Renewable Power Generation System Using PWM Controlled-Asymmetrical High Gain Full Bridge Converter

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Abstract--**PWM controlled PV system develops high efficient controllable system. The proposed converter achieves ZVS and ZCS switching, can be implemented with asymmetrical full bridge high gain converter which improves the conversion efficiency in conventional boost converters. PWM with feedback controlling is employed for the voltage control of the system. A power management system is designed for the proposed system to manage power flow among different sources. A simulation model using MATLAB/Simulink for high gain converter employed in a PV system has been developed and simulation studies are carried out to verify the system performance under different load conditions. The proposed converter is able to provide high efficiency and high voltage gain, so that it is suitable for high voltage applications.**

Keywords — DC-DC converter , Zero voltage switching (ZVS) , Zero current switching(ZCS), Photovoltaic generation system (PV).

I. INTRODUCTION

An asymmetrical full bridge boost DC/DC switching converter is proposed to improve renewable systems. Such a new step-up power converter in a PV system provides a low input current ripple injected into the photovoltaic generator, and at the same time provides a low voltage ripple to the load. Low-ripple and high boosting conditions make this converter an ideal candidate for photovoltaic systems design, in particular for grid-connected applications. The converter circuitry is analyzed, and a design procedure is proposed in terms of typical photovoltaic systems requirements.

Photovoltaic power systems are efficient alternatives to provide electrical energy providing redundancy for critical applications, energy generation, and the reduction of traditional energy generation that impacts the environment. Similarly, photovoltaic generators have been intensively used in residential applications and autonomous and portable applications. Photovoltaic systems require a power electronics interface to define their operating point at optimal conditions for any load. For that DC/DC and DC/AC converters are widely used.. The double-stage approach is widely accepted due to its application in distributed generation system based on multiple generators, as well as in stand-alone DC applications, where a single DC/DC converter is required [1].

The PV applications commonly adopt boosting converters for grid-connected applications due to the requirement of increasing the voltage to the grid connected inverter operating conditions. Other characteristics required in PV applications are a low current ripple injected to the PV and high conversion efficiency. The current ripple magnitude is an important factor in the selection of power converters for PV applications

because high current ripples produce an oscillation around the maximum power point (MPP) that reduces the energy extracted from the PV generator. So that most commonly employed converter is boost converter, but in such a boost converter, the current ripples injected to the PV generators depend on the inductor size, switching frequency, input capacitor, and high frequency power source impedance; therefore, in order to reduce the current ripple, it is necessary to increase the converter inductance or input capacitance. This can be addressed by using an additional filter between the PV generator and the power converter, also increasing power losses, size, weight, cost, and the order of the system.

II. PHOTOVOLTAIC SYSTEM

Photovoltaic (PV) is a method of generating electrical power by converting solar power into direct current electricity, using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials now used for photovoltaic system include mono crystalline silicon, cadmium telluride, poly crystalline silicon and Amorphous silicon. Due to the increased demand for different renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

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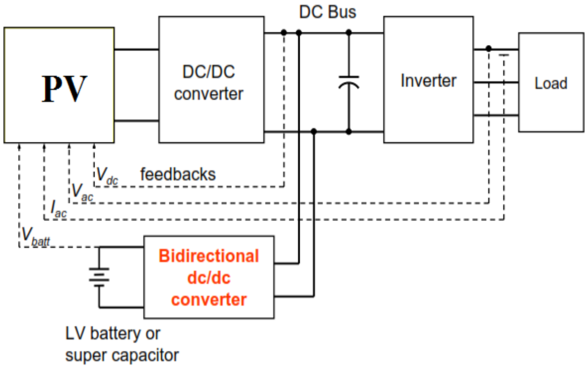

Fig.1. Photovoltaic Generation System

(PV) cells are environmentally friendly once they are made but have some other drawbacks. They produce a low voltage that is not compatible with the electric grid and common appliances. This means that the power must be converted into a higher voltage and then inverted to an AC voltage. Also, the PV voltage is prone to fluctuations due to variables like shading and angle of the sun.

One method used to produce a large DC voltage from PV modules is to put several in series. The power from the PV modules are put directly into a DC-AC inverter. This system does not require a DC-DC converter that is the power loss to this part of the system does not exist. There are however several large drawbacks. If there is any shading occurs on any of the PV modules the voltage will drop across the whole system and will possibly make the power produced by the rest of the modules unusable. This system also limits the control of the DC voltage going into the DC-AC inverter again putting limits to when the power from the PV can be used.

Another method used is to dedicate a DC-DC converter and a AC-DC inverter [2] to each module. The power from the PV module is directed into a DC-DC converter that has high gain capabilities and then to a DC bus. It is then send to a DC-AC inverter and then to the grid or a load. This method makes shading less of an issue as each module has its own DC-DC converter. This however introduces new sources of power loss to the system. The DC-DC converter is also required to produce a large gain which can put strain on its components and also make the converter less efficient.

In photovoltaic application, low current ripple and high conversion efficiency is necessary . The current ripple magnitude is an additional factor in the selection of power converters for photovoltaic applications because high current ripples are reduced to a great extend with proper selection of high gain converter, and hence its power production and life time increases . In the photovoltaic case, the current ripple impacts the power generation since it produces an oscillation around the Maximum Power Point (MPP) reducing the energy extracted from the photovoltaic generator. Those characteristics make the boost converter a good candidate to interface the photovoltaic and inverter circuit. Instead, traditional buck or buck-boost converters will require an additional filter to interact with the power source due to the discontinuous input current of those topologies.

In a photovoltaic system, by using appropriate boost converter, the current ripples can be reduced. Depending upon the inductor size, switching frequency, input capacitor and power source high frequency impedance we can select high gain converter, thereby reduce the current ripple. It is necessary to increase the converter inductance or input capacitance and modify the dynamics of the system. This can be addressed by using an additional filter between the power generator and the power converter, increasing also the power losses, size, weight, cost and order of the system. So inorder to achieve high voltage demand, a high efficiency dc-dc converter is needed.

III. ASYMMETRICAL HIGH GAIN CONVERTER

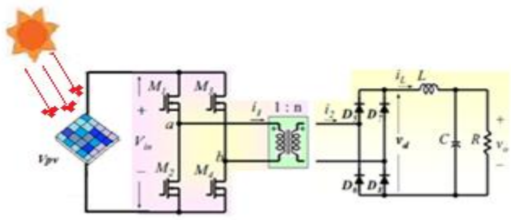

Fig.2. High Gain Asymmetrical converter

An asymmetrical full bridge DC-to-DC converter comprises an asymmetrical full bridge circuit which includes main switches and auxiliary switches, a capacitor connected in series to the branch circuit of the auxiliary switches, and a transformer having a primary winding and a secondary winding. The primary winding of transformer is connected to the common point of each leg of the full bridge [3]. A rectification circuit is connected at the secondary winding of the transformer to obtain dc voltage output. In operation, an asymmetrical control method is applied for these main switches and auxiliary switches. Main switches and auxiliary switches turn on and turn off compensatively. A linear control characteristic of output voltage to switching duty cycle and an optimal reset of the transformer core is achieved by this invention.

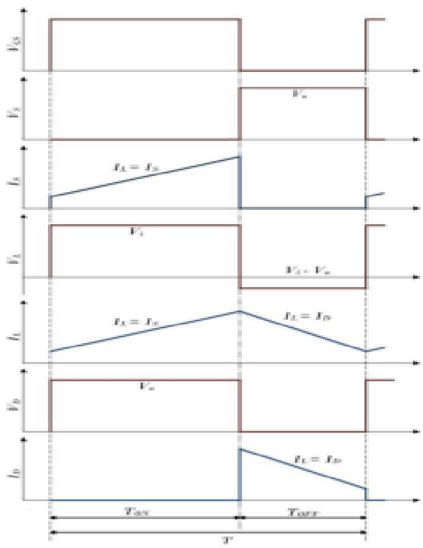

Fig.3. Current and voltage wave forms for DC-DC boost converter in CCM

The boost converter uses fast switching on the order of 100 kHz in order to control the gain produced by it. figure 3 shows the current and voltage wave forms that are produced for the boost circuit of figure 2. First the switch is turned on meaning there will be current flowing through it. When this is the case, the voltage across the inductor, VL , is known to be the input voltage, Vi. It is also known that the voltage across an inductor is proportional to the change of current over the change of time where L is the inductance of the inductor. Therefore the ΔiL can be found for when the switch is on. The full-bridge converter working in CCM, the output voltage can be calculated by,

$$Vo = 2ViD\frac{Ns}{Np}$$

The boost converter is a low cost converter with a simple topology that can be easily adjusted and is able to achieve high gains. The gating on the switch can be done with well developed microchips or integrated circuits. In order for the boost converter to work properly it must have a smooth input current which is consistent with the type of current produced by a PV module . High efficiency can be achieved with medium and low duty ratios.

The main advantage of using this type asymmetrical converter for boost up is soft switching, no conduction loss penalty and fixed switching frequency. The soft switching PWM converter is defined here as the combination of converter topologies and switching strategies that result in zero voltage and/or zero current switching on the switch . A small delay between driving signals for switches M1(M4) and M2(M3) is a dead time for the switches. It prevents cross conduction and allows ZVS. The operating frequency of MOSFETs is normally limited to 20-30 kHz because of their current tailing problem. To operate at higher switching frequencies, it is required to reduce the turn-off switching losses. ZVS with substantial external capacitor or ZCS can be a solution. The ZCS, however, is deemed more effective since the minority carriers are swept out before turning off. The zero-voltage zero-current switching (ZVZCS) PWM converters are derived from the full-bridge phase-shifted zero-voltage (FB-PS-ZVS) PWM converters.

IV. Feedback Controlled PWM

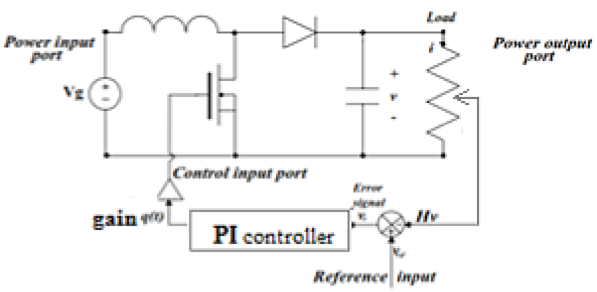

Fig.4. Boost converter with PWM controller

The figure 4 shows a basic step-up (boost) converter structure with PWM controller capable of producing an output voltage greater in magnitude than the DC input voltage. This method of gating structure is used here for the asymmetrical converter. This structure utilizes only switches, inductors and capacitors.

The switches are realized using power semiconductors devices, such as transistors and diodes. The transistors are controlled to turn on and off as required to perform the function of the ideal switch.

$$M(D) = \frac{1}{D'} = \frac{1}{(1-D)}$$

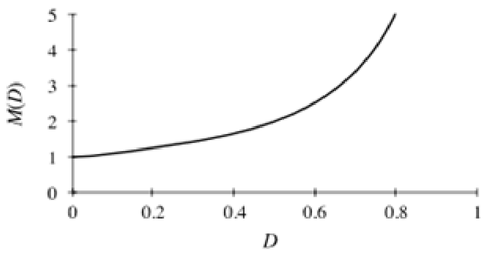

Fig.5. Control Characteristic

The duty ratio *D* is the fraction of time the switch spends in different position, and is a number between zero and one. The complement of the duty ratio *D'* is defined as *(1-D)*. In general, the duty ratio is a variable *d(t)* that can change its value every *kth* cycle to fit itself to the requirements of the control signal *Ks.*

The equation M(D) shows that the output voltage magnitude can be controlled through the variation of the duty ratio. In the figure 5 it can be seen the control characteristic of the boost converter calculated using equation given above, that allows the duty ratio *D* to be adjusted inorder to regulate the converter output voltage using a controller as in figure 4.

V. Simulation of High Gain Converter

A. Simulation circuit

The given circuit by simulation gives the waveforms in PSIM software, using the library of the physical model of the photovoltaic panel. The figure 6 shows the circuit simulated. Using the physical model of a photovoltaic panel was able to simulate the behavior of converter with high-precision. With this new library has been traced the curve of the panel that will be used. Note that to prove that the MPPT was functioning properly, a source with two levels (Step Voltage Source) was used to simulate a variation in solar radiation.

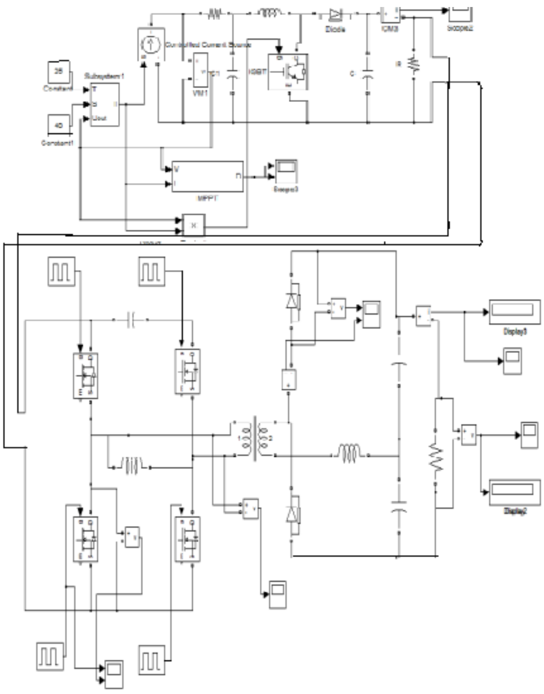

Fig.6. Simulation Circuit

The simulation circuit consists of PV module and high gain full bridge converter. The key waveforms of the switches M1 to M4 and diodes D01 and D02 converter by means of soft switching are obtained. It gives the currents I*s* and I*t*, the clamping capacitor voltage V*c* and the switching voltage V*s*. For the simulation, all elements were modeled ideal except for the transformer which had a magnetization current on the primary side.

B. Simulated waveforms

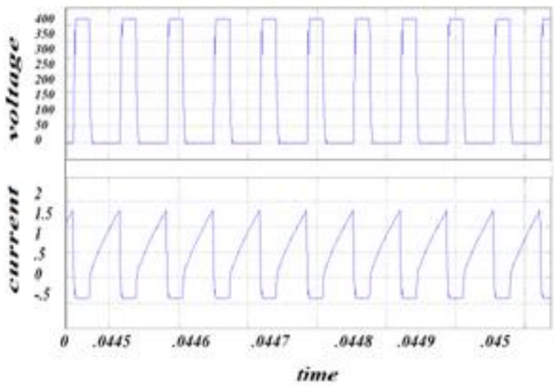

Fig 6.1. Output voltage and current across the diode

Figures 6.1, 6.2 and 6.3 shows the resultant voltage, current across the diode and inductive load and output voltage across the load terminals of power switch. Primary Inductance is considered to be 100μH is selected for appropriate result.

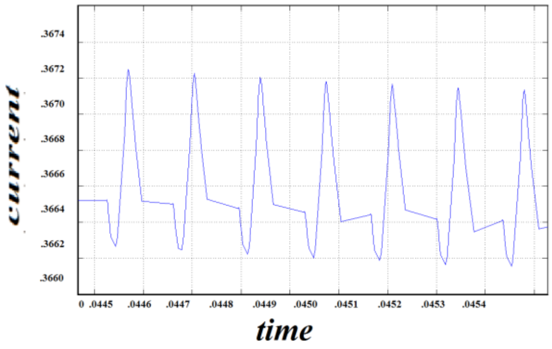

Fig .6.2. Output current through the load

Analysis of converter is performed in continuous mode of operation with duty cycle D = 0.42, Switching frequency fcs = 75 KHz. An input voltage of 48V was used with a desired 400V, 150W output. The components included in the simulink model of boost converter are inductance, L=10 μH, capacitance, C*in* = 3300 μF, C1=6.8 μF, C2=1 μF, C0=680 μF and resistance R = 100**Ω**. The output voltage and current of boost converter are 375 V and .386 A respectively. A PV panel along with the MPPT controlled boost converter fed up the PWM inverter. The output voltage of PV boost system with the MPPT is always confined to 375 V DC in order to meet the requirement of proposed inverter.

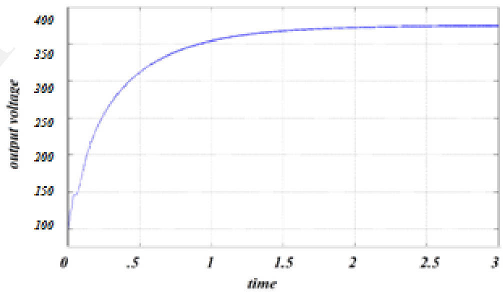

Fig.6.3. Output voltage waveform

According to above results, the maximum conversion efficiency of the high step-up converter is very high , which is comparatively higher than conventional converters. The main advantage of using high gain converter is to improve the efficiency , dc–dc conversion, larger voltage gain, and provide favorable ac power control quality, and maximum irradiation.

VI. EXPERIMENTAL SETUP

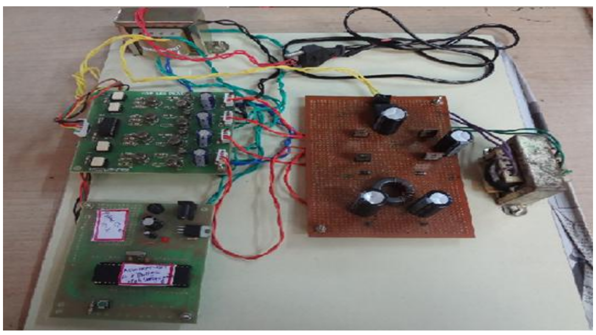

Fig.7. Hardware Circuit

The hardware implementation of asymmetrical high gain converter is shown above. The controller circuit used here includes a PIC microcontroller. A center tapped transformer is used in the rectifier stage and the input voltage is assumed to be supplied from preregulator. A DC-DC converter with a 150W/40V output has been selected for design. According to the design guidelines, the prototype was implemented.

The control circuit was implemented with a constant-frequency pulse width modulation controller KA7552 from Fairchild. The PWM output of KA7552 is fed to MIC4428 which has one inverting plus one non inverting output. They are then fed to IR2110s which generate gate signals for each bridge. FQP85N06 is used for M1 and M2 and FQP32N20C is used for M3 and M4. The ultrafast recovery diode RF2001T4S from Rohm is used for output diodes Do1 and Do2.

Compared with a discrete MOSFET and PWM controller solution, the Fairchild -series can reduce total cost, component count, size, and weight, while simultaneously increasing efficiency, productivity, and system reliability.

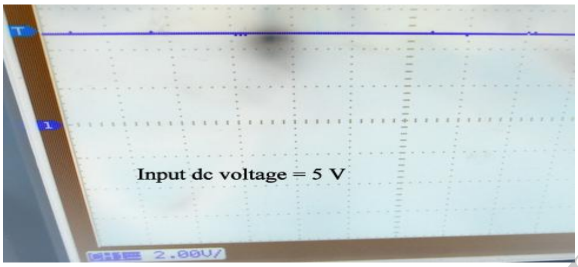

Fig.7.1. Input dc voltage

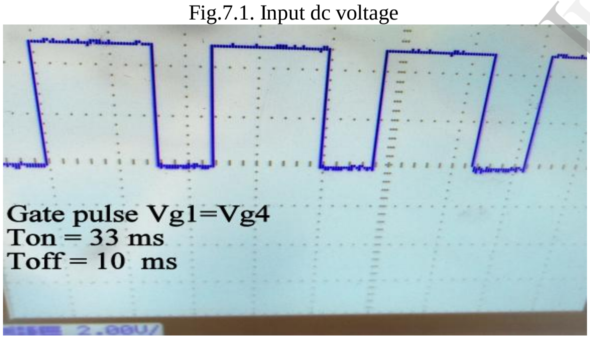

Fig .7.2 . Gate pulse for S1 and S4

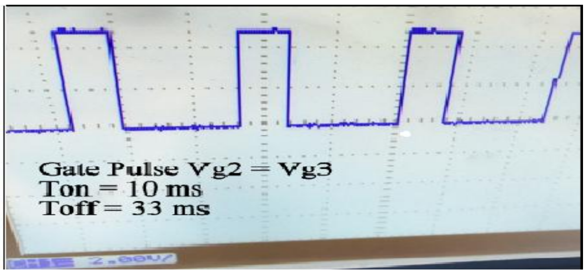

Fig .7.3 . Gate Pulse for S2 and S3

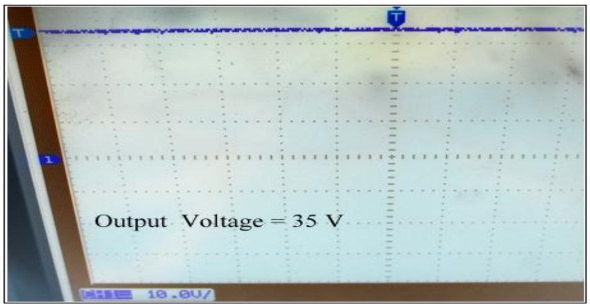

Fig.7.4 . Output dc voltage

For an input dc voltage of 5V, the voltage boost up upto 35 V is obtained. The gate pulse for the switches, which are asymmetrical , are provided in the hardware circuit with a turn on period of 33ms and turn off period of 10ms.

VII. Conclusion

Renewable system using asymmetrical boost converter with PWM controlling is designed and analyzed. The converter was developed by breaking the symmetry of traditional boost converters. The Boost converter with Coupled Inductors is used here and for a given small input dc voltage, a high gain with about 98 % efficiency is obtained. Different high boost ratio dc-dc converter circuit were presented to show how to design low-cost and high-efficiency converters for renewable energy such as solar panel integration applications, fuel cell, uninterruptable power supplies and designed procedure has been developed and verified by simulation.

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