Solar PV Boosting Inverter

Praful Nandankar*
Department of Electrical Engineering
Government Polytechnic, Gadchiroli

Akash Dasarwar
Department of Electrical Engineering
Government Polytechnic, Gadchiroli

Ganesh Kachare
Department of Electrical Engineering
Government Polytechnic, Gadchiroli

Manuscript History
Number: IJIRAE/RS/Vol.04/Issue03/MRAE10106
Received: 03, March 2017
Final Correction: 20, March 2017
Final Accepted: 27, March 2017
Published: March 2017

Abstract— For application of PV systems, a major deterrent factor in their use is high initial investment. A focus has therefore been placed on new, cheap and innovative inverter solutions. As a result of this, a single stage inverter topology and a new configuration are proposed. In two stage circuit, the first stage takes care of MPPT and boosting the PV voltage while second stage inverts the first stage output into the required AC form. A two stage configuration has drawbacks such as high part count, lower efficiency, lower reliability, high cost and large size. These drawbacks are overcome by the circuit proposed in this paper. The new inverter circuit proposed in this paper is designed and simulated in a simulation environment. The improved topology increases the voltage, reduces the power loss and enhances the various electrical parameters. This enhancement and improvement of electrical quantities is explained with the help of different formulae and figures. With the use of this improve circuitry; the efficiency of the PV Array can be increased. The proposed inverter design and its implementation are given with operational results.

Keywords — Inverters, Boost inverter, DC-AC Converter, power semiconductor switches.

I. INTRODUCTION

Due to the increase in industrial revolution, the world energy demand has also increased. Photovoltaic (PV) system has taken a great attention since it appears to be one of the most promising renewable energy sources. the PV solar generation is preferred over the other renewable energy sources due to the advantages such as absence of fuel cost, cleanliness, pollution free and little maintenance. Solar inverter is a critical component in a solar energy system. It converts DC power output into AC that can be fed into the grid and directly influences the efficiency and reliability of solar energy system. Grid connected PV systems have become very popular because they do not need battery backups to ensure MPPT. The grid can absorb any amount of power and so the maximum utilization of the available solar power is ensured. In this grid connected PV system, the inverter is the heart of the system which is responsible for converting DC power into the required AC power.

Topologies of grid connected PV systems are classified into three types, namely multistage, two stage and single stage.

1. MULTISTAGE

Multistage comprises of two stages for processing the PV power as per the requirement. In this process, the first two stages account of conditioning of power and improvement of low voltage whereas the last stage performs the function of converting AC power into DC power. The major drawback of using this circuitry is its large size, high cost, low efficiency, and reliability.

2. TWO STAGE

In this configuration, the first stage comprises of usually DC-DC converter and the second stage takes care of the inversion process with the help of inverter. As all the switching operation takes place at high frequency, so such systems are more prone to EMI problems, low reliability, high switching losses etc.

3. SINGLE STAGE

In this stage, all the functions that is inverting, boosting and power conditioning all are performed in a single stage. The advantages of this give rise to optimum number of components, reduced weight and cost, compact, high reliability and efficiency. In this paper, a new inverter is proposed which is designed and simulated in a simulation environment.

The improved topology increases the voltage, reduces the power losses and enhances the various electrical parameters. With the use of this improve circuitry; the efficiency of the PV Array can be increased. The simulation results are taken for a input voltage of 12V dc supply which is stepped up to a higher ac output voltage in a single stage.

II. CIRCUIT TOPOLOGY WITH ITS OPERATION

The main key point or attraction of this inverter topology is that it generates AC output voltage larger than the DC input.

A. CIRCUIT TOPOLOGY

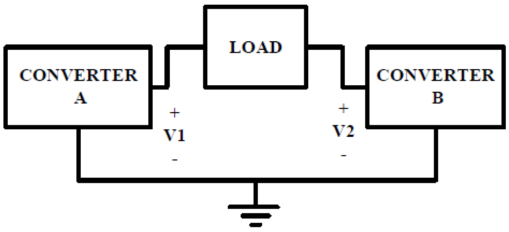


Fig. 1 Block diagram of boost inverter

The converters as shown in the block diagram generates a DC biased sine wave output so that each source produces a uni-polar voltage. The modulation of each converter is 180 degree out of phase with each other to maximize the voltage digression across the load. The load is connected differentially across the converters.

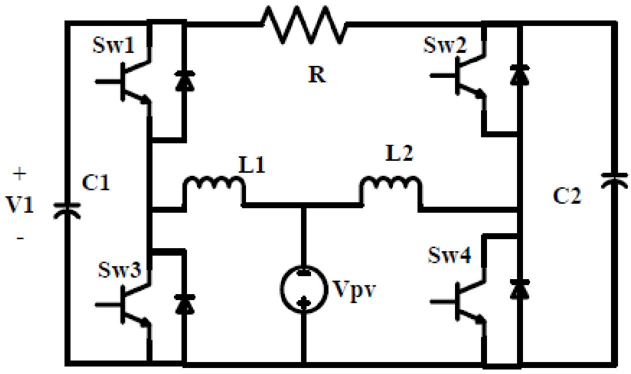


Fig. 2 Boost DC-AC converter

The Proposed circuit shown in Fig. 2. consists of two DC-DC converters. First converter comprises of two MOSFET switches named as S_{W1}, S_{W3}, inductor L_1 and capacitor C_1. Second converter is made up of MOSFET switches S_{W2}, S_{W4}, inductor L_2 and capacitor C_2. From Fig.2, it can be seen that DC bias appears at both ends of the loads so the differential DC voltage across the load with respect to ground is zero. DC-DC converters need to be current bidirectional. This circuit mainly consist of four MOSFET switches which are preferred over IGBT for high output frequencies because in case of IGBT, reverse recovery current flows through them which makes them not usable for higher frequencies. Capacitor C_1 and C_2 are used to remove the ripple from output voltage and stabilize the output waveform. The function of inductor is to store the energy which helps to boost the value of output voltage. Boost DC-AC converter comprises of two legs. Each leg produces an uni-polar voltage and two legs are differentially connected across the load. Due to a differential connection, an ac voltage is obtained across the load. The two voltages V_1 and V_2 are 180^0 out of phase . These two uni-polar voltages are equal in amplitude and frequency but with a dc offset.

B. OPERATION OF DC-AC CONVERTER

The complicated mesh assembly comprises of very basic structure elements. This arrangement consists of basically two converter sets. There are four MOSFETs used which works in a complementary manner. Only two switches are operated at a time so that, it has minimum switching and conduction losses. First leg comprises of two switches S_{W1} and S_{W3} and other leg comprises of S_{W2} and S_{W4}. The two switches of the same leg should not operate simultaneously otherwise, a dead short circuit will occur at that leg. So for preventing this dead band of 200ns is given for switching. Four switches in DC-AC converter are operated with the help of SPWM technique. The triangular waveform of fixed frequency and amplitude is compared with sinusoidal waveform of variable amplitude and fixed frequency. The sinusoidal frequency of 50 Hz is used inside the comparator. From the comparator, four SPWM pulses are obtained.These four pulses are applied to four switches of DC-AC converter. During ON time, switches S_{W3} and S_{W4} will operate. The DC voltage source is common to both the legs of DC-AC converter. The DC voltage source is applied to both the inductors L_1 and L_2. The voltage source provides energy to two inductors L_1 and L_2. During OFF time, the polarity of inductor reverses which will cause switches S_{W1} and S_{W2} to turn on. The turning ON of switches S_{W1} and S_{W2} releases energy from inductors L_1 and $L_2$and now this released energy is supplied to load.

C. Analysis of DC-AC Converter

The cconduction mode is given by

$$\frac{V_1}{V_{dc}} = \frac{1}{1-D} \quad (1)$$

The voltage gain for the boost inverter can be derived, assuming that the two converters are 180 out of phase, and then the output voltage is given by

$$V_o = V_1 - V_2 = \frac{V_{dc}}{1-D} - \frac{V_{dc}}{D} \quad (2)$$

$$\frac{V_o}{V_{dc}} = \frac{2D-1}{D(1-D)} \quad (3)$$

Where, D is duty cycle.

V_1 = output voltage of converter 1
V_2= output voltage of converter 2
V_{dc} = Input dc voltage from solar panels
V_o = Output ac voltage.

The zero output voltage is obtained for D =0.5 using (3). If the duty cycle is varied around this point, then there will be an ac voltage at the output.

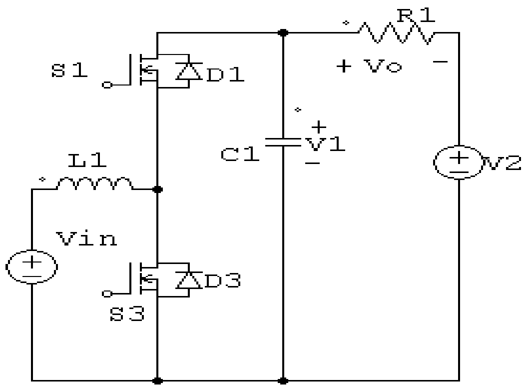
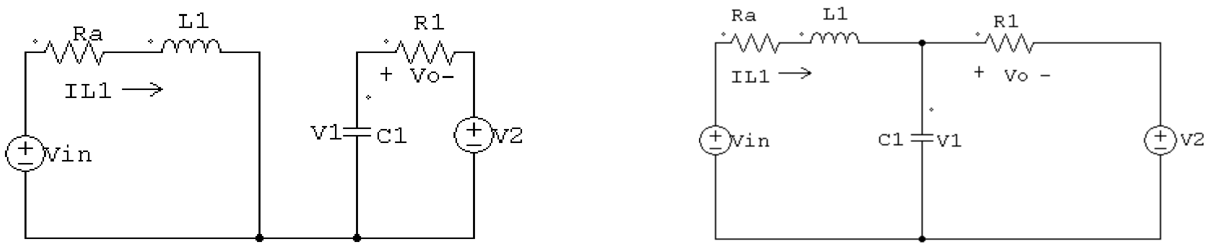


Fig. 3. *Equivalent circuit for boost inverter*

The operation of the boost inverter is better explained with the help of current bidirectional boost dc–dc converter shown in Fig. 3. In the description of the converter operation, assume all the components are ideal and the converter operates in a continuous conduction mode. Fig. 4(a) and 4(b) shows two topological modes for a period of operation. When the switch S_3 is closed and S_1 is open [Fig. 4(a)], current I_{L1} rises quite linearly, diode D1 is reverse polarized, capacitor C_1 supplies energy to the output stage, and voltage V_1 decreases. When the switch S_3 is closed, complete V_{in} voltage comes across inductor L_1. Due to this action, energy gets stored inside the inductor L_1. Once the switch S_3 is open and S_1 is closed [Fig. 4(b)], current I_{L1} flows through capacitor C_1 and the output stage. The current I_{L1} decreases while capacitor C_1 is recharged.



(a) (b)

Fig. 4. *(a) and (b) Modes of operation of inverter.*

III. PERFORMANCE OF BOOST CONVERTER

The performance results for single phase DC-AC converter is obtained by simulation. The basic model representing the building components are given for the dc-ac converter. The specifications of these components are given in the Table I. The simulation for single phase DC-AC converter is done by considering the parameters illustrated in Table I.

TABLE I. CIRCUIT PARAMETERS FOR ANALYSIS

Parameters	Values
Inductors (L_1, L_2)	800 µH
MOSFET	32A,200V
Capacitors (C_1, C_2)	220uF,100V

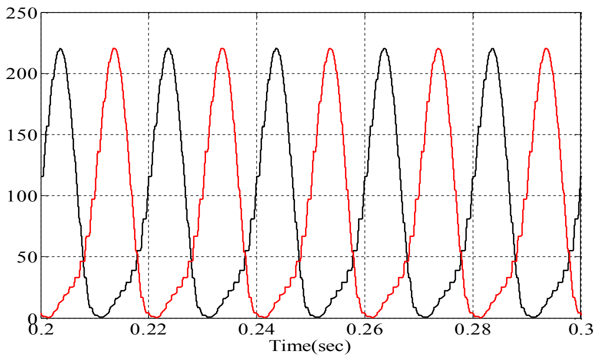


Fig. 5. Voltage V_1, V_2 and time characteristics

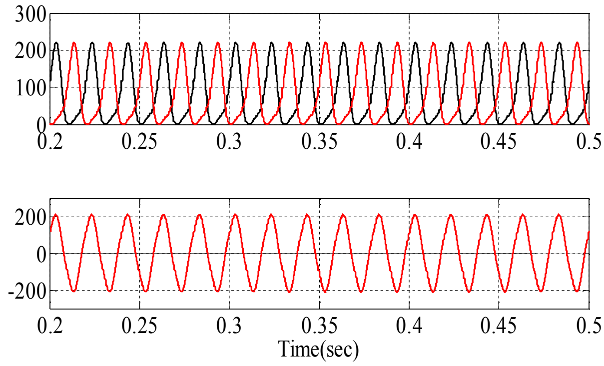


Fig. 6. Output voltage waveform across the load

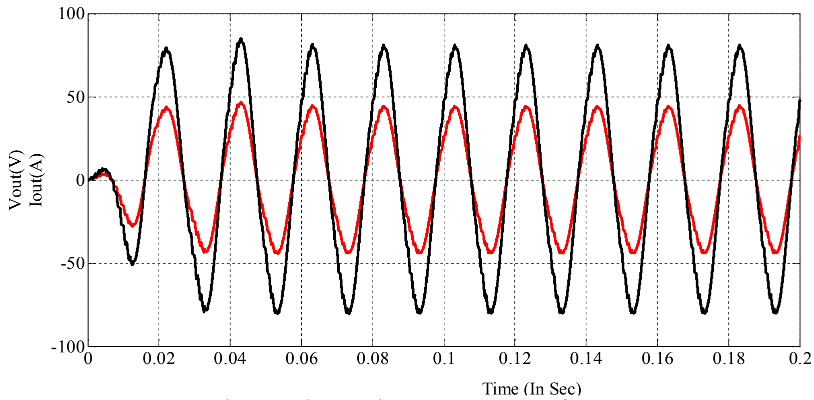


Fig. 7 Voltage and current output waveform

Fig. 5 shows the uni-polar voltages for two legs obtained across two capacitors C_1 and C_2. Capacitors C_1 and C_2 prevents high frequency ripple to enter into the load and maintains the voltages at a particular level. The two voltages V_1 and V_2 are 180^0 out of phase and are equal in amplitude and frequency. Fig. 6 shows the output voltage waveform obtained across the load. The output voltage is a bipolar voltage which is obtained due to differential connection of two legs. The output voltage is equal to the difference between two voltages. Fig. 7 shows the voltage and current waveform obtained across load. The output voltage and output current waveform are in same phase as the load is resistive.

IV. CONCLUSIONS

This paper presented the design, analysis and realization of single phase dc-ac converter. This single phase dc-ac converter is fed from Photo-voltaic solar cells. This converter uses a single stage for boosting and inversion. The efficiency of the proposed converter is improved by employing a single stage. The two legs are differentially connected across the load. The larger ac output voltage is obtained across the load. The converter is simulated in MATLAB environment. The simulation results are obtained for output voltage, inductor currents and voltage across switch. The simulation results confirmed high voltage ratio of dc-ac converter and high efficiency operation due to a single stage. The simulation results are presented to support the operation feasibility of this converter and validate the proposed dc-ac converter.

REFERENCES

[1] M. Abdulkadir, A. S. Samosir and A. H. M. Yatim, "Modelling and simulation based approach of photovoltaic system simulink model", ARPN J.Engg and Appl. Sciences, Vol .7, no. 5, pp. 616-623, May 2012.

[2] S. Jain and V. Agarwal,"Comparison of the performance of maximum power point tracking schemes applied to single-stage grid-connected photovoltaic systems", IET Electr. Power Appl., Vol. 1, No. 5, pp. 753–762, Sept. 2007.

[3] F. Liu, S. Duan, Fei Liu, B. Liu, and Y.Kang, "A Variable Step Size INC MPPT Method for PV Systems", IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2622–2628, July 2008.

[4] T. Esram and P. L. Chapman, “Comparison of photovoltaic array maximum point tracking techniques,” IEEE Trans. Energy Convers., vol. 22, no. 2, pp. 439–449, Jun. 2007.

[5] S. B. Kjaer, J. K. Pedersen and F. Blaabjerg, “A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules”, IEEE Trans. Ind. Electron., vol. 41, no. 5, pp. 1292–1306, Sept. 2005.

[6] Y. Xue, L. Chang, S. B. Kjær, J. Bordonau, and T. Shimizu, “Topologies of single phase inverter for small distributed power generators: An overview”, IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1305–1314, Sep. 2004.

[7] F. Kang, S. Park, S. E. Cho and J. Kim, “Photovoltaic power interface circuit incorporated with a buck-boost converter and a full-bridge inverter,” Elsevier Science Applied Energy, vol 82, no. 3, pp. 266-283, 2005.

[8] Y. Huang, M. Shen, F. Z. Peng, and J. Wang, “Z-source inverter for residential photovoltaic systems,” IEEE Trans. Power Electron., vol. 21, no. 6, pp. 1776–1782, Nov. 2006.

[9] C. M. Wang, “A novel single-stage full bridge buck-boost inverter”, IEEE Trans. Power Electron., vol. 19, no. 1, pp. 150–159, Jan. 2004.

[10] M. F. Rahman, L. Zhong,“A new, transformer less, Photovoltaic array to utility grid interconnection,” in Proc. IEEE PEDS, vol. 1, pp.-139-143, 1997.

