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Design of Boost Inverter for Solar Power Based Stand Alone Systems

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ABSTRACT--- This paper presents a new ideology called as boost inverter which converts input DC supply into AC directly without using any filter circuit. The main part of today's research work is to use solar energy efficiently. While using for AC autonomous loads, the output from the solar panel should not suffer any losses during the various power conversion stages. The conventional voltage source inverter, which is currently in usage, produces an AC output voltage lower than the DC input supply and thus it requires another power conversion stage. It can be used to drive the loads only after removing the ripples using a filter. The main objective of the project is to produce an AC output voltage higher than the DC input voltage in a single stage. Thus the number of power conversion stages is reduced by using boost inverter circuit. Since Pulse Width Modulation technique is used to drive the circuit, the requirement of a filter at the output is not needed.

Keywords: Solar energy, Boost inverter, Pulse width modulation, Filter

I. INTRODUCTION

With the increase in population, need for efficient energy management and the production of more electrical energy without polluting the environment is becoming an important factor of concern. If electricity is generated by burning fossil fuels, it will deplete the resources on earth and thereby polluting the land surface. Hence we should go for alternative methods of generating electricity such as solar energy, wind energy and hydropower. In this paper, generation of electricity from solar panels are taken for the study [1][2].

The DC voltage which is obtained from the photovoltaic array of the solar panel has to be inverted. It can't be used to drive the load as it is of lower voltage and hence it has to be boosted to higher voltage [3][4]. Major energy extracted from the panel is used to drive the load and care is taken to prevent the loss of energy involved during the conversion processes. Effective utilization of energy can be achieved by the boost inverter model specified in this project. In addition to this, a battery has been used to supply the load in case if the output of the solar panel is interrupted, thus ensuring uninterrupted power supply to the load [5][6].

EXISTING SYSTEM

The conventional method of using the renewable energy resource is shown in Fig.1. The DC output from the PV array is boosted to some higher level dc voltage using a DC-DC converter. Then it is fed into an inverter circuit as its output is much lesser than the input from the converter, it has to be again stepped up to 230V using a step up transformer [7]. This stepped up voltage is applied to the load after removing the ripples using a filter. Thus it is seen that the existing system comprises of multi-level cascaded topology consisting of various blocks for power conversion stages, which involves loss of energy in each stage. Depending upon the power and voltage levels, this can result in high volume, weight, cost and reduced efficiency.

PROPOSED SYSTEM

The boost inverter circuit produces a boosted ac output higher than the dc input. Thus dc-dc converter, inverter and the transformer are altogether replaced by a single block. Since PWM technique is used, the output from the boost inverter is free from ripples and thus filter is also not needed [8][9]. Hence the load can be directly connected to the output of the boost inverter circuit. This system, thus reduces the number of power conversion stages and hence the losses when compared with the existing system. The block diagram representation of proposed system is shown in Fig.2.

The PWM pulses are produced using the PIC microcontroller, where the sine wave (reference wave) is compared with the triangular wave (carrier wave). According to whether the sine wave or the triangular wave has greater magnitude, either positive or negative pulses are generated. This resultant waveform is termed as the Pulse Width Modulated pulse. The frequency of the PWM pulse can be varied by varying the frequency of the reference wave. This PWM pulse is used to trigger the IGBTs to produce the output of the boost inverter [10].

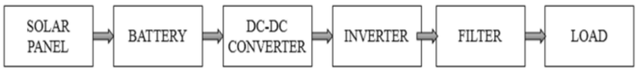

Fig.1. Block diagram of conventional solar energy conversion system

II. PROPOSED BOOST INVERTER TOPOLOGY

The block diagram of the proposed system consists of various blocks such as the solar panel, battery, boost inverter circuit, driver circuit for the switches, microcontroller and the power supply for the driver and controller circuit.

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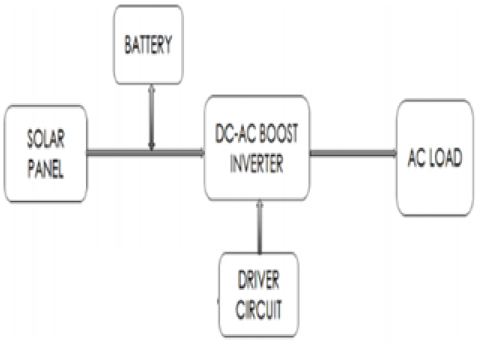

Fig.2. Block diagram of proposed system

The power electronic circuits that convert DC to AC are generally termed as inverters. In simple words, they are said to transfer power from a DC source to an AC load. When the gain of the inverter is constant, varying output voltage can be obtained by varying the input voltage. At the same time, when input voltage of an inverter is constant, varying output voltage can be obtained by varying the gain of the inverter, which is the ratio of AC output voltage to the DC input voltage of an inverter. This is usually accomplished using pulse width modulation technique [3][5].

Depending upon the number of phases and also based on their working, inverter circuits are classified into two phase and three phase. In all the inverter types the AC output voltage is lesser than the DC input voltage and hence they require a second power conversion stage. In order to overcome this disadvantage, boost inverter topology has been introduced [6][7].

There are two dc-dc converters feeding a resistive load as shown in the Fig.3. The two converters produce a biased dc output such that each source produces only a unipolar voltage as shown in the Fig.4.

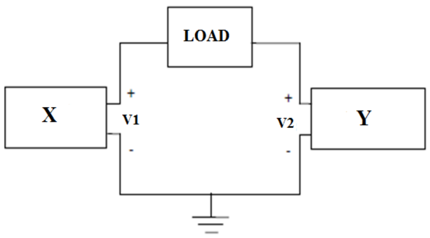

Fig.3. Basic block diagram of boost inverter circuit

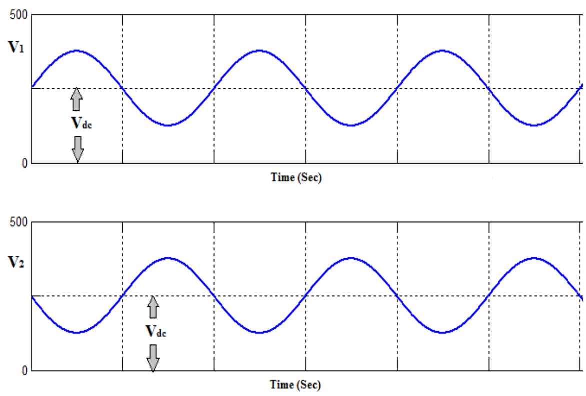

Fig.4. Output Unipolar voltage of DC-DC converter

The phase modulation of each converter is 180 degrees out of phase with the other so that the voltage excursion across the load is maximized.

MODES OF OPERATION

The boost inverter circuit is shown in Fig.5. The circuit consists of four switches S1, S2, S3 and S4, two capacitors C1, C2 and inductors, L1 and L2. Four diodes D1, D2, D3 and D4 are connected anti parallel to the switches which are used for freewheeling purpose. Usually, in any circuit with an inductor and a switch, these diodes are used.

These diodes serve as feedback devices which provide a path for the inductive current, when the switch is turned off. If the diodes are not used, the inductor current ceases instantly, resulting in the generation of high voltage peaks. The operation of the boost inverter circuit can be divided into two modes.

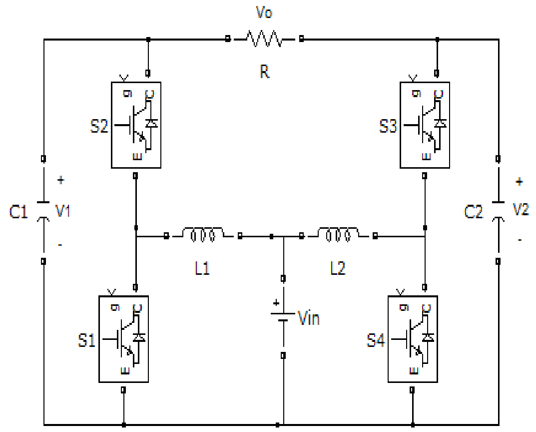

Fig.5. Boost inverter circuit

MODE 1:

When switches S1 and S3 are in close condition, S2 and S4 are in open condition, the current through the inductor L1, rises linearly. The capacitor C1 supplies the load through the switch S3, L1, L2 and the source. The capacitor C2 gets recharged through the source, inductor L2 and the switch S3. Thus the current of the inductor L2 decreases and the capacitor C2 is getting recharged at a voltage higher than the input because of the action of inductor L2.

MODE 2:

When the switches S1 and S3 are in open condition, S2 and S4 are closed, the capacitor C2 discharges and supplies the load with the boosted voltage which it has received through the inductor L2 in the previous mode. Thus the load is supplied with an increased voltage than the input, by the capacitor C2, but in opposite direction when compared with the previous mode and hence the inverter operation is achieved [9].

Simultaneously, the current in inductor L2 increases linearly through the switch S4. Also, as the switch S2 is closed, the voltage source, inductor L1, switch S2 and the capacitor C1 forms a closed loop. Hence, the current of the inductor L1 decreases and recharges the capacitor C1, which

got discharged during the previous mode of operation.
The average output of the converter X, which operates under the boost mode is,

$$\frac{V_x}{V_{in}} = \frac{1}{1-D} \qquad (1)$$

Similarly the average output of the converter Y is given by,

$$\frac{V_y}{V_{in}} = \frac{1}{D} \qquad (2)$$

where D is the duty cycle. The average output voltage is given by,

$$V_o = \frac{V_{in}}{1-D} - \frac{V_{in}}{D} \qquad (3)$$

The DC gain of the boost inverter is given by,

$$\frac{V_o}{V_{in}} = \frac{2D-1}{D(1-D)} \qquad (4)$$

From the above equations, it is seen that the output voltage of the boost inverter becomes zero, when the duty cycle D is 0.5. Thus, when the duty cycle is kept around unity, maximum voltage appears across the load [10]. The gain characteristics of boost inverter is shown in the Fig.6.

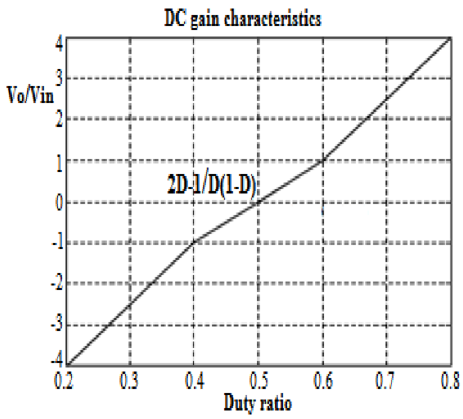

Fig.6. DC gain characteristics of boost inverter

III. RESULTS AND DISCUSSIONS

The boost inverter circuit has been built as simulink model with two inductors, two capacitors and four IGBT switches named as S1, S2, S3 and S4 as shown in figure 8. The PWM pulse is generated by comparing triangular waveform and sine waveform. Triangular wave is generated by using the repeating sequence block with the time values. These two waveforms are given as inputs to the relational operator which compares the two and produces the PWM pulses. The pulse is directly given to two of the switches, S1 and S3. The pulse is then inverted using the logical operator NOT and is given to other two switches, S2 and S4. The output is measured across the load using current and voltage measurement blocks. It is followed by RMS function block parameter to display the RMS AC output voltage. Scope is used to display the current and voltage waveforms of the output. The simulink model of the boost inverter circuit is shown in Fig.7.

Using the Simulink model of the boost inverter circuit, the output has been checked for various values of inductor, capacitor and input voltages. The parameters of boost inverter with resistive load is shown in table-I.

TABLE I Specifications of boost inverter circuit

Parameters	Values
Inductor, L=L1=L2 (Mh)	8
Capacitor, C=C1=C2 (µF)	775
Resistor, R (Ω)	200
Input DC Voltage, V_{in} (V)	105
Output AC Voltage, V_o (V)	215
Switching Frequency, f_s(KHz)	10

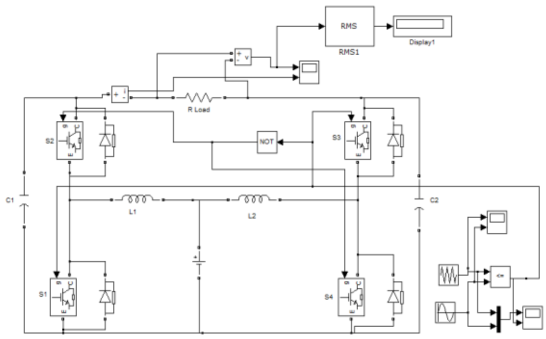

Fig.7. Simulink model of Boost inverter circuit.

During mode 1 operation, inductor L1, capacitor C2 gets charged and inductor L2, capacitor C1 gets discharged. During mode 2 operation, inductor L2, capacitor C1 gets charged and inductor L1, capacitor C1 gets discharged. The output voltage and current waveform of the boost inverter are shown in Fig.8.

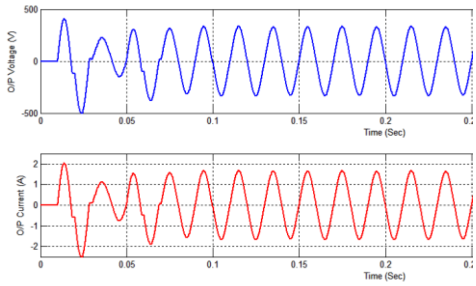

Fig.8. Voltage and Current waveform of Boost inverter.

IV. HARDWARE DESCRIPTION AND RESULTS

The hardware design of the proposed topology has been built for a lamp load. Since it is a prototype, the model has been designed to give an AC output of about 40V for a DC input of 12V. The Figure 9 shows the hardware model of the proposed topology.

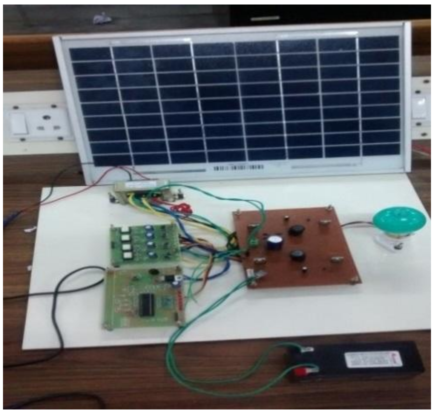

Fig.9. Working model of proposed system.

Each of the switches will possess a design of components as shown in the Fig.9. The circuit consists of three important sections: (1) boost inverter circuit (2) microcontroller circuit and (3) driver circuit. The MOSFET switch is used for the prototype model as it is suitable for low voltage applications. Thus the boost inverter circuit consists of four MOSFET switches. The IRF840 is an 8A, 500V, N channel MOSFET, which is best suited for the prototype.

Each of the MOSFET switches are driven using a driver circuit separately. Thus there are four driver circuits totally present for isolation purpose, so that it protects the microcontroller circuit from damage in case of malfunction of the inverter circuit and also for amplification purpose, to provide amplified signal to the switches from the microcontroller, so that the losses during switching is reduced.

The hardware has been designed in such a way that, the solar panel acts as a source, which simultaneously charges the battery and provides input to the boost inverter circuit.

The Fig.10 below shows that hardware output voltage waveform of the boost inverter circuit for the input 5V DC supply. It is observed that the RMS value output voltage is around 15.3V.

Fig.10. Hardware output voltage for 5V input.

The Fig.11 below shows that waveforms of capacitor C1 and C2. It is observed that when the voltage of capacitor C1 is high, the voltage of capacitor C2 is low. Thus it is clearly obtained fact that both the capacitors are 180 degrees out of phase with each other.

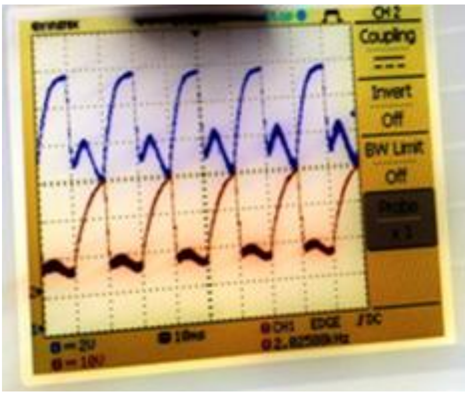

Fig.11. Hardware output voltage of capacitors

When the auto synchronous load is connected in between these two capacitors, an inverted output voltage i.e., AC output voltage is obtained.

Table IISpecification of hardware results

Input voltage (volts)	Output voltage (volts)
2.5	12
4.5	13.8
5	15.3
5.7	17.5

The above table II shows the specification of hardware results of the proposed topology for various input voltages.

V. CONCLUSION

The Boost inverter circuit has been studied both in simulation and hardware. From table II it is evident that boost inverter circuit produces an AC output voltage higher than DC input voltage. Hence the boost inverter circuit is suitable for various applications where an output voltage higher than the input is needed such that uninterrupted power supplies circuits. As it eliminates various blocks in the already existing system, it is considered to offer economical and technical advantages when compared with the conventional voltage source inverter.

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