

## Interleaved Boost Converter Using ZVT for Solar Energy Generation

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**Abstract.** Now a day energy demand is very essential, for that purpose introducing various power sources. This paper addresses a solar energy generation system. In order to overcome the increase of energy demand, it is necessary to make the PV generation system more flexible and expandable for that, the back stage power circuit is composed of a ZVT-Interleaved boost converter. For a typical solar-tracking electricity generation system output voltage is relative low. High voltage gain is necessary to improve the grid connected function. A full bridge inverter with bidirectional power flow which can stabilize the dc bus voltage and shape the output current. A simple MPPT method based on power balance is applied to reduce the system complexity and cost. A prototype has been build and tested to verify the theoretical analysis of the paper.

### 1. Introduction

The source of conventional energy are limited and every nation is planning to make an alternative arrangement to come out of the deficiencies of energy generating through depleting conventional sources of energy .So emphasis is given to the renewable energy programmes to keep the generating capacity upgraded. Solar energy is the energy that is present in sunlight. It is becoming cheaper to generate electricity from solar energy and in many ways it is competitive with other sources of energy like coal or oil.

- Increasing efficiency of PV cell, it becomes more cost.
- Efficiency of converter.
- Tracking the solar path to increase the use of solar energy.

### 2. Steady State Model of ZYT-Interleaved Boost Converter

Figure 1 shows the ZVT interleaved boost converter with winding coupled inductor. The winding coupled inductor Offer the voltage gain extension [1]-[4]. The active clamp circuits gives the ZVT commutation for the main switches and the auxiliary switches.  $S_1$  and  $S_2$  are the main switchers  $S_{c1}$  and  $S_{c2}$  are the active clamp switches.  $D_1$  and  $D_2$  are the output diodes. The coupling method of the winding inductor is marked by open circle and asterisks .The equivalent circuit model is shown in fig2 where  $L_1$  and  $L_2$  are the magnetizing inductor.  $L_{k1}$  and  $L_{k2}$  are the leakage inductance.  $C_1$  and  $C_2$  are the clamped

capacitors.  $N$  is the turns ratio  $n_2/n_1$ .

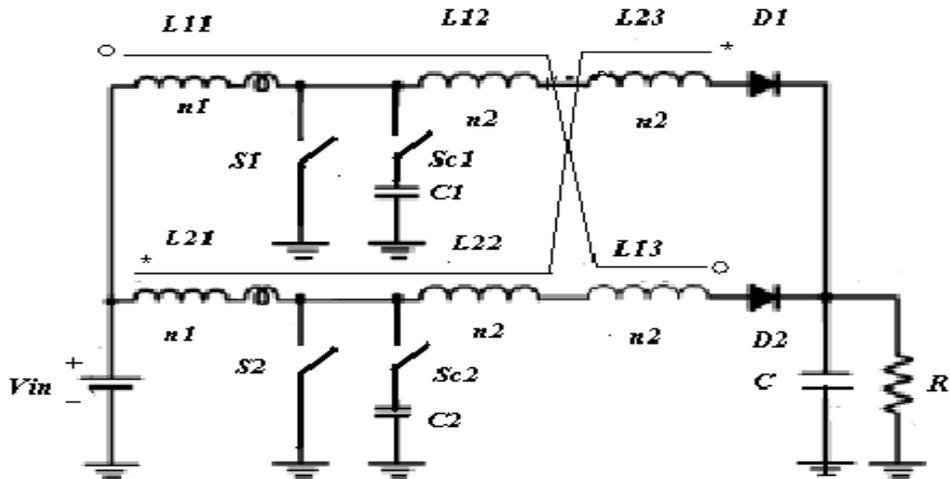


Figure 1: ZVT interleaved boost converter

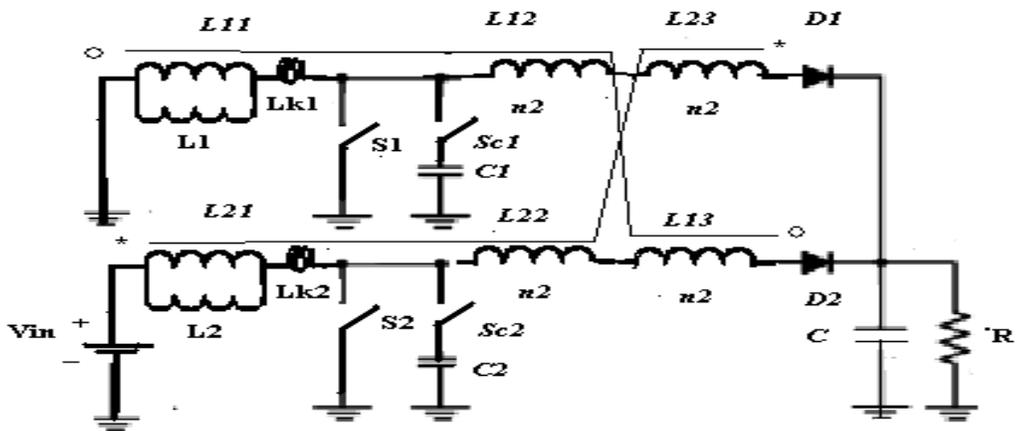
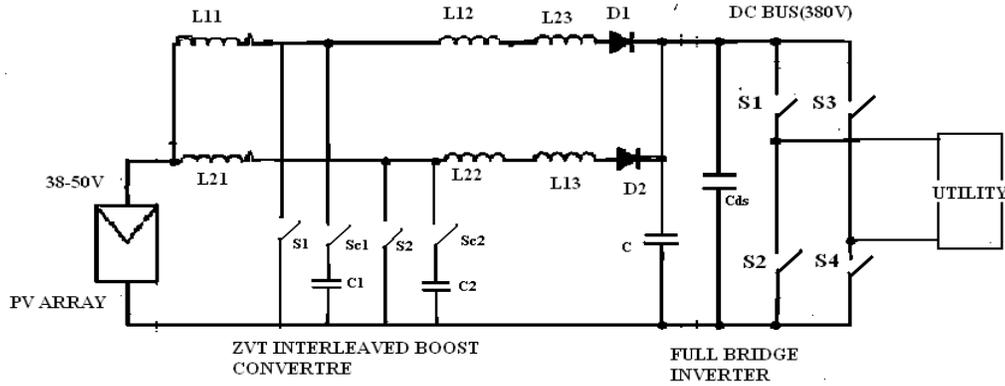


Figure 2: Equivalent circuit of ZVT interleaved boost converter

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**Figure 3:** Proposed PV power system

ZVT converter has three following advantages.

(i) Voltage gain is increased by using proper turn ratio .As the turn ratio increases, the voltage gain increases without the extreme duty ratio,which can reduce the input and output current ripples. The voltage gain is given by,

$$M=V_{out}/V_{in}=N+1/1-D \quad (1)$$

(ii) Voltage stress of the main switches is reduced, as the turn ratio increases. Therefore low voltage and high performance device can be used to reduce the switching and conduction losses. And the voltage spikes are clamped effectively and the leakage energy is recovered. The voltage stress of the main switches are given by

$$V_{ds}=V_{out}/N+1 \quad (2)$$

(iii) ZVT soft switching is achieved for both main switches and auxiliary switches during the whole switching transition which means the switching losses are reduce greatly. The diode reverse - recovery losses are reduced greatly because the di/dt of the diode current is controlled by the leakage inductor of a coupled boost inductor.

To simplify the calculation, the following conditions are considered.

(i)The clamp capacitance is large enough so the voltage ripple on the main switches can be ignored and the voltage  $V_{ds}$  is taken as a constant when they turn off.

(ii)The magnetizing inductance is much larger than the leakage inductance so that the magnetizing current  $I_m$ , the dead time of the main switches and the corresponding auxiliary switches are ignored.

From the graph the following approximation are given

$$\Delta I_f \approx \Delta I_r \approx \Delta I \quad (3)$$

$$V_{Lk1} \approx V_{Lk2} \approx V_{LK} \quad (4)$$

The equation of the output voltage is always true by the Kirchhoff voltage law

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$$V_{OUT} = V_{ds1} + V_{n2}^o + V_{n2}^* \quad (5)$$

where  $V_{n2}^o$  and  $V_{n2}^*$  respectively, represents the voltage of the second winding  $L_{12}$  the voltage of the third winding  $L_{23}$ .

**Stage (i) Main switch  $S_1$  is off and  $S_2$  is on**

Based on the voltage second balance to the magnetizing inductor, the switching voltage of  $S_1$  is given by,

$$V_{ds1} = V_{in}/(1-D) \quad (6)$$

From the wave form we can found that

$$V_{LK} = V_{LK1} = L_{k1} \times \Delta I_f / \Delta t_1 = L_{k1} \times \Delta I / (1D) / F_c \quad (7)$$

As shown in fig. 2 the voltage on the winding coupled inductors are decided by

$$V_{n1}^o = V_{L1} = V_{ds1} - V_{LK1} \quad (8)$$

$$V_{n2}^o = N \times V_{in} \quad (9)$$

$$V_{n2}^* = N \times (V_{in} - V_{LK2}) \quad (10)$$

where  $V_{n1}$  represents the voltage of the first winding  $L_{11}$

Therefore, substituting (6), (9) and (10) in to (5) the equation of the output voltage in stage (i) is obtain as

$$V_{out} = (N-1) \times \underline{V_{ds1}} - 2 \times N \times V_{LK} = (N+1/1-D) \times V_{in} - 2 \times N \times L_{k1} \times \Delta I \quad (11)$$

**Stage (ii) Main switches  $S_1$  is on and  $S_2$  is on**

From the waveform in fig4, it can be found that

$$V_{ds1} = 0 \quad (12)$$

$$V_{LK} = V_{LK1} = L_{k1} \times \Delta I_f / \Delta t_2 = L_{k1} \times \Delta I / \Delta t_2 \quad (13)$$

Considering the polarity of the voltage on the winding coupled inductor in stage (ii), the voltage expression for the winding coupled inductor can be obtained by,

$$V_{n1}^o = V_{L1} = V_{LK1} - V_{in} \quad (14)$$

$$V_{n2}^o = n \times V_{n1}^o \quad (15)$$

$$V_{n2}^* = N \times (V_{LK2} + V_{in}) \quad (16)$$

Therefore substituting (12), (15) and (16) in to (5) we can obtain the output voltage of stage b.

$$V_{OUT} = 2 \times N \times V_{LK} = 2 \times L_{k1} \times \Delta I / \Delta t_2 \quad (17)$$

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The charge through the two output diodes in one switching period can be decided by

$$Q_1 = 2Q_{D1} = (\Delta_{t1} + \Delta_{t2}) \times \Delta I / N \quad (18)$$

Change through the load in one switching period is

$$Q_2 = (V_{out} / R) \times (1 / f_s) \quad (19)$$

Therefore the charge conservation equation can be found that

$$(\Delta_{t1} + \Delta_{t2}) \times \Delta I / N = (V_{out} / R) \times (1 / f_s) \quad (20)$$

Therefore, the (11), (17) and (20) can be solved to obtain the expression for the steady state model of the converter.

$$M = \frac{V_{out}}{V_{in}} = \frac{(N+1) \sqrt{\{(1-D)R\}^2 + 8N^2 + f_s L_{k1} R} - (1-D)R}{4N^2 \times f_s \times L_k} \quad (21)$$

where,  $L_k$  is the equivalent leakage inductance of the winding coupled inductor, and  $L_k = L_{k1} = L_{k2}$ , and  $R$  is the equivalent load of the converter.

### 3. Solar Panel

Solar panel is refer to a photovoltaic module which is an assembly of solar cells used to generate electricity. In all cases, the panels are typically flat, and are available in various heights and widths An array is an assembly of solar-thermal panels or photovoltaic (PV) modules; the panels can be connected either in parallel or series depending upon the design objective. However, solar-thermal panels are still in production, and are common in portions of the world where energy costs, and solar energy availability, are high. Recently there has been a surge toward large scale production of PV modules. The largest solar panel in the world is under construction in the south of Portugal. A 52,000 photovoltaic module, 11-megawatt facility covering a 60- hectare.

### 4. Maximum Power Point Tracker (MPPT)

MPPT solutions are developed to ensure the optimum utilization of PV module [8, 11]. The implementation generally involves sensing the output current and voltage of PV modules. Such realizations are costly and complex.

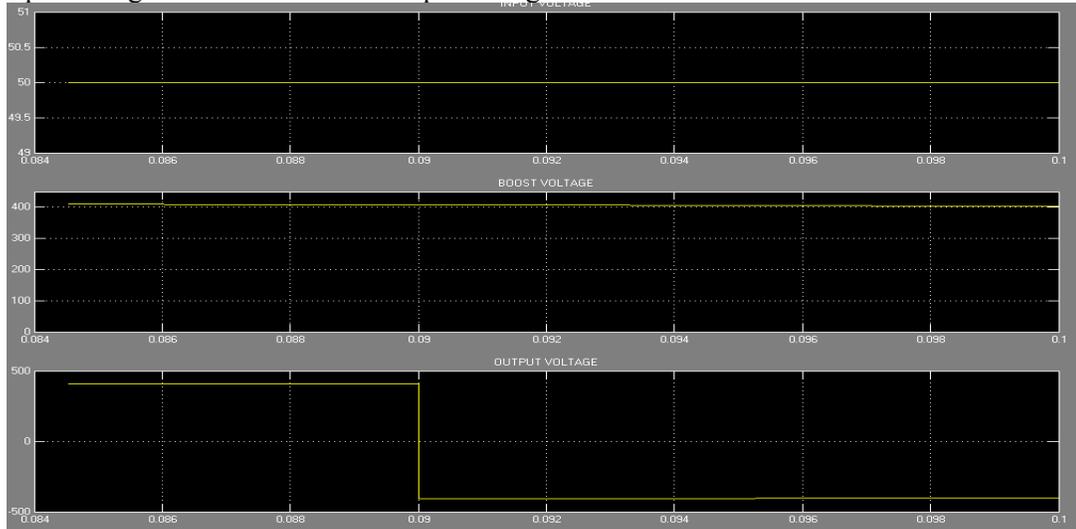
This paper presents a simple maximum power point tracker (or MPPT) that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load. PV cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to  $V/I$  as specified by Ohm's Law. A PV cell has an exponential relationship between current and voltage, and the maximum power point (MPP) will occurs where the resistance is equal to the negative of the differential resistance ( $V/I = -dV/dI$ ). Maximum power point trackers utilize some type of

control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell. MPPT increases the total power harvested by 50%.

## 5. Experimental Results

### Simulation result.

Fig.9 shows the experimental results of the ZVT interleaved boost converter when the input voltage is 38-50V and the out put voltage is 380v .



**Figure 4:** Simulation result of the proposed system

## 6. Conclusion

The paper proposed a photovoltaic power system with high voltage gain .The proposed PV system employs a high step up ZVT- interleaved boost converter with winding coupled inductors .A full bridge inverter with bidirectional power flow is used to stabilize the DC bus voltage and shape the output current .Further more a simple MPPT solution is applied in the PV system and a good performance is obtained.

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