

Design of Single-Stage Buck Boost Converter for Inverter Applications

N.V.Yeswanth¹, M.Kavitha², M.Rajasekhar Patnaik³, L.Anil Kumar⁴

^{1,2,3,4}B.TECH Students, Electrical & Electronics Engineering, AITAM, Tekkali, Srikakulam, A.P India

Abstract- The main objective of this project to reduce the Total Harmonic Distortion (THD) the transformer can be replaced by buck and boost converter there by it also increase the efficiency. This design employs a single stage switch mode buck and boost converters which has been presented for photovoltaic inverter applications. The proposed design employs a single-stage switch mode buck converter and a single-stage switch mode boost converter. So the converters are designed that the boost converter provides an output voltage of 312V DC from 24V source while the buck converter provides an output voltage of 7.07V pulsated DC from 312V AC grid. The designed buck and boost converters are then employed to run a single-phase full bridge inverter which can be simulated using the PSIM software. The results show that the designed converters can be used to replace transformers from conventional inverter circuit to make low-THD, highly efficient and cost effective transformer-less inverter-topology

Index Terms- PSIM, Buck, Boost, Buck Boost, Single Phase grid tie Inverter

I. INTRODUCTION

In photovoltaic (PV) system there needs to be a conversion of the solar energy into electrical one through PV arrays using inverter circuit. In conventional inverters, step-up transformers (forward, push-pull, or fly back type) are used to convert unregulated voltage of the PV cells into regulated voltage for the inverter input. The main drawback of using a transformer is that it is heavy, bulky, and expensive and has high THD. In order to overcome these limitations, this article proposes to employ a single-stage boost converter in order to make the transformer-less inverter. The boost converter is so designed that it provides an output of 312V DC, which is the inverter input.

Moreover, to make a grid-tie inverter, the inverter's phase, frequency and amplitude will have to be the same as that of the grid parameters. To fulfill these

grid synchronization conditions, the voltage sample from the grid is taken to produce the gate pulses for switching the inverter's MOSFET s by decreasing the grid voltage to 5VRMS(7.07VAC) using a step-down transformer. Another important point is that the inverter switching is controlled by using microcontroller and its limit cannot be exceeded beyond 5V DC (7.07V AC). In order to attain these features and avail the inverter with advantages of being cost effective, compact and to have dilated THD, in this paper, a single-stage buck converter is recommended to replace the step-down transformer. The buck converter is so designed that it provides an output of 7.07V AC or 5V RMS, which has an output in the shape of an envelope. This envelope is compared with a high frequency triangular wave to produce sinusoidal pulse width modulated (SPWM) signals which are used as the gate signals of the inverter. The buck frequency matches with the grid frequency since the input of buck converter is taken from the grid. The inverter's phase is matched with the grid by applying a zero crossing phase detector with SPWM signal. The inverter's parameters are designed mathematically, and the designed inverter is simulated via PSIM software to verify the inverter's output performances.

II.CONVERTER DESIGN AND RESULTS

Design of Boost Converter

Duty cycle

Duty cycle of the boost converter is calculated considering efficiency of the converter is 95%; the efficiency is added to the duty cycle calculation because this calculation gives a more reasonable duty cycle than just the equation without the efficiency factor.

$$D = 1 - \frac{V_{in}}{V_{out}} \times \eta$$

Inductor Selection

In conventional process the inductor value is chosen from the recommended data sheets. Since no inductor value is given for such a large scale voltage conversion 24V DC to 312V DC. Hence to obtain a good estimated inductor value, the following equation is used which is generated by solving Equation

$$L_{boost} = \frac{V_{in}V_{out} - V_{in}}{\Delta I_L \times F_s \times V_{out}}$$

Capacitor Selection

For this design, the output capacitor values can be adjusted to the desired output voltage ripple by using the following

$$C_{boost} = \frac{I_{out} \times D}{F_s \times \Delta V_{out}}$$

Design Specifications

The design specifications of boost converter are enlisted in Table-I

Actual Meaning	Symbol	Value
Input Voltage	V _{in}	24V
Maximum output voltage	V _{out}	312V
Minimum switching frequency of the converter	f _s	5KHz
Maximum inductor current	I _{LMax}	2500A
Estimated inductor ripple current (7% of inductor current)	ΔI _L	177A
Desired output voltage ripple (0.13% of output voltage)	ΔV _{out}	0.408 V
Maximum output current (V _{out} /R)	I _{out}	9.75A
Converter working efficiency	η	95%

Table I: Design Specifications of Boost Converter

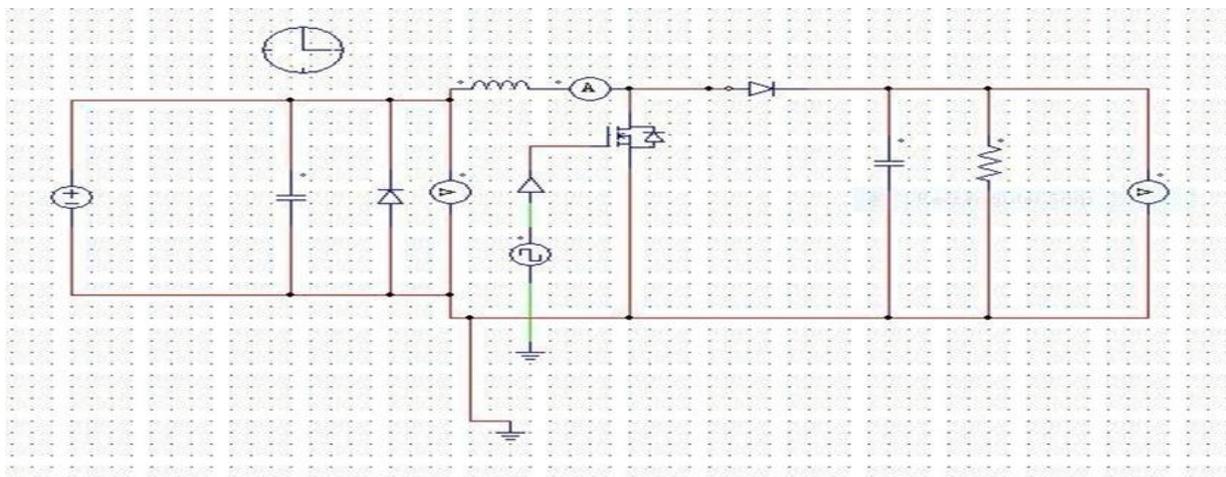


Fig1: PSIM simulation circuit of the boost

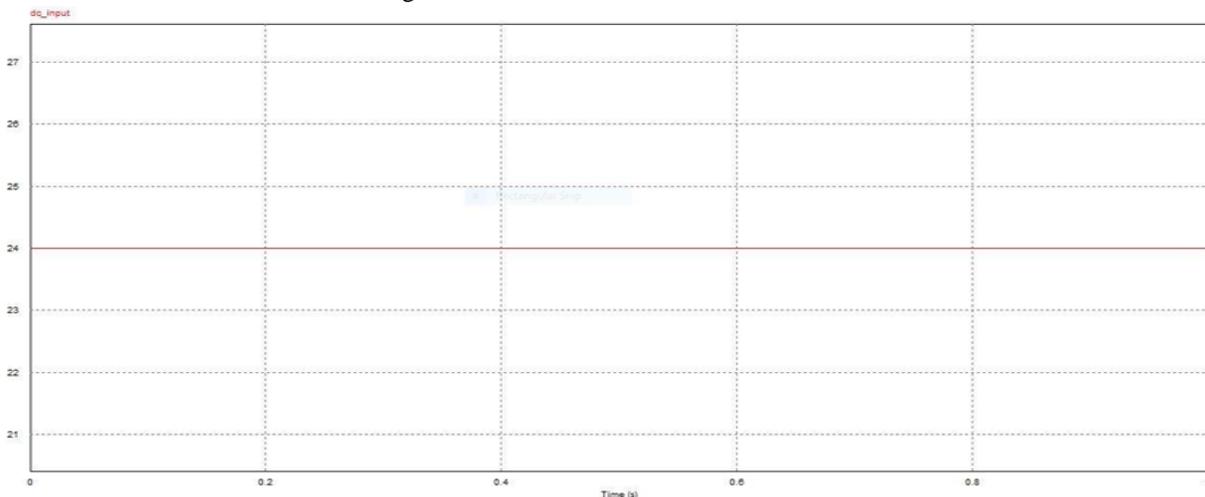


Fig2: D.C input to the boost converter

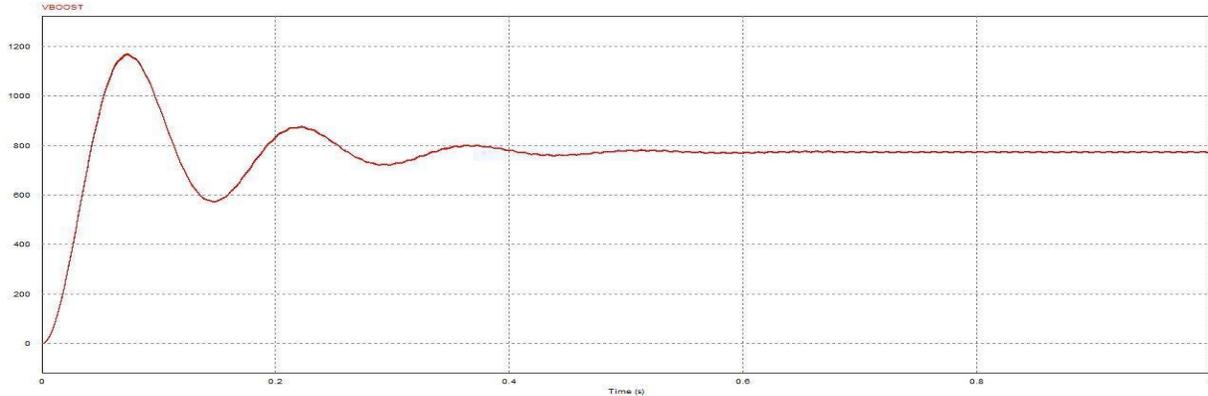


Fig3: Boost converter output in PSIM

Design of Buck Converter

Duty cycle

Duty cycle of the buck converter is calculated considering efficiency of the converter is 95%; the efficiency is added to the duty cycle calculation to gives a more reasonable duty cycle than just the equation without the efficiency factor

$$D = \frac{V_{in}}{V_{out}} \times \eta$$

Inductor Selection

In order to limit the current ripple a smoothing inductor is being used. The inductor value has been chosen from the recommended datasheets in conventional process. Since no inductor value range is given for large scale voltage conversion(312V to 7.07V),hence to make a good estimation of the right inductor value following equations

$$L_{buck} = \frac{V_{out}V_{in} - V_{out}^2}{\Delta I_L \times F_s \times V_{in}}$$

Output Capacitor Selection

The basics election of the output capacitor is based on the ripple voltage, ripple current and on the loop

stability. In the present design, the following equations can be used to adjust the output capacitor values for buck converter,

$$C_{buck} = \frac{\Delta I_L}{8 \times F_s \times \Delta V_{out}}$$

Design Specifications

The design specifications of buck converter are enlisted in Table-II:

Actual Meaning	Symbol	Value
Input Voltage	V _{in}	312V
Maximum output voltage	V _{out}	7.07V
Minimum switching frequency of the converter	f _s	25KHz
Maximum inductor current	I _{LMax}	0.61A
Estimated inductor ripple current (10% of inductor current)	ΔI _L	0.061A
Desired output voltage ripple (1% of output voltage)	ΔV _{out}	0.05V
Converter working efficiency	η	95%

Table I: Design Specifications of Buck Converter

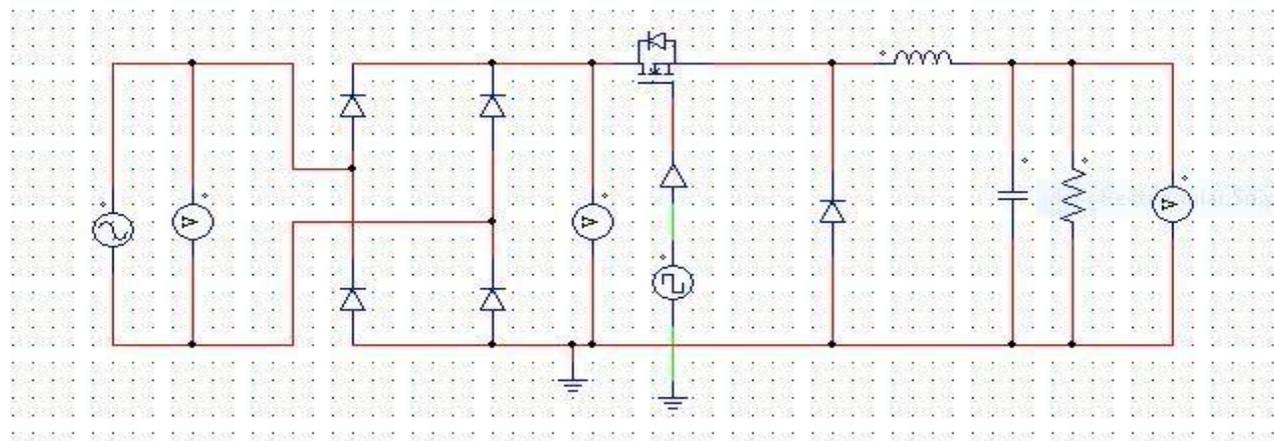


Fig4: PSIM simulation circuit of the buck converter using the designed circuit parameters

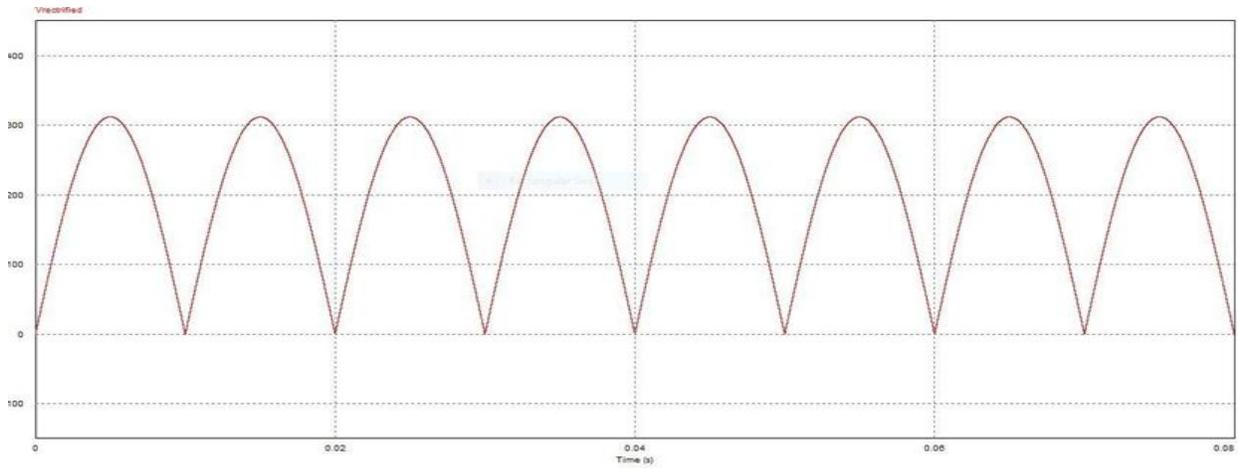


Fig5: Rectified input to the buck converter

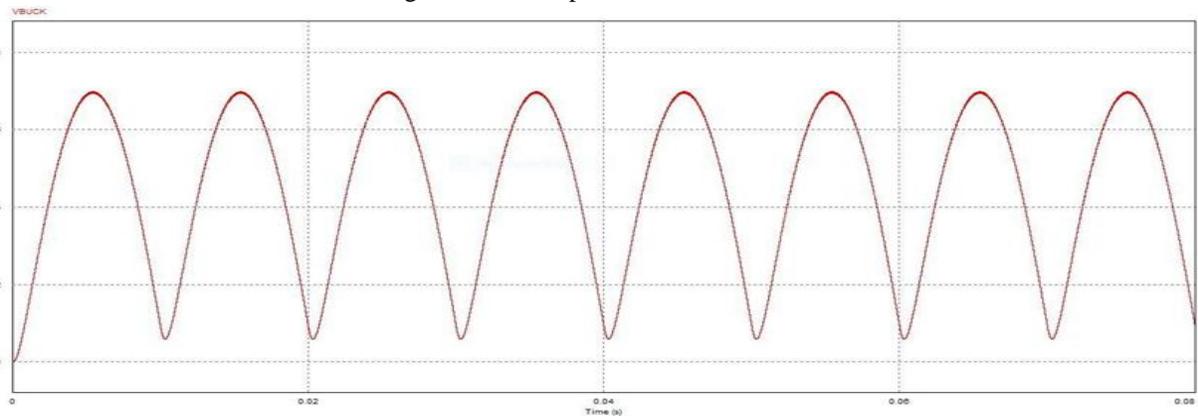


Fig6: Output of buck converter in PSIM

Application of Buck Boost Converter to Single Phase Grid-Tie Inverter

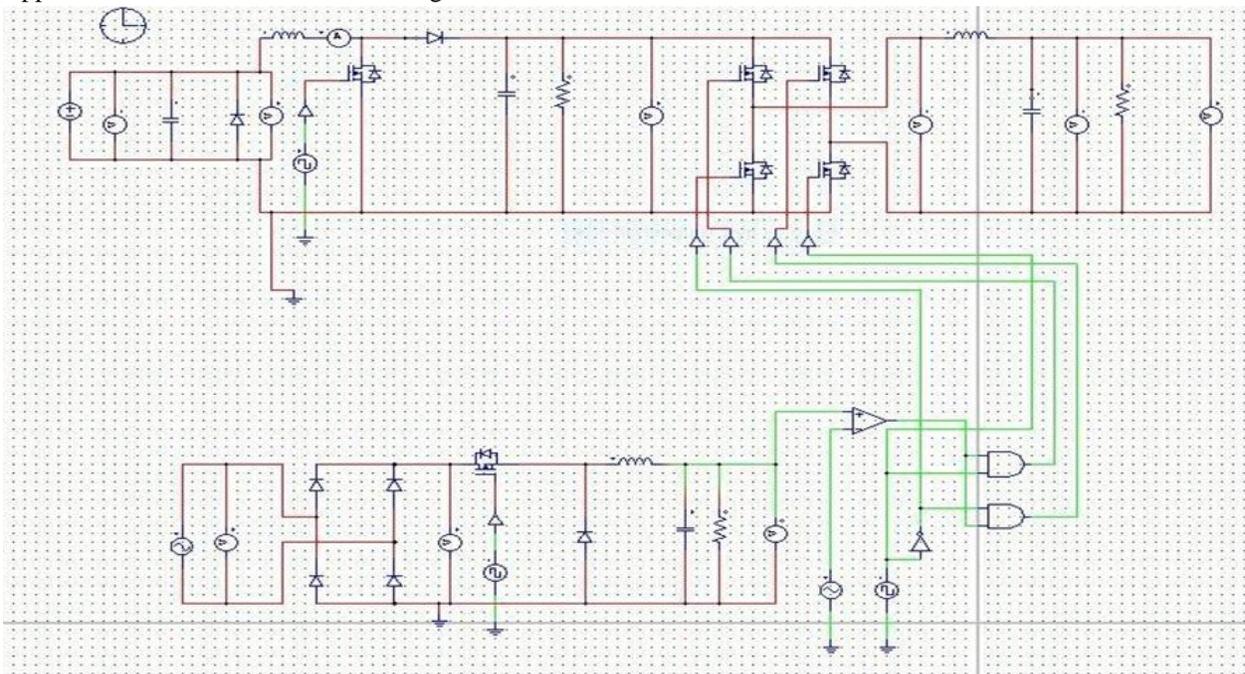


Fig7: Schematic diagram of inverter circuit using buck and boost converters

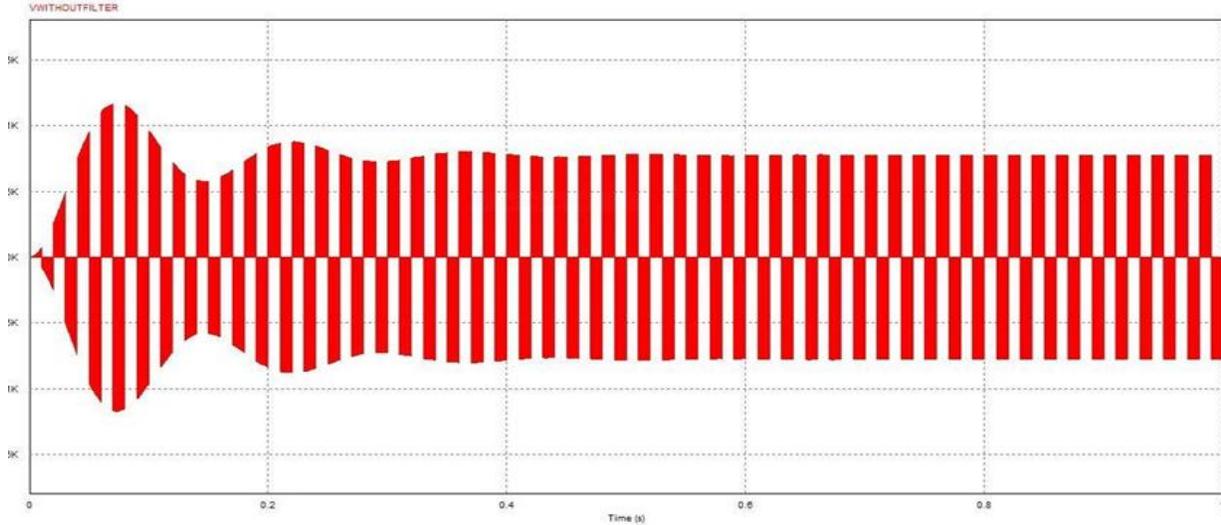


Fig8: Output voltage waveform without filtering in PSIM

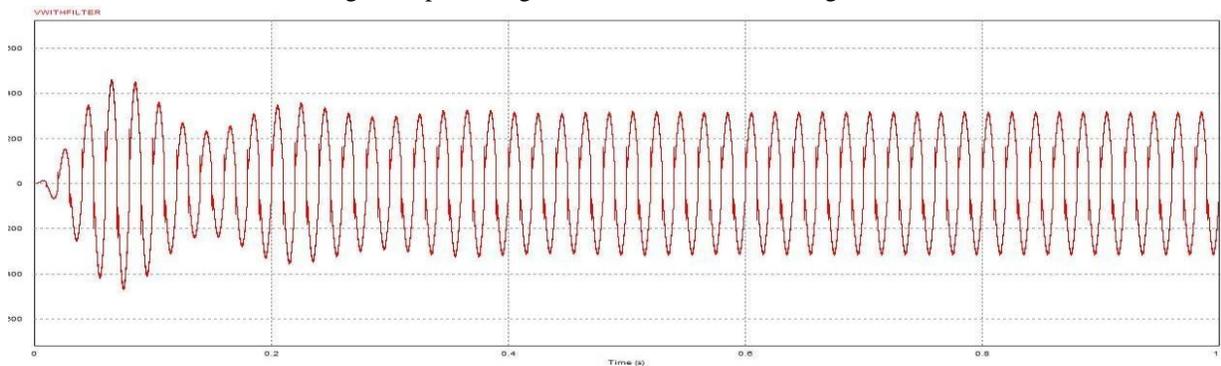


Fig9: Inverter output voltage waveform in PSIM

III. CONCLUSION

The main conclusion is that a transformer in a inverter makes it more complex, heavy weighted and has high influence on total harmonic distortion. In order to minimize these disadvantages from the inverter this single stage buck-boost converter is proposed

This design will make the inverter cost effective and highly efficient. THD of the circuit is 0.02% which is below the IEEE519 standard. Therefore, the proposed transformerless inverter is cost effective, lightweight and efficient with less THD.

It is found, from the design parameters of buck and boost converter, that the duty cycle for boost converter is 85% which is quite large for the conventional MOSFET switching. And for buck converter, the duty cycle is 2% which is very small and practically not feasible to turn on the MOSFET.

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