Solar Power Generation Using ZVT interleaved Boost Converter

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Abstract: The paper proposed is based on the implementation of a photovoltaic(PV) power system with high voltage gain. For a typical solar-tracking electricity generation system output voltage is relative low. High voltage gain is necessary to improve the grid connected function. The proposed PV system employs ZVT Boost converter with winding coupled inductor which can boost a low voltage of PV array to a high Dc bus voltage. 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.

Keyword: PIC µc, ZVT Boost converter, photocell, Maximum power point tracking(MPPT)Photo voltaic(PV)system.

I.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 has been used for thousands of years in many different ways by people all over the world. As well as its traditional human uses are cooking, heating, and drying, it is used today to generate electricity where other power supplies are absent, such as in remote places and in space. 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.

A solar tracker is a device for orienting a day lighting reflector, solar photovoltaic panel or concentrating solar reflector or lens toward the sun. The sun's position in the sky changes with the season and time of day as the sun moves across the sky. Solar powered equipment works best when pointed at or near the sun, so a solar tracker can increase the effectiveness of such equipment over any fixed position, at the cost of additional system complexity.

In remote areas the sun is a cheap source of electricity because instead of hydraulic generators solar cells can be used to generate electricity. While the output of solar cells depends on the intensity of sunlight.

PV cell is achieved rapidly by development of semiconductor. Also, price of solar cell is descending continuously. Therefore, photovoltaic system is a very important alternative energy and increasing constantly.

There are three methods for increasing the efficiency of photovoltaic system.

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

Increasing the efficiency of the converter is proposed in this paper. Efficiency of the converter is achieved by using a ZVT interleaved boost converter with winding coupled inductor.

II.STEADY STATE MODEL OF ZVT-INTERLEAVED BOOST CONVERTER

Fig.1 Shows the ZVT interleaved boost converter with winding coupled inductor. The winding coupled inductor offers voltage gain extension [1]-[4] the active clamp circuits gives the ZVT commutation for the main switches and the auxiliary switches S1 and S2 are the main switches S1, and S2, are the active clamp switches. D1 and D2 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 Fig.2, where L1 and L2 are the magnetizing inductor, L1 and L2 are the leakage inductance. C1 and C2 are the clamped capacitors. N is the turns ratio n = n1

Fig. 1 ZVT interleaved boost converter

Fig. 2 Equivalent circuit of ZVT interleaved boost converter
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

\[ M = \frac{V_{\text{out}}}{V_{\text{in}}} = N + 1 - D \quad (1) \]

(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

\[ V_{ds} = \frac{V_{\text{out}}}{N + 1} \quad (2) \]

(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.

(iv) The two interleaved and inter coupled boost converter cells are provided with a strict symmetry. Based on the previous assumptions, the wave forms of the converter are shown in Fig. 4

\[ V_{\text{out}} = \frac{(N - 1)}{x} - 2 \times N \times V_{\text{LK}} \]

\[ = \frac{(N+1/1-D)}{x}V_{\text{in}}-2xNxL_{\text{K1}}x\Delta I \quad (11) \]
Stage(ii)Main switches $S_i$ is on and $S_j$ is on

From the waveform in fig 4, it can be found that

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

$$V_{lk} = V_{lk1} = L_{k1} \cdot \Delta t_0 / \Delta t_2$$
$$= L_{k1} \cdot \Delta t / \Delta t_2 \quad (13)$$

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

$$V_{m1} = V_{L1}$$
$$= V_{LK1} - V_{in} \quad (14)$$
$$V_{n2} = nXV_{m1} \quad (15)$$
$$V_{n2} = nX(V_{LK2} + V_{in}) \quad (16)$$

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

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

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

$$Q = (V_{out}/R) \cdot x (1/f_0) \quad (18)$$

Change through the load in one switching period is

$$Q_t = (V_{out}/R) \cdot x (1/f_0) \quad (19)$$

Therefore the charge conservation equation can be found that

$$(\Delta t_1 + \Delta t_2) \cdot \Delta t / N$$

$$= (V_{out}/R) \cdot x (1/f_0) \quad (20)$$

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

$$M = V_{out}/V_{in}$$

$$(N+1)\sqrt{[(1-D)R]^2 + 8N^2f_c L_{k1} R - (1-D)R}$$

$$4N^2f_c L_{k1} R$$

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.

III. PIC16F84A ARCHITECTURE

There are three types of PIC16F84A packaging designs available in the market PDIP (18-Lead Plastic Dual In-line), SOIP (18-Lead Plastic Small Outline), SSOP (20-Lead Plastic Shrink Small Outline). PDIP type packaging will be used for the solar tracker embedded design. Figure 3 illustrates the PIC16F84A PDIP [11] and shows the name and pin positions [7,12]. The PDIP has three key features that satisfy the objective. These are [13,14]

- 8-bit multi channel analog to digital Converter
- 13 input/output pin

- 64 bytes of data EEPROM memory

The internal hardware architecture of PIC16F84A is represented by the block diagram shown in the below figure 5.

All the blocks of figure. 5 are main bits of hardware and the lines that connect them are called buses. These buses are basically small parallel lines which data can be passed simultaneously from one hardware block to the other. The number besides each bus indicates the number of lines present within that bus, denoting the bits that can be sent along these buses.

IV. FULL- BRIDGE INVERTER.

The full bridge inverter shown in fig.6 is a voltage source inverter. It has the capability to force the instantaneous load current to accurately follow the sinusoidal reference wave, which synchronizes with the utility grid voltage. And the high power factor the low THD and the fast dynamic response are achieved. The bidirectional power flow facilitates the compensation of the DC bus and the AC side voltage variation.

Full bridge inverter

The inverter can deliver and accept both real and reactive power. The inverter has two legs. Each leg consists of two power control devices. The load is connected between the midpoint of the two phase legs. Each power control device has a diode connected in anti parallel to it. This diodes provides an alternate path for load current if the power switches are turn off. For example if the lower IGBT in the left leg is conducting and carrying current towards the
negative DC bus this current would commutate into the diode across the upper IGBT of the left leg if the lower IGBT is turned off. Control of circuit is accomplished by varying the turn on time of the upper and lower IGBT of each inverter leg with the provision of never turning on both at the same time to avoid a short circuit of the DC bus. In fact the modern drives does not allow this to happen even if the controller would erroneously command both controller devices to be turned on. The controller will therefore alternate the turn on command for the upper and lower switch, i.e turn the upper switch on and the lower switch off and vice versa. The drive circuit should add some additional blanking time (typically 500-1000ns) during the switch transitions to avoid any overlap in the condition intervals.

The controller will control the duty cycle of the conduction phase of the switches. The average potential of the centre point of each leg will be given by the DC bus voltage multiplied by the duty cycle of the upper switches, if the negative side of the DC bus is used as a reference. If this duty cycle is modulated with a sinusoidal signal with a frequency much smaller than the switching frequency the short term average of the current potential will follow the modulation signal.

For a single phase inverter the modulation of the two legs are inverse of each other such that if the left leg has a large duty cycle for the upper switch, the right leg has a small one. The frequency, wave shape and the amplitude of the inverter out put voltage can be controlled as long as the switching frequency is at least 25 to 100 times higher than the fundamental output frequency of the inverter. The actual generation of PWM signals is done using microcontroller Fig 8 shows the control block diagram of photovoltaic power system.

Fig. 7 Control block diagram of PV power system

V. 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. Solar panels typically find use in residential, commercial, institutional, and light industrial applications.
VIII .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.

REFERENCES


