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A Novel High Step up And High efficiency DC-DC converter for Grid Connected or Standalone PV applications

M. Kiran
M.Tech (POWER ELECTRONICS)
EEE Department
Pathfinder engineering college
Hanmakonda, Warangal , Telangana

N. Avinash
Assistant Professor, 2years exp
EEE Department
Pathfinder engineering college
Hanmakonda, Warangal,Telangana

Abstract—The distributed generation (DG) systems based on the renewable energy sources have rapidly developed in recent years. These DG systems are powered by micro sources such as fuel cells, photovoltaic (PV) systems, and batteries. PV distributed system in which the solar source is low dc input voltage. PV sources can also connect in series to obtain sufficient dc voltage for generating actuality voltage; however, it is difficult to realize a series connection of the PV source without incurring a shadow effect. High step-up dc–dc converters are generally used as the frontend converters to step from low voltage (12–40 V) up to high voltage (380–400 V). High step-up dc–dc converters are required to have a large conversion ratio, high efficiency and small volume. A novel high step-up dc–dc converter for a distributed generation system is proposed in this paper. Through a voltage multiplier module, an asymmetrical interleaved high step-up converter obtains high step-up gain without operating at an extreme duty ratio. The voltage multiplier module is composed of a conventional boost converter and coupled inductors. Finally, the prototype circuit witha 40-V input voltage, 400-V output, and 1000-W output power is operated to verify its performance. The highest efficiency is 96.8%. In base paper author discussed only about the High Step up converter, in extension to this work we can use PV source as input to the converter and later the system can be used as a Standalone system or connected to grid and make it as a grid connected system.

Index terms-- High Step up DC-DC converter, PV sources, Grid connected system.

Introduction: Renewable energy attracts interest for power generation because the non renewable energy like petrol, diesels etc are diminishing and energy crisis is an important concern in most of the nations. In renewable energy, solar energy attracts more because it has more advantage compare to other renewable energy s like the selection of area is not complicated, the systems can either be operated as isolated systems or connected to the grid as a part of an integrated system, it has no moving parts; it has a long lifetime and low maintenance requirements and most importantly it is one solution that offers eco friendly power . Photovoltaic system requires a power electronics interface to be connected to the grid.

The most commonly used dc/dc converter is a boost converter which provides an acceptable voltage conversion ratio and also requests a continuous current from the power source . The characteristics required in photovoltaic applications are low current ripple injected to the power source and high conversion efficiency. The interleaving technique

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connects dc/dc converters in parallel to share the power flow between two or more conversion chains. However, the conventional interleaved converter has some disadvantages like the duty ratio is extremely large in order to get a high gain, this increases the current ripple, conduction losses and the turnoff losses. Then, the switches voltage stress is the high and the output diode reverse recovery problem is very severe, which induces additional voltage and current stresses and losses and also the electromagnetic interference (EMI) noise is very serious. To improve voltage gain interleaved structures can be used with transformers or the inductors . Interleaved converters is able to reduce output current ripple without any modification on the PWM technique (need phase shift only) and circuit theory of boost converter . When the duty cycle is high the voltage gain is theoretically infinite. So the switch turn on period becomes long as the duty cycle (D) increases causing conduction losses to increase. The single switch boost converter power rating is limited to switch rating . Interleaved parallel topology is the solution to increase the power and reduce input current ripple allowing lower power rated switches to be used.

PHOTOVOLTAIC SYSTEM

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter. The Block diagram of the PV system is shown in Fig.1. A. Photovoltaic cell A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited1

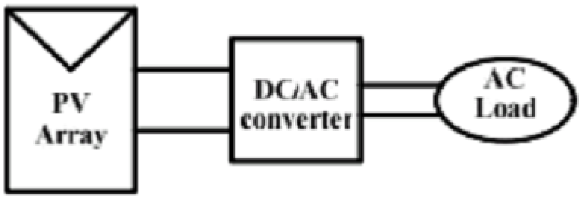

Fig.1. Block diagram representation of Photovoltaic system

The equivalent circuit of PV cell is shown in the fig.2.

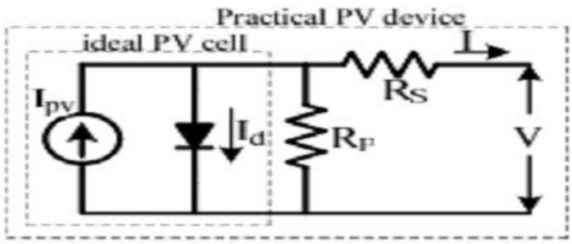

Fig.2. Practical PV device

In the above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp represent series and parallel resistance respectively. The output current and voltage form PV cell are represented by I and V. The I-V characteristics of PV cell are shown in fig.3. The net cell current I is composed of the light generated current IPV and the diode current ID.

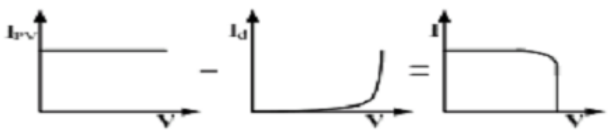

Fig.3. Characteristics I-V curve of the PV cell

PRINCIPLE OF OPERATION

A voltage multiplier is an electrical circuit that converts electrical power from a lower voltage to a higher voltage. Module, which is stacked on a boost converter to form an asymmetrical interleaved structure . Primary windings of the coupled inductors with np turns are employed to decrease

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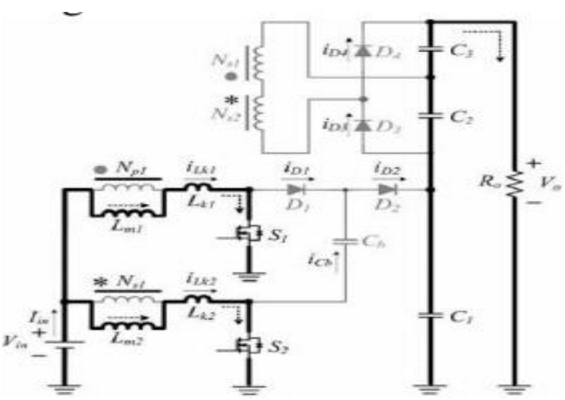
input current ripple, and secondary windings of the coupled inductors with ns turns are connected in series to extend voltage gain. The turns ratios of the coupled inductors are the same. The proposed high step-up converter with voltage multiplier module is shown in Fig. 3. A conventional boost converter and two coupled inductors are located in the voltage multiplier module, which is stacked on a boost converter to form an asymmetrical interleaved structure. Primary windings of the coupled inductors with Np turns are employed to decrease input current ripple, and secondary windings of the coupled inductors with Ns turns are connected in series to extend voltage gain. The turns ratios of the coupled inductors are the same.

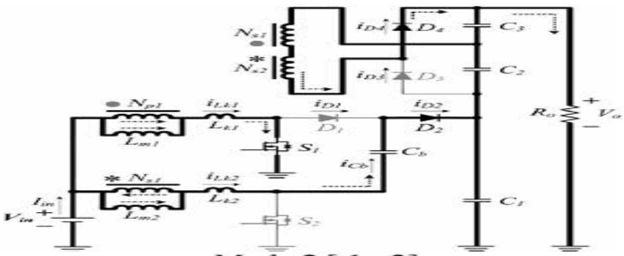
The coupling references of the inductors are denoted by " ." and " ∗" .The proposed converter operates in continuous conduction mode (CCM), and the duty cycles of the power switches during steady operation are interleaved with a 180◦phase shift; the duty cycles are greater than 0.5.

Mode 1 [t0, t1]: At t=t0 , the power switches S1 and S2 are both turned ON. All of the diodes are reversed biased. Magnetizing inductors Lm1 and Lm2 as well as leakage inductorsLk1 and Lk2 are linearly charged by the input voltage source Vin .



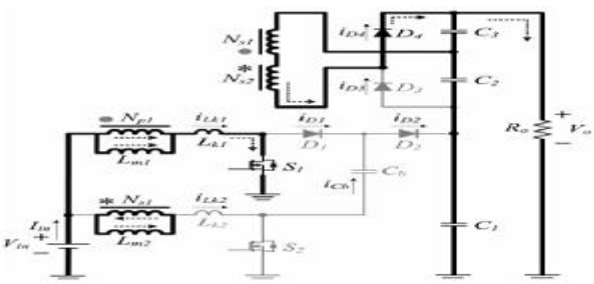
Mode 1 [t0, t1]

Mode 2 [t1, t2]: At t=t1 , the power switch S2 is switched OFF, thereby turning ON diodes D2 and D4 . The energy that magnetizing inductor Lm2 has stored is transferred to the secondary side charging the output filter capacitor C3. The input voltage source, magnetizing inductor Lm2, leakage inductorLk2 , and voltage-lift capacitor Cb release energy to the Output filter capacitor C1 via diode D2 , thereby extending the voltage on C1.



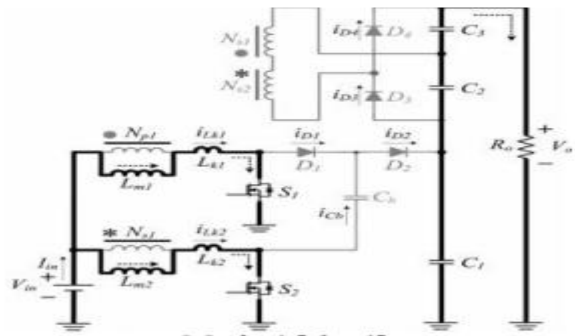
Mode 2 [t1, t2]

Mode 3 [t2, t3]: At t=t2 , diode D2 automatically switches OFF because the total energy of leakage inductor Lk2 has been completely released to the output filter capacitor C1 . Magnetizing inductor Lm2 transfers energy to the secondary side charging the output filter capacitor C3 via diode D4 until t3.



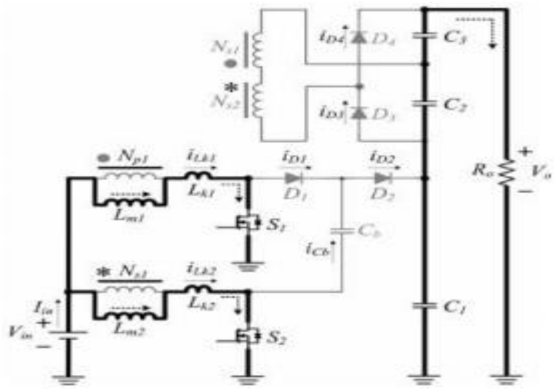
Mode 3 [t2, t3]

Mode 4 [t3, t4]: At t=t3, the power switch S2 is switched ON and all the diodes are turned OFF. The operating states of modes 1 and 4 are similar.



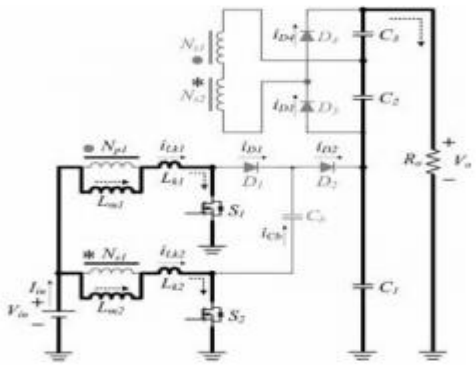
Mode 4 [t3, t4]

Mode 5 [t4, t5]: At t=t4, the power switch S1 is switched OFF, which turns ON diodes D1 and D3. The energy stored in magnetizing inductor Lm1 is transferred to the secondary side charging the output filter capacitor C2. The input voltage source and magnetizing inductor Lm1 release energy to voltage lift capacitor Cb via diode D1, which stores extra energy in Cb.



Mode 5 [t4, t5]

Mode 6 [t5, t0]: At t=t5 , diode D1 is automatically turned OFF because the total energy of leakage inductor Lk1 has been completely released to voltage lift capacitor Cb. Magnetizing inductor Lm1 transfers energy to the secondary side charging the output filter capacitor C2 via diode D3 until t0.



Mode 6 [t5, t0]

STEADY-STATE ANALYSIS

The transient characteristics of circuitry are disregardedto simplify the circuit performance analysis of the proposed converter in CCM, and some formulated assumptions are asfollows:

1) all of the components in the proposed converter are ideal;

2) leakage inductors Lk1 and Lk2 are neglected;

3) voltage VCb, VC1, VC2 , and VC3 are considered to be constant because of infinitely large capacitance.

A. Voltage Gain

The first-phase converter can be regarded as a conventional boost converter; thus, voltage VCb can be derived from

$$V_{Cb} = \frac{1}{1-D}V_{\text{in}} \quad (1)$$

When switch S1 is turned ON and switch S2 is turned OFF, voltage VC1 can be derived from

$$V_{C1} = \frac{1}{1-D}V_{\text{in}} + V_{Cb} = \frac{2}{1-D}V_{\text{in}} \quad (2)$$

The output filter capacitors C2 and C3 are charged by energy transformation from the primary side. When S2 is in turn-on state and S1 is in turn-off state, VC2 is equal to induced voltage of Ns1 plus induced voltage of Ns2 , and when S1 is in turn-on state and S2 is in turn-off state, VC3 is also equal to induced voltage of Ns1 plus induced voltage of Ns2 . Thus, voltages Vc2 and Vc3 can be derived from

$$V_{C2} = V_{C3} = n \cdot V_{\text{in}}\left(1+\frac{D}{1-D}\right) = \frac{n}{1-D}V_{\text{in}}$$

(3)

The output voltage can be derived from

$$V_o = V_{C1} + V_{C2} + V_{C3} = \frac{2n+2}{1-D}V_{\text{in}}$$

(4)

The voltage gain of the proposed converter is

$$\frac{V_o}{V_{\text{in}}} = \frac{2n+2}{1-D} \quad (5)$$

Equation (5) confirms that the proposed converter has a high step-up voltage gain without an extreme duty cycle.

B. Voltage Stresses on Semiconductor Components

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The voltage ripples on the capacitors are ignored to simplify the voltage stress analyses of the components of the proposed converter. The voltage stresses on power switches S1 and S2 are derived from

$$V_{S1} = V_{S2} = \frac{1}{1-D} V_{\text{in}} \quad (6)$$

The voltage stresses on the power switches S1 and S2 related to the output voltage Voand the turns ratio n can be expressed as

$$V_{S1} = V_{S2} = V_o - \frac{2n+1}{1-D} V_{\text{in}} \quad (7)$$

Equations (6) and (7) confirm that low-voltage-rated metal–oxide–semiconductor field-effect transistors (MOSFETs) withlow RDS−ON can be adopted for the proposed converter toreduce conduction losses and costs. This feature makes our converter suitable for high step-up and high-power applications. The voltage stresses on the power switches account for half of output voltage Vo , even if turns ratio n is 0. The voltage stress on diode D1 is equal to VC1, and the voltage stress on diode D2 is voltage VC1 minus voltage VCb. These voltage stresses can be derived from

$$V_{D1} = V_{C1} = \frac{2}{1-D} V_{\text{in}} \quad (8)$$

SIMULATION RESULTS

High step-up converter with a voltage multiplier module:

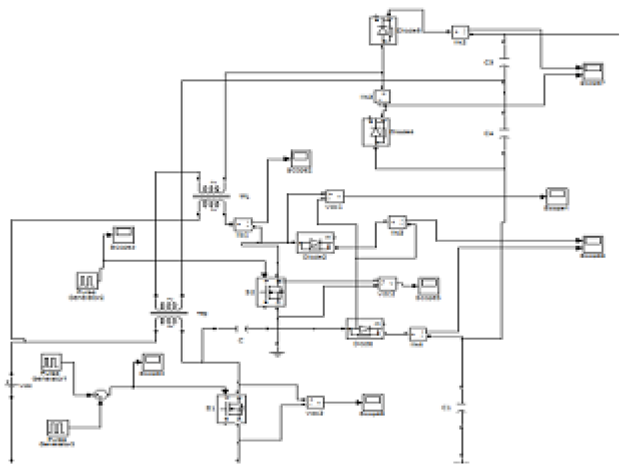

Fig.4 Matlab/simulink model of proposed converter

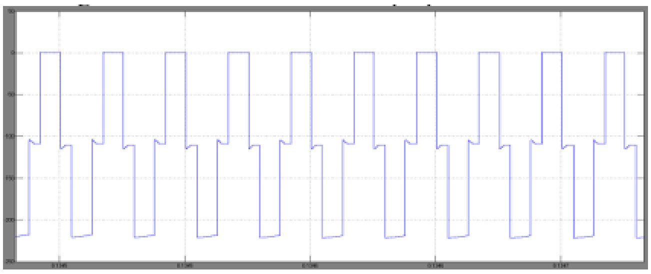

Fig.5 Simulated output waveform of switch voltage

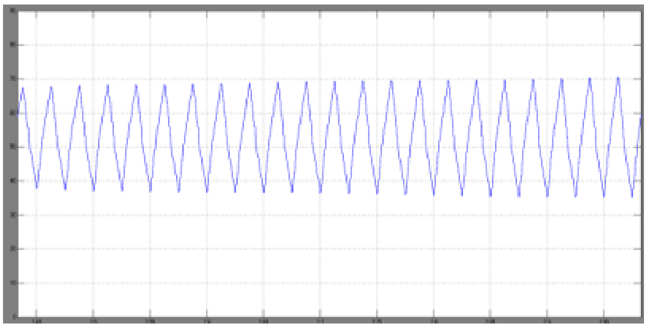

Fig.6 shows the Primary side current

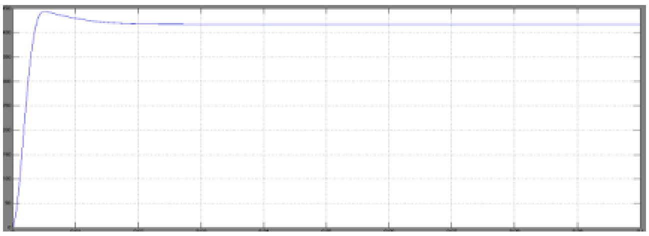

Fig.7 shows the Output voltage of proposed converter

CONCLUSION

This work done has presented the topological principles, and simulation results for a proposed converter. In proposed converter presented to the PV as input source and grid connected on load side. The proposed converter has been successfully implemented inan efficiently high step-up conversion without an extreme duty ratio and a number of turns ratios through the voltage multiplier module and voltage clamp feature. In this concept High Step up DC-DC converter for Grid Connected or Standalone PV applications to improve the efficiency of output voltage. The above all results are shown and verified by using Matlab/simulink software. These switches, conducted to low voltage rated and low on-state resistance MOSFET, can be selected. From the aforementioned work done, the voltage gain and the extreme duty cycle to reduce the current ripple to reduce the switch voltage to make low-voltage MOSFETs available to re duce the power device cost and conduction losses and to alleviate the output diode reverse recovery problem to reduce the reverse recovery losses.

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