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Review of Step up Converter with Voltage Multiplier for Photovoltaic System

Mr. Bhushan S. Chaudhari,
Research Scholar, Electrical Engineering Dept,
SSBT's COET, Jalgaon (MS), India.

Mr. M. M. Ansari,
Assistant Professor, Electrical Engineering Dept,
SSBT's COET, Jalgaon (MS), India.

Mr. N. S. Mahajan,
Assistant Professor, Electrical Engineering Dept,
SSBT's COET, Jalgaon (MS), India.

***Abstract:** Now a day the utilization of photovoltaic energy becomes an important source of electrical energy with the advancement in power electronic technology. The step up converters is one of inevitable part of renewable energy system, for connecting the photovoltaic panel to the grid or AC load through an inverter. The MPPT (Maximum Power Point Tracking) maximizes the power production for PV panel. The advantages of step up converters includes improving voltage gain without using extreme duty ratio, the reduction of voltage stress, current ripple and conduction losses are desirable for renewable energy applications. The review of various topologies for step up converter and their performance with voltage multiplier circuits are discussed in this paper. The merits and demerits of these steps up converters are discussed. Efficiency improves because the energy stored which is in leakage inductances is recycled to the output terminal. Finally, for the prototype circuit with a 40 V input voltage, output 380 V, and also 1000 W output power is operated to verify its performance. The highest efficiency of the step up converter for photovoltaic system is 96.8%.*

***Keywords:** Step up converter, voltage multiplier, renewable energy, photovoltaic system, MPPT.*

I. INTRODUCTION

With the development in power electronics technologies the renewable energy sources utilization become an increasing trend for electrical energy. The photovoltaic system is a feasible energy source in research and development work in power system and power electronics. For the better consumption of solar energy a high reliable, low cost, design are required for the PV integrated high step up topologies. The DC/AC inverters control the output voltage of DC/DC converter and generate a fundamental real power required for the loads. The conventional boost converter provide step up conversion without high gain due the limitation of conduction losses in the circuit parameters. The gain reaches infinite, when the duty cycle tends to unity. High performance dc to dc converter can be obtained with MPPT technique and islanding detection for photovoltaic system are now considered for the interface to the grid or ac utilities. The gain depends on the I2R losses in the inductors and the power electronic devices connected [1]. The voltage gain is difficult to obtain with conventional boost topologies because of the parasitic components, which limits the frequency and the system size. A voltage multiplier is a device which converts the low voltage input to a higher voltage by means of capacitors and diodes combined circuit. The voltage multiplier helps in reducing the turn's ratio of transformer for better performance. The conventional boost converters are provided with voltage multipliers to increase the voltage gain without having high duty cycle and reduce the voltage stress across the switches. The voltage multiplier reduces the peak current flowing through the switch and enhances the dynamic response with the increase of turn OFF period [2] [3].

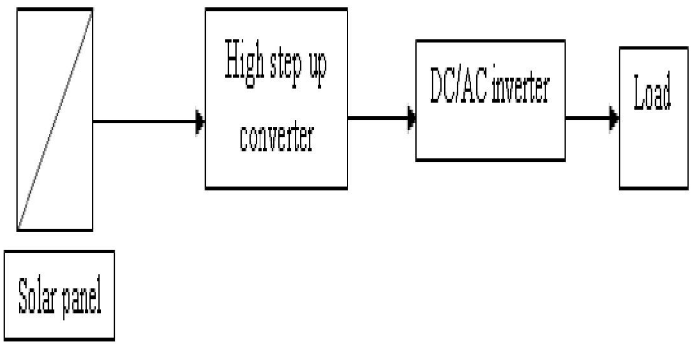

Fig. 1 Block diagram of photovoltaic system

The importance of renewable energy resources increases day by day because of their eco-friendly nature and limited sources of non-renewable energy resources. So that the world focus increases towards the utilization of these energy resources. Photovoltaic systems carries major role in the production of energy than other renewable resources. But these system gives less output so that the step up converters was suggested for such system But the suggested converter are conventional type converter and fails to attain high output. In fact, their efficiency is also less. For this reason, certain modifications were done and the new converter i.e. boosts and fly back was suggested to come out from this problem [3]. Also, the converters having inductor coupling for the purpose of improvement of conversion ratio were also suggested. Thus, by using such converters low voltage can be converted into high voltage. Away from this, conventional converters have single switch and thus produced large ripple in current which increases losses in conduction in case of high rating applications. Thus, the new converter was suggested in case of solar photovoltaic system by using module of voltage multiplier given in [4]. But, in this system SPWM method is used for converters and inverters.

II. PHOTOVOLTAIC TECHNOLOGY

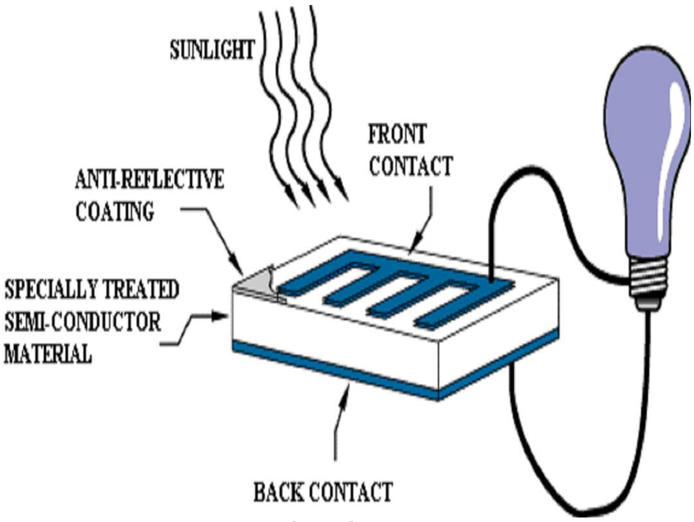

Fig. 2 Photovoltaic Process

Photovoltaic's is the field of technology and research related to the devices which directly convert sunlight into electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic effect involves the creation of voltage in a material upon exposure to electromagnetic radiation. The photovoltaic effect was first noted by a French physicist, Edmund Becquerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric. The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon. One of the properties of semiconductors that makes them most useful is that their conductivity may easily be modified by introducing impurities into their crystal lattice. For instance, in the fabrication of a photovoltaic solar cell, silicon, which has four valence electrons, is treated to increase its conductivity [4]. On one side of the cell, the impurities, which are phosphorus atoms with five valence electrons (n-donor), donate weakly bound valence electrons to the silicon material, creating excess negative charge carriers. However, the diffusion of carriers does not occur indefinitely, because the imbalance of charge immediately on either sides of the junction originates an electric field. This electric field forms a diode that promotes current to flow in only one direction. Ohmic metal-semiconductor contacts are made to both the n-type and p-type sides of the solar cell, and the electrodes are ready to be connected to an external load. When photons of light fall on the cell, they transfer their energy to the charge carriers. The electric field across the junction separates photo-generated positive charge carriers (holes) from their negative counterpart (electrons). In this way an electrical current is extracted once the circuit is closed on an external load [7].

III. SOLAR CELL

The photovoltaic effect was first reported by Edmund Becquerel in 1839 when he observed that the action of light on a silver coated platinum electrode immersed in electrolyte produced an electric current.

Forty years later the first solid state photovoltaic devices were constructed by workers investigating the recently discovered photoconductivity of selenium. In 1876 William Adams and Richard Day found that a photocurrent could be produced in a sample of selenium when contacted by two heated platinum contacts. The photovoltaic action of the selenium differed from its photoconductive action in that a current was produced spontaneously by the action of light. No external power supply was needed. In this early photovoltaic device, a rectifying junction had been formed between the semiconductor and the metal contact. In 1894, Charles Fritts prepared what was probably the first large area solar cell by pressing a layer of selenium between gold and another metal. In the following years photovoltaic effects were observed in copper {copper oxide thin _lm structures, in lead supplied and thallium supplied [8]. These early cells were thin film Schottky barrier devices, where a semitransparent layer of metal deposited on top of the semiconductor provided both the asymmetric electronic junction, which is necessary for photovoltaic action, and access to the junction for the incident light. The photovoltaic effect of structures like this was related to the existence of a barrier to current flow at one of the semiconductor {metal interfaces (i.e., rectifying action) by Goldman and Brodsky in 1914. Later, during the 1930s, the theory of metal {semiconductor barrier layers was developed by Walter Schottky, Neville Mott and others. western world led to a sudden growth of interest in alternative sources of energy, and funding for research and development in those areas. Photovoltaic’s was a subject of intense interest during this period, and a range of strategies for producing photovoltaic devices and materials more cheaply and for improving device Efficiency were explored. Routes to lower cost included photo electrochemical junctions, and alternative materials such as polycrystalline silicon, amorphous silicon, other `thin _lm' materials and organic conductors. Strategies for higher efficiency included tandem and other multiple band gap designs. Although none of these led to widespread commercial development, our understanding of the science of photovoltaics is mainly rooted in this period [10].

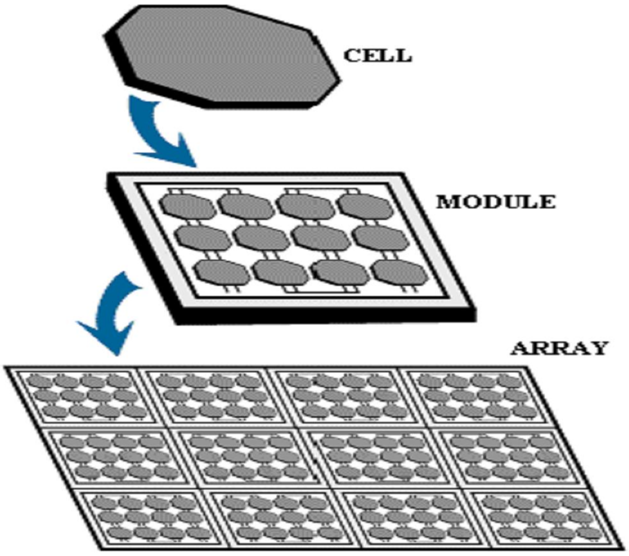

Fig.3 Solar Cell

The photovoltaic system consists of high step up converter, inverter, solar module and load. Hysteresis method and SPWM method are the control methods used for converters. The solar model is designed for 40V output [5] and [6]. As solar module generates low output, its output is given to the high step up converter. It increases the gain in voltage efficiently up to 380V. The output of converter is given to the inverter and then from inverter it is given to the load. The system contains the module of voltage multiplier which consists of two inductors which are coupled and the boost converter. The inductors which are coupled have primary windings and secondary winding.

IV. OPERATING PRINCIPLE DESCRIPTION

The proposed high step-up converter with voltage multiplier module is shown in Fig. 4. A step up 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.

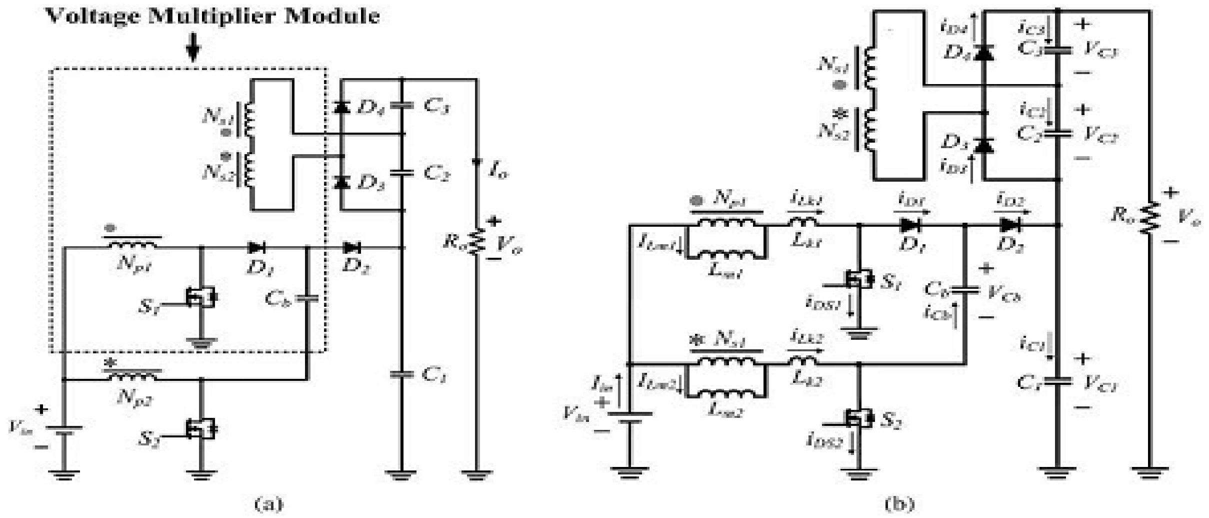

Fig.4 Step up converter with voltage multiplier module

The equivalent circuit of the proposed converter is shown in Fig. 4, where Lm1 and Lm2 are the magnetizing inductors, Lk1 and Lk2 represent the leakage inductors, S1 and S2 denote the power switches, Cb is the voltage-lift capacitor, and nis defined as a turns ratio Ns/Np. 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. The key steady waveforms in one switching period of the proposed converter contain six modes.

A. Mode I

[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 inductors Lk1 and Lk2 are linearly charged by the input voltage source Vin.

B. Mode II

[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 inductor Lk2, and voltage-lift capacitor Cb release energy to the output filter capacitor C1 via diode D2, thereby extending the voltage on C1.

C. Mode III

[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.

D. Mode IV

[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.

E. Mode V

[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 Lm 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.

F. Mode VI

[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.

The advantages of the proposed converter are as follows:
1) The step up converter is characterized by a low input current ripple and low conduction losses, making it suitable for high power applications.
2) The step up converter achieves the high step-up voltage gain that renewable energy systems require.
3) Leakage energy is recycled and sent to the output terminal, and alleviates large voltage spikes on the main switch.
4) The main switch voltage stress of the converter is substantially lower than that of the output voltage.
5) Low cost and high efficiency are achieved by the low rDS (on) and low voltage rating of the power switching device.

V. VOLTAGE GAIN

From the equivalent circuit of the proposed converter, the first phase converter is considered as a conventional boost converter. Thus the voltage derived from VCb can be expressed as,

$$V_{cb} = [\ 1/(1 - D)\ ]\ .\ V_{in} \qquad [1]$$

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

$$V_{c1} = [\ 1/\ (1 - D)\ ]\ .\ V_{in} + V_{cb} = [\ 2\ /\ (\ 1 - D\ )\ ]\ .\ V_{in} \qquad [2]$$

The energy transformation from the primary side charges the output filter capacitors C2 and C3. When the power switch S2 is in turn-on state and the power switch S1 is in turn-off state, VC2 is equal to the induced voltage of Ns1 and the induced voltage of Ns. And when the power switch S1 is in turn-on state and the power switch S2 is in turn-off state, VC3 is also equal to induced voltage of Ns1 and the induced voltage of Ns2.

VI. DESIGN OF THE PROPOSED CONVERTER

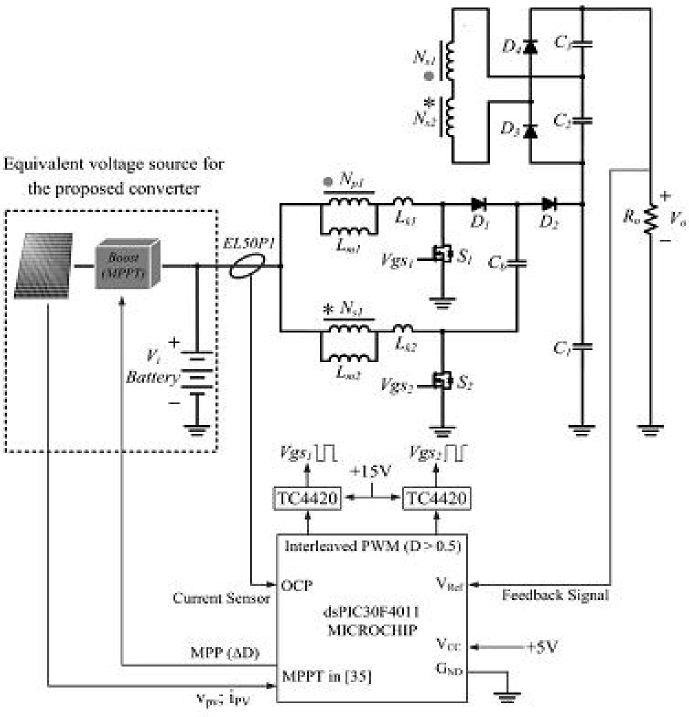

Fig.5 Control Strategy for the proposed converter

A prototype of the proposed high step-up converter with a 40-V input voltage, 380-V output voltage, and maximum output power of 1 kW is tested. The switching frequency is 40 kHz.

The design consideration of the proposed converter includes components selection and coupled inductors design, which are based on the analysis presented in the previous section. In the proposed converter, the values of the primary leakage inductors of the coupled inductors are set as close as possible for current sharing performance. Due to the performances of high step-up gain, the turn's ration can be set 1 for the prototype circuit with a 40 V input voltage, 380 V output to reduce cost, volume, and conduction loss of winding.

VII. CONCLUSION

This paper has offered the principles, a steady state analysis, and also experimental results for a proposed asymmetrical interleaved converter. The proposed converter has been successfully employed in an efficiently high step-up conversion without an excessive duty ratio. The interleaved PWM scheme decreases the currents that pass through each power switch and constrained the input current ripple. The experimental results indicate that leakage energy is recycled through capacitor Cb to the output terminal. The voltage stresses over the power switches are also restricted. Higher efficiency is obtained. Thus, the proposed asymmetrical interleaved converter is suitable for PV systems and other renewable energy applications which need high step-up and high-power energy conversion.

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