

A NOVEL TECHNIQUE FOR FAST ACTING MPPT FOR INTERLEAVED BOOST CONVERTER IN SOLAR PHOTOVOLTAIC SYSTEM

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Abstract—In this paper, a MPPT algorithm for soft switching modified Interleaved boost converter for solar PV system is proposed to reduce the switching losses in converter. Conventional DC-DC converters will operate at high frequencies which results in high switching voltage stress, high output voltage ripple and noise. These problems deteriorate the performance of conventional boost converters and lead to low voltage gain. To overcome the above problems, soft switching modified interleaved boost converter with dual coupled Inductors is used. Current ripple at the input side is minimized by parallel connected primary windings of two coupled inductors by sharing the input current. Output voltage ripple and switch voltage stress is minimized by series connected output capacitors. Moreover, secondary of two coupled inductors are connected in series to regenerative capacitor by a diode for boosting the input voltage from PV array and balancing the primary parallel currents through coupled inductors.

Keywords—PV System, MPPT Algorithm, DC-DC Converter, Soft Switching Interleaved Boost Converter

I. INTRODUCTION

Now a day's many industries requires high voltage gain DC-DC converters. For example Fuel-cells and solar photovoltaic system requires high step-up and large input current DC-DC converters to boost the low voltage to high voltage for a grid connected systems. High intensity discharge lamps, (HID), electric vehicles and back-up energy systems requires high voltage gain DC-DC converters to raise a battery voltage of 12v upto 100v at steady operation. [1],[2]. A low battery voltage of 48v needs to convert to 380v in some telecommunications systems and UPS by high step-up converters [3], [4]. Generally, in a boost converter the voltage gain is limited by the parasitic elements of the power devices, Inductor and capacitor. Moreover, a high duty ratio operation may include serious reverse recovery problem of diode rectifier and large ripple current which increases the conduction losses.

Many switching topologies based on the conventional boost converter had been presented for high step-up voltage gain [5]-[9]. In order to handle the high input currents and to reduce the ripple currents, interleaved boost control is introduced in boost converters. Voltage stress of the power devices is equivalent to output voltage in boost converters. Thus high switch voltage stress, diode reverse recovery problem are still major challenges. To solve aforementioned drawbacks, authors proposed a modified interleaved boost converter with dual Inductors and voltage multiplier to satisfy the high step-up applications and low input current ripple.

This paper proposes modified interleaved boost converters with dual Inductor for high step-up and high power applications. This configuration has the advantages of high voltage gain, low output ripple and a low voltage stress across the switches. The proposed converter is able to turn ON the active switches at zero current and minimizes the reverse recovery problem of diodes by reasonable leakage Inductances of the coupled Inductors.

II. SYSTEM MODELING

A. Mathematical Modeling of PV Array

A photovoltaic system converts solar energy into electricity. The PV technology uses photovoltaic cells which absorbs photons of light and release electron charges. Several PV cells are connected in series and parallel combination constitutes a PV panel or PV module to produce desired output power. The inverter is used to convert the DC power into AC. The energy extracted from the PV system is one of the reliable natural energy sources because of its eco friendly nature. To achieve the maximum efficiency, it is necessary to extract the maximum power from the PV panels.

The simple equivalent circuit of a PV cell consists of an ideal current source in parallel with an ideal diode is shown in Figure 1.

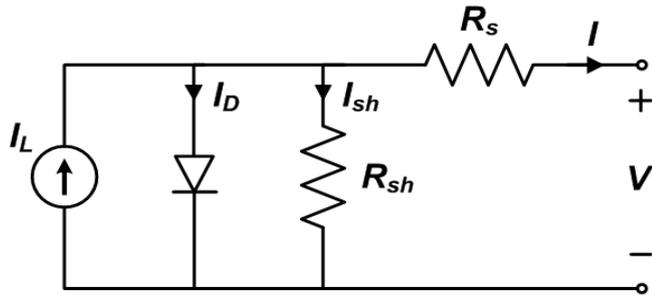


Figure 1 Equivalent model of the PV Cell

The series resistance R_s represents the internal resistance to the current flow. The shunt resistance R_{sh} is inversely related to leakage current to the ground. For an ideal PV cell, $R_s = 0$ (no series loss) and $R_{sh} = \infty$ (no leakage to ground). The typical values of $R_s = 0.05$ to 0.10Ω and $R_{sh} = 200$ to 300Ω . The energy conversion efficiency of PV cell is sensitive to small variations in R_s , but is insensitive to variations in R_{sh} . A small increase in R_s can decrease the PV output significantly.

The process of modeling of solar cell is developed based on the following equations [10], [11]. The output-terminal current I is equal to

$$I = I_L - I_D - I_{sh} \tag{1}$$

where,

I_L , Light generated current

I_D , Diode Current

I_{sh} , Shunt Leakage current

$$I = I_L - I_{0cell} \left(e^{\frac{q*V}{\alpha*k*T}} - 1 \right) \tag{2}$$

where,

$I_{0,cell}$: Reverse saturation current of the diode[A].

q : Electron charge [$1.60217646 \times 10^{-19}c$].

k : Boltzmann constant [$1.3806503 \times 10^{-23}J/k$].

T : Temperature of the p-n junction.

α : Diode identity factor which lies between 1&2 for mono crystalline silicon.

B. I-V and P-V Characteristics:

The V-I curve of the BP SX 150S PV module simulated with the MATLAB model as shown Figure 2. The V-I curve of PV module has unique operating point called maximum power point (MPP). The coordinates of this operating point are the operating voltage and current. At this MPP, the module operates with the maximum efficiency and produces the maximum output power.

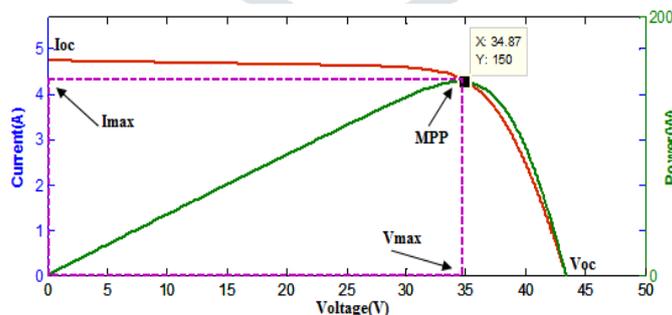


Figure 2 V-I curves of BPSX 150s PV module with MPP

C. Maximum Power Point Tracking Algorithm

The photovoltaic energy is an inexhaustible and clean energy resource. However, the capital cost of PV installation is high. Hence, it is necessary to maximize the output power without increasing the number of PV modules. The output power from the PV array varies with solar irradiance and temperature. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the PV array discussed in [12], [13]. The PV array has a unique operating point that can supply maximum power to the load. This point is called the maximum power point (MPP). The locus of this point has a nonlinear variation with solar irradiance and the cell temperature. Thus, in order to operate the PV array at its MPP, the PV system must contain a maximum power point tracking (MPPT) controller.

In MPPT controller, duty cycle is the control parameter. The MPPT controller tune the duty cycle (α) to its optimal value under variations in solar irradiance and temperature. The MPPT circuit consists of power circuit and the controller. The two configurations of MPPT scheme are shown in Figure 5. In this case, the duty cycle (α) is continuously tuned until the MPP is reached.

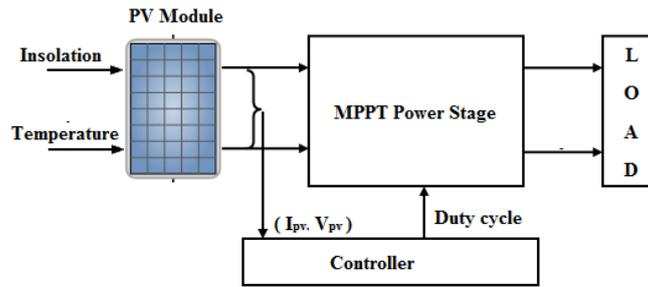


Figure 3 MPPT control through input parameters

D. DC-DC Converter

The output power of PV array varies with surrounding conditions such as change in irradiation and temperature etc. This affects the efficiency of PV system. Thus DC/DC converter is required to transfer power from PV array to load with high efficiency. In this research work modified interleaved boost converters with dual Inductor is designed.

III. PROPOSED SOFT SWITCHING INTERLEAVED BOOST CONVERTER(SSIBC)

The main part of MPPT hardware is a DC-DC converter the block diagram shown in Figure 4. It tracks the MPP and guarantees the DC link voltage under low irradiance condition. The conventional DC/DC converters such as buck, boost, buck-boost, cuk, sepic, and zeta converters etc. are operated under high switching frequencies resulting in high switching losses, noises, and component stresses. These problems deteriorate the performance of conventional boost converters and leads to the reduction of output power. To solve aforementioned drawbacks, authors proposed a modified interleaved boost converter with dual Inductors and voltage multiplier to satisfy the high step-up applications and low input current ripple.

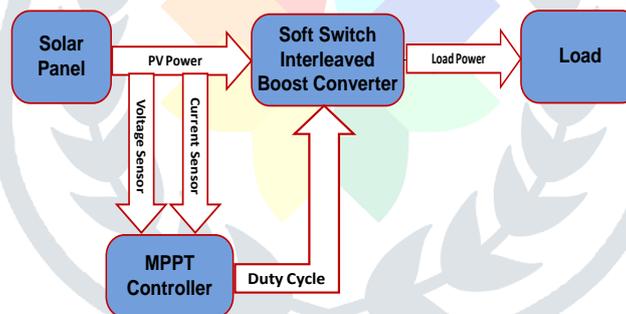


Figure 4 Block diagram of Proposed DC/DC conversion

A. Principle of operation of SSIBC

The proposed topology is shown in figure. The SSIBC of two single-phase boost inverters that are linked in parallel and inverters operating 180 degree out of phase with 30 kHz switching frequency, corresponding circuit and gate control diagrams as shown in Figure 5(a) and 5(b). This circuit having two parts (i) Modified Interleaved boost converter and (ii) voltage multiplier. The main functions of modified Interleaved boost control: (ii) low output ripple due to interleaved series connected capacitors (iii) low switch voltage stress

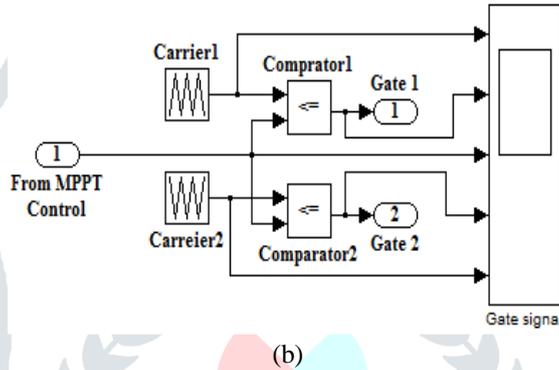
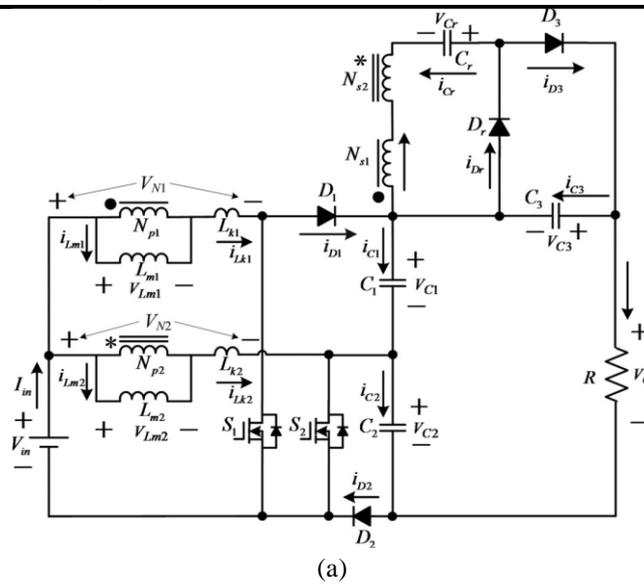


Figure 5 (a) Circuit diagram of SSIBC (b) Gate control signal

The operating stages can be explained as follows

First stage (t₀ – t₁):- At t=t₀, Power switch S₁ is turn ON with ZCS due to leakage Inductance L_{k1}, while S₂ remains turned ON, all the diodes are turned OFF except D₃. The current falling rate through D₃ can be controlled by leakage Inductances and minimizes the reverse recovery problem. The magnetizing Inductances L_{M1} and L_{M2}, leakage inductances L_{K1} and L_{K2} are linearly charged by the input voltage source V_{in}

Second stage (t₁ – t₂):- At t=t₁ switch S₂ is turn OFF, diodes D₂ and D_r turn ON. The input voltage source, magnetizing Inductances L_{K2} discharges the energy to C₂ through diode D₂. When total energy of leakage Inductance L_{K2} discharges completely to the capacitor and magnetizing Inductance L_{M2} still discharges energy to secondary side charging the capacitor C_r through diode D_r.

Second stage (t₂ – t₃):- A t= t₂ switch S₂ is turned ON with ZCS condition. S₁ remains in ON state. The current flowing through D_r is controlled by L_{K1} and L_{K2} which minimizes the diode reverse recovery problem.

B. Voltage Gain Expression

At stage second

$$V_0 = V_{c1} + V_{c2} + V_{c3} \tag{1}$$

At stage three

$$V_{cr} = V_{s1} - V_{s2} = KNV_{c2} \tag{2}$$

$$V_{c3} = V_{cr} + V_{s2} - V_{s1} = KN(V_{c1} + V_{c2}) \tag{3}$$

Voltage across the capacitors C₁ and C₂ are obtained as

$$V_{c1} = V_{c2} = \frac{V_{in}}{1 - D} \tag{4}$$

Voltage across the capacitors C₃ and C_r are obtained as

$$V_{c3} = \frac{2KN}{1 - D} V_{in} \tag{5}$$

$$V_{cr} = \frac{KN}{1 - D} V_{in} \tag{6}$$

Substituting (4) and (5) in (1) to obtain output voltage

$$V_0 = \frac{V_{in}}{1-D} + \frac{V_{in}}{1-D} + \frac{2KN}{1-D} V_{in} \quad (7)$$

Voltage gain is obtained as the ration of output voltage to the input voltage

$$\frac{V_0}{V_{in}} = \frac{2}{1-D} (1 + KN) \quad (8)$$

If the impact of leakage inductances is neglected the coefficient of coupling $K=1$. Then voltage gain is rewritten as

$$\frac{V_0}{V_{in}} = \frac{2(1+N)}{1-D} \quad (9)$$

The voltage stress on the power switches S_1 and S_2 are derived from

$$V_{s1-stress} = V_{s2-stress} = \frac{V_{in}}{1-D} = \frac{V_0}{2(1+N)} \quad (10)$$

The voltage stress on the diodes D_1 , D_2 , D_3 and D_r related to the turns ratio and the output voltage can be derived as

$$V_{D1-stress} = \frac{2V_{in}}{1-D} = \frac{V_0}{(1+N)} \quad (11)$$

$$V_{D2-stress} = \frac{V_{in}}{1-D} = \frac{V_0}{2(1+N)} \quad (12)$$

$$V_{D3-stress} = V_{Dr-stress} = \frac{2NV_{in}}{1-D} = \frac{NV_0}{(1+N)} \quad (13)$$

IV. RESULTS OF SIMULATION AND DISCUSSION

In this section proposed interleaved boost converter is connected between the SPR-305-WHT module and resistance. The boost converter is controlled by a MOSFET gate signal which are generated by considering the duty cycle from MPPT algorithm.

This paper aims at exhibiting the performance and efficiency of the proposed Boost converter and comparing with classical one .PV module was chosen to change the solar radiation, maintaining the temperature as constant at 25°C and the resistive load is 20Ω

First, MPPT Algorithm with incremental conductance was tested under the varying irradiance profile. Second, the proposed boost converter with MPPT Algorithm was also tested under same conditions. The varying radiations with both methods are exposed in fig 7 (a) & 7 (b).

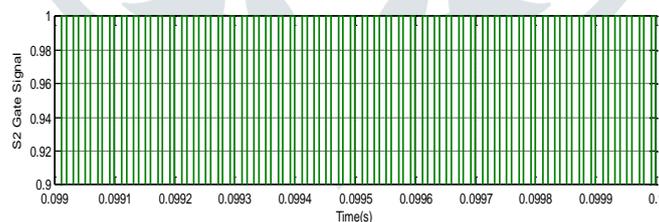
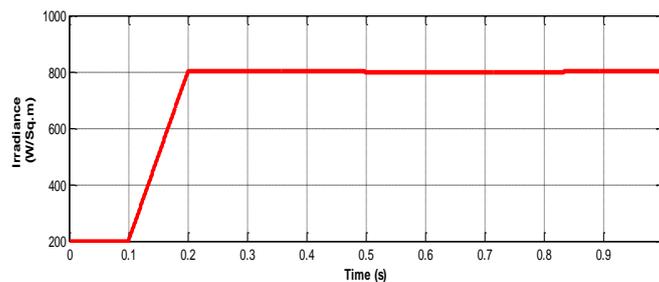
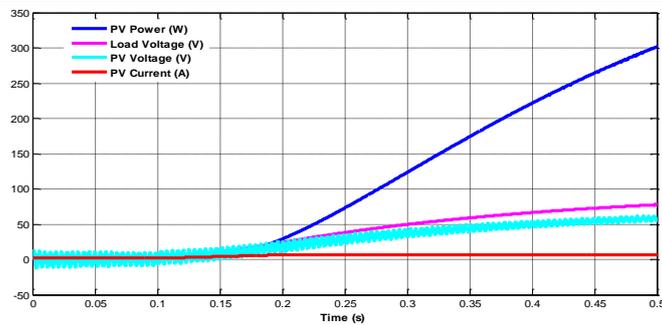


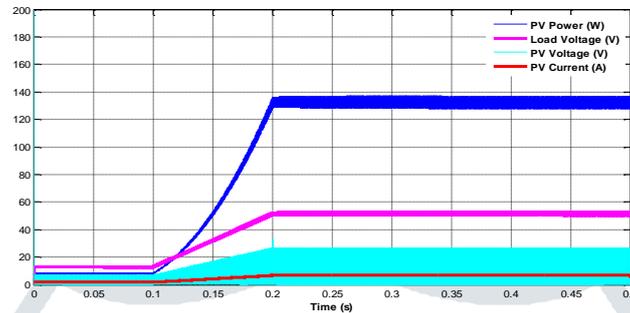
Fig 5: Control Gate signal of soft switch interleaved boost converter



(a)



(b)



(c)

Fig 7: Results of simulation: (a) irradiance, (b) with basic Incremental Conductance algorithm, (c) with interleaved boost converter.

From these results it can be confirmed that I_{pv} , P_{pv} are significantly affected by the variation of radiation than V_{pv} which is slightly effected. Also, by comparing V_{pv} and V_L , it can be confirmed that the soft switch interleaved boost converter is step-up voltage when compared with conventional boost converter.

Under standard test conditions ($G=1000\text{w/m}^2$, $T=25^\circ\text{C}$) the PV module generates 150W of power, 64.2 V of voltage and 5.96A of current. These output values vary when radiation level decreases or increases.

V. CONCLUSION

The proposed SSIBC is suitable to interface for PV cells to convert low voltage input into a high voltage output. The proposed boost interleaved converter with MPPT algorithm has advantages when compared to the classical boost converter are reduces voltage stress, faster transient response for varying irradiation, low input current ripple, high efficiency, reduction in electromagnetic emission and improved reliability.

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