

An Innovative Converter to Reduce Current Stress While Constraining Current Ripple in Renewable Energy System

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Abstract:

Our nation has increased its dependence on foreign oil supplies instead of decreasing it due to natural constraints. This increased dependence impacts more than just our national energy policy. Renewable energy is reliable and plentiful and will potentially be very cheap once technology and infrastructure improve. In this paper a high step-up converter is implemented for a photovoltaic system. A voltage multiplier used here provides high voltage gain without extreme duty cycle. The voltage multiplier is composed of a conventional boost converter and coupled inductors. An extra conventional boost converter is integrated into the first phase to achieve a considerably higher voltage conversion ratio.

The two-phase configuration not only reduces the current stress through each power switch, but also constrains the input current ripple, which decreases the conduction losses of metal-oxide-semiconductor field-effect transistors (MOSFETs). It also functions as a clamp circuit which alleviates the voltage spikes across the power switches. So, the low-voltage-rated MOSFETs can be adopted for reductions of conduction losses and cost. Efficiency improves because the energy stored in leakage inductances is recycled to the output terminal.

Keywords:

Stepup Converter, MOSFETs, PV Cells, renewable energy, Voltage Multiplier.

Introduction: Renewable sources of energy are increasingly valued worldwide because of energy shortage and environmental contamination. Renewable energy systems generate low voltage output; thus, high step-up dc/dc converters are widely employed in many renewable energy applications, including fuel cells, wind power, and photovoltaic systems. Among renewable energy systems, photovoltaic systems are expected to play an important role in future energy production.

Photovoltaic Systems:

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. Solar photovoltaic modules, which are a result of combination of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible.

Functioning Of The Photovoltaic Cells:

The word "photovoltaic" consists of two words: photo, a Greek word for light, and voltaic, which defines the measurement value by which the activity of the electric field is expressed, i.e.

the difference of potentials. Photovoltaic systems use cells to convert sunlight into electricity. Converting solar energy into electricity in a photovoltaic installation is the most known way of using solar energy. The light has a dual character according to quantum physics. Light is a particle and it is a wave. The particles of light are called photons. Photons are massless particles, moving at light speed. The energy of the photon depends on its wavelength and the frequency, and we can calculate it by the Einstein's law, which is:

$$E = h V$$

where:

E - photon energy

h - Planck's constant $h = 6.626 \times 10^{-34} \text{Js}$

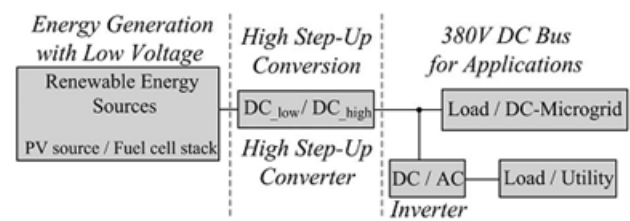
V - photon frequency

Voltage Multiplier Circuits:

A voltage multiplier is a circuit that produces a d.c. voltage equal to a multiple of the peak input voltage. It consist two or more peak detectors or rectifiers. Voltage multipliers found applications in circuits, where high voltage with low current is required such as picture tube in TV receivers, oscilloscopes, etc. A voltage multipliers an electrical circuit that converts AC electrical power from a lower voltage to a higher DC voltage by means of capacitors and diodes combined into a network. Depending on the output voltage, multipliers can be of different types

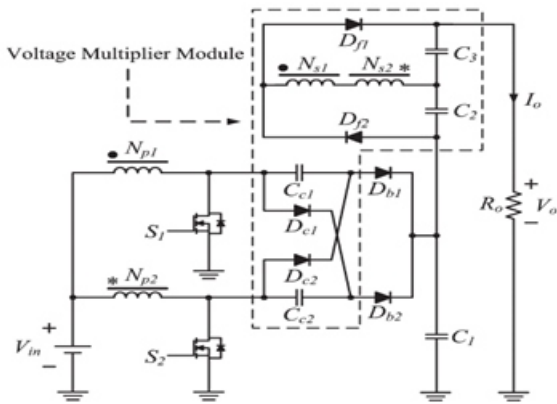
- Voltage doublers
- Voltage tiplers
- Voltage quadrupler

In this paper, an asymmetrical interleaved high step-up converter that combines the advantages of the aforementioned converters is proposed, which combined the advantages of both. In the voltage multiplier module of the proposed converter, the turns ratio of coupled inductors can be designed to extend voltage gain, and a voltage-lift capacitor offers an extra voltage conversion ratio. The high step-up conversion may require two-stage converters with cascade structure for enough step-up gain, which decreases the efficiency and increases the cost. Thus, a high step-up converter is seen as an important stage in the system because such a system requires a sufficiently high step-up conversion with high efficiency. Theoretically, conventional step-up converters, such as the boost converter and flyback converter, cannot achieve a high



Typical renewable energy system:

step-up conversion with high efficiency because of the resistances of elements or leakage inductance; also, the voltage stresses are large. Thus, in recent years, many novel high stepup converters have been developed . Despite these advances, high step-up single-switch converters are unsuitable to operate at heavy load given a large input current ripple, which increases conduction losses. The conventional interleaved boost converter is an excellent candidate for high-power applications and power factor correction. Unfortunately, the step-up gain is limited, and the voltage stresses on semiconductor components are equal to output voltage. Hence, based on the aforementioned considerations, modifying a conventional interleaved boost converter for high step-up and high-power application is a suitable approach. To integrate switched capacitors into an interleaved boost converter may make voltage gain reduplicate, but no employment of coupled inductors causes the step-up voltage gain to be limited .Oppositely, to integrate only coupled inductors into an interleaved boost converter may make voltage gain higher and adjustable, but no employment of switched capacitors causes the step-up voltage gain to be ordinary. Thus, the synchronous employment of coupled inductors and switched capacitors is a better concept; moreover, high step-up gain, high efficiency, and low voltage stress are achieved even for high-power applications . The proposed converter is a conventional interleaved boost converter integrated with a voltage multiplier module, and the voltage multiplier module is composed of switched capacitors and coupled inductors. The coupled inductors can be designed to extend step-up gain, and the switched capacitors offer extra voltage conversion ratio. In addition, when one of the switches turns off, the energy stored in the magnetizing inductor will transfer via three respective paths; thus, the current distribution not only decreases the conduction losses by lower effective current but also makes currents through some diodes decrease to zero before they turn off, which alleviate diode reverse recovery losses.



Proposed high step-up converter

The advantages of the proposed converter are as follows.

- 1) The proposed converter is characterized by low input current ripple and low conduction losses, which increases the lifetime of renewable energy sources and makes it suitable for high-power applications.
- 2) The converter achieves the high step-up gain that renewable energy systems require.
- 3) Due to the lossless passive clamp performance, leakage energy is recycled to the output terminal. Hence, large voltage spikes across the main switches are alleviated, and the efficiency is improved.
- 4) Low cost and high efficiency are achieved by employment of the low-voltage-rated power switch with low RDS(ON); also, the voltage stresses on main switches and diodes are substantially lower than output voltage.
- 5) The inherent configuration of the proposed converter makes some diodes decrease conduction losses and alleviate diode reverse recovery losses.

STEADY-STATE ANALYSIS:

The transient characteristics of circuitry are disregarded to simplify the circuit performance analysis of the proposed converter in CCM, and some formulated assumptions are as follows.

- 1) All of the components in the proposed converter are ideal.
- 2) Leakage inductors Lk1, Lk2, and Ls are neglected.

3) Voltages on all capacitors are considered to be constant because of infinitely large capacitance.

4) Due to the completely symmetrical interleaved structure, the related components are defined as the corresponding symbols such as Dc1 and Dc2 defined as Dc.

STEP-UP GAIN:

The voltage on clamp capacitor Cc can be regarded as an output voltage of the boost converter; thus, voltage VCc can be derived from

$$V_{C_c} = \frac{1}{1-D} V_{in}$$

When one of the switches turns off, voltage VC1 can obtain a double output voltage of the boost converter derived from

$$V_{C1} = \frac{1}{1-D} V_{in} + V_{C_c} = \frac{2}{1-D} V_{in}$$

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

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

The output voltage can be derived from

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

In addition, the voltage gain of the proposed converter is

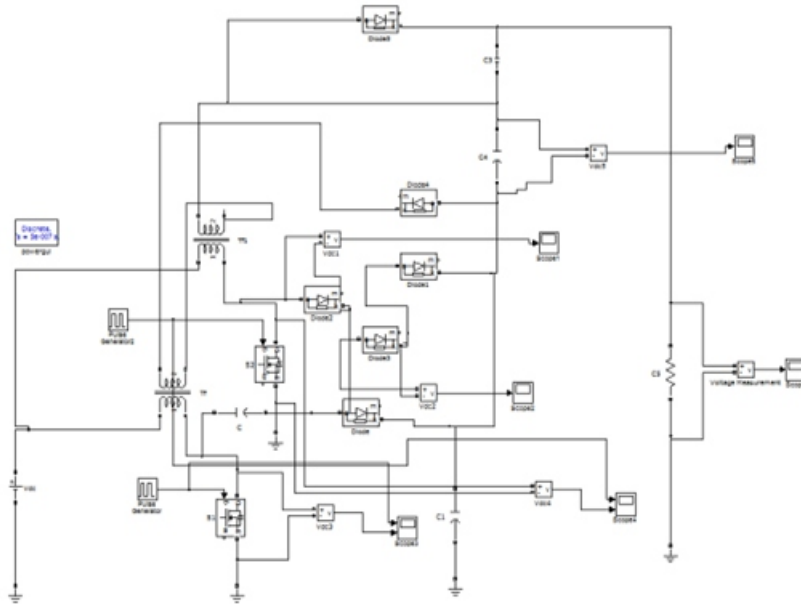
$$\frac{V_o}{V_{in}} = \frac{2n+2}{1-D}$$

Above Equation confirms that the proposed converter has a high step-up voltage gain without an extreme duty cycle. The curve of the voltage gain related to turn ratio n and duty cycle is shown in Fig. When the duty cycle is merely 0.6, the voltage gain reaches ten at a turn ratio n of one; the voltage gain reaches 30 at a turn ratio n of five.

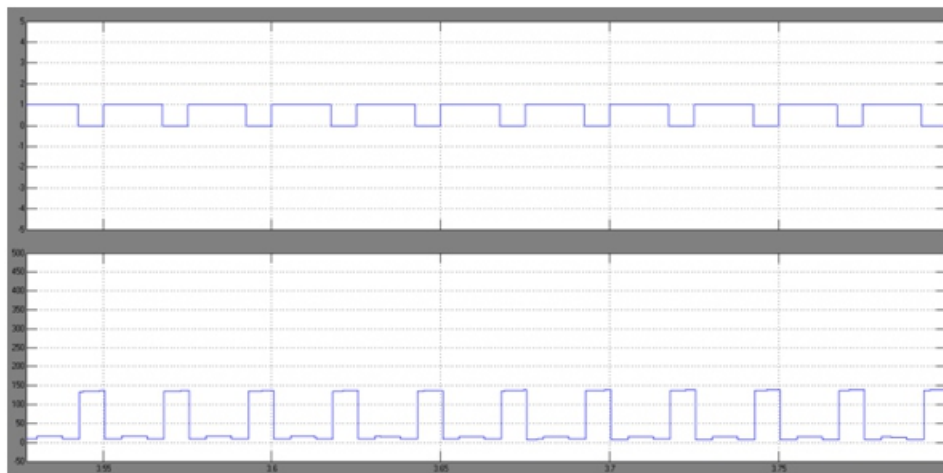
SIMULTION RESULTS:

Here the simulation carried by two different cases they are 1) high step-up interleaved converter with a voltage multiplier module 2) PV as input source of proposed converter with inverter module.

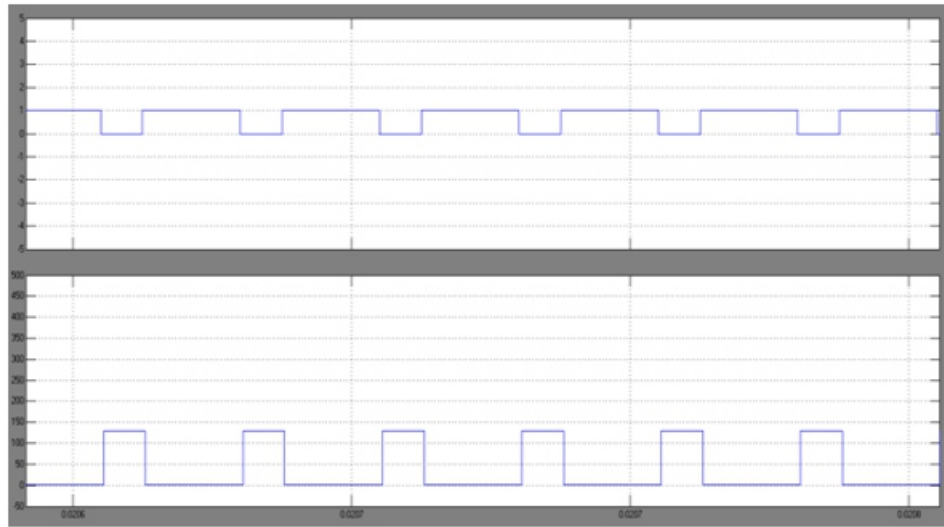
Case-1 High step-up interleaved converter with a voltage multiplier module



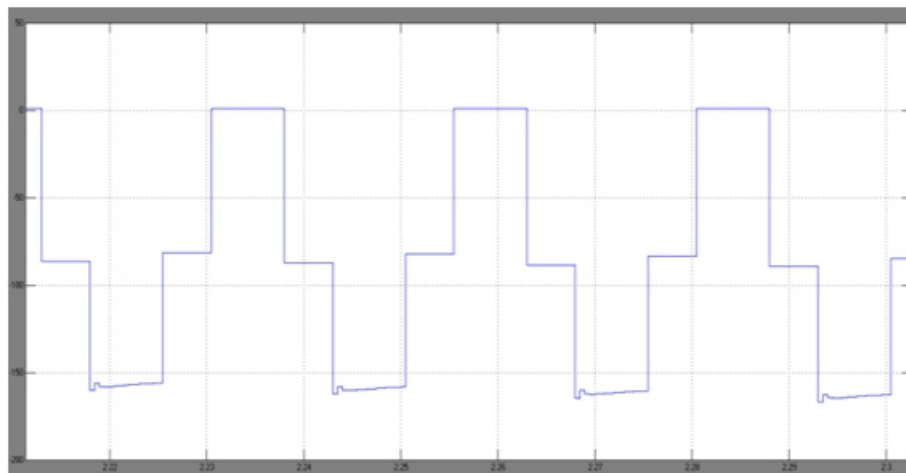
Simulink model of conventional high step-up interleaved converter with a voltage multiplier module



power switch S1 gating pulse and output voltage



power switch S2 gating pulse and output voltage



shows the simulated output waveform voltage across switched capacitor



output voltage of clamp diode



shows the ooutput voltage of conventional high step-up interleaved converter

CONCLUSION:

This paper has presented the theoretical analysis of steady state, related consideration, simulation results. The proposed converter has successfully implemented an efficient high step-up conversion through the voltage multiplier module. The interleaved structure reduces the input current ripple and distributes the current through each component.

In addition, the lossless passive clamp function recycles the leakage energy and constrains a large voltage spike across the power switch. Meanwhile, the voltage stress on the power switch is restricted and much lower than the output voltage (380 V).

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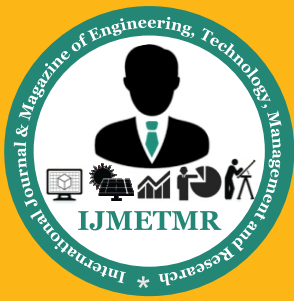
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