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Design and Analysis of High Step-Up Converter with a Voltage Multiplier Module for a Solar Photovoltaic System with Maximum Power Point Tracker

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ABSTRACT: A novel high step-up converter is proposed for a frontend solar photovoltaic system. 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. 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. In addition the proposed converter functions as an active clamp circuit which alleviates large voltage spikes across the power switches. Thus, 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. Finally, the prototype circuit with a 40V input voltage, 380V output and 1000W output power is operated to verify its performance. The highest efficiency is 96.8%.

KEYWORDS: Voltage Multiplier Module, Solar PV System, MPPT, Boost Converter, Duty Cycle, Renewable Energy Sources.

I. INTRODUCTION

Renewable sources of energy are increasingly valued worldwide because of energy shortage and environmental contamination. Renewable energy systems generate low voltage output [1]. Thus, high step-up DC/DC converters are widely employed in many renewable energy applications such as fuel cells, wind power and solar photovoltaic systems. Among renewable energy systems solar photovoltaic systems are expected to play a vital role in future energy resources [3]. Such systems transform light energy into electrical energy and convert low voltage into high voltage via a step up converter which can convert energy into electricity using a grid by grid inverter or store energy into a battery set [5]. Fig 1 shows a typical solar photovoltaic system that consists of a solar module, a high step up converter, a charge discharge controller, a battery set and an inverter. The high step-up converter performs importantly among the system because the system requires a sufficiently high step-up conversion. Theoretically, conventional step-up converters, such as the boost converter and flyback converter, cannot achieve a high step-up conversion with high efficiency because of the resistances of elements or leakage inductance.

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that physically moves the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are

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completely different. The problem considered by MPPT methods is to automatically find the voltage VMPP or current IMPP at which a PV array delivers maximum power under a given temperature and irradiance. In this section, commonly used MPPT methods are introduced in an arbitrary order.

II. SYSTEM AND DESCRIPTION

Photovoltaic is the field of technology and research related to the devices which directly convert sunlight into electricity using semiconductors that exhibit the photovoltaic effect [4]. Photovoltaic effect involves the creation of voltage in a material upon exposure to electromagnetic radiation. A PV array consists of a number of PV modules, mounted in the same plane and electrically connected to give the required electrical output for the application [7]. The PV array can be of any size from a few hundred watts to hundreds of kilowatts, although the larger systems are often divided into several electrically independent sub arrays each feeding into their own power conditioning system.

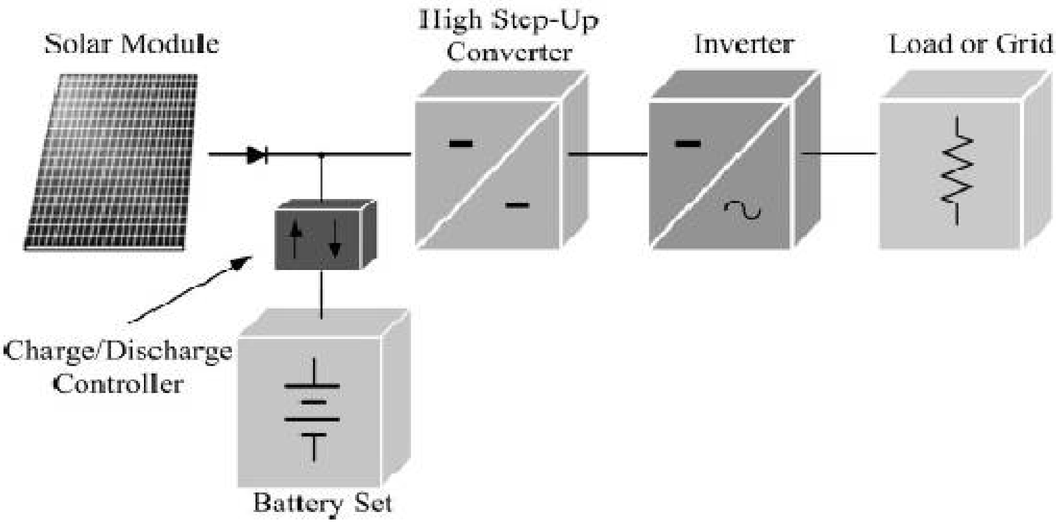

Fig. 1 Typical Solar Photovoltaic System

There are two main system configurations stand alone and grid connected. As its name implies, the stand-alone PV system operates independently of any other power supply and it usually supplies electricity to a dedicated load or loads [8]. It may include a storage facility (e.g. battery bank) to allow electricity to be provided during the night or at times of poor sunlight levels [9]. Stand-alone systems are also often referred to as autonomous systems since their operation is independent of other power sources. By contrast, the grid-connected PV system operates in parallel with the conventional electricity distribution system. It can be used to feed electricity into the grid distribution system or to power loads which can also be fed from the grid. It is also possible to add one or more alternative power supplies (e.g. diesel generator, wind turbine) to the system to meet some of the load requirements [2]. These systems are then known as hybrid systems [10]. Hybrid systems can be used in both stand alone and grid connected applications but are more common in the former because provided the power supplies have been chosen to be complementary, they allow reduction of the storage requirement without increased loss of load probability [6].

III. PROPOSED METHODOLOGY

The proposed high step-up converter with voltage multiplier module is shown in fig 2. 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 N_P 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 turn's ratios of the coupled inductors are the same.

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The equivalent circuit of the proposed converter is shown in fig 3, where L_{m1} and L_{m2} are the magnetizing inductors, L_{k1} and L_{k2} represent the leakage inductors, S_1 and S_2 denote the power switches, C_b is the voltage-lift capacitor and n is defined as a turn's ratio N_S /N_P.

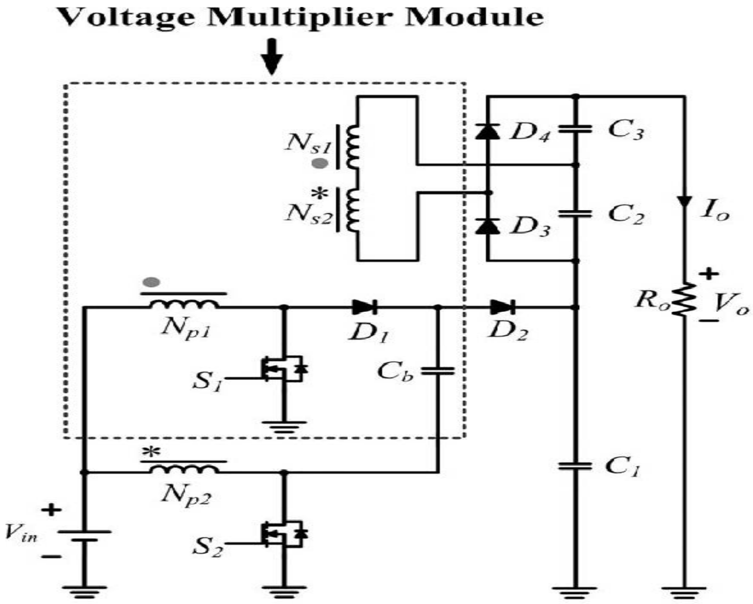

Fig. 2 Proposed high step-up converter with a voltage multiplier module

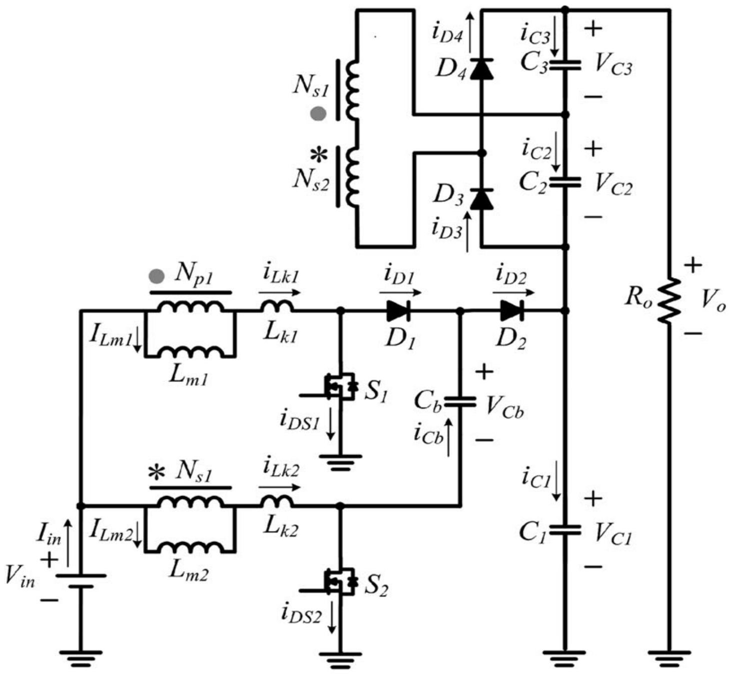

Fig. 3 Equivalent circuit of the proposed converter

It considers a network with N mobile unlicensed nodes that move in an environment according to some stochastic mobility models. It also assumes that entire spectrum is divided into number of M non-overlapping orthogonal channels having different bandwidth. The access to each licensed channel is regulated by fixed duration time slots. Slot timing is

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assumed to be broadcast by the primary system. Before transmitting its message, each transmitter node, which is a node with the message, first selects a path node and a frequency channel to copy the message. After the path and channel selection, the transmitter node negotiates and handshakes with its path node and declares the selected channel frequency to the path. The communication needed for this coordination is assumed to be accomplished by a fixed length frequency hopping sequence (FHS) that is composed of K distinct licensed channels. In each time slot, each node consecutively hops on FHS within a given order to transmit and receive a coordination packet. The aim of coordination packet that is generated by a node with message is to inform its path about the frequency channel decided for the message copying.

IV. SCOPE OF RESEARCH

Furthermore, the coordination packet is assumed to be small enough to be transmitted within slot duration. Instead of a common control channel, FHS provides a diversity to be able to find a vacant channel that can be used to transmit and receive the coordination packet. If a hop of FHS, i.e., a channel, is used by the primary system, the other hops of FHS can be tried to be used to coordinate. This can allow the nodes to use K channels to coordinate with each other rather than a single control channel. Whenever any two nodes are within their communication radius, they are assumed to meet with each other and they are called as contacted. In order to announce its existence, each node periodically broadcasts a beacon message to its contacts using FHS. Whenever a hop of FHS, i.e., a channel, is vacant, each node is assumed to receive the beacon messages from their contacts that are transiently in its communication radius.

IV. SIMULATION RESULTS

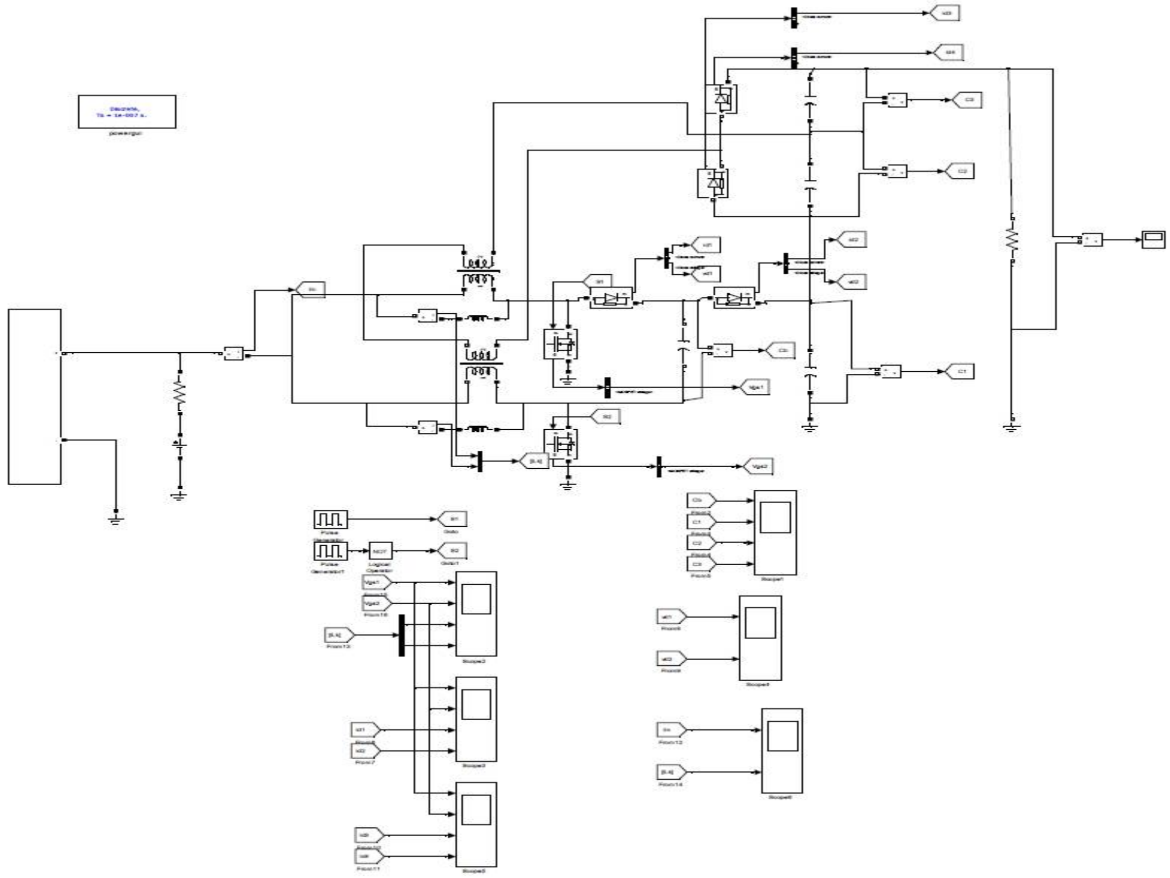

Fig. 4 Simulation Circuit for High Step-Up Converter with a Voltage Multiplier Module for a Solar Photovoltaic System with Maximum Power Point Tracker

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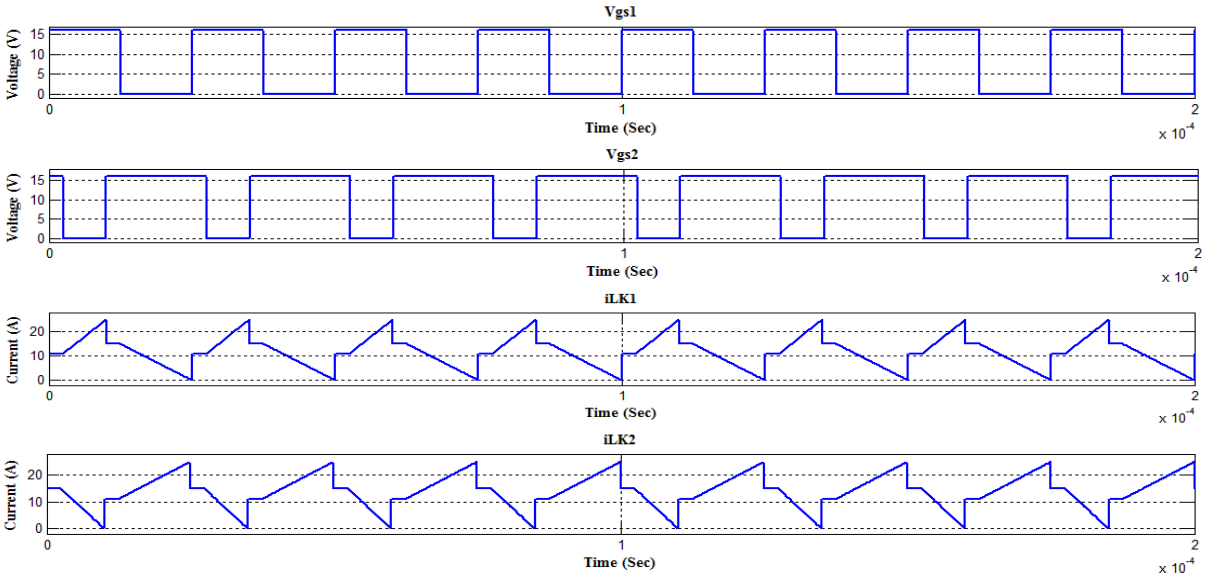

Fig. 5 Output Waveforms for $V_{gs1,}V_{gs2.}i_{LK1} and\ i_{LK2}$

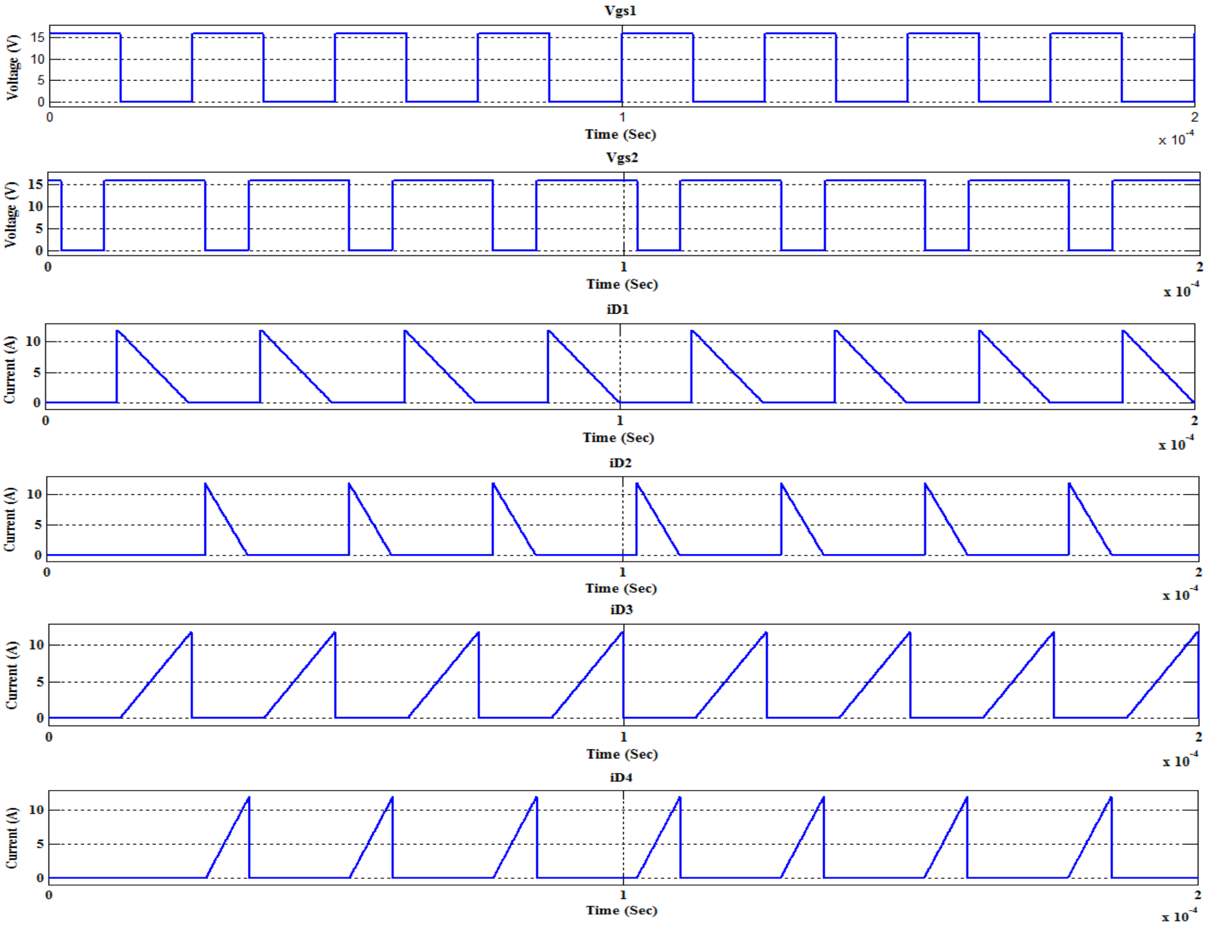

Fig. 6 Output Waveforms for $V_{gs1,}V_{gs2.}i_{D1,}i_{D2,}i_{D3}\ and\ i_{D4}$

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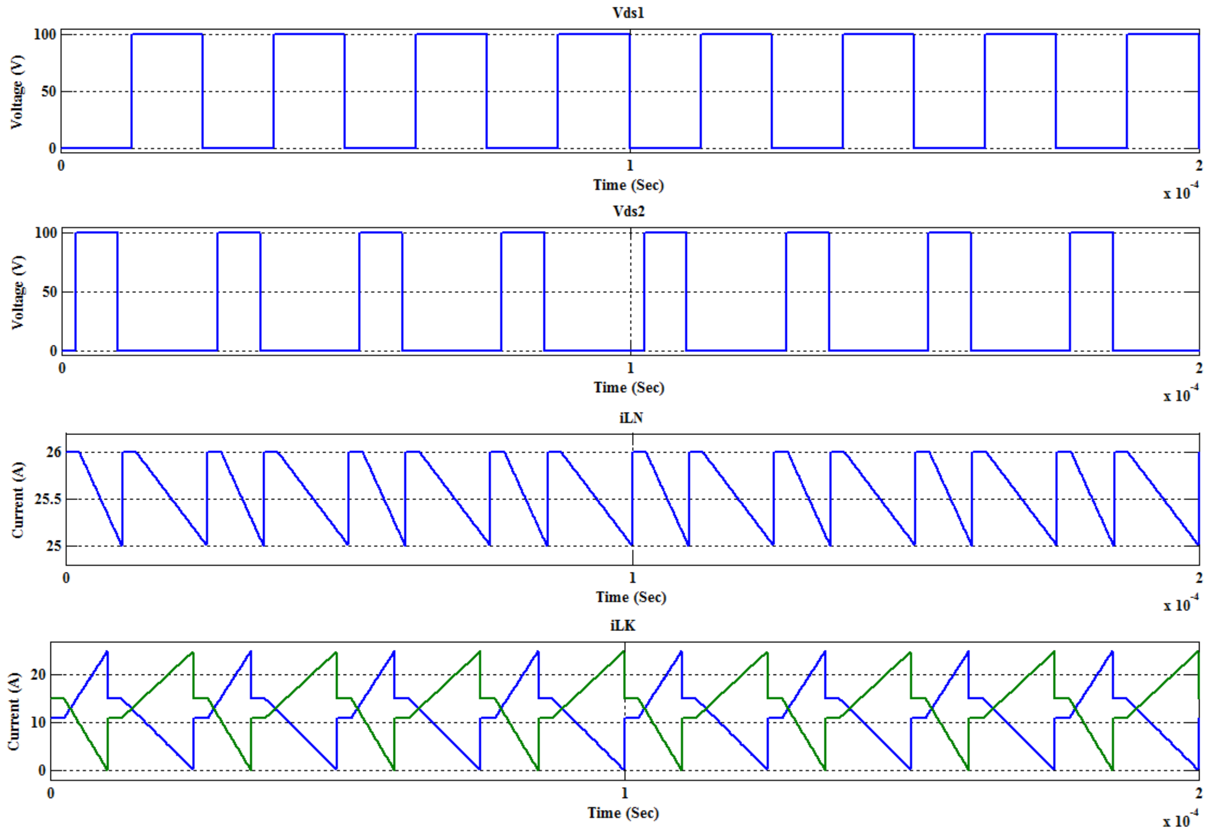

Fig. 7 Output Waveforms for $V_{ds1,}V_{ds2.}i_{LN}$ and i_{LK}

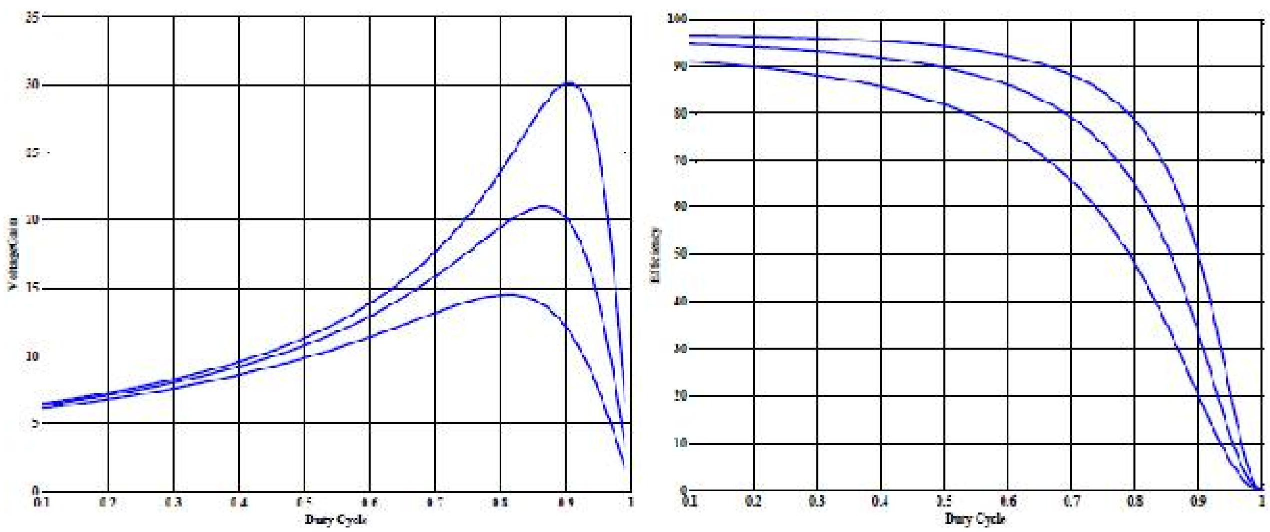

Fig. 8 System Voltage Gain and Efficiency

V.CONCLUSION

This paper has presented the design principles, steady state analysis and simulation results for a proposed converter. The proposed converter has been successfully implemented in an efficiently high step-up conversion without an

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extreme duty ratio and a number of turn's ratios through the voltage multiplier module and voltage clamp feature. The interleaved PWM scheme reduces the currents that pass through each power switch and constrained the input current ripple by approximately 6%. The simulation results indicate that leakage energy is recycled through capacitor C_b to the output terminal. Meanwhile, the voltage stresses over the power switches are restricted and are much lower than the output voltage (380V). These switches, conducted to low voltage rated and low ON state resistance MOSFET can be selected. Furthermore, the full-load efficiency is 96.1% at Po = 1000 W, and the highest efficiency is 96.8% at Po = 400 W. Thus, the proposed converter is suitable for solar photovoltaic systems or other renewable energy applications like wind, fuel cell etc., that need high step-up high power energy conversion.

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