

# Grid Connected Photovoltaic System Using High Gain DC-DC Converter With Voltage Multiplier Circuit

Nova Sunny, Santhi B

Department of Electrical and Electronics Engineering, Rajagiri School of Engineering and Technology

Kakkanad, India

Head of Department, Department of Electrical and Electronics Engineering, Rajagiri School of Engineering and Technology, Kakkanad, India

**ABSTRACT:** In this paper, a high step – up converter which is suitable for renewable energy system connected to grid is proposed . Conventional step – up converters required for grid application cannot achieve high step – up conversion with high efficiency because of the resistances of elements or leakage inductance. The proposed converter is a conventional interleaved boost converter with voltage multiplier module which 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 sources.

**KEYWORDS:** high step-up, photovoltaic (PV) system, voltage multiplier module.

## I. INTRODUCTION

Nowadays, renewable energy is increasingly valued and employed worldwide because of energy shortage and environmental contamination[1]-[3]. Renewable energy systems generate low voltage output, and thus, high step-up dc/dc converters have been widely employed in many renewable energy applications such fuel cells, wind power generation, and photovoltaic (PV) systems [4]-[6].Such systems transforms low voltage to high voltage via step up converter and produce ac using grid tie inverter. Fig 1 shows a typical renewable energy system that consists of renewable energy sources, a step-up converter, and an inverter for ac application. Output of renewable resources are very low ,in order to achieve grid application a very high input is required for the inverter. This can be achieved by using power electronics converters. In order to achieve high step up conversion, it 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 because such a system requires a sufficiently high step-up conversion with high efficiency.

Conventional converters like boost converter has limited step up gain and voltage stress across the switch is same as that of the output voltage. Despite these advances, high step-up single-switch converters are unsuitable to operate at heavy load given a large input current ripple, which increases conduction losses. The conventional interleaved boost converter is an excellent candidate for high-power applications and power factor correction. Unfortunately, the step-up gain is limited, and the voltage stresses on semiconductor components are equal to output voltage. Hence, based on the aforementioned considerations, modifying a conventional interleaved boost converter for high step-up and high-power application is a suitable approach.

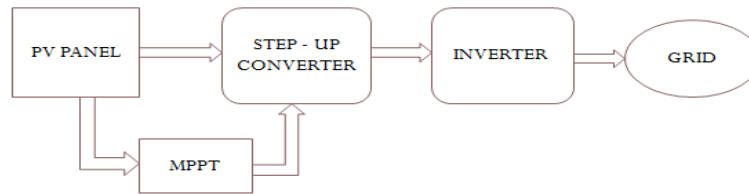


Fig.1. Block diagram of photovoltaic system connected to grid

The proposed converter is a conventional interleaved boost Converter integrated with a voltage multiplier module, and the voltage multiplier module is composed of switched capacitors and coupled inductors. The coupled inductors can be designed to extend step-up gain, and the switched capacitors offer extra voltage conversion ratio which is required for grid application. In proposed scheme, PV array is tied with grid through Single phase Voltage source Inverter (VSI). High gain dc-dc converter is placed between PV array and inverter. The maximum power in PV array is tracked using incremental conductance based MPPT controller. The MPPT controller controls duty cycle of the converter. PLL is used to get the phase and frequency information of grid voltage.

## II. SYSTEM DESCRIPTION

### A. MODELING OF PV PANEL

By connecting the PV cells in series and parallel can produce desired output power. PV panel is modeled with the help of design equations. The terminal equation for the current and voltage of the array is given by

$$I = N_p I_{ph} - N_p I_s \left[ \exp\left( \frac{q \left( \frac{V}{N_s} + \frac{I R_s}{N_p} \right)}{K T_c A} \right) - 1 \right] - \frac{N_p V}{N_s} + I R_s$$

$N_p$  and  $N_s$  are no of parallel and series cells.  $I_{ph}$  is the photocurrent,  $I_s$  is the cell saturation current,  $q$  is an electron charge and  $T_c$  is the working temperature,  $A$  is an ideal factor,  $R_{sh}$  is a shunt resistance and  $R_s$  is a series resistance of solar cell.

$$I_{ph} = [I_{sc} + K_i(T_c - T_{ref})] H$$

Where ,

$I_{sc}$  is the short circuit current,  $K_i$  is the short circuit current temperature coefficient,  $T_{ref}$  cell reference temperature and  $H$  is the solar insolation in  $KW/m^2$

Cell's saturation current varies with the cell temperature which is given by

$$I_s = I_{rs} (T_c/T_{ref})^3 \exp[qEG(T_c - T_{ref})/T_{ref}T_c A]$$

$I_{rs}$  is the cell's reverse saturation current at a reference temperature and standard solar radiation.  $EG$  is the band gap energy of the semiconductor used in the cell.

### B. Incremental conductance for MPPT

Incremental conductance Algorithm for mppt is used to track the maximum power Point (mpp) of the photovoltaic panels, and generate the control signal for the high gain dc- dc converter. The algorithm compares the actual conductance  $- I_{pv}/V_{pv}$  and the incremental conductance  $dI_{pv}/dV_{pv}$  [7].

$$\text{If } dI_{pv}/dV_{pv} > -I_{pv}/V_{pv}$$

then the operating point is on the left of the MPP so,  $\alpha$  is varied to increase  $V_{pv}$

Department of Electrical & Electronics Engineering, College of Engineering Perumon, Kollam, Kerala – 691601, India

$$\text{If } dI_{pv}/dV_{pv} < -I_{pv}/V_{pv}$$

then the operating point is on the right of the MPP, so  $\alpha$  is varied to decrease  $V_{pv}$

$$\text{If } dI_{pv}/dV_{pv} = -I_{pv}/V_{pv}$$

then the operating point is in the MPP, so, the value of  $\alpha$  is maintained.

where  $dI_{pv}$  and  $dV_{pv}$  are the PV current and voltage variations, respectively. Thus, the duty cycle  $\alpha$ , used to generate the PWM signal for the MOSFET switching.

### III. HIGH STEP-UP INTERLEAVED CONVERTER WITH A VOLTAGE MULTIPLIER MODULE

#### A. HIGH GAIN DC – DC CONVERTER

The proposed high step-up interleaved converter with a voltage multiplier module is shown in Fig. 2. 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 flyback converter, and the other phase whose switch is in ON state performs as a forward converter. 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  $N_s$  turns are connected in series to extend voltage gain. The turn ratios of the coupled inductors are the same.

The equivalent circuit of the proposed converter is shown in Figure 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 turns ratio  $N_s/N_p$ . The duty cycles of the power switches during steady operation are interleaved with a  $180^\circ$  phase shift and the key steady waveforms in one switching period of the converter contain six modes.

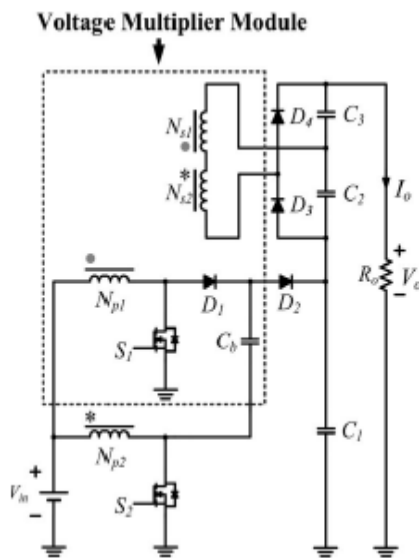


Fig. 2. Proposed high step-up converter.

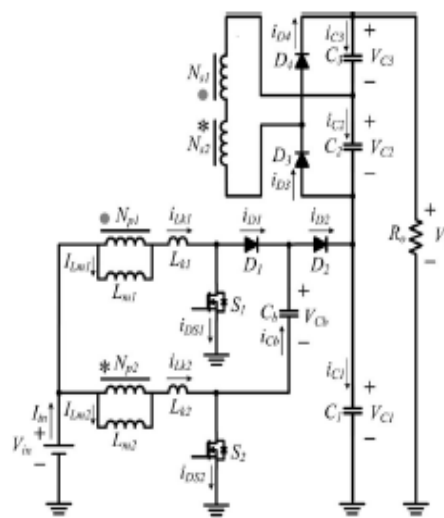


Figure 3: Equivalent Circuit

## B . MODEL ANALYSIS

Operation of the converter can be explained in six modes. Steady state waveform is given in Fig4

**Mode 1**  $[t_0, t_1]$ : At  $t= t_0$ , the power switches  $S_1$  and  $S_2$  are both turned ON. All the diodes are reversed-biased. Magnetizing inductors  $L_{m1}$  and  $L_{m2}$  as well as leakage inductors  $L_{k1}$  and  $L_{k2}$  are linearly charged by the input voltage source  $V_{in}$ .

**Mode 2**  $[t_1, t_2]$ : At  $t= t_1$ , the power switch  $S_2$  is switched OFF, thereby turning ON diodes  $D_2$  and  $D_4$ . The energy that magnetizing inductor  $L_{m2}$  has stored is transferred to the secondary side charging the output filter capacitor  $C_3$ . The input voltage source, magnetizing inductor  $L_{m2}$ , leakage inductor  $L_{k2}$ , and voltage-lift capacitor  $C_b$  release energy to the output filter capacitor  $C_1$  via diode  $D_2$ , thereby extending the voltage on  $C_1$ .

**Mode 3**  $[t_2, t_3]$ : At  $t= t_2$ , diode  $D_2$  automatically switches OFF because the total energy of leakage inductor  $L_{k2}$  has been completely released to the output filter capacitor  $C_1$ . Magnetizing inductor  $L_{m2}$  transfers energy to the secondary side, charging the output filter capacitor  $C_3$  via diode  $D_4$  until  $t_3$ .

**Mode 4**  $[t_3, t_4]$ : At  $t= t_3$ , the power switch  $S_2$  is switched ON and all the diodes are turned OFF. The operating states of modes 1 and 4 are similar.

**Mode 5**  $[t_4, t_5]$ : At  $t= t_4$ , the power switch  $S_1$  is switched OFF, which turns ON diodes  $D_1$  and  $D_3$ . The energy stored in magnetizing inductor  $L_{m1}$  is transferred to the secondary side charging the output filter capacitor  $C_2$ . The input voltage source and magnetizing inductor  $L_{m1}$  release energy to voltage-lift capacitor  $C_b$  via diode  $D_1$ , which stores extra energy in  $C_b$ .

**Mode 6**  $[t_5, t_0]$ : At  $t= t_5$ , diode  $D_1$  is automatically turned OFF because the total energy of leakage inductor  $L_{k1}$  has been completely released to voltage-lift capacitor  $C_b$ . Magnetizing inductor  $L_{m1}$  transfers energy to the secondary side charging the output filter capacitor  $C_2$  via diode  $D_3$  until  $t_0$ .

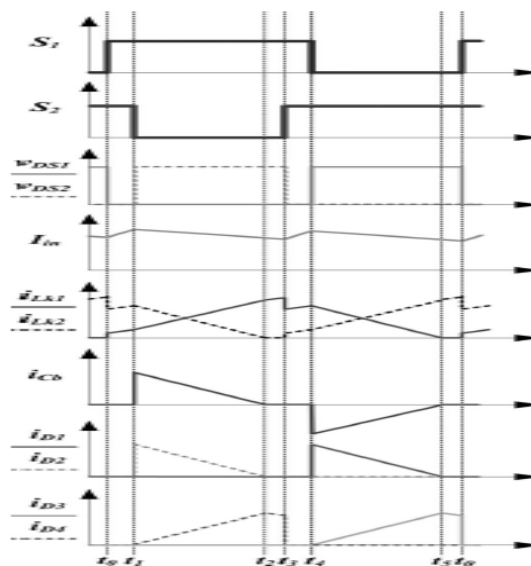


Fig 4 steady state waveform

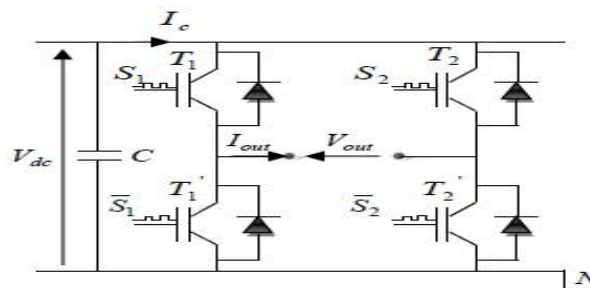
**C. DESIGN**

The electrical specifications are  $V_{in} = 40\text{ V}$ ,  $V_o = 300\text{ V}$ , and  $f_s = 40\text{ kHz}$ . The major components have been chosen as follows: Magnetizing inductors  $L_{m1}$  and  $L_{m2} = 133\text{ }\mu\text{H}$ ; turn ratio  $n = 1$ ; capacitors  $C_{c1}$ ,  $C_{c2}$ ,  $C_2$ , and  $C_3 = 220\text{ }\mu\text{F}$ ; and  $C_1 = 470\text{ }\mu\text{F}$ .

Leakage inductors  $L_{k1}$  and  $L_{k2}$  are  $1.6\text{ }\mu\text{H}$ .

**IV. SINGLE PHASE DC – AC INVERTER**

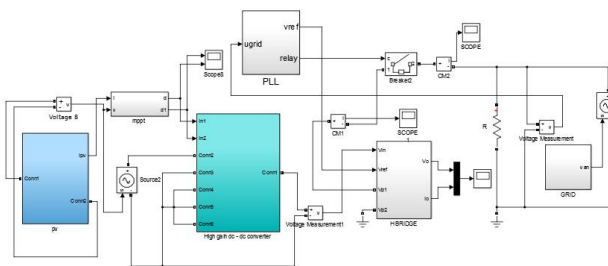
A full bridge inverter is used to convert DC voltage and current to AC voltage and current. The inverter is controlled by a PWM signal, which in turn controls the inverter switches [8].



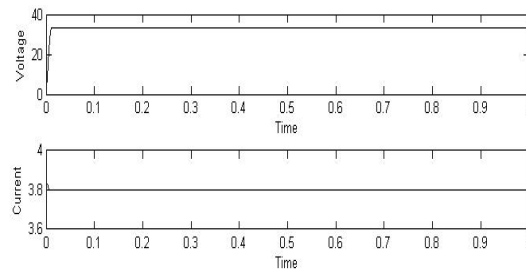
**Fig.5** Single-phase full bridge inverter

**V. SIMULATION**

The system consists of a solar panel, a converter to step up the output voltage of the solar panel, an inverter which is connected to a single phase grid.



**Fig 6.** Simulation circuit of full system



**Fig7** Solar output voltage and current

Solar panel produces an output voltage of 33.5V which is stepped up to 300V using a high gain DC – DC converter with a voltage multiplier circuit. The output DC is converted into AC using a single phase inverter. AC is given to the grid through an LCL filter. The grid voltage is sensed and given to the PLL circuit, from there a reference sine wave is produced having a frequency same as the grid voltage is given as the reference for SPWM. The generated pulses control the inverter and change the parameter and produce an output which is synchronized with the grid.

Department of Electrical & Electronics Engineering, College of Engineering Perumon, Kollam, Kerala – 691601, India

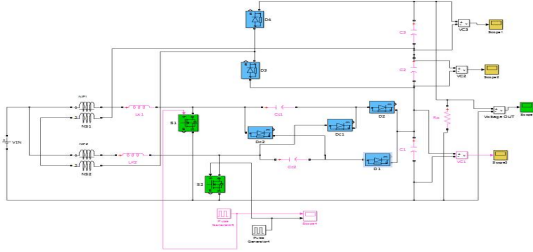


Fig 8. Simulation circuit for high gain dc - dc converter

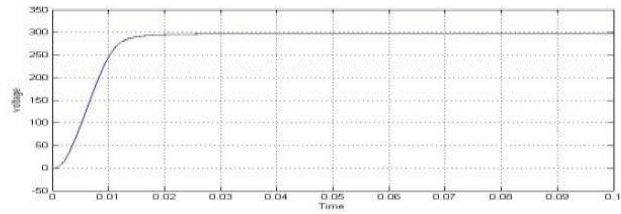


Fig 9. Converter output voltage

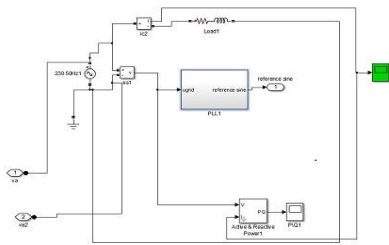


Fig 10 Reference sine wave generation

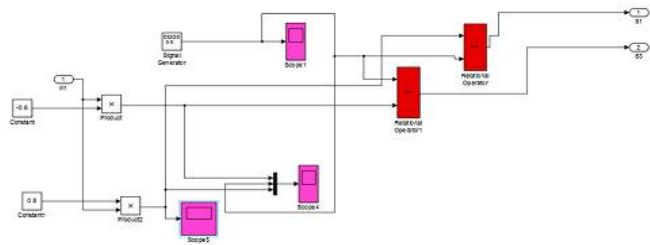


Fig 11 SPWM generation

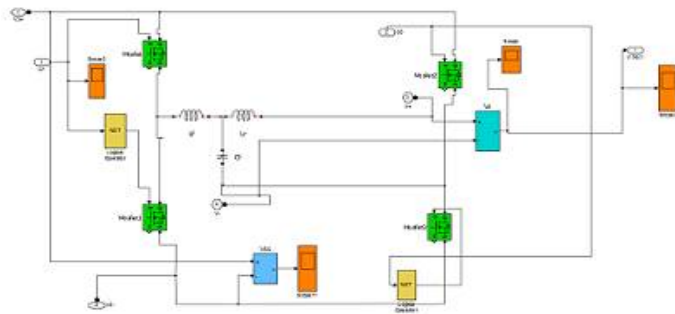


Fig 12 Inverter circuit

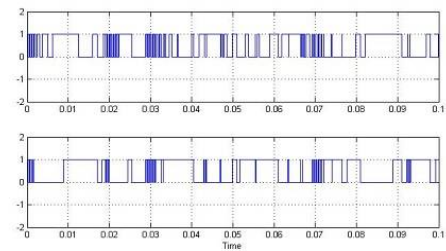


Fig 13 Control pulses for inverter switches

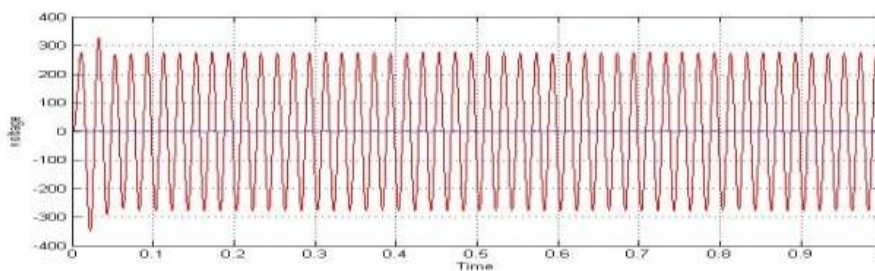


Fig 14 Inverter output voltage



## VI. CONCLUSION

The grid connected solar power plant can be done in place where excess solar energy is available. Simulation of photovoltaic system connected to single phase grid using high gain dc-dc converter is presented. By using this converter the duty ratio of power switches and power conversion rate can be maintained in an acceptable range. It shows high conversion rate as compared to conventional boost converter.

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Fig 13 Pulses for inverter switches