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An Interleaved High Step-Up Boost Converter With Voltage Multiplier Module for Renewable Energy System

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Abstract - *This paper presents a high step up DC-DC converter with voltage multiplier module. Through a voltage multiplier module composed of switched capacitors and coupled inductors, a conventional interleaved boost converter obtains high step-up gain without operating at extreme duty ratio. High boost dc-dc converters play an important role in renewable energy sources such as fuel energy systems, DC-back up energy system for UPS, high intensity discharge lamp and auto mobile applications. Renewable energy sources such as photovoltaic energy are available in both clean and economical due to new advancement in technology and use of good and efficient cells. The configuration of the proposed converter not only reduces the current stress but also constrains the input current ripple, which decreases the conduction losses and lengthens the lifetime of the input source. DC power can be converted into AC power at desired output voltage and frequency by using an inverter. The coupled inductors can be designed to extend step-up gain, and the switched capacitors offer extra voltage conversion ratio. Hence, large voltage spikes across the main switches are alleviated, and the efficiency is improved. 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.*

***Key Words*: Switched Capacitors, Coupled Inductors bridge Inverters, Boost–fly back converter, high step-up, photovoltaic (PV) system, voltage multiplier module.**

1. INTRODUCTION

Renewable energy sources such as photovoltaic energy are available in both clean and economical due to new advancement in technology and use of good and efficient cells. Solar energy is advantageous compared to any other renewable energy sources available. The efficient and fast growth in the field of solar energy result in Photovoltaic (PV) system design for various application with reliable operation and application for more reliable and efficient operation. PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of PV module depends on the solar insolation, the cell temperature and output voltage of PV module. Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of PV system applications.

DC-to-DC converter is a device that converts low value of dc input voltage to another dc output voltage. Typically the output produced is at a different voltage level than the input. In addition, the DC-to-DC converters are applicable in noise isolation and power bus regulation. The high step up DC-DC converter with coupled inductor and voltage multiplier is discussed in this report. High boost DC-DC converters operating at high voltage regulation are widely proposed in many industrial applications. High boost dc-dc converters play an important role in renewable energy sources such as fuel energy systems, DC-back up energy system for UPS, high intensity discharge lamp and auto mobile applications. The converters require increasing low dc voltage to high dc voltage. The conventional boost converters produces high voltage gain with increasing high values of duty cycle. A voltage gain is difficult to achieve with conventional topologies of DC-DC converters because several reasons such as parasitic components, the requirement of an high duty cycles, which limits the switching frequency and component size. Converters with transformers provide solutions to achieve a high voltage gain, a low voltage stress on the active switch, and a high efficiency without the increase of high duty ratio. The transformer can be replaced with coupled inductors to reduce the conduction or core losses in the system.

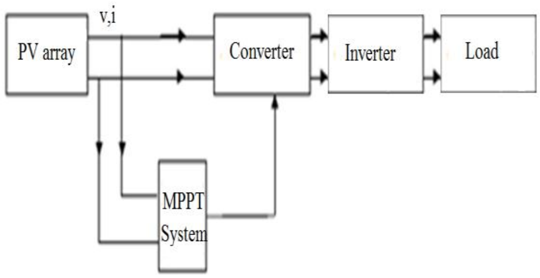

Fig -1: Block diagram of the system

1.1 PV Panel

A PV array is a group of several PV cells which are electrically connected in series and parallel circuits to generate the required current and voltage. The characteristics have a current source region and a voltage source region. The impedance is low at voltage source region, whereas high at current source region. Solar radiation is an important factor determining the I-V characteristics, hence these factors are required for the designing and implementation of solar cell. The short circuit current increases with the increase in solar radiation and open circuit voltage decreases with increase in temperature for constant radiation on surface of the cell. Partial shading is a phenomenon occurring in solar cells causing several numbers of maximum power points. The diodes are provided for reducing the reverse currents caused due to the problems of partial shading. These reverse current causes heating on solar cells, affecting the efficiency and performance at higher temperatures.

The electrical system connecting to the photovoltaic system depends on cell temperature, also sudden change in weather condition result in varying solar irradiation on the surface. The output voltage and current varies with the change in these parameters. These will affect in tracking maximum power from the cell.

1.2 Maximum Power Point Tracking (MPPT)

MPPT technique is to extract maximum power from photovoltaic systems. MPPT maintains the operation of maximum power with efficient MPPT techniques and they differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking etc. Hill Climbing Techniques are used for tracking maximum power. Here the PV system uses P & O algorithm because of simplicity, less time and parameters requirement. The algorithm starts with setting the reference voltage and power of the module.

Perturbation and Observation method is a Hill climbing method. In this method the operating voltages are increased or decreased for attaining a maximum point of operating and it compares the present value with previous value in each cycle of perturbation. The perturbation value decrease or increase the value of power, then the voltages are adjusted for obtaining a maximum power point. The operating point shifts with the perturbation on voltages, with a step increase or decrease in the duty cycle of the converter connected. The operating point oscillates around the maximum point causing power loss is a disadvantage of this method of tracking power. The step size is decreased to reduce the oscillation around the operating point. If the power and voltage are increased comparing to the previous cycle, then increase the voltage in order to track maximum power from left of the curve. If the change in power is increased and change in voltage is decreased, then decrease the voltage to track MPP from right of the curve. If the change in power is decreased and change in voltage is increased, then also decrease the voltage to track the operating point back to MPP, which is moving away from maximum point.

2. OPERATING PRINCIPLES OF CONVERTER

The step up converter is a non-isolated topology for boosting low voltage input to high voltage output. The input current is usually continuous in nature and is supplied to the load by either the conduction of diodes or capacitors. The boost converter with voltage multiplier by means of coupled inductor insertion increases the output voltage, hence the voltage gain and efficiency, with low value of duty cycle. The output voltage across the load is the sum of the voltage from boost converter and the voltage across the voltage multiplier capacitors. The required duty cycle can be obtained by adjusting the voltage multiplier, which increases the output voltage. The voltage multiplier module is composed of two coupled inductors and two switched capacitors and is inserted between a conventional interleaved boost converter to form a modified boost–flyback–forward interleaved structure.

When the switches turn off by turn, the phase whose switch is in OFF state performs as a fly back converter, and the other phase whose switch is in ON state performs as a forward converter.

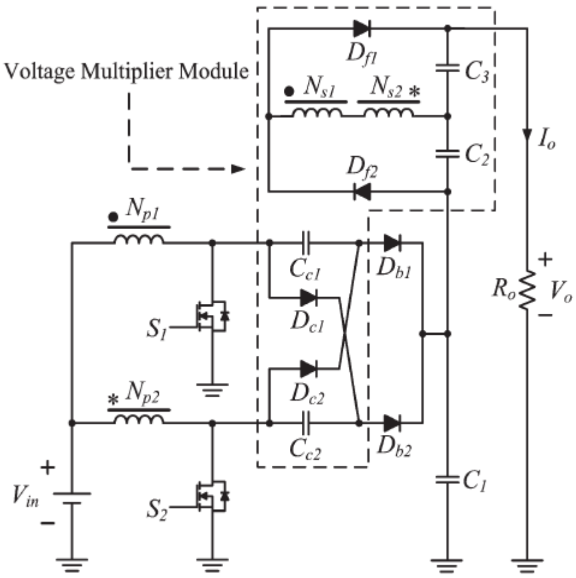

Fig -2: High step up converter with voltage multiplier

The equivalent circuit of the proposed converter is shown below, where *Lm*1 and *Lm*2 are the magnetizing inductors; *Lk*1 and *Lk*2 represent the leakage inductors; *Ls* represents the series leakage inductors in the secondary side; *S*1 and *S*2 denote the power switches; *Cc*1 and *Cc*2 are the switched capacitors; and *C*1, *C*2, and *C*3 are the output capacitors.

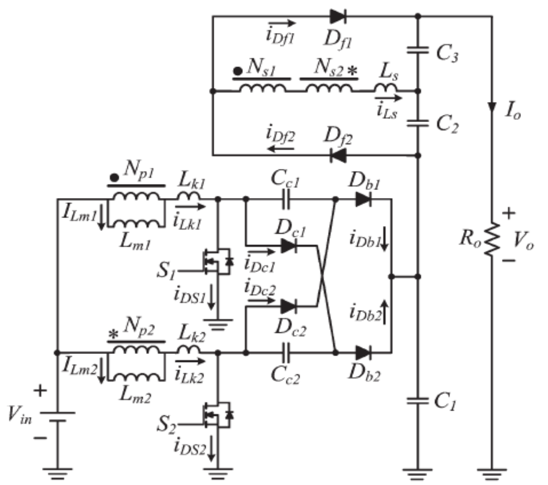

Fig -3: Equivalent circuit of High step up converter

When the switch S1 in the ON state, the magnetizing inductor, Lm1 is in the charging state. The reverse polarity of Lm2 causes diodes Dc2 and Db2 forward biased. Energy stored in Lm2 is transferred to the secondary side of the coupled inductor. The current through the series leakage inductor,Ls flows to the output terminal through the output capacitor C3 and flyback forward diode. When the switch S2 in the ON state, the magnetizing inductor, Lm2 is in the charging state. The reverse polarity of Lm1 causes diodes Dc1 and Db1 forward biased. Energy stored in Lm1 is transferred to the secondary side of the coupled inductor. The current through the series leakage inductor,Ls flows to the output terminal through the output capacitor C2 and flyback forward diode.

3. SIMULINK MODEL

The simulation is done on MATLAB simulink. The output of the PV system is connected to the boost converter and then to an inverter for connecting to ac loads. The simulink model of the system is shown below. The PV output voltage greatly governed by temperature while PV output current has approximate linear relationship with solar irradiances. Due to the high capital cost of PV array, MPPT control techniques are essential in order to extract the maximum available power from PV array in order to maximize the utilization efficiency of PV array.

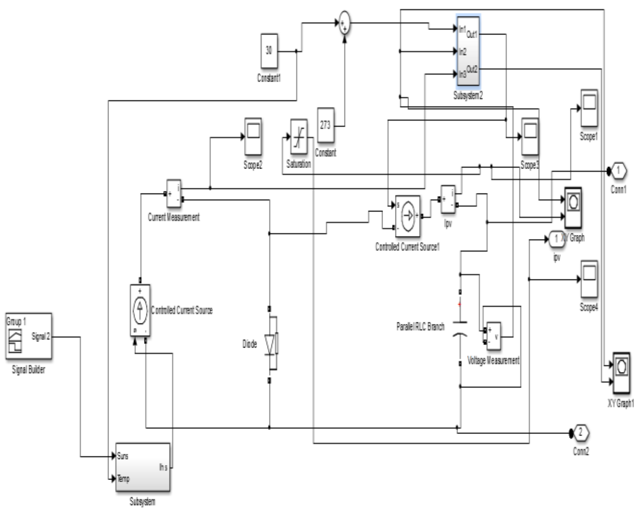

Fig -4: Simulink model of the PV Panel

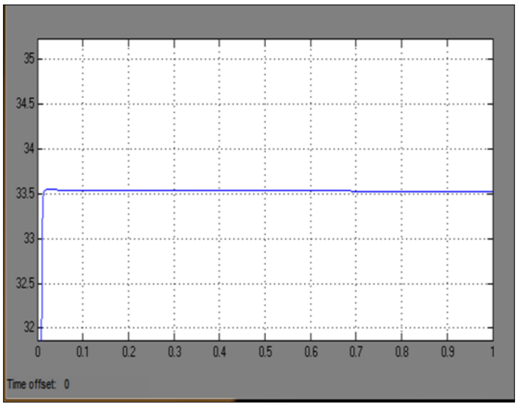

Fig -5: Input Voltage from PV Panel

The MPPT technique is simulated with the principle of P & O algorithm. The signal obtained from the algorithm are given to the gate of boost converter for the operation. The simulation model of the MPPT algorithm with P and O algorithm is shown below.

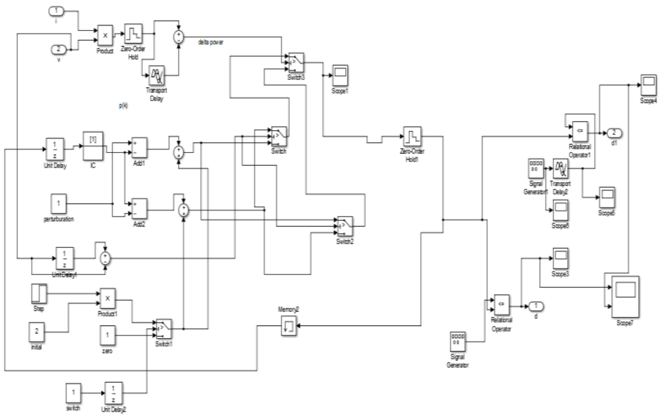

Fig -6: Simulink model of the MPPT

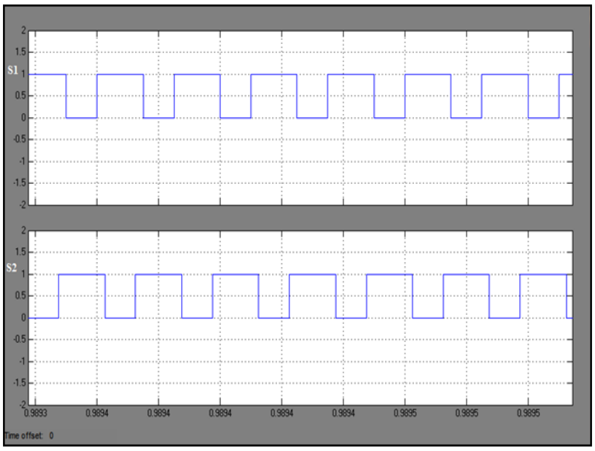

Fig -7:Gate Pulses to Switches

The high gain high step up converter with voltage multiplier is simulated on MATLAB software environment with photovoltaic system. The simulation was done with an input of 30-35 V supply to obtain an output of 300-400 V with combination of boost converter with voltage multiplier. The interleaved boost converter topology is designed for minimizing the switching losses and to improve the efficiency. The advantages of interleaved boost converters are to reduce current ripple and increases life of PV module. The capacitors C2 and C3 are designed for 220 µF and C1 for 470µF. The frequency is adjusted to 40 kHz by means of a pulse generator to obtain a gate pulse for the both the MOSFET switches. In the simulation of boost converter with voltage multiplier the voltage across load VL, voltage across switch VS, voltages across capacitors VC1, VC2 and VC3 are obtained. The design consideration of the high boost converter integration with voltage multiplier includes components selection and coupled inductor design. Due to the performance of high step up gain the turns ratio are set as 1:1. The boost converter with voltage multiplier can be efficiently implemented for step up conversion without extreme duty cycle.

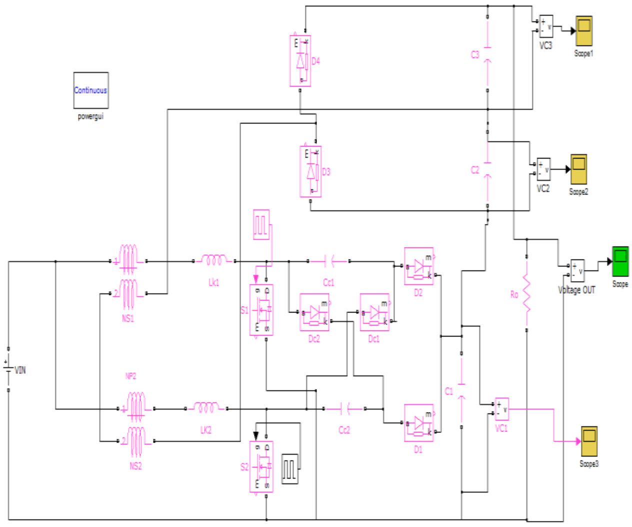

Fig -8: Simulink model of the High Step up Converter

The H Bridge inverters are connected to the output of high step up converter for connecting it to the ac loads. The reference sine wave of fundamental frequency is compared with four carrier triangular waves for generating basic pulses for the inverter. The triangular pulses are selected for a frequency of 25kHz.

The basic pulses are produced by comparing the triangular carrier waves with reference sine wave inverter. The output of converter is given to a multilevel inverter for inverting the dc voltage to ac voltage.

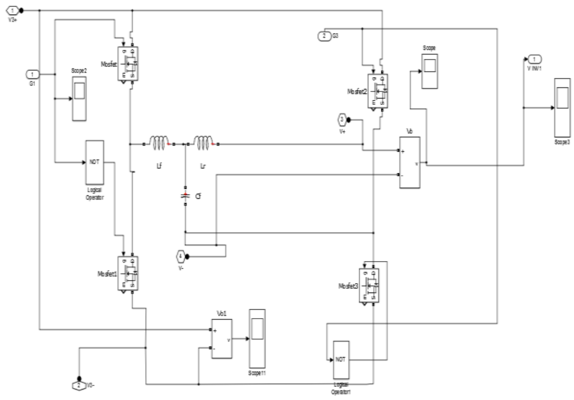

Fig -9: Simulink model of the Inverter

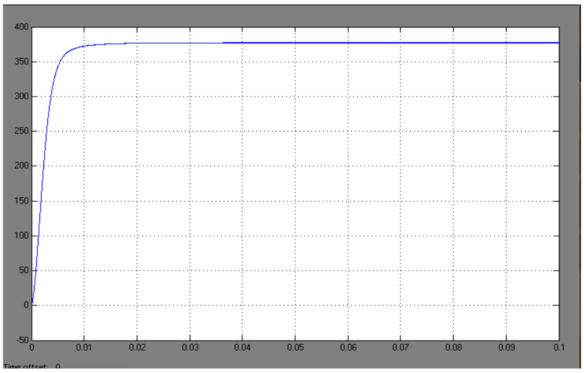

Fig -10: Output voltage of the High Step up Converter

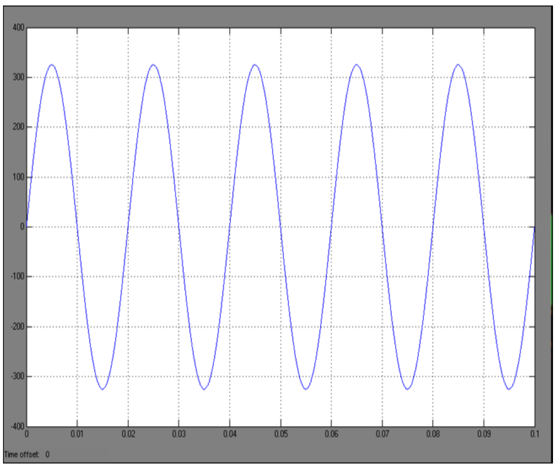

Fig -11: Output voltage of the Inverter

4. HARDWARE IMPLEMENTATION

Prototype for high boost converter with voltage multiplier on integration with coupled inductor is implemented. The converter circuit is designed using Printed Circuit Board (PCB) design. PIC 16F877A microcontroller is used in the controller part to generate PWM pulses for the MOSFET switches. A printed circuit board, or PCB, is used to mechanically support and electrically connect electronic components using conductive pathways, or traces, etched from copper sheets laminated onto a non-conductive substrate. The manufacturing process consists of two methods; print and etch, and print, plate and etch. The single sided PCBs are usually made using the print and etch method. The double sided plate through - hole (PTH) boards are made by the print plate and etch method.

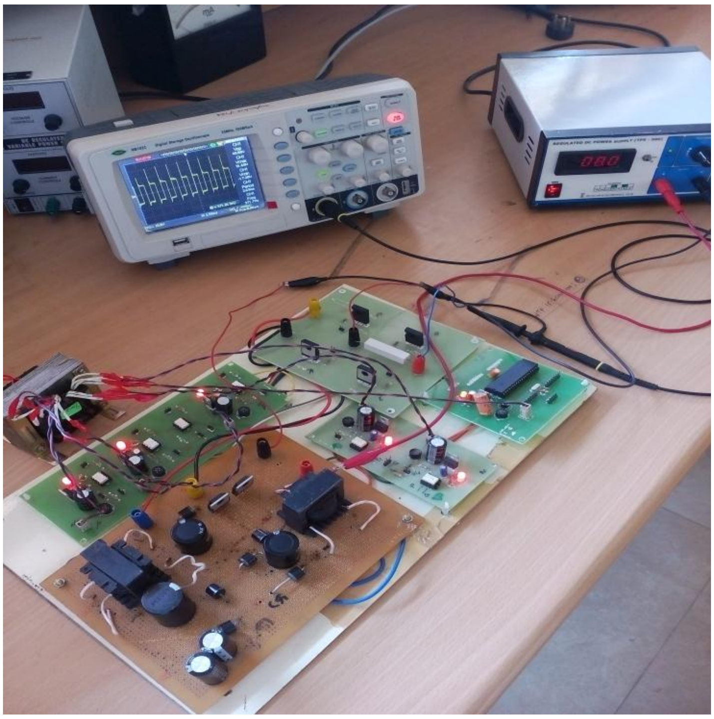

Fig -12: Hardware set up of the system

5. EXPERIMENTAL RESULTS

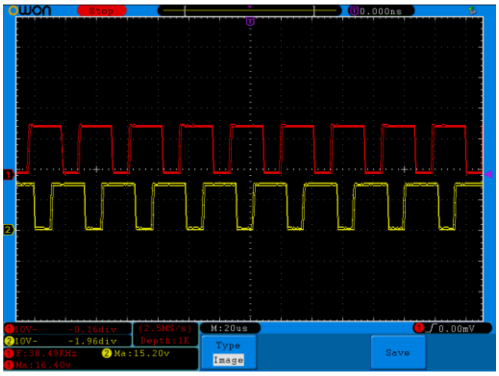

Fig -13: Switching pulses of the Converter

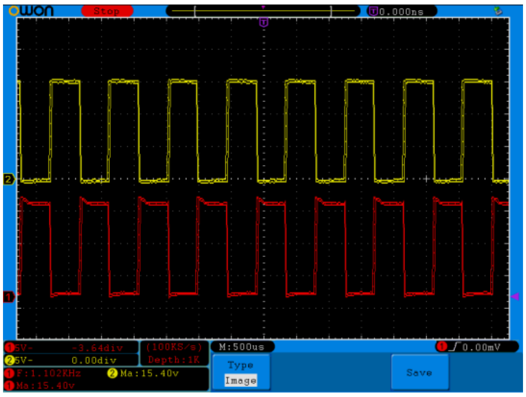

Fig -14: Switching pulses of the Inverter

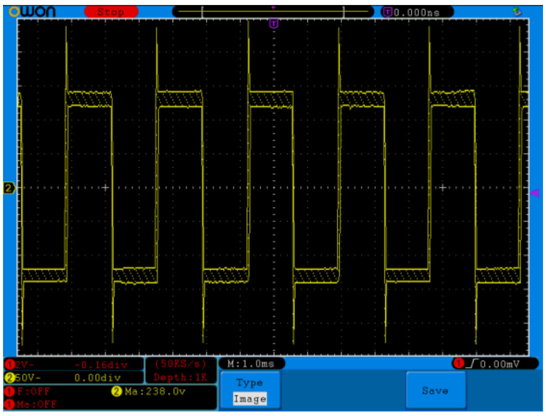

Fig -15: Output voltage from the Inverter

6. CONCLUSIONS

A High step-up converter has been implemented in this paper. A large voltage step-up with reduced voltage stress across the main switches, important when employed in grid-connected systems based on battery storage, like renewable energy systems and uninterruptible power system applications. Other characteristics of the converter are: voltage balancing between output capacitors, low input-current ripple, high switching frequency, which reduce the structure volume and weight, simple switching control, as just a simple voltage-loop control based on the conventional boost was implemented, and the possibility to make the voltage gain even higher by increasing the transformer turns-ratio. 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. We can extend this system to huge commercial loads by increasing the power ratings of PV module. Also we can improve monitoring by using suitable current, voltage sensors into the system. Thus, the converter is suitable for high-power or renewable energy applications that need high step-up conversion.

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