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A Novel High Step-Up Converter to Reduce Current Stress While Constraining Current Ripple in Renewable Energy System Which Cuts the Conduction Losses and Extends the Lifespan of the Input Source

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Abstract:

Our nation has increased its dependence on foreign oil supplies instead of decreasing it due natural constrains. 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, Volatge Multipler.

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.

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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 = 6.626×10 − 34Js

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 tipplers
- Voltage quadrupler

BATTERY

Energy Storage:

Electricity is more versatile in use than other types of power, because it is a highly ordered form of energy that can be converted efficiently into other forms. Forexample, it can be converted into mechanical form with efficiency near 100% orinto heat with 100% efficiency. Heat energy, on the other hand, cannot be convertedinto electricity with such high efficiency, because it is a disordered form of energyin atoms. For this reason, the overall thermal-to-electrical conversion efficiency ofa typical fossil thermal power plant is less than 50%.

Disadvantage of electricity is that it cannot be easily stored on a large scale. Almost all electric energy used today is consumed as it is generated. This poses no hardship in conventional power plants, in which fuel consumption is continuously varied with the load requirement. Wind and photovoltaic’s (PVs), both being intermittent sources of power, cannot meet the load demand at all times, 24 h a day, 365 d a year.

The present and future energy storage technologies that may be considered for stand-alone wind or PV power systems fall into the following broad categories:

- Electrochemical battery
- Flywheel
- Compressed air
- Superconducting coil

The battery stores energy in an electrochemical form and is the most widely used device for energy storage in a variety of applications. There are two basic types of electrochemical batteries:

The primary battery, which converts chemical energy into electric energy. The electrochemical reaction in a primary battery is nonreversible, and the battery is discarded after a full discharge. For this reason, it finds applications where a high energy density for one-time use is required.

The secondary battery, which is also known as the rechargeable battery. The electrochemical reaction in the secondary battery is reversible. After a discharge, it

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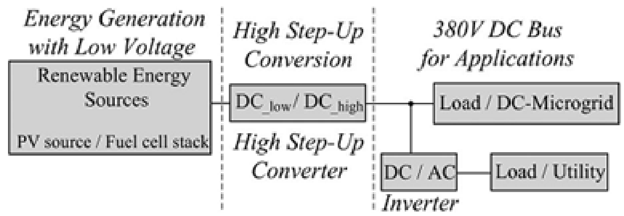
can be recharged by injecting a direct current from an external source. This type of battery converts chemical energy into electric energy The internal construction of a typical electrochemical cell is shown in Figure. It has positive and negative electrode plates with insulating separators and a chemical electrolyte in between. The two groups of electrode plates are connected to two external terminals mounted on the casing. The cell stores electrochemical energy at a low electrical potential, typically a few volts. The cell capacity, denoted by *C*, is measured in ampere-hours (Ah), meaning it can deliver *C* A for one hour or *C*/*n*A for *n* hours.

The battery is made of numerous electrochemical cells connected in a series–parallel combination to obtain the desired battery voltage and current. The higher the battery voltage, the higher the number of cells required in series. The battery rating is stated in terms of the average voltage during discharge and the ampere-hour capacity it can deliver before the voltage drops below the specified limit. The product of the voltage and ampere-hour forms the watthour (Wh) energy rating the battery can deliver to a load from the fully charged condition. The battery charge and discharge rates are stated in units of its capacity in Ah. For example, charging a 100-Ah battery at *C*/10 rate means charging at 100/10 = 10 A. Discharging that battery at *C*/2 rate means drawing 100/2 = 50 A, at which rate the battery will be fully discharged in 2 h. The state of charge (*SOC*) of the battery at any time is defined as the following:

$$SOC=\frac{\text{Ah Capacity remaining in the battery}}{\text{Rapid Ah capacity}}$$

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 structurefor enough step-up gain, which decreases the efficiency andincreases the cost. Thus, a high step-up converter is seen as animportant stage in the system because such a system requires asufficiently high step-up conversion with high efficiency.Theoretically, conventional step-up converters, such as theboost 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 voltagestresses are large. Thus, in recent years, many novel high stepupconverters have been developed . Despite theseadvances, high step-up single-switch converters are unsuitableto operate at heavy load given a large input current ripple, whichincreases conduction losses. The conventional interleaved boostconverter is an excellent candidate for high-power applicationsand power factor correction. Unfortunately, the step-up gain islimited, and the voltage stresses on semiconductor componentsare equal to output voltage. Hence, based on the aforementioned considerations, modifying a conventional interleavedboost converter for high step-up and high-power application isa suitable approach. To integrate switched capacitors into aninterleaved boost converter may make voltage gain reduplicate,but no employment of coupled inductors causes the step-upvoltage gain to be limited . Oppositely, to integrateonly coupled inductors into an interleaved boost converter maymake voltage gain higher and adjustable, but no employmentof switched capacitors causes the step-up voltage gain to beordinary .

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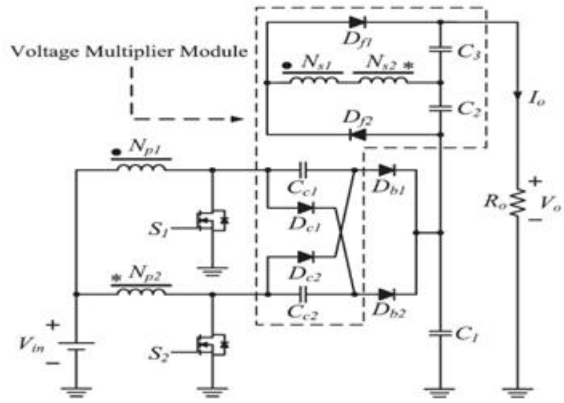
Thus, the synchronous employment ofcoupled inductors and switched capacitors is a better concept;moreover, high step-up gain, high efficiency, and low voltagestress are achieved even for high-power applications .The proposed converter is a conventional interleaved boostconverter integrated with a voltage multiplier module, and thevoltage multiplier module is composed of switched capacitorsand coupled inductors. The coupled inductors can be designedto extend step-up gain, and the switched capacitors offer extravoltage conversion ratio. In addition, when one of the switchesturns off, the energy stored in the magnetizing inductor willtransfer via three respective paths; thus, the current distributionnot only decreases the conduction losses by lower effectivecurrent but also makes currents through some diodes decreaseto zero before they turn off, which alleviate diode reverserecovery 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-STATEANALYSIS:

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

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 asDc1 and Dc2 defined as Dc.

STEP-UP GAIN:

The voltage on clamp capacitorCc can be regarded as anoutput voltage of the boost converter; thus, voltageVCccan bederived from

$$V_{Cc} = \frac{1}{1-D} V_{\text{in}}.$$

When one of the switches turns off, voltageVC1can obtain adouble output voltage of the boost converter derived from

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

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The output filter capacitorsC2andC3are charged by energytransformation from the primary side. When S2is in ONstateandS1is in OFFstate,VC2is equal to the induced voltage ofNs1plus the induced voltage ofNs2, and whenS1is inONstateandS2is in OFFstate,VC3is also equal to the induced voltageofNs1plus the induced voltage ofNs2. Thus, voltagesVC2andVC3can be derived from

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

The output voltage can be derived from

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

In addition, the voltage gain of the proposed converter is

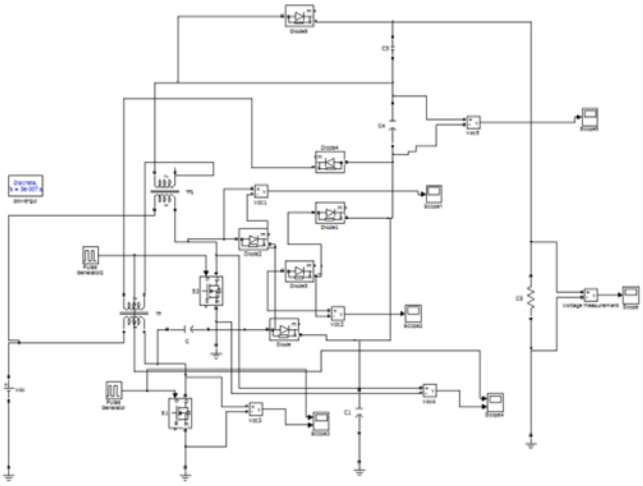
$$\frac{V_o}{V_{\text{in}}} = \frac{2n+2}{1-D}$$

Above Equation confirms that the proposed converter has a highstep-up voltage gain without an extreme duty cycle. The curveof the voltage gain related to turn rationand duty cycle is shown in Fig. When the duty cycle is merely 0.6, the voltagegain reaches ten at a turn rationof one; the voltage gain reaches30 at a turn rationof five.

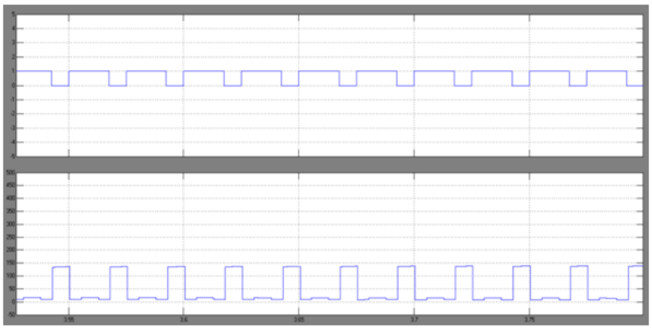
SIMULTION RESULTS:

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

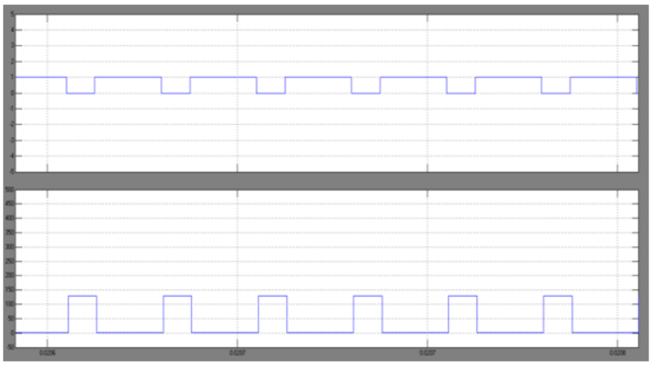
1: High step-up interleaved converter with a voltage multiplier module



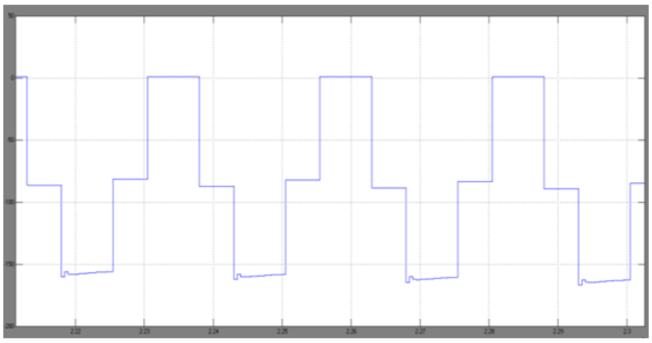
Simulink model of conventional high step-up interleaved converter with a voltage multiplier module



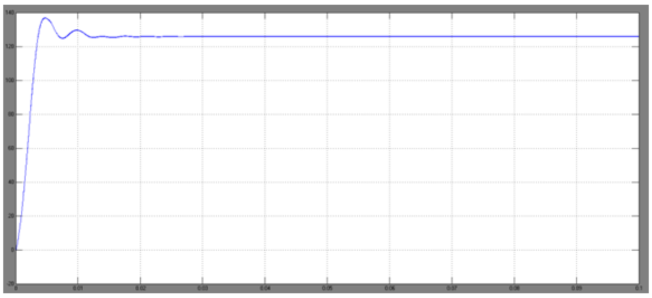
Power switch S1 gating pulse and output voltage



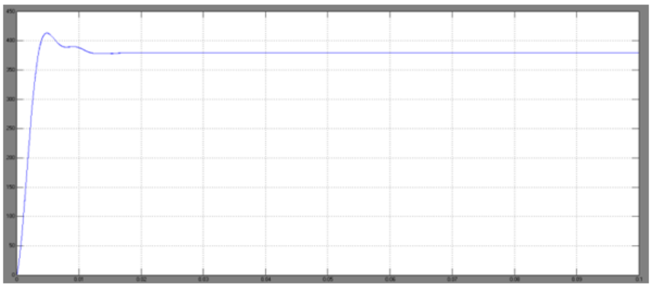
Power switch S2 gating pulse and output voltage



shows the simulated output waveform voltage across switched capacitor

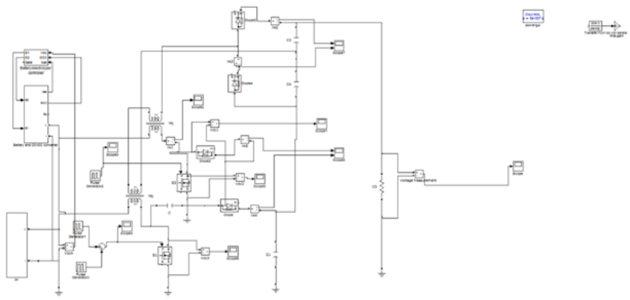


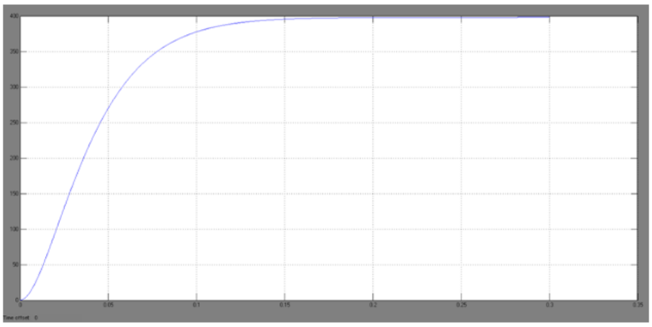
output voltage of clamp diode

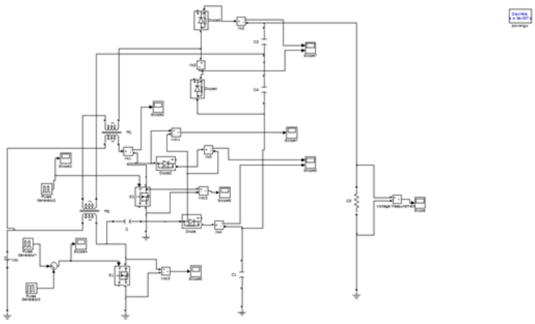


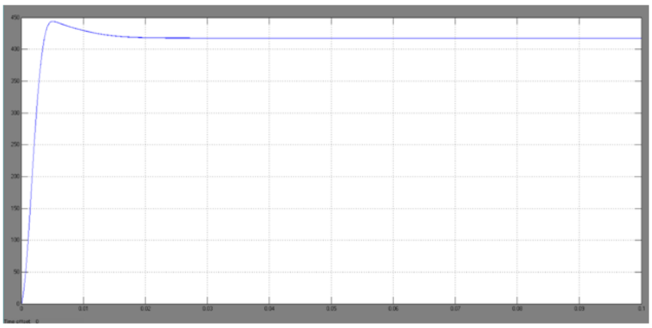
Shows the ooutput voltage of conventional high step-up interleaved converter

2: PV as input source of proposed converter with inverter module









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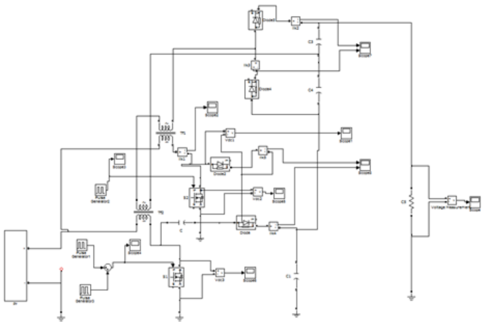

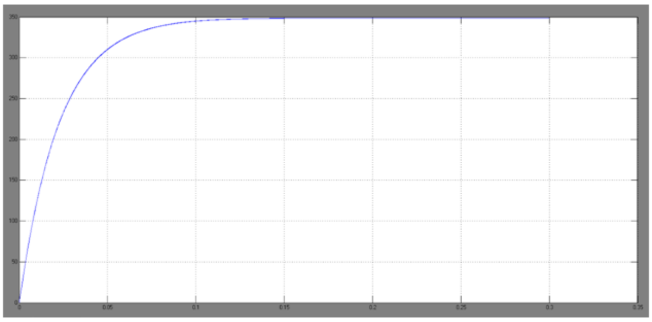

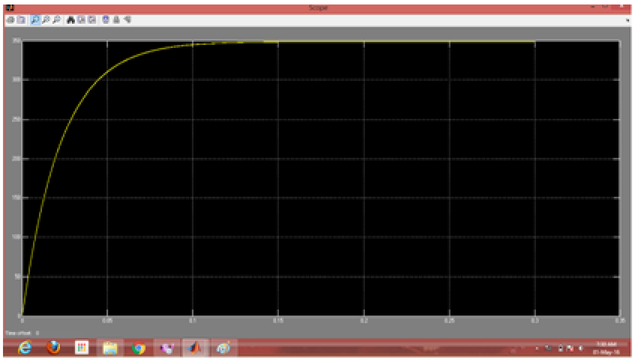

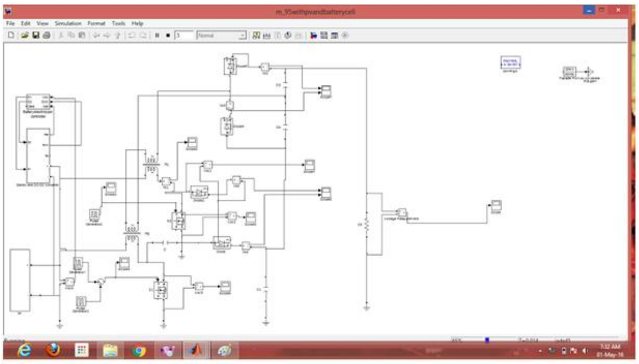

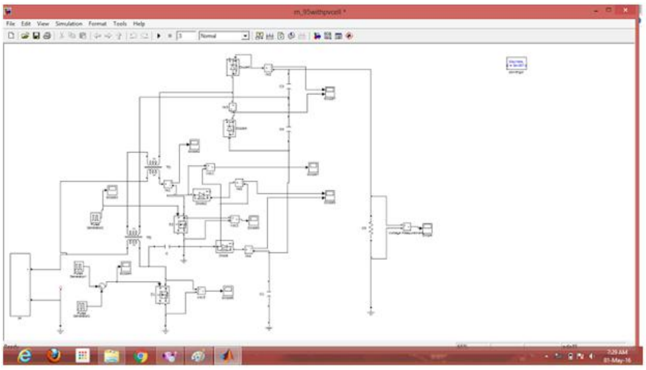

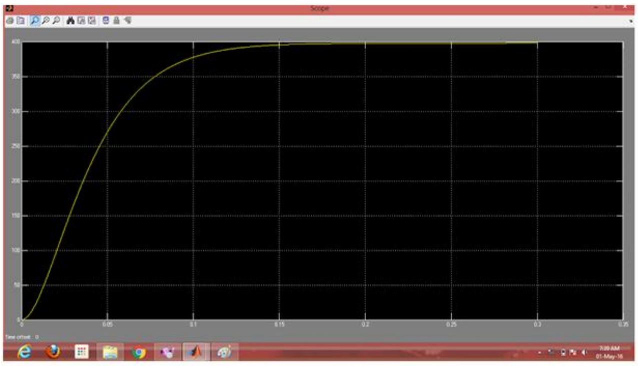

CONCLUSION:

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).

REFERENCES:

[1] Kuo-Ching Tseng and Chi-Chih Huang, High Step-Up High-Efficiency Interleaved Converter With Voltage Multiplier Module for Renewable Energy System, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 61, NO. 3, MARCH 2014.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

[2] GundepallySwathi&Dr.D.Padmavathi, High Step up Voltage Multiplier Module for a Hybrid EnergyConversion System, International Journal & Magazine of Engineering,Technology, Management and Research (IJMETMR), Volume No: 2 (2015), Issue No: 11 (November),

http://www.ijmetmr.com/olnovember2015/GundepallySwathi-DPadmavathi-28.pdf

[3] Y. Xiong, X. Cheng, Z. J. Shen, C. Mi, H. Wu, and V. K. Garg, "Prognostic and warning system for power-electronic modules in electric, hybrid electric, and fuel-cell vehicles,"IEEE Trans. Ind. Electron., vol. 55, no. 6, pp. 2268–2276, Jun. 2008.

[4] A. K. Rathore, A. K. S. Bhat, and R. Oruganti, "Analysis, design and experimental results of wide range ZVS active-clamped L–L type currentfed DC/DC converter for fuel cells to utility interface,"IEEE Trans. Ind. Electron., vol. 59, no. 1, pp. 473–485, Jan. 2012.

[5] T. Zhou and B. Francois, "Energy management and power control of a hybrid active wind generator for distributed power generation and grid integration," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 95–104, Jan. 2011.

[6] N. Denniston, A. M. Massoud, S. Ahmed, and P. N. Enjeti, "Multiplemodule high-gain high-voltage DC–DC transformers for offshore wind energy systems,"IEEE Trans. Ind. Electron., vol. 58, no. 5, pp. 1877– 1886, May 2011.

[7] H. Tao, J. L. Duarte, and M. A. M. Hendrix, "Line-interactive UPS using a fuel cell as the primary source,"IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 3012–3021, Aug. 2008.

[8] K. Jin, X. Ruan, M. Yan, and M. Xu, "A hybrid fuel cell system,"IEEE Trans. Ind. Electron., vol. 56, no. 4, pp. 1212–1222, Apr. 2009.

[9] A. I. Bratcu, I. Munteanu, S. Bacha, D. Picault, and B. Raison, "Cascaded DC–DC converter photovoltaic systems: Power optimization issues,"IEEE Trans. Ind. Electron., vol. 58, no. 2, pp. 403–411, Feb. 2011.

[10] R. J. Wai, W. H. Wang, and C. Y. Lin, "High-performance stand-alone photovoltaic generation system,"IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 240–250, Jan. 2008.

[11] R. J. Wai and W. H. Wang, "Grid-connected photovoltaic generation system,"IEEE Trans. Circuits Syst. I, Reg. Projects, vol. 55, no. 3, pp. 953– 964, Apr. 2008.

[12] L. Gao, R. A. Dougal, S. Liu, and A. P. Iotova, "Parallel-connected solar PV system to address partial and rapidly fluctuating shadow conditions," IEEE Trans. Ind. Electron., vol. 56, no. 5, pp. 1548–1556, May 2009.