Design and Analysis of a Dc to DC Boost Converter Renewable Energy Sources

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Abstract-*Renewable energy source are evolved from natural sources. Photovoltaic cell (PV cell) is commonly used as Renewable energy sources. A derived DC-DC boost converter is suggested for reliable renewable energy sources. A DC to DC Boost converter topology is discussed in this paper for renewable energy sources. The merits of this methodology are reduced EME (Electromagnetic emission), low input current ripple and fast transient response. In suggested topology, an auxiliary inductor and 2 identical inductors are used to reduce the switching loss and switching stress of Boost Converter connected with PV system, used Pulse width modulation technique for fire the switches. The performance of Boost Converter along with PV cell system is analyzed by Matlab/Simulation software*

Keywords-DC-DC Converter, EME, ZVS, PWM technique.

I. INTRODUCTION

Power converters are mostly employed in where boosting is required for different applications DC to DC Boost converters are usually given as pre-regulators or even integrated with the latter stage circuits or rectifiers into single-stage circuits [1- 2]. Most renewable energy sources, such as photovoltaic have quite low voltage output and require series connection or a Dc to dc voltage booster to provide enough voltage output.

Some soft-switching techniques, gaining the features of zero-current switching (ZCS) or zero-voltage switching (ZVS) for DC-DC converters, have been proposed to substantially reduce switching losses, hence, gain high efficiency at increased frequencies. There are many quasi-resonant or resonant converters with the advantages of ZVS or ZCS [7]. The main problem with these kinds of power converters is that the DC voltage stresses on the power switches are too high in the resonant converters. Passive snubbers achieving Zero Voltage Source are attractive [3]-[4], since no extra active power switches are required, and therefore, feature a simpler control scheme and lower cost.

Power Converters with interleaved operation are fascinating techniques nowadays. An interleaved converter with a coupled inductor is proposed to provide a lossless clamp [5]. Additional active switches are also added to provide soft-switching characteristics. These converters are able to provide lower output ripple and higher output power.

This paper focus on soft switching technique for an Dc to Dc boost converter composed of two shunted elementary DC to DC boost conversion units and an auxiliary inductor [6]. This system is able to turn on both the active power electronics switches at zero voltage to reduce their switching losses and evidently get the higher conversion efficiency. Since the two parallel operated boost units are similar, operation analysis and design for the this DC to Dc power converter module becomes simple. The simulation results show that this DC to Dc power converter module performs very well with the output efficiency as high as 97%.

II. PHOTOVOLTAIC SYSTEM AND DC TO DC BOOST CONVERTER CIRCUIT CONFIGURATION

Solar cells produce current when Sun-light falls on them. In this paper the solar photovoltaic cell is simulated for any ambient temperature, sun-light intensity and other internal parameters. An equivalent circuit is developed for easy analysis of solar photovoltaic cell. The photovoltaic cell is a electrical device, which produces electrical power when exposed to sun-light and they are connected to Dc to DC boost converter. In proposed model the current is considered as controlled constant current source, and the voltage changes based on the Sunlight irradiation level. So the equivalent model contains a constant current source. The equivalent model is shown in Fig 1.

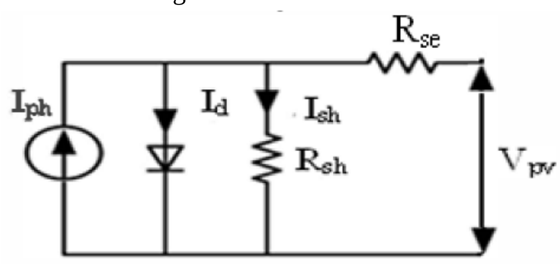

Fig.1. Equivalent Circuit for a Solar Cell

From the equivalent circuit, the current produced by the solar cell is given by,

$$I = I_L - I_D - I_{SH} \quad (1)$$

where,

I = Output current (Amperes)

I_L = Photo generated current (Amperes)

I_D = Diode current (Amperes)

I_{SH} = Shunt current (Amperes)

The current through these elements is governed by the voltage across them,

$V_j = V + IR_S$ (2)

where,

V_j = Voltage across both diode and resistor R_{SH} (Volts)

V = Voltage across the output terminals (Volts)

I = Output current (Amperes)

R_S = Series resistance (Ω)

By the Shockley diode equation, the current diverted through the diode is,

$$I_D = I_O\left\{exp\left[\frac{qV_j}{nkT}\right] - 1\right\} \quad (3)$$

where,

I_O = Reverse saturation current (Amperes)

n = Diode ideality factor (1 for an ideal diode)

q = Elementary charge

k = Boltzmann's constant

T = Absolute temperature

By Ohm's law, the current diverted through the shunt resistor is,

$$I_{SH} = \frac{V_j}{R_{SH}} \quad (4)$$

Substituting these into the Equation (1) produces the characteristic equation of a solar cell, which gives solar cell parameters to the output current and voltage,

$$I = I_L - I_O\left\{exp\left[\frac{q[V+IR_S]}{nkT}\right] - 1\right\} - \frac{V+IR_S}{R_{SH}} \quad (5)$$

The circuit is focused on higher power applications. The inductors L_1 and L_2 are probable to operate under continuous conduction mode, hence the peak inductor current can be alleviated along with less conduction losses on active power electronics switches. In continuous conduction mode operation, the inductances of L_1 and L_2 are related only to the current ripple specification. Inductances of L_S dominate the output power range and Zero Voltage Source operation.

Fig 2 shows the soft switching Dc to Dc boost converter system. Inductor L_1, IGBT active power electronics switch S_1, and D_1 diode comprise one step-up conversion unit, while the power electronics switch S_2 and D_2 forms the other one. D_{sx} and C_{sx} are the intrinsic anti-parallel diode and output capacitance of IGBT S_x respectively. The input voltage source V_{in}, via the two paralleled converters, replenishes output capacitor C_0 and the load.

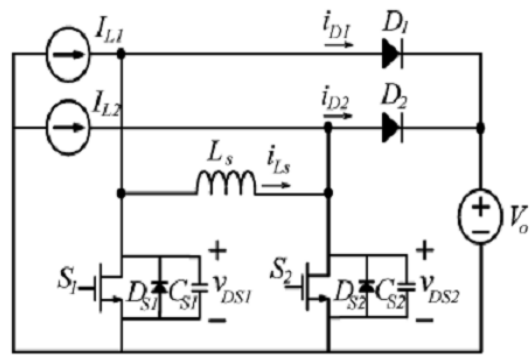

Fig 2. *Soft switching converter module*

Inductor L_s is connected with the two active power electronics switches to release the electric charge stored within the output capacitor C_{sx} prior to the turn ON of power electronics Switches S_x to fill zero-voltage turn ON (Zero Voltage Source), and therefore, increases the converter efficiency.

III. OPERATION OF Dc to Dc BOOST CONVERTER

Before examining on the circuit, the following assumptions are predefined.

1) The output capacitor C_0 should be large enough to neglect the output voltage ripple.
2) The forward voltage drops across IGBT S_1, S_2 and diodes D_1, D_2 are neglected.
3) Inductors L_1, L_2 have large inductance and their currents are identical constants, i.e., $L_1 = L_2 = I_L$.
4) Output capacitances of switches C_{s1} and C_{s2} have the same values, i.e. $C_{S1} = C_{S2} = C_S$
5) The two active switches S_1 and S_2 are operated with pulse width modulation control techniques. They are fired with identical frequencies and duty ratios. Rising edges of the two firing gate signals are separated apart for half of the switching cycles. The complete operation of the converter can be divided into eight modes, the equivalent circuits and waveforms are shown in Fig 3..

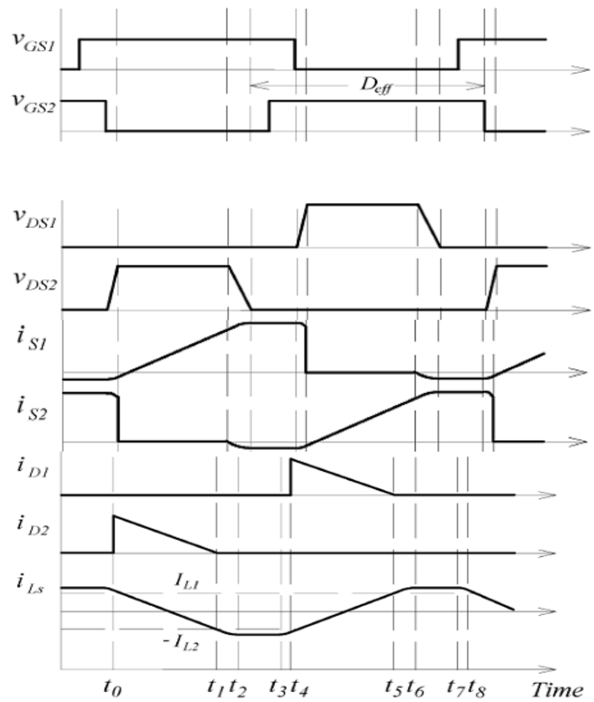

Fig.3. waveforms of Boost Converter

A. Mode I :{ t_0< t <t_1 referring to Fig 4.1}

Prior to this mode, the firing signal for switch S_2 has already transited to low state and the voltage v_{DS2} rises to V_0 at t_0. At the beginning of this mode, current flowing through S_2 completely commutates to D_2 to supply the load. Current i_{S1} returns from negative value toward zero; I_{L1} flows through Ls. Due to the zero voltage on v_{DS1}, the voltage across inductor Ls is V_0, i.e. i_{Ls} will decrease linearly at the rate of V_0/L_s. Meanwhile, the current flowing through S_1 ramps up linearly.

As i_{Ls} drops to zero, current i_{s1} contains only i_{L1} while i_{D2} equals. The current I_{L2} and current I_{LS} will reverse its direction and flow through S1 together with $I_{L1.}$ As i_{LS} increases in negative direction, i_{D2} consistently reduces to zero. At this moment i_{LS} equals I_{L2} diode D_2 turns OFF, and thus this mode comes to an end.

Despite the minor deviation of i_{S1} from zero and from i_{L1} currents, $i_{Ls} i_{S1}$ i_{D2} and the duration of this mode 1 can be approximated as

$$i_{ls}(t) = I_L - \frac{V_0}{L_S}t$$

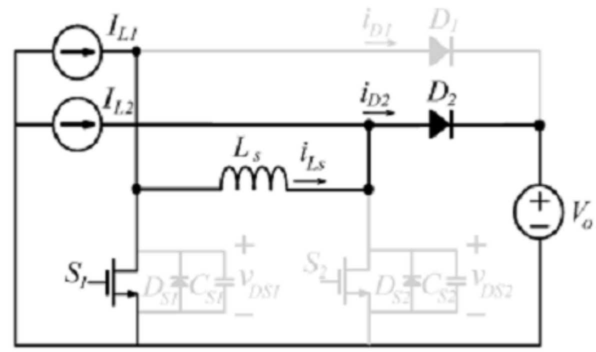

Fig 4.1.

$$i_{s1}(t) = \frac{V_0}{L_s}t$$

$$i_{D2}(t) = 2I_L - \frac{V_0}{L_S}t$$

$$t_{01} = \frac{\left(\frac{3}{4} - D_{eff}\right)T_S - sin^{-1}\left(V_0 \Big/ \left(V_0 + \frac{2I_L}{\omega C_S}\right)\right)}{\omega}$$

Where $D_{eff}$is the effective duty ratio to be explained later and

$$\omega = 1 \Big/ \sqrt{L_S C_S}$$

B. Mode II {t_1< t < t_2, referring to Fig 4.2}

Whereas diode D_2 stops conducting, capacitor C_{s2} is not clamped at V_0 anymore. The current flowing through $L_s$and i_{Ls} continues increasing and commences to discharge C_{s2}. This mode will terminate as voltage across switch S_2, v_{DS2} drops to zero. Voltage v_{DS2} and current i_{ls}can be equated as

$$v_{DS2}(t) = V_0 \cos\omega(\omega t)$$

$$I_{Ls}(t) = -V_0 \omega C_S \sin(\omega t) - I_L$$

$$t_{12} = \frac{\pi}{2\omega}$$

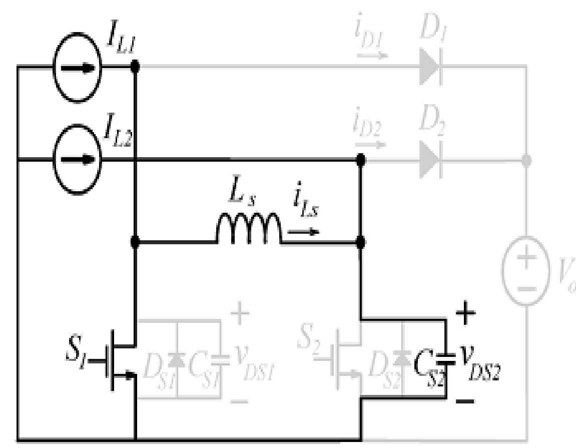

Fig.4.2.

C. Mode III {t2 < t < t3, referring to Fig 4.3}

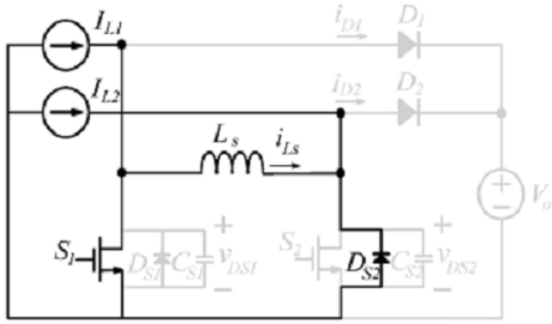

Fig.4.3.

At t = t_2, voltage v_{DS2} decreases to zero. After this instant D_{s2}, the anti-parallel diode of S_2 begins to conduct current. The negative directional inductor current i_{ls} freewheels through S_1 and D_{s2}, and holds at a magnitude that equals $i_{ls}(t2)$ a little higher than $I_{L.}$ During this mode, the voltage on switch S_2 is clamped to zero, and it is adequate to gate S_2 at zero-voltage turn ON.

D. Mode IV {t_3< t < t_4, referring to Fig 4.4}

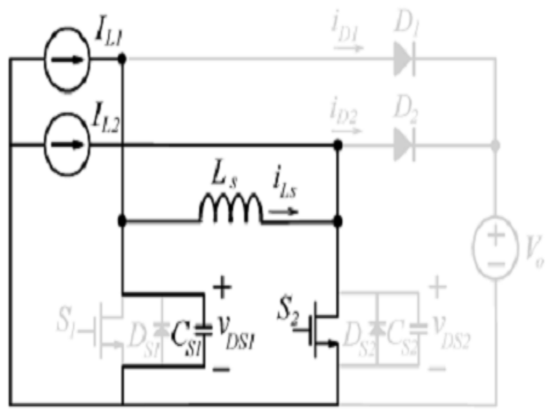

Fig.4.4.

The switch S_1 turns OFF at t = t_3. Current i_{LS}begins to charge the capacitor C_{S1} the charging current includes i_{LS} and I_{L1}. Since the capacitor C_{S1} retrieves a little electric charge, i_{LS}decreases a little and resonates toward $-I_{L2,}$ In fact, I_{LS}will not equal $-I_{L2,}$ at i_{LS}even with a slightly higher magnitude. However, by ignoring the some discrepancy, the voltage on switch S_1 and current through $L_S$can be approximated as while the capacitor voltage v_{CS1} ramps to V_0, D_1 will be forward biased, and thus this mode will come to an end.

Modes I-IV describes the scenario of power electronics switch S_2 between OFF-state proceeding to Zero voltage source turn -ON. Operations from modes V-VIII are the counterparts for switch S_1 due to the similarity, hence they are omitted here.

IV. SIMULINK MODEL

As above explanation the whole circuit is the combination of PV cell and an DC to DC boost converter, boost the small DC voltage to desired voltage level. Here the IGBT is replaced by IGBT/DIODE, has less switching losses. The complete simulink model is shown in fig 5.

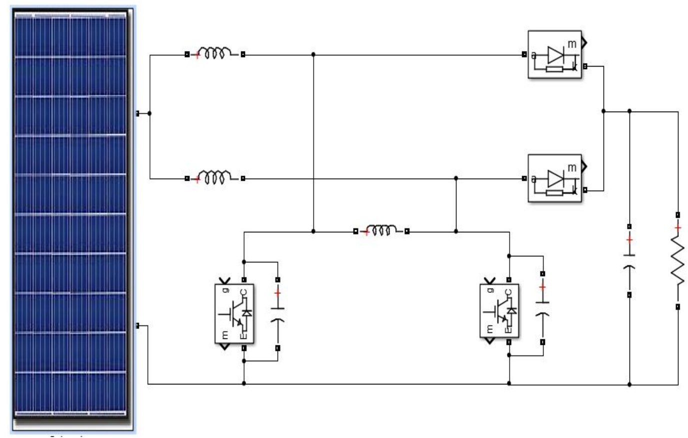

Fig.5. Simulink model of an Efficient Boost Converter

The parameters of the circuit are given in the table shown below.

Table.1.CIRCUIT PARAMETER

Parameters	**Values**
Shunt Resistance (R_{sh}) PV Cell	0.001Ω
Series Resistance (R_s) PV Cell	10000Ω
Inductors L_1& L_2	300μH
Output Capacitor	330μF
Inductor L_S	270μH
Input Voltage	18.77V
Output voltage	60.0V
Switching Frequency	20KHz

V. RESULTS

The Overall results are shown in fig 3 and the simulation result is shown in fig 9. The simulation result is almost equal to the theoretical results. The input DC voltage is achieved by photovoltaic cell and this PV cell voltage is boosted and with the help of a DC to DC Boost converter the small voltage is boosted.

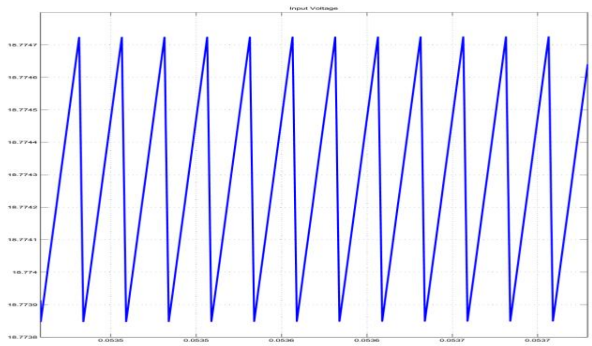
Fig 6. Input voltage ripple contents

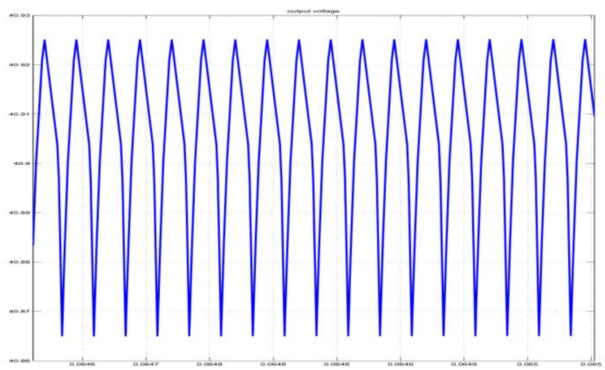
Fig.7. Output voltage ripple contents

The ripple contents of input DC voltage and output DC voltage is shown in fig 6 and 7 respectively.

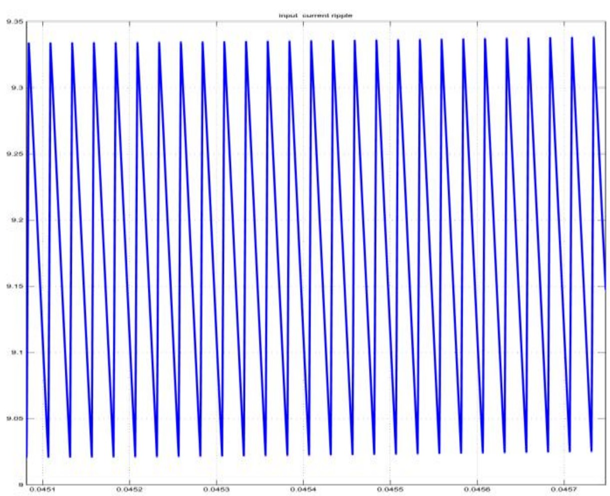
Fig.8. Input Current ripple

The ripple present in input current is very low, can be seen in fig 8.

Here shown the input power and output power of the circuit, which have 97% efficiency. Fig 10 showing the input and output power of the circuit.

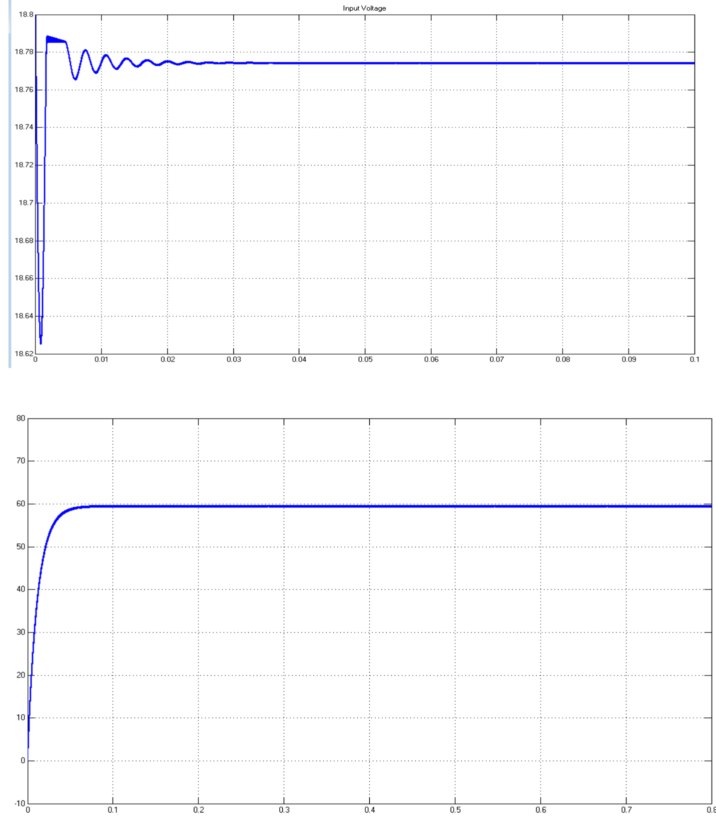
Fig.10. (a) Input voltage (b) Output Voltage

VI. CONCLUSION

This paper has proposed a dual boost converter with zero voltage turn-on. It inherits the merits of interleaved converters, i.e. low output voltage ripple. The detail analysis has presented the design and control equations. Inductor determines the performance of the converter. The converter can be controlled by varying switching frequency to deal with the fluctuation of input voltage and output load. In simulation result, the circuit efficiency achieves 97% due to its ZVS characteristics.

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