INTERLEAVEDBUCK BOOST INVERTER FOR DISTRIBUTED GENERATION SYSTEM

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Abstract—This paper presents a non-inverting interleaved buck boost inverter for DC-AC energy conversions. The energy derived from the renewable energy sources cannot be directly connected to the load. For applications that require a stable DC bus voltage, an efficient converter is needed. Two non inverting buck boost converters are integrated with an interleaved operation for DC-DC conversion. Thus, a switch and a diode can be omitted, reducing cost. A modified z source inverter is integrated with the buck boost converter for DC-AC energy conversion. The operating principle and steady-state analysis are discussed in detail. The interleaved operation reduces current ripple at the output. The converter is simulated using MATLAB 2010 and waveforms are analyzed. Higher voltage conversion ratio can be obtained without using transformer topologies.

Keywords— Buck boost converter, Distributed Generation (DG) system, Continuous conduction mode (CCM),z-source inverter, Interleaving technique.

INTRODUCTION

Conventional fossil-fuel-based energy sources such as crude oil, coal and natural gas are rapidly being exhausted, and energy derived from these sources causes serious environmental pollutions. Renewable energy technologies have become a prominent and rapidly growing portion of the worlds energy portfolio. Renewable energy comes from many commonly known sources such as solar power, wind, running water and geothermal energy. Renewable energy sources are wonderful options because they are limitless. Also another great benefit from using renewable energy is that many of them do not pollute our air and water, the way burning fossil fuels does. Among these two major forms are fuel cell based and photovoltaic cell based energy sources. Any such renewable energy system requires a suitable converter to make it efficient. Several converter types are capable of providing both step-up and step-down voltage conversion for renewable energy systems, including the inverting buck boost converter, the flyback converter, the Cuk converter and the single-ended primary-inductance converter (SEPIC)[4][6]. However, these converters greatly stress the switches. The Cuk and SEPIC converters utilize two pairs of inductors and capacitors to transform energy into the output, and are thus large and inefficient. Another disadvantage is that the output polarity is reversed in the inverting buck boost and Cuk converters[3]. The flyback converter has a high-leakage inductance and its efficiency is low. The main application of a step-down/step-up or buck-boost converter is in regulated DC power supplies, where a negative-polarity output may be desired with respect to the common terminal of the input voltage, and the output voltage can be either higher or lower than the input voltage. But single-switch buck-boost topology have the problem of an increase in the component stresses and component sizes[1]. In order to solve the common-ground issue for the input and output, a two-switch non-inverting buck boost converter can be used. High efficiency can be achieved by using the interleaving technique. Interleaved converters are used for sharing the load current in high power applications[2][5]. It has the advantage of high equivalent switching frequency and reduced output current ripples. Two non-inverting buck boost converters are integrated with an interleaved operation[7]. Thus, a switch and a diode can be omitted, reducing cost. The interleaved operation reduces both the current ripple at the output and the current stress of the diodes. Traditional full bridge inverters do not have the flexibility of handling a wide range of dc input voltages. Especially when the dc voltage is lower than the ac voltage, heavy line frequency step up transformers are required. Although these inverters demonstrate robust performance and high reliability, they demand higher volume, weight and cost for DG system applications. By using Z source network[10] as an intermediate circuit it can control the dc link voltage[11][12]. So the interleaved buck boost converter is integrated with a modified z-source inverter. DC voltage obtained from the renewable energy sources is efficiently converted.

PRINCIPLE AND WORKING

Figure 1 shows the general block diagram of renewable energy conversion system. From the block diagram it can be seen that voltage supplied from energy sources goes through two stages of conversion before it is supplied to grid.

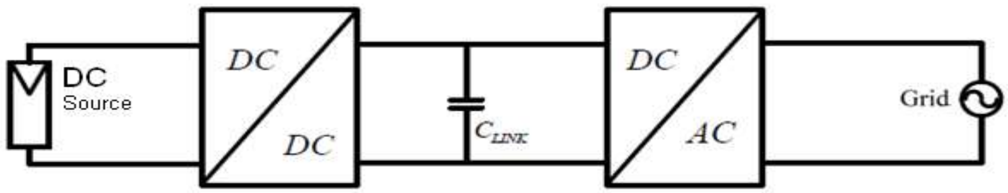


Figure 1. General block diagram of renewable energy conversion system

The voltage from the energy source is first converted to into variable dc using a non-inverting interleaved buck boost converter. This variable dc voltage is then converted to ac voltage by using a modified z-source inverter and is given to grid.The capacitor link acts as a voltage source to the inverter.

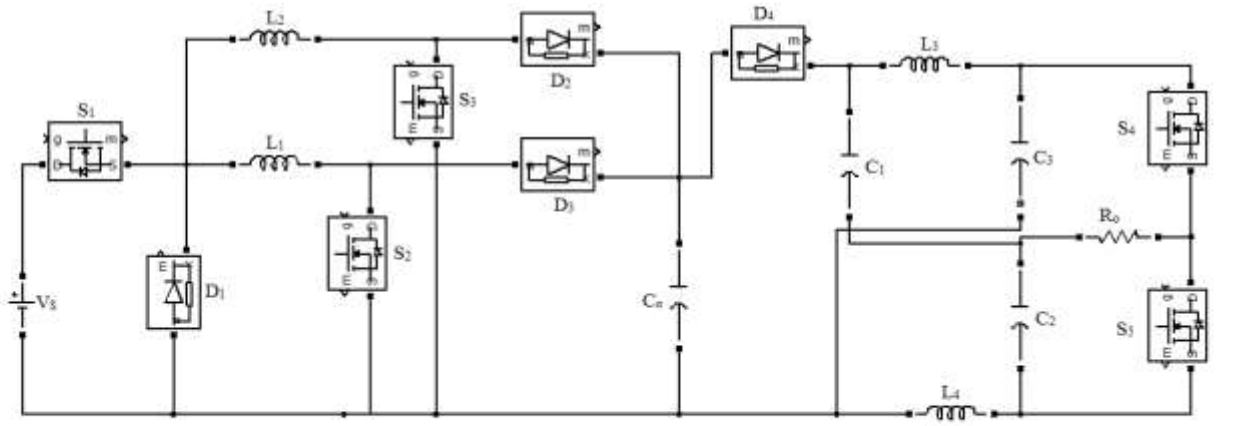


Figure 2. Interleaved buck boost inverter

The circuit can be divided into two sections, first is a DC-DC converter where a buck boost converter effectively converts the DC input voltage and the second is a DC-AC converter where a modified z-source inverter is used for the conversion. A DC link connects both the sections. Figure 2 shows the circuit configuration of the interleaved buck boost inverter. The first section consists of three power switches, two inductors, three diodes and one capacitor. Two non-inverting buck boost converters are integrated with an interleaved operation. To simplify the circuit analysis, the following conditions are assumed. The power metal oxide field-effect transistors(MOSFET) and the diodes are ideal. The output capacitor C_o is large enough so that the output voltage ripple can be ignored. Thus, V_{co} is considered to be constant in one-switching period. Inductors L_1 and L_2 are equal. Inductor currents i_{L1} and i_{L2} are operated in continuous conduction mode (CCM). Second section consists of two power switches, two inductors, one diode and three capacitors. The load is connected between the common node of the two series capacitors and the common node of the two switches. Working of first section consists of 4 modes and that of second stage consists of 3 modes.

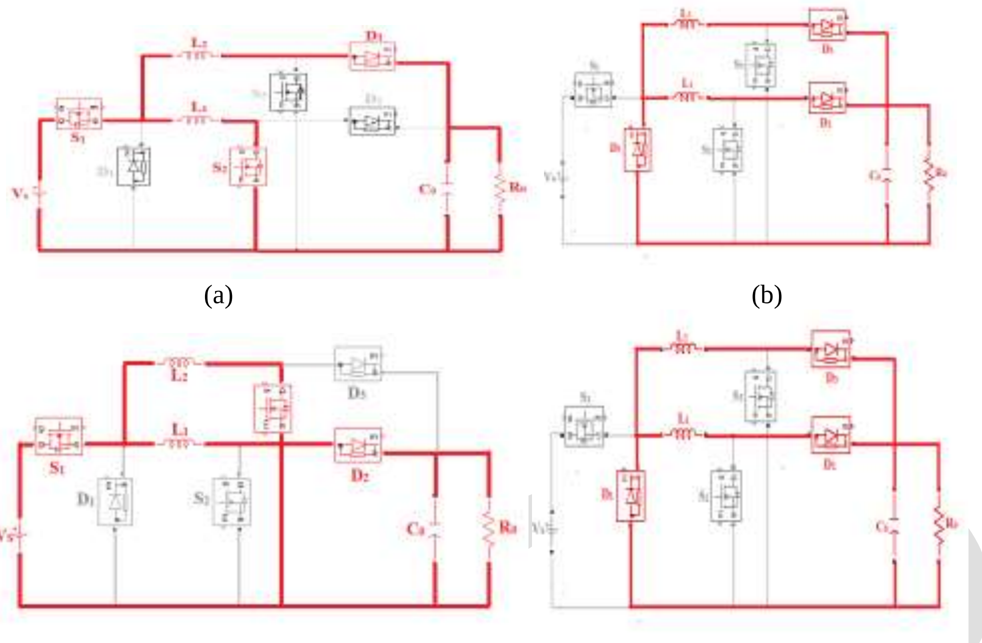
A. **DC-DC Converter**

Mode I: In mode I , S_1, S_2 and D_3 are turned on and S_3, D_1 and D_2 are turned off. Figure.3(a). shows the current flow path of the converter in this mode. In, inductors L_1 and L_2 store their energies from input voltage V_s. Inductor current i_{L1} increases linearly and i_{L2} increases or decreases linearly this interval depending on whether the converter is operating in buck or boost mode. In this mode, inductor current i_{L2} decreases linearly. The load is supplied by capacitor C_0 and inductor L_2.

Mode II: In this mode, S_1, S_2 and S_3 are turned off and D_1, D_2 and D3 are turned on. Figure.3(b). shows the current flow path for this mode. In this interval, the energy stored in inductors L_1 and L_2 is released to capacitor C_0 and load R_0. Inductor currents i_{L1} and i_{L2} decrease linearly.

Mode III: In mode III S_1, S_3 and D_2 are turned on and S_2, D_1 and D_3 are turned off. Figure.3(c) shows the current flow path of the converter in this mode. In this interval, inductors L_1 and L_2 store their energies from input voltage V_s. Inductor current i_{L2} increases linearly, and i_{L1} increases or decreases depending on whether the converter is operating in buck or boost mode. In this mode, inductor current i_{L1} decreases linearly. The load is supplied by capacitor C_0 and inductor L_1.

Mode IV: In this mode, S_1, S_2 and S_3 are turned off and D_1, D_2 and D_3 are turned on. The current owing path in this mode is the same as mode II. Figure. 3(d.) shows the current flow path of the converter in this mode. In this interval, the energy stored in inductors L_1 and L_2 is released to capacitor C_0 and load R_0. Inductor currents i_{L1} and i_{L2} decrease linearly.



(a) (b)

(c) (d)

Figure 3.(a).Mode *I*operation. (b).Mode *II* operation. (c).Mode *III* operation.(4).Mode *IV*operation

B. Modified z-source inverter

Figure 4 shows the diagram of modified z source inverter.It consist of three operating modes.

1) *ModeI:*Figure 5(a) shows the circuit diagram of mode I operation. The inverter is in active state. Upper transistor is conducting and lower transistor is substituted by its freewheeling diode.
2) *ModeII:*Figure 5(b) shows the circuit diagram of modeII operation.The inverter is in active state. Lower transistor is conducting and upper transistor is actively like a diode.
3) *ModeIII:* Figure 5(c) shows the circuit diagram of mode IIIoperation. In this mode upper and lower switches are conducting. The inverter is in shoot through state.

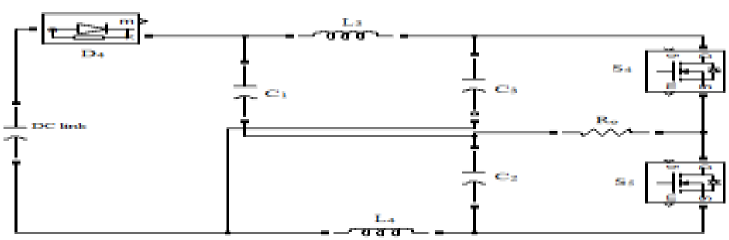
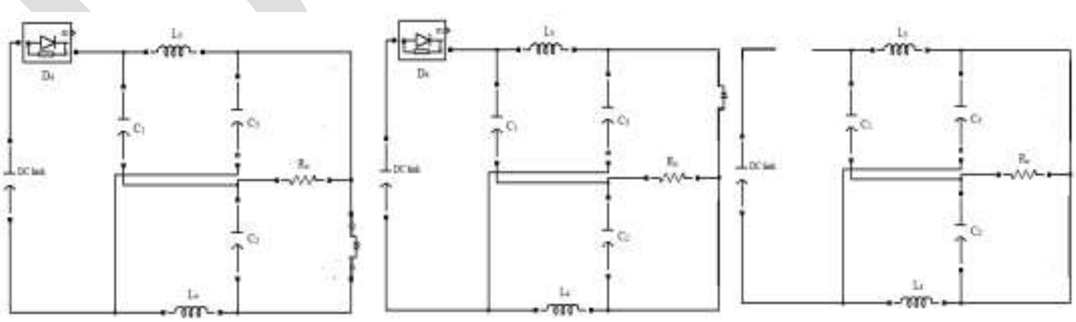


Figure 4. Modified **z source inverter**



(a) **(b)** **(c)**

Figure 5.(a).Mode *I* operation. (b).Mode *II* operation. (c).Mode *III* operation.

DESIGN OF COMPONENTS

Input voltage V_S = 36V
Output voltageV_0 = 28V
Switching frequency f_S = 50kHz

Voltage gain $\frac{V_o}{V_S}=\frac{2D}{1-D}$ ……………………………….(1)

Duty cycle D = 28%

Inductor $L_1 = L_2 = \frac{R_O(1-2D)}{f_S}$ = 10μH ……………………………………..(2)

Capacitor $C_o = \frac{V_O D}{V_{co} R_0 f_s}$ = 874μF ……………………………………………(3)

Inductor $L_3 = L_4$ = 10μH

Capacitor $C_1 = C_2$ = 47μF

C_3 = 100μF

SIMULINKMODELAND RESULTS

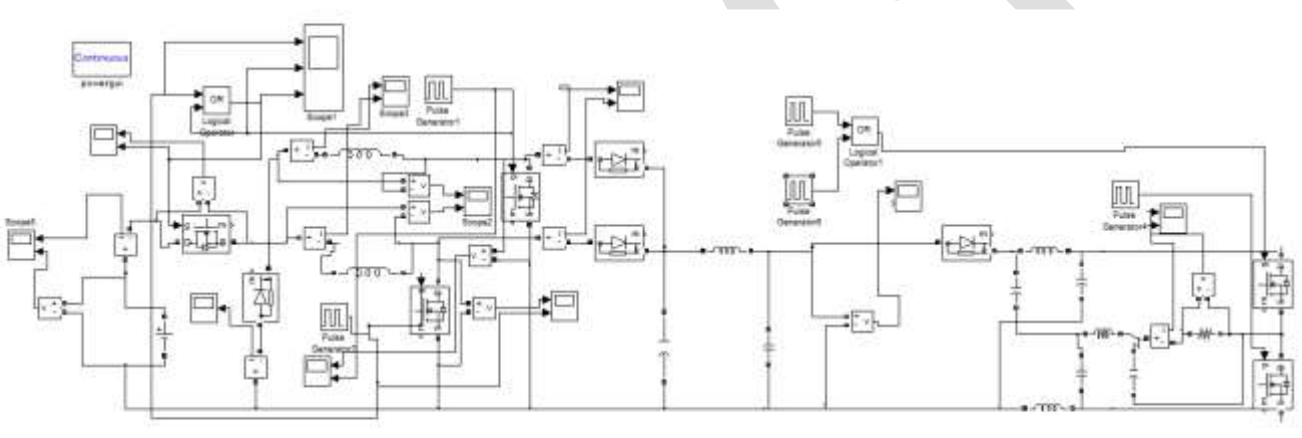


Figure 6. Simulink model of buck boost inverter

Simulink model of interleaved buck boost inverter with Π filter is shown in figure 6. Output voltage and current ripples are significantly reduced with the addition of Π filter.For simulation of the DC-DC converter, parameters of the different circuit components are taken as: For an input voltage of V_s = 36V, f_s(switching frequency) = 50kHz, simulation is performed in MATLAB 2010 for non-inverting interleaved buck boost converter for an output voltage of V_o = 28V. The parameters used includes L_1=L_2 =10μH and C_o(Output capacitor) = 874μF,duty cycle D = 28%.

SIMULATION RESULTS

Simulated waveforms obtained are shown below:

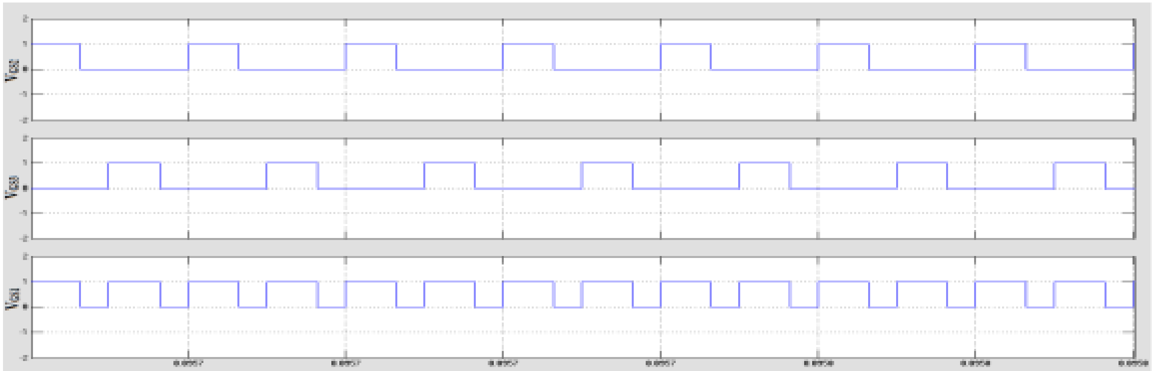


Figure 7.Switching pulses V_{GS1},V_{GS3},V_{GS2}

Figure 7 shows the waveform of switching pulses provided to the three switches, where V_{gs1}- the gate signal of the switch S_1,V_{gs2} - the gate signal of the switch S_2 and V_{gs1}-the gate signal of the switch S_3. The frequencies of switches S_2 and S_3 are twice those of the main switches, which mean that the circuit can behave as an interleaved circuit during two phases, which increases power density and reduces the output voltage ripple.

Figure 8 shows the current waveform of inductor L_1 and L_2. During one switching period 4 modes of operations have occurred. In mode I, i_{L1} increased and i_{L1} decreased. In mode II energy stored in both inductors are released so both inductor currents are decrease linearly. In mode III i_{L1} decrease linearly and i_{L2} increases linearly. Mode IV same as that of mode II.

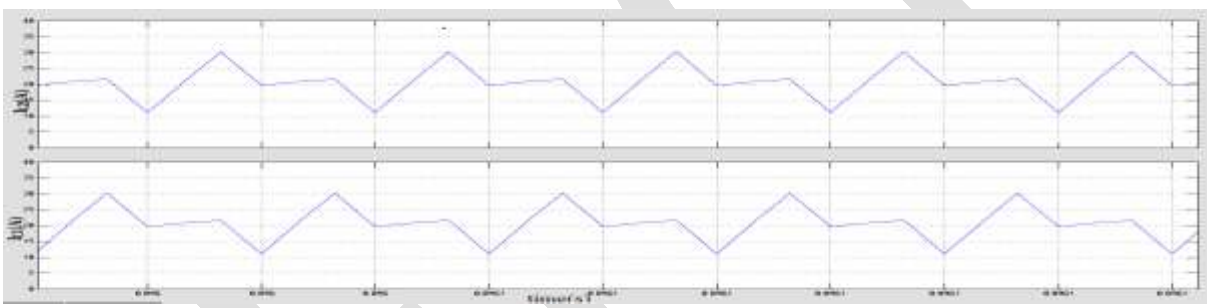


Figure 8.Inductor currents I_{L2}& I_{L1}

Figure 9.shows voltage waveforms of inductor L_1 and L_2.During one switching period 4 modes of operations have occurred. In mode I voltage across L_1 is V_s and across L_2 is V_s- V_o. In mode II voltage across L_1 is-V_o and across L_2 is -V_o. Inmode III voltage across L_1 is V_s-V_o and across L_2 is V_s. Mode IV same as that ofmode II.

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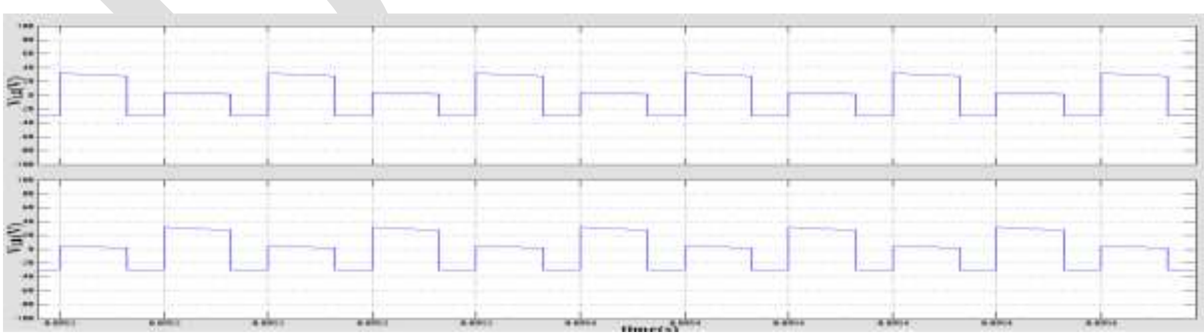

Figure 9. Inductor voltages V_{L2}& V_{L1}

Figure 10 shows the output voltage and current waveform of the inverter. Z source network acts as a dc link energy storage sub circuit. It reduce the inrush current and harmonics due to the two inductors and act as a second order filter and handle undesirable voltage sags.

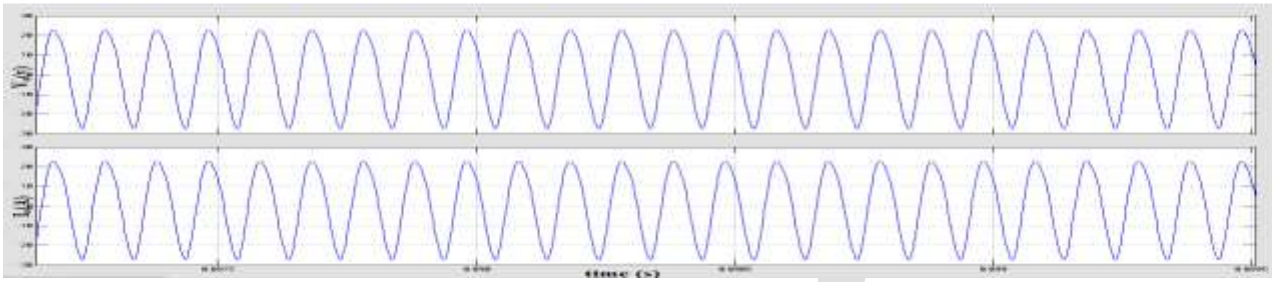

Figure 10. a).Output voltage b). Output current

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CONCLUSION

Non-inverted interleaved buck boost inverter was analysed and simulated using MATLAB 2010. A non-inverting interleaved buck boost converter is integrated with a modified z source inverter to form an efficient DC–AC conversion system for distributed generation system. The interleaved buck boost converter can achieve higher voltage conversion ratio without using transformer. From input voltage of 36V the DC-DC converter can achieve the targeted output voltage 28V with reduced current ripples. Since the output polarity is non- inverting, the common ground issue is resolved. One power switch and one diode are omitted and thereby saving cost and increasing power density. The interleaved technique is used to produce a low-output current ripples. This converter is well suited for fuel cell powered applications. Instead of high voltage rated electrolytic capacitors , series smaller rated capacitors are used in modified z source inverter. The integrated operation of interleaved buck boost converter and modified z source inverter provide efficient DC-AC energy conversion system.

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