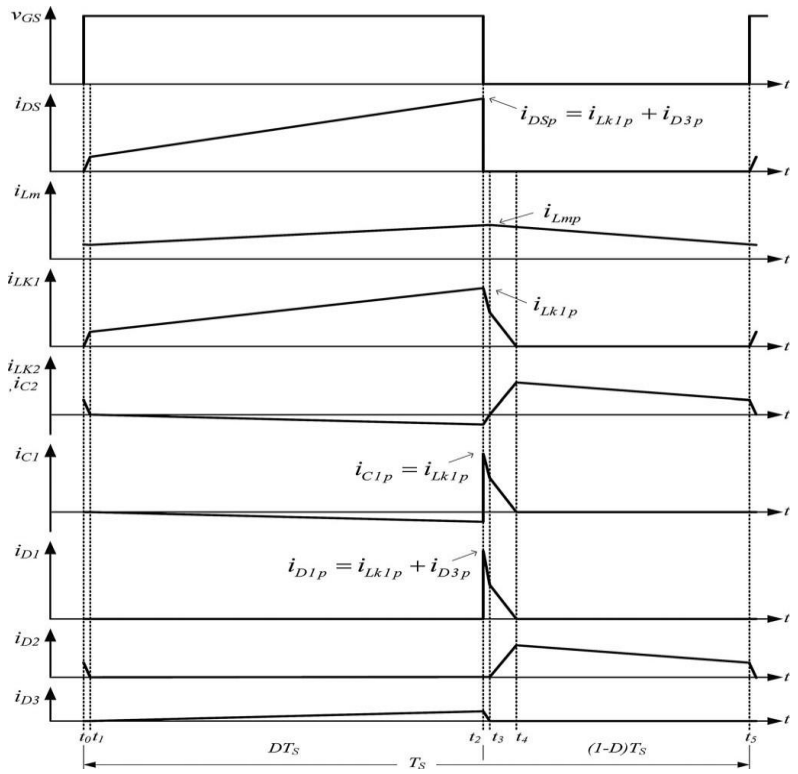


Figure: 2

Mode III [t2, t3]: During this transition interval, secondary leakage inductor Lk2 keeps charging C3 when switch S1 is OFF. The current flow path is shown in Fig. 5(c), where only diode D1 and D3 are conducting. The energy stored in leakage inductor Lk1 flows through diode D1 to charge capacitor C1 instantly when S1 is OFF. Meanwhile, the energy of secondary leakage inductor Lk2 is series connected with C2 to charge output capacitor C3 and the load, because leakage inductance Lk1 andLK2 are far smaller thanLm, iLk2 rapidly decreases, but iLm is increasing because magnetizing inductor Lm is receiving energy from Lk1. Current iLk2 decreases until it reaches zero; this mode ends at t = t3.

Mode IV [t3, t4]: During this transition interval, the energy stored in magnetizing inductor Lm is released to C1 and C2 simultaneously. The current flow path is shown in Fig. 5(d). Only diodes D1 and D2 are conducting. Currents iLk1 and iD1 are continually decreased because the leakage energy still flowing through diodeD1 keeps charging capacitor C1. The Lm is delivering its energy through T1 and D2 to charge

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capacitor C2. The energy stored in capacitor C3 is constantly discharged to the load R. These energy transfers result in decreases in iLk1 and iLm but increases in iLk2 . This mode ends when current iLk1 is zero, at t=t4

Mode V [t4 , t5]: During this interval, only magnetizing inductor Lm is constantly releasing its energy to C2 . The iLm is decreasing due to the magnetizing inductor energy flowing through the coupled inductor T1 to secondary winding N2 , and D2 continues to charge capacitor C2 . The energy stored in capacitor C3 is constantly discharged to the load R. This mode ends when switch S1 is turned ON at the beginning of the next switching period.

4. DCM Operation

Mode I [t0, t1]: During this interval, source energy Vin is series connected withN2, C1, and C2 to charge output capacitor C3 and load R; meanwhile, magnetizing inductor Lm is also receiving energy from Vin.

The iLm, iLk1 , and iD3 are increasing because the Vin is crossing Lk1 , Lm, and primary winding N1 ; Lm and Lk1 are storing energy from Vin ; meanwhile, Vin also is serially connected with secondary winding N2 of coupled inductor T1 , capacitors C1, and C2 ; then they all discharge their energy to capacitor C3 and load R. The iin , This mode ends when switch S1 is turned OFF at t = t1.

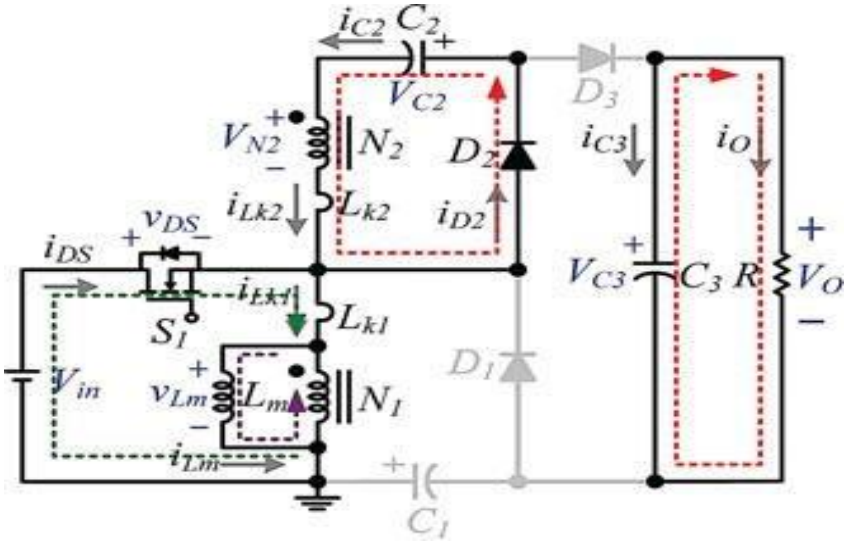


Figure: 3

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Mode II [t1, t2]: During this transition interval, secondary leakage inductor Lk2 keeps charging C3 when switch S1 is OFF. Only diode D2 and D3 are conducting. The energy stored in leakage inductor Lk1 flows through diode D1 to charge capacitor C1 instantly when S1 is OFF. Meanwhile, the energy of secondary leakage inductor Lk2 is series-connected with C2 to charge output capacitor C3 and the load. Because leakage inductance Lk1 andLK2 are far smaller than Lm, iLk2 decreases rapidly, but iLm is increasing because magnetizing inductor Lm is receiving energy from Lk1 . Current iLk2 reduces down to zero, and this mode ends at t = t2. **See Figure: 4**

Mode III [t2, t3]: During this transition interval, the energy stored in coupled inductor T1 is releasing to C1 and C2. Only diodes D1 and D2 are conducting. Currents iLk1 and iD1 are continually decreased because leakage energy still flowing through diode D1 keeps charging capacitor C1. The Lm is delivering its energy through T1 andD2 to charge capacitorC2 .The energy stored in capacitor C3 is constantly discharged to the load R. These energy transfers result in decreases in iLk1 and iLm but increases in iLk 2. This mode ends when current iLk1 reaches zero at t = t3. **See Figure: 5**

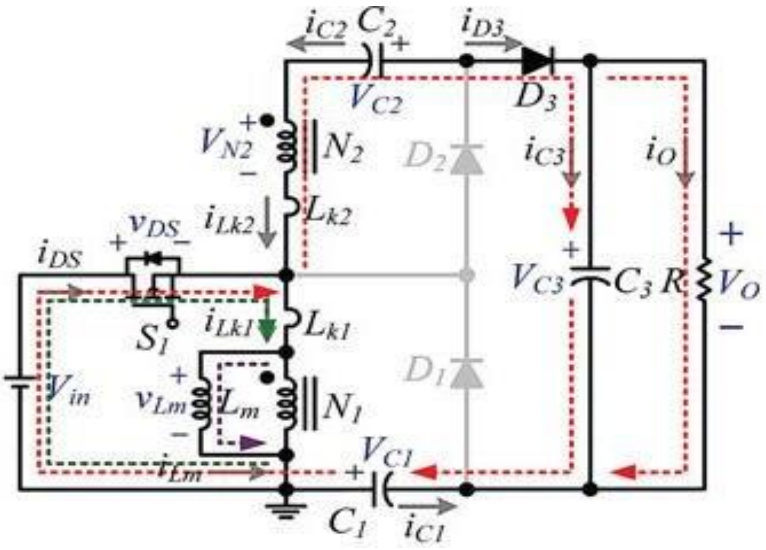


Figure: 4

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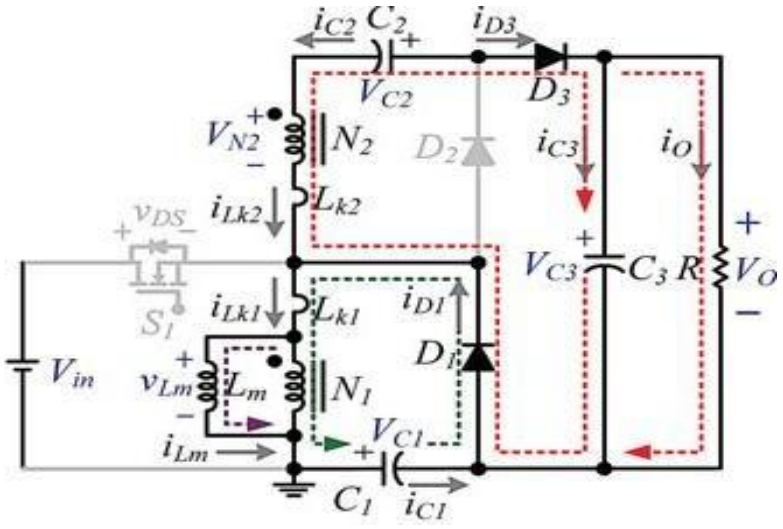


Figure: 5

Mode IV [t3 , t4]: During this interval, only magnetizing inductor Lm is constantly releasing its energy to C2 . Only diodeD2 is conducting.

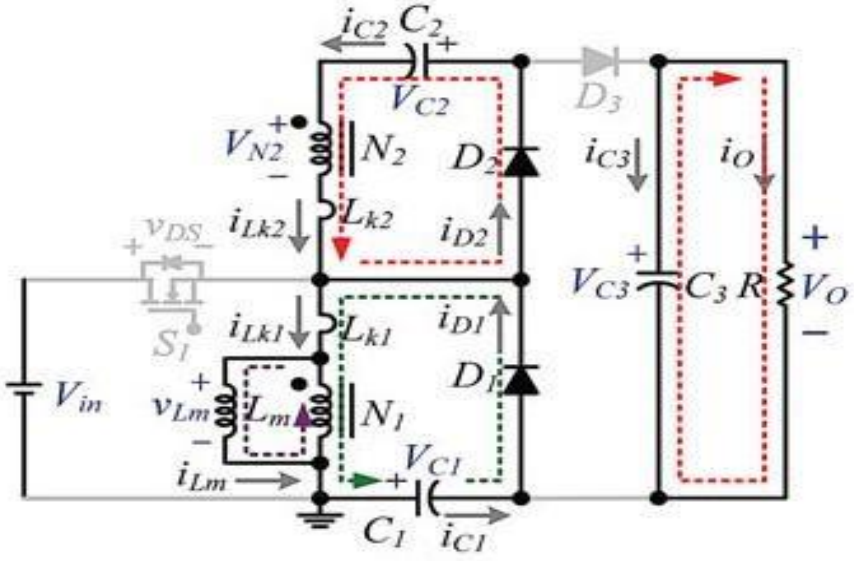


Figure: 6

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The iLm is decreasing due to the magnetizing inductor energy flowing through the coupled inductor T1 to secondary winding N2 , and D2 continues to charge capacitor C2 . The energy stored in capacitor C3 is constantly discharged to the load R. This mode ends when current iLm reaches zero at t = t4.

Mode V [t4 , t5]: During this interval, all active components are turned OFF; only the energy stored in capacitor C3 is continued to be discharged to the load R. This mode ends when switch S1 is turned ON at the beginning of the next switching period.

IV. SIMULATIONS RESULTS

In this paper the DC–DC boost converters with new coupled inductor for the solar power applications. This has to achieve high step-up voltage gain by adjust the turn's ratio of the coupled inductor and varying the capacitor with proper rating of all the parameters.

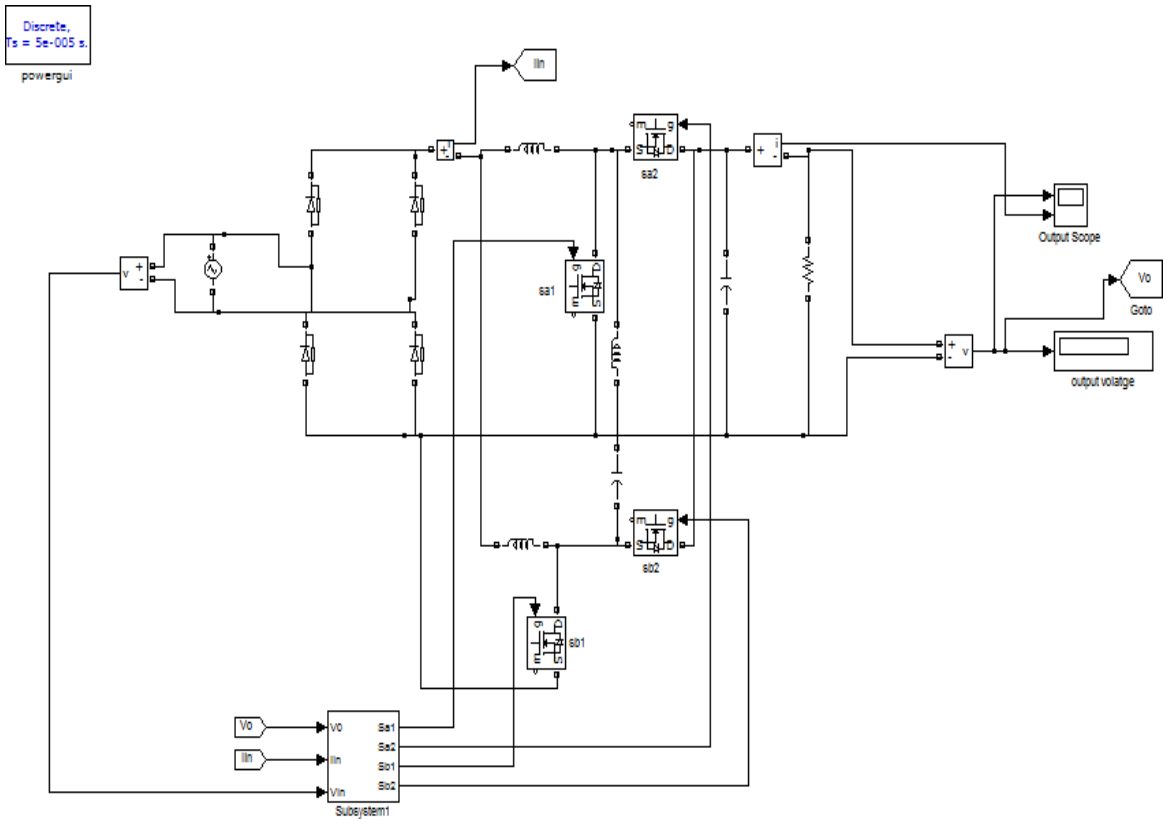


Fig. 7 Proposed AC-DC interleaved Boost Converter

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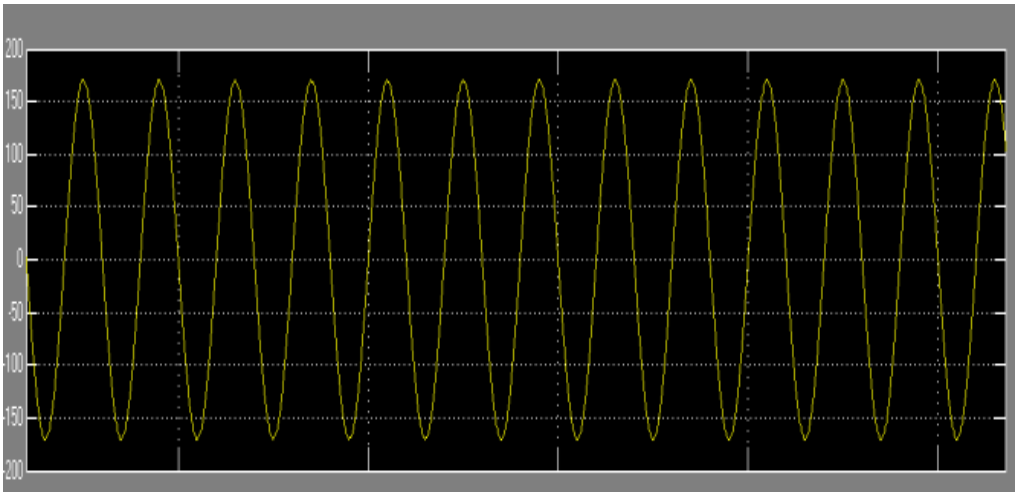


Fig: 8 Input Voltages

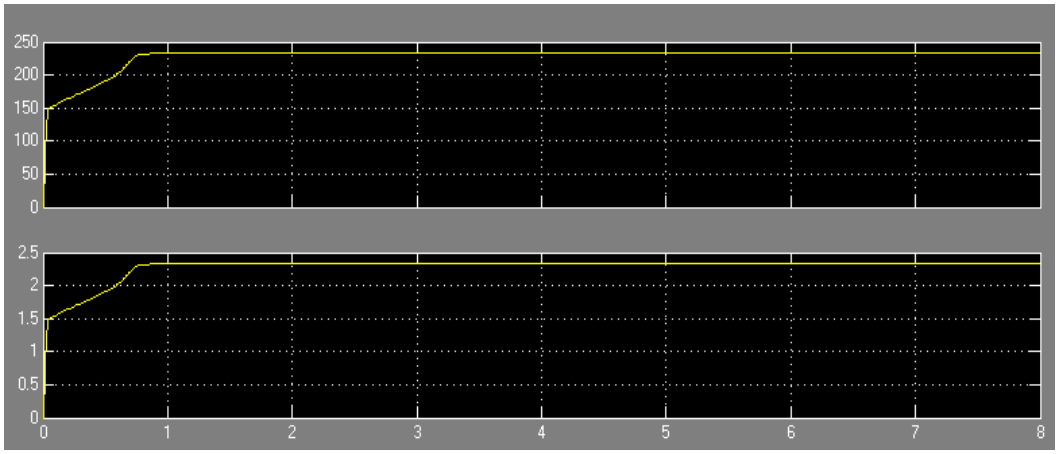


Fig: 9 Output Voltages and Current.

CONCLUSION

In this paper, ZVS based interleaved boost converter is analysed and the operating principle is explained using MATLAB simulation and mathematical equations. The ZVS and ZCS techniques are used to reduce the stress in input and output voltages/currents, reducing the switching losses, reducing the size of filter capacitor and overall cost. When compared to conventional switching methods the proposed method is improving the overall performance as well as increasing the efficiency of the converter. Interleaved boost converter is used in power electronics applications like Photovoltaic converters, fuel cell applications, and power factor correction circuits.

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