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***Research Paper***

# INTERLEAVED BOOST CONVERTER

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Interleaved boost converter is a converter where boost converters are connected in parallel. In this paper a IBC for input voltage of 15 V and 60 V is proposed. The topology is used to increase the efficiency and reliability.

***Keywords:*** Interleaved boost converter, Continuous Conduction Mode (CCM), Total Harmonic Distortion (THD)

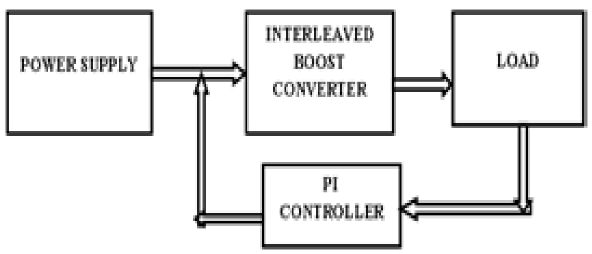
## INTRODUCTION

The Interleaved Boost Converter (IBC) consists of two boost converters connected in parallel with a 180° phase delay, and operating at the same frequency. The IBC has better characteristics when compared to a boost converter with improved efficiency, reduced size, greater reliability and lower Total Harmonic Distortions (THD). The gating pulses of the two switches in the converter are shifted by a phase difference of 360/n where n is the number of parallel boost converters.

The converter considered is operating in Continuous Conduction Mode (CCM) which results in lower input peak current (amplitude) and less conduction losses. It operates at larger duty cycle say 0.5 due to high output voltage and low input voltage. The input current for the IBC is the sum of each inductor currents and as the two devices are phase shifted by 180°, the input current ripples are small.

The proposed interleaved boost converter is as shown in Figure 1.

**Figure 1: Block Diagram of the Proposed Interleaved Boost Converter**




The input is an unregulated DC voltage, which is obtained by rectifying line voltage. DC-DC converters are switched mode DC to DC converter and are used to convert unregulated DC input to controlled DC output. The IBC

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consists of two boost converters in parallel with a phase delay of 180° operating in CCM mode. The converter uses two MOSFET switches, two inductors, two diodes, one capacitor and a resistive load.

## PROPOSED TOPOLOGY

### Proposed IBC

The circuit diagram and the ideal waveforms of the currents in the inductors L1 and L2 for interleaved boost converter operating at CCM are shown in Figures 2 and 3.

**Figure 2: Interleaved Boost Converter**

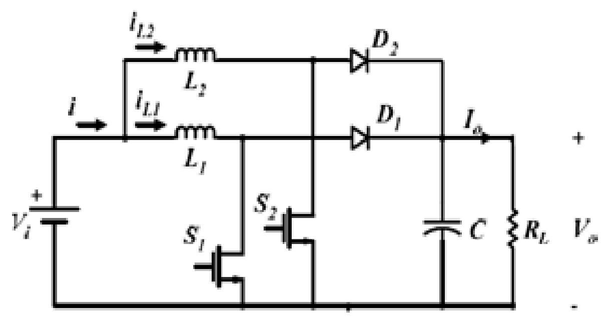
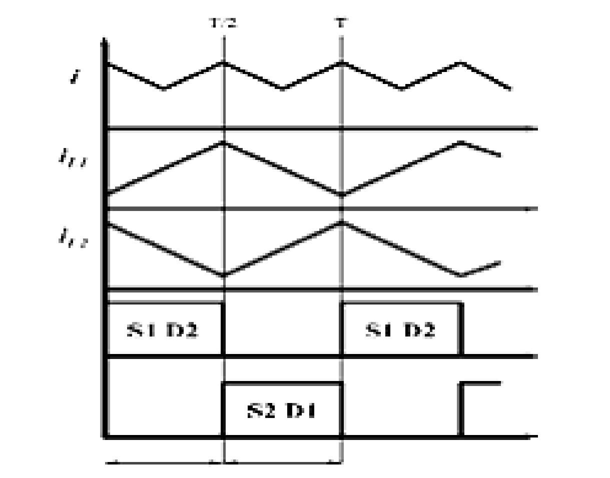



**Figure 3: Ideal Waveforms of Inductor Currents for IBC in CCM**




When the device S1 is turned ON, the current in the inductor iL1 increases linearly. During this period energy is stored in the inductor L1. When S1 is turned OFF, diode D1 conducts and the stored energy in the inductor ramps down with a slope based on the difference between the input and output voltage. The inductor starts to discharge and transfer the current via the diode to the load. After a half switching cycle of S1, S2 is also turned ON completing the same cycle of events. Since both the power channels are combined at the output capacitor, the effective ripple frequency is twice than that of a single-phase boost converter. The amplitude of the input current ripple is small.

### Design Parameters

#### *Boost Ratio*

The boosting ratio of the converter is a function of the duty ratio. It is same as in conventional boost converter. It is defined as:

$$\frac{Vo}{Vin} = \frac{1}{1-D}$$

where *Vo* is the output voltage, *Vin* is the input voltage and *D* is the duty ratio.

#### *Input Current*

The input current can be calculated by the input power and the input voltage.

$$Iin = \frac{Pin}{Vin}$$

where *Pin* is the input power and *Vin* is the input voltage.

#### *Inductor Current Ripple Peak-To-Peak Amplitude*

$$\Delta I_{l1,l2} = \frac{Vin * D}{fs * L}$$

where is the *fs* switching frequency, *D* is the duty cycle, *Vin* is the input voltage and *L* is the inductance.

### *Selection of Inductor and Capacitor*

The operation of IBC, the inductor is used to transform the energy from the input voltage to the inductor current and to convert it back from the inductor current to the output voltage. As per the principle the two inductors are identical in order to balance the current in the two boost converters.

The value of the inductor can be found out by the following formula

$$L = \frac{Vin * D}{\Delta Il * fs}$$

where $V_s$ represents the source voltage and $\Delta I_l$ represents the inductor current ripple, *D* represents the duty ratio. The value of the capacitor is given by the formula

$$C = \frac{Vin * D}{R * \Delta Vo}$$

where *Vo* represents the output voltage (*V*), *D* represents the duty ratio, *R* represents the resistance and $\Delta Vo$ represents the change in the output voltage.

### Parameters Considered

The value of the parameters considered in the simlation is shown in Table 1.

**Table 1: Parameters Considered**

| Parameter | Symbol | Value | | Unit |
|---|---|---|---|---|
| Input Voltage | $V_{in}$ | 60 | 15 | V |
| Output Voltage | $V_{out}$ | 120 | 30 | V |
| Inductotrs | $L_1$, $L_2$ | 1.25 | 1.25 | mH |
| Output Capacitor | $C_o$ | 330 | 30 | µF |
| Resistance | $R_o$ | 120 | 60 | Ω |
| Switching Freqency | $f_s$ | 100 | 100 | KHz |
| Duty Cycle | $D$ | 0.5 | 0.5 | - |

## SIMULATION AND RESULTS

Using MATLAB/SIMULINK the simulation of interleaved boost converter is performed. The waveforms of the input voltage, output voltage, inductor currents, and voltage ripple are shown.

### Open Loop Simulation

### *For $V_{in}$ = 60 V, D = 0.5*

The open loop simulation circuit is shown in Figure 4, Input voltage $V_{in}$ = 60 V, Duty cycle = 0.5, Inductances $L_1$ and $L_2$ = 1.25 mH, Capacitance $C_o$ = 330, Resistance $R_o$ = 120 Ω, switching frequency = 100 KHz. Output voltage of approximately 120 V is obtained. MOSFET switches are used because of its high commutation speed and high efficiency at low voltages.

**Figure 4: Open Loop Simlation Circuit for IBC**

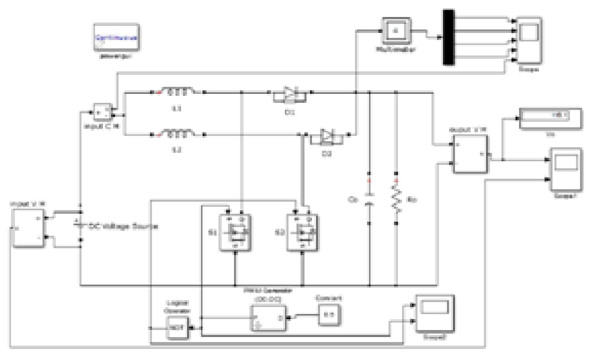
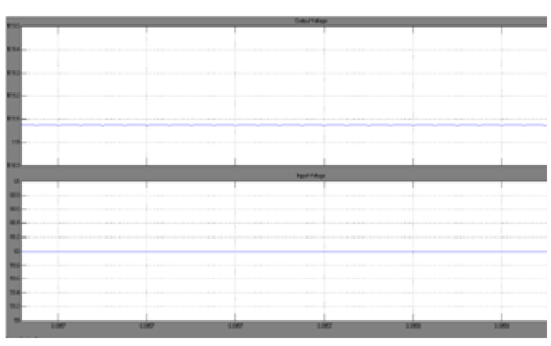


**Figure 5: Waveforms for Output and Input Voltage**



The waveforms for the output voltage and the input voltage is shown in Figure 5, current through the inductors $L_1$ and $L_2$, capacitor voltage and input current shown in 6, the output voltage ripple shown in Figure 7, the pulses applied to the switches are shown in Figure 8.

**Figure 6: Waveforms for Two Inductor Currents, Capacitor Voltage and Input Current**

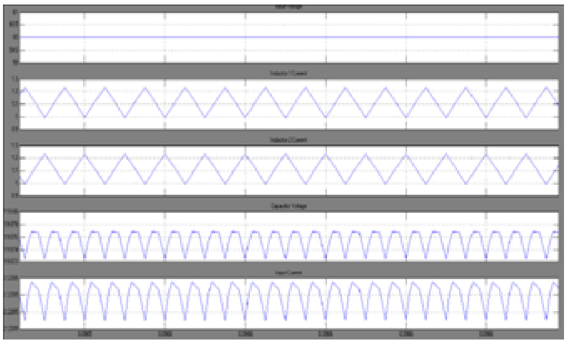


**Figure 7: Output Voltage Ripple**

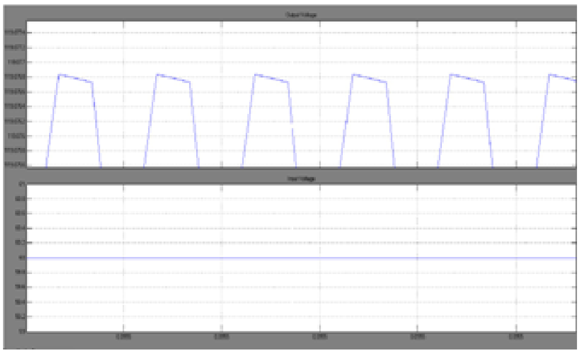
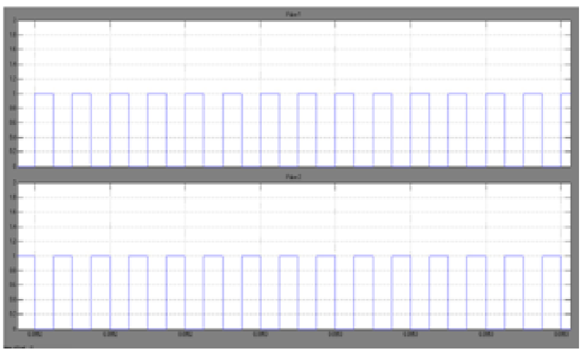


**Figure 8: Gate Pulses for the IBC**



### For $V_{in}$ = 15 V, D = 0.5

Input voltage $V_{in}$ = 15 V, Duty cycle = 0.5, Inductances $L_1$ and $L_2$ = 1.25 mH, Capacitance $C_o$ = 30, Resistance $R_o$ = 60Ω, switching frequency = 100 KHz. A output voltage of approximately 30 V is obtained.

The waveforms for the output voltage and the input voltage is shown in Figure 9, current through the inductors $L_1$ and $L_2$, and input current shown in 10, the output voltage ripple shown in Figure 11.

**Figure 9: Waveforms for Output and Input Voltage**

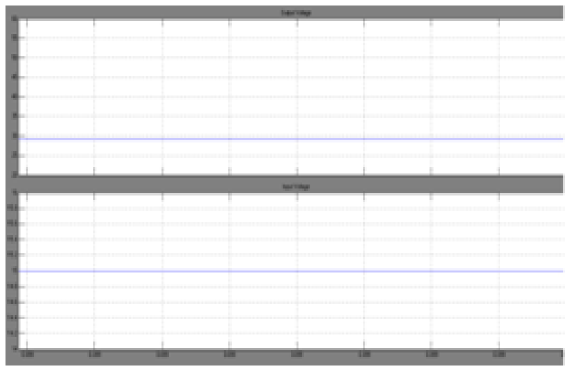


**Figure 10: Waveforms for Two Inductor Currents, and Input Current**

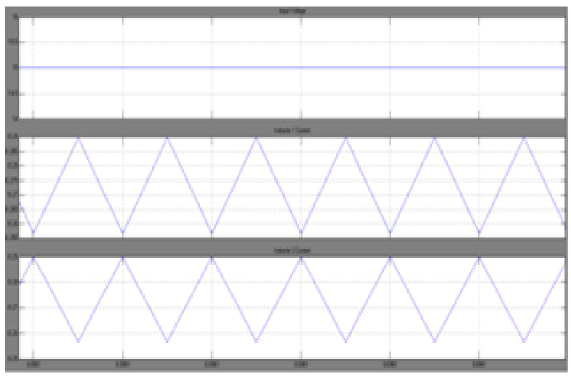


**Figure 12: Output Voltage Ripple**

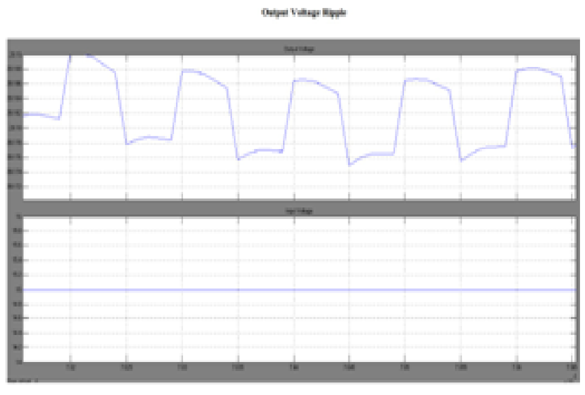


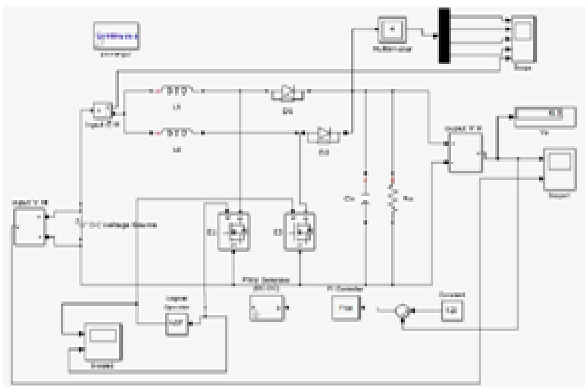
**Table 2: Variation of Output Voltage with Duty Ratio**

| Duty Cycle | $V_{in}$ = 60 V | $V_{in}$ = 15 V |
|---|---|---|
| 50% | 119.1 V | 29.92 V |
| 60% | 148.4 V | 38.58 V |
| 70% | 197.5 V | 46.22 V |
| 80% | 293.9 V | 64.48 V |
| 90% | 559.2 V | 164.1 V |

## Closed Loop Simulation

The closed loop simulaion circuit for the converter is shown in Figure 12 where $V_{in}$ = 15 V, $D$ = 0.5, $C_o$ = 30 μF, $L_1$ and $L_2$ = 1.25 mH, $f_s$ = 100 KHz, $V_o$ = 30 V. A PI controller is used.

**Figure 12: Closed Loop Simulation Circuit of IBC**



## Ac-Dc Interleaved Boost Converter

The open loop simulation circuit is shown in Figure 13, $V_{in}$ = 15 V, $D$ = 0.5, $L_1$ and $L_2$ = 1.25 mH, $C_o$ = 330 μF, $R_o$ = 60 Ω, $f_s$ = 100 KHz, $V_o$ = 30 V.

**Figure 13: Ac-Dc IBC**

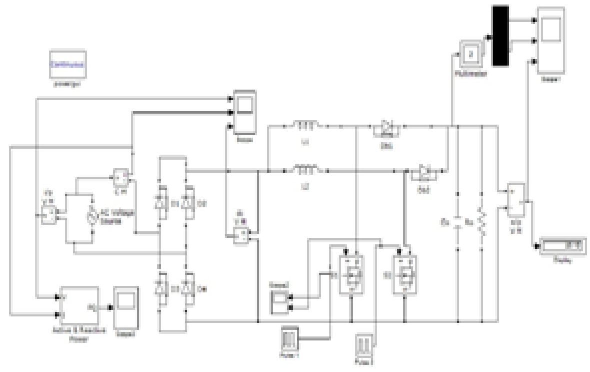


**Figure 14: Inductor Currents and Output Voltage**

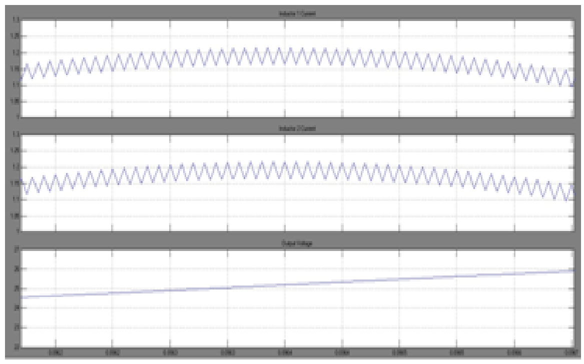
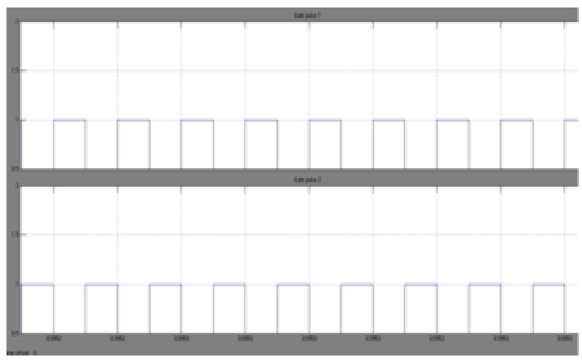


**Figure 15: Gate Pulses for the Switches**



The waveforms for the output voltage and current through the inductors $L_1$ and $L_2$ are shown in Figure 14, the gate pulses for the switches is shown in Figure 15.

## CONCLUSION

In this paper interleaved boost converter operating at input voltages 60 V and 15 V is proposed. The simulation results are obtained for open loop operation for dc-dc IBC and ac-dc IBC.

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