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A Single Stage Inverter for Photovoltaic Application

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***Abstract*: Renewable energy technologies offers clean, abundant energy gathered from self renewing resources such as sun, wind etc. As power demand increases, power failure also increases. So, renewable energy source can be used to provide constant loads. But the voltage range of photovoltaic cell is influenced by several environmental factors and it varies in wide range. So the inverter system must operate in both buck and boost modes. This paper presents a single stage buck boost inverter topology. The voltage boosting is done with the help of ac-ac unit composed of active switches. Thus reducing the passive elements and this increases the efficiency of the system. Operational analyses in both modes are presented. MATLAB simulink model is developed. Experimental results are presented to verify the operation.**

***Key words:* AC-AC unit, Buck-Boost, Photovoltaic, single stage inverter.**

I. INTRODUCTION

Among the wide range of problems facing our world today, there is a global consensus that green house gas(GHGs) a mission have the largest negative impact on our environment. GHGs include Carbon dioxide, Methane, Nirous oxide, sulphur-Hexafluoride, Hydro fluorocarbon and per-fluorocarbons. GHGs allow sunlight to enter the atmosphere, but trap the heat radiated off the earth surface. This results in global warming. the financial incentives, along with carbon emission limits not the only factor pushing the government in the direction of renewable and clean energy. The scarcity of fossil fuels and their rapid depletion worldwide has made a it necessary to search for alternative energy sources that would meet the current level of demand. Recent development and trends in electrical power consumption indicate an increasing use of renewable energy. Renewable energy sources such as solar energy, wind energy have been deemed clean, inexhaustible unlimited and environmental friendly[1]. Photovoltaic energy is one of the major source of renewable energy. Photovoltaic energy offers added advantage over other renewable energy sources in that they give off no noice and require practically no maintenance.

Solar energy is a radiant light and heat from the sun that has been harnessed by humans since ancient times using a range of ever evolving technology. Experts believe that by the end of this century solar enery shall subsidize upto 64% of total global energy requirement. The solar energy obtained from the PV cells or modules is DC. But the majority loads are AC.

Hence, the energy from PV module need to be converted to appropriate form, that is to AC form. Therefore an inverter should be used to convert DC to AC[2]. A power inverter is an electrical device that converts direct current to an alternating current. the output can be set in any required voltage and frequency with the use of transformers and control circuits. Since the output of the photovoltaic system varies in wide ranges due to the environmental factors, the power inverter used must have the capability to do both bucking and boosting operations in order to generate constant ac voltage at the output. Topologies for this coverter can be separated in two distinct categories, voltage source inverter (VSI) and current source inverter (CSI). The VSI can only perform voltage buck conversion whereas CSI can perform voltage boost conversion.

In the VSI a dc voltage source supported by a relatively large capacitor feeds the main converter circuit. The full bridge inverter is the commonly used VSI topology. Here the ac output voltage is limited below and cannot exceed the dc rail voltage. therefore, VSI is buck inverter for dc to ac power conversion and boost rectifier for ac to dc power conversion. In CSI a dc current source feeds the main converter circuit. Here the ac output voltage has to be greater than original dc voltage that feeds the dc inductor. Therefore, the current source inverter is a boost inverter for dc to ac power conversion and a buck rectifier for ac to dc power conversion [3]. In order to boost the output of

VSI there are two common solutions. First one is to add a step-up transform in the full-bridge inverter as in Fig.1. But this increases the overall weight and volume of the system. The second solution is the use of a two stage cascaded structure as in Fig.2. The dc-dc converter the voltage boosts and the dc-ac converter perform the inversion. This cascade structure has poor stability and low efficiency.

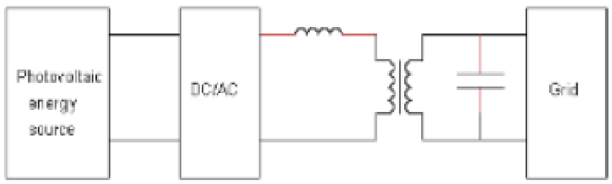

Fig.1. Inverter with Transformer

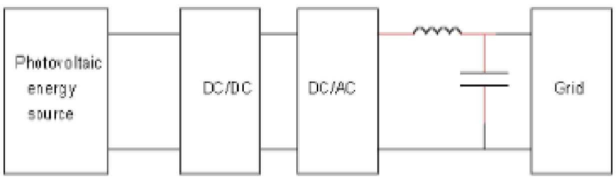

Fig.2. Inverter with Cascade Structure

A diode assisted buck boost VSI was proposed[4] by F.Gao which can perform a wide range buck boost conversion with many additional passive elements. The addition of passive and active elements cause many losses is one of the major drawback of the system. An Impedance source converter was introduced[5] which consists of X shaped passive impedance network to couple the main power converter and power source, the Z source inverter[6]. Many passive elements are used in this topology also, which is the major drawback. also the size and weight of over all system is very high. all these topologies exhibit the same two stage power processing as the two stage structure. This paper presents a single stage buck boost inverter to overcome the problems of traditional solutions for buck boost inverter. The AC/AC unit composed of active switches performs like a step-up transformer and boost the output ac voltage.

II.CIRCUIT DESCRIPTION

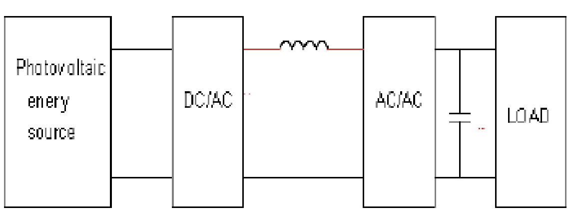

Fig.3. Single Stage Buck Boost Inverter

The general structure of the single stage buck boost inverter shown in Fig.3. The variable voltage from the photovoltaic energy source is connected to the DC/AC system which is a full bridge voltage source inverter and the transformed used in the traditional single stage structure is replaced by "ac/ac" unit. The ac/ac unit performs the voltage boost conversion and the dc/ac unit performs the voltage buck conversion. The ac/ac unit consists of four active switches.

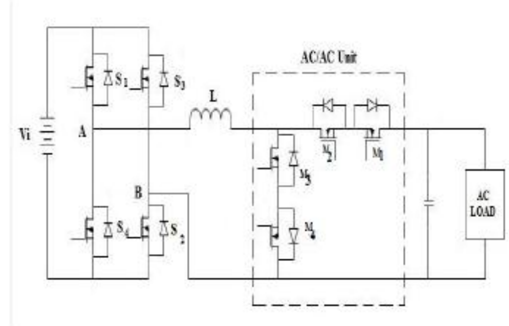

Fig.4. Overall Circuit

III. OPERATION PRINCIPLE AND WORKING OF THE SYSTEM

The switches of the single phase full bridge inverter is controlled by sinusoidal pulse width modulation(SPWM) strategy. The ouptput voltage of the inverter can be written as

Vio = MVinsin ωt (1)
where 'M'is the modulation ratio.
Vo= (2)
Vio
D D = 1-d; where d is the duty ratio

The operating principle of the ac/ac unit is same as that of boost ac/ac converter. The output voltage is given by Vo = MVinsin ωt (3) where 'd' is the duty ratio of M3 or M4 according to the cycle of operation (whether positive or negative).

The system operated in the buck mode when the input voltage is higher than the desired output voltage. This is achieved by keeping D equal to 1. here M1 and M2 are always turned on while M3 and M4 switches in the line frequency. When the desired output is higher than the input voltage, the system operates in the boost mode. This is achieved by setting modulation index M to 1, and boosting the voltage is achieved by adjusting D. the output voltage is equal to

$$V_o = \frac{V_{in}\sin \omega t}{D} \quad (4)$$

A. Positive Half cycle

During the positive half cycle of the buck mode M1,M2 and M4 are switched on and M3 is switched off. And in the positive half cycle of the boost mode M2 and M4 are switched on and M1 and M3 switches in the line frequency.

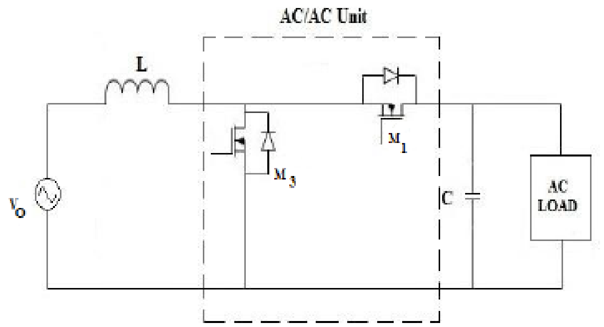

Fig. 5. Positive Half Cycle

B. Negative Half Cycle

In the negative half cycle of the buck mode M1, M2 and M3 are switched on and M4 is switched off. During the negative half cycle of the boost mode M1 and M3 are switched on and M2 and M4 switches in the line frequency.

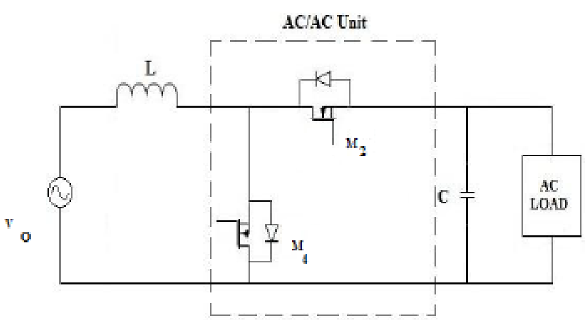

Fig.6. Negative Half Cycle

C. Control circuit

The modulation scheme used for generating switching pulses for the inverter and ac/ac unit is shown in the Fig.4. Sinusoidial pulse with modulation signal are generated by comparing sine wave and high frequecny triangular wave.

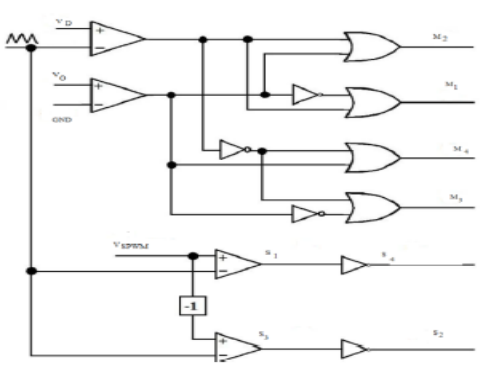

Fig. 7. Modulation Scheme

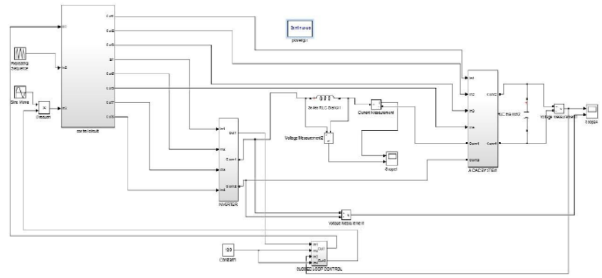

Fig.8. MATLAB/simulink model of the system

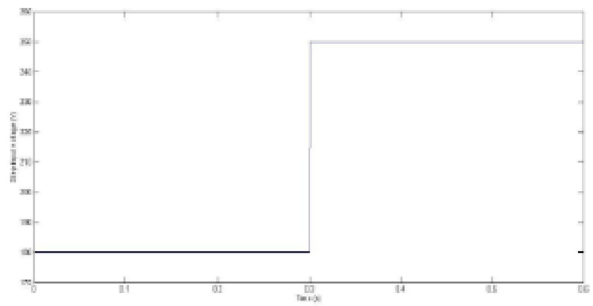

Fig.9. Step input

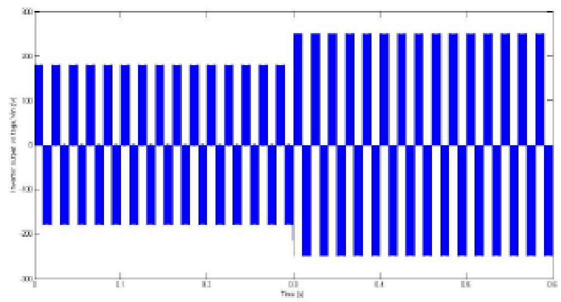

Fig.11. Output AC Voltage

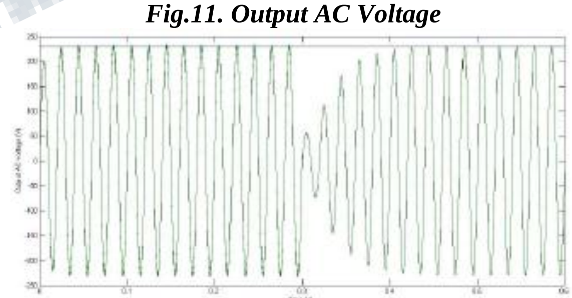

Fig.10. Inverter Output Voltage

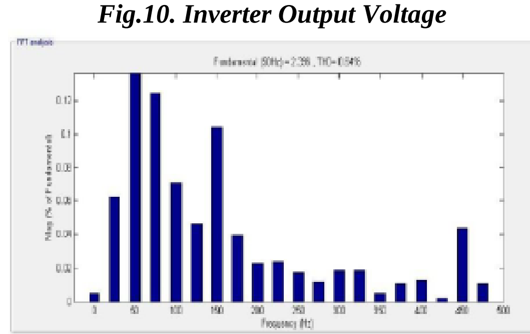

Fig.12. THD Analysis

The THD analysis of the output voltage in open loop control circuit is shown in Fig.12. The harmonic spectrum of the output voltage modulation index 0.5 is plotted in the figure. Total Harmonic Distortion (THD) of the output voltage after filtering is obtained as 0.64%.

V. CONCLUSION

This paper presents closed loop control of buck boost inverter for photo voltaic applications. This inverter achieves both buck and boost operations within wide range of inputs. THD value after filtering is only 0.64% which is within the IEEE limit. This helps in reducing the system volume and cost and increasing the system efficiency and power density.

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