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Analysis of Three Phase Interleaved Boost Converter

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ABSTRACT

DC-DC Boost converters are basic converters that convert voltage of the lower level to a higher level. It is used in various applications like automotive, power amplification, communication. But it has high input and output ripple content and also it cannot accomplish a high step-up change. Therefore different modified topologies are developed to reduce the problems. One of them is interleaved converters. In this type, the ripple content is less compared to conventional boost converters. This paper compares the working of conventional boost converter and three-phase interleaved boost converter.

Keywords: *Boost converter, interleaved boost converter, input and output ripple*

1. INTRODUCTION

DC-DC converters convert dc voltage of one level into another. There are different types of converters. The basic converters are a buck, boost, and buck-boost. Buck converters convert the higher level of voltage into a lower level. Boost converters convert low value to a high value. In a buck-boost converter, the output voltage is either greater than or less than the input voltage. The output voltage depends on the duty ratio of the converter.

DC-DC boost converters (step-up converters) convert low input voltage to a high output voltage. It consists of a semiconductor switch, a diode, and an inductor. To reduce the ripple, a filter capacitor is connected to the output. Boost converter is used in different applications like electric vehicles, photovoltaic and fuel cell. But the conventional boost converter has some drawbacks. It has a high input and output ripples. It results in high turn off current and power conduction losses and more EMI issues. The voltage stress on the switch and diode increases. The cost of such high voltage switches is higher than the low voltage switches. There are different configurations used to remove these problems. Interleaved is one of them. Interleaving, also called a multi-phasing technique is used for reducing the size of filter components. It consists of a parallel combination of inductors, switches, and diodes connected to a common capacitor and load.

2. CONVENTIONAL BOOST CONVERTER

Figure 1 shows the conventional boost converter. In a boost converter, the output value is always higher than the input value. The boost converter has two distinct states:

1) ON state - when the switch T is closed, the inductor current starts to increase.

2) OFF state - when the switch T is open, the inductor discharges through diode, capacitor and load.

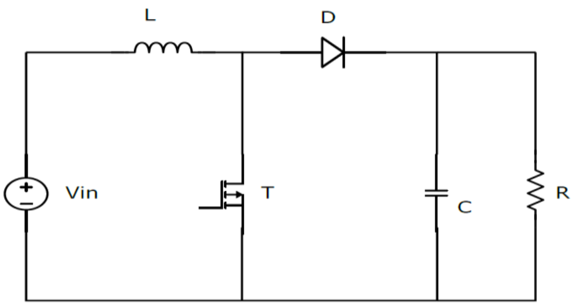

Fig 1: Conventional Boost Converter

The boost converter has two modes of operation, Continuous mode, and Discontinuous mode. In continuous mode, the inductor current never falls to zero. In discontinuous mode, the inductor current falls to zero. The inductor may be completely discharged before the end of a whole commutation cycle due to high ripple current.

3. INTERLEAVED BOOST CONVERTER

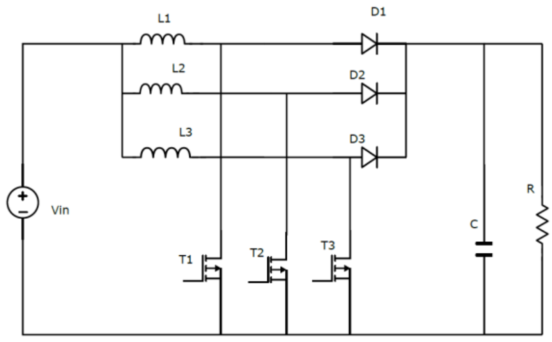

Fig 2: 3-Phase Interleaved Boost Converter

A three phase interleaved boost converter is shown in figure 2. It consists of parallel combination of three switches, three diodes and three inductors which are connected to a common filter capacitor and load. The switching parameters are identical. There is a phase shift of $(2\pi)/N$, where N is the no: of phases. Here N=3, therefore phase shift is 120°. The

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interleaved boost converter has less input and output ripples than conventional boost converter. Hence the size of the inductors and filter capacitor can be minimized. The output current of the source is divided by 1/3 times separately. Therefore the current stress can be reduced. The values of the inductors are same. If it is not equal, there will be circulating current which imposes more stress in the switching devices.

A. Working Principle

There are three converter operations according to the duty cycle. Here the duty cycle is taken in between 1/3 and 2/3. In this state there are six stages of operation. The assumptions are:

- In the conducting state, each switch is taken as resistor r_T.
- In the conducting state, diode is taken as resistor r_D.

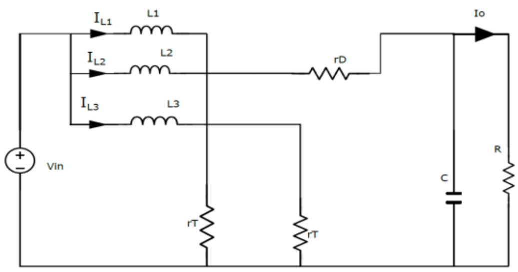

Fig 3: Mode 1

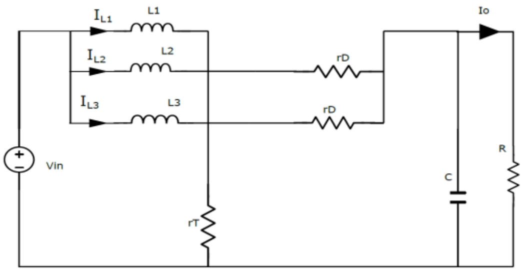

Fig 4: Mode 2

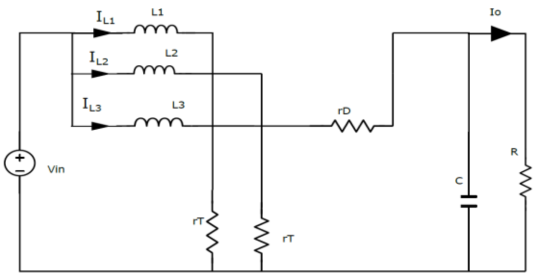

Fig 5: Mode 3

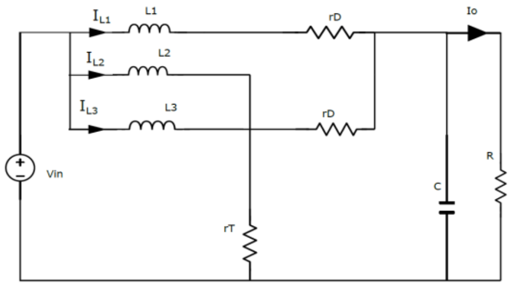

Fig 6: Mode 4

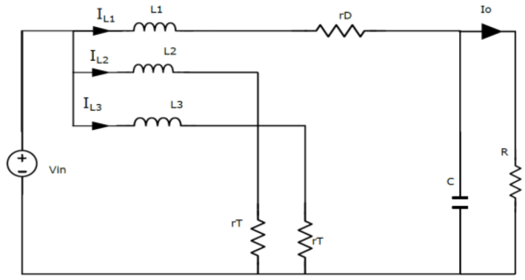

Fig 7: Mode 5

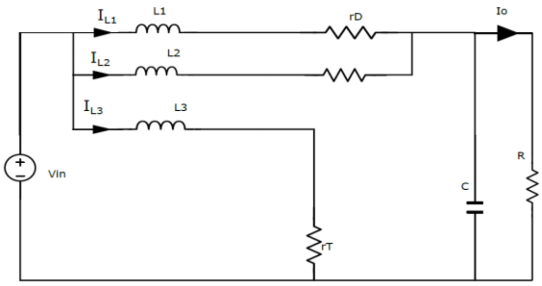

Fig 8: Mode 6

4. DESIGN OF CONVENTIONAL AND INTERLEAVED BOOST CONVERTER

Let frequency = 25Hz, V_{in}= 25V, P_{out}= 50W

Input current ripple, ΔI_{in}= 5%

Output voltage ripple, ΔV_o= 1%

$$D = 1 - \frac{V_{in}}{V_o} = 1- \frac{25}{50} = 0.5 \qquad (1)$$

$$L = \frac{D\,V_{in}}{f_s,\Delta I_{in}} = \frac{0.5 \times 25}{25000 \times 0.05} = 10\text{mH} \qquad (2)$$

$$R = \frac{V_o}{I_o} = \frac{50}{1} = 50\ \Omega \qquad (3)$$

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$$I_o = \frac{P_o}{V_o} = \frac{50}{50} = 1\ \Omega \qquad (4)$$

$$I_{in} = \frac{I_o}{1-D} = \frac{1}{1-0.5} = 2\text{A} \qquad (5)$$

$$C_o = \frac{D\ I_o}{f_s, \Delta V_o} = \frac{0.5 \times 1}{25000 \times 0.01} = 2\text{mF} \qquad (6)$$

Considering the same specifications, the inductor and capacitor values of three phase IBC are calculated as:

$$L_1 = L_2 = L_3 = \frac{D\ V_{in}}{f_s,\ \text{N}\ \Delta I_{in}} = \frac{0.5 \times 25}{25000 \times 3 \times 0.05} = 3\text{mH} \qquad (7)$$

$$C_o = \frac{D\ I_o}{f_s\ N\ ,\Delta V_o} = \frac{0.5 \times 1}{25000 \times 3 \times 0.01} = 0.67\text{mF} \qquad (8)$$

5. SIMULATION RESULTS

Table I: Parameters used for simulation

Parameters	Conventional	Interleaved
Duty ratio	50%	50%
Frequency	25kHz	25kHz
Input voltage	25V	25V
Output power	50W	50W
Inductor	10mH	3mH
Filter capacitor	2mF	0.67mF
Load	50Ω	50Ω

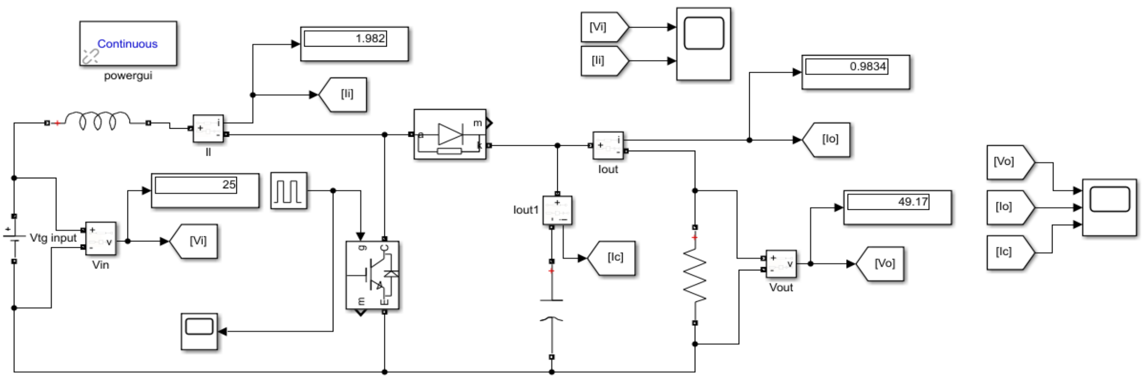

Fig 9: Open loop simulation of conventional boost converter

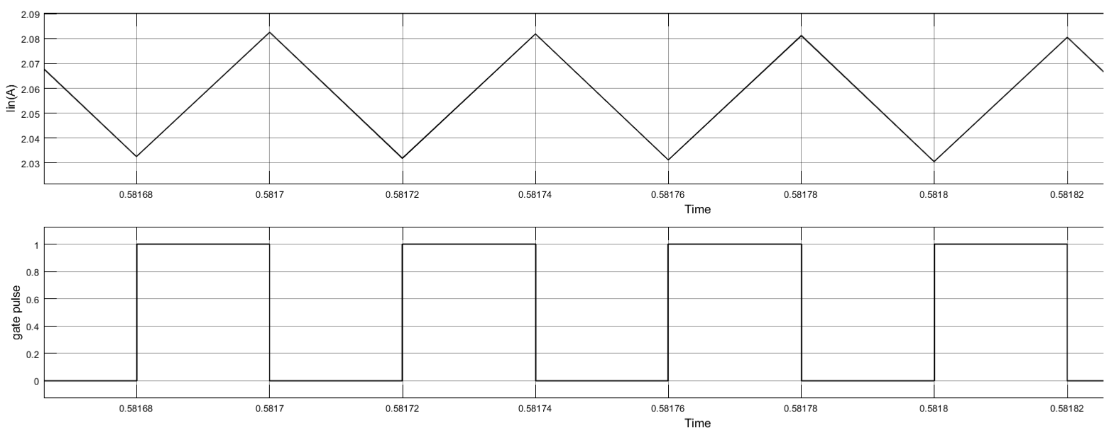

Fig 10: Inductor current and gate pulse of boost converter

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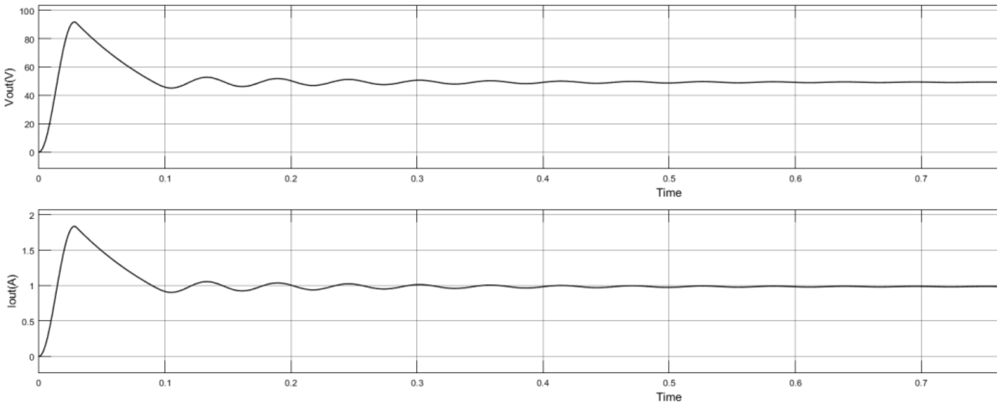

Fig 11: Output voltage and current of boost converter

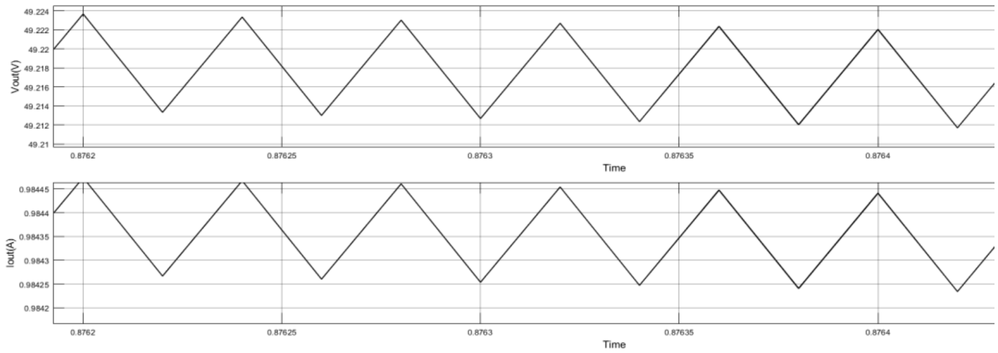

Fig 12: Ripple in voltage & current waveform of boost converter

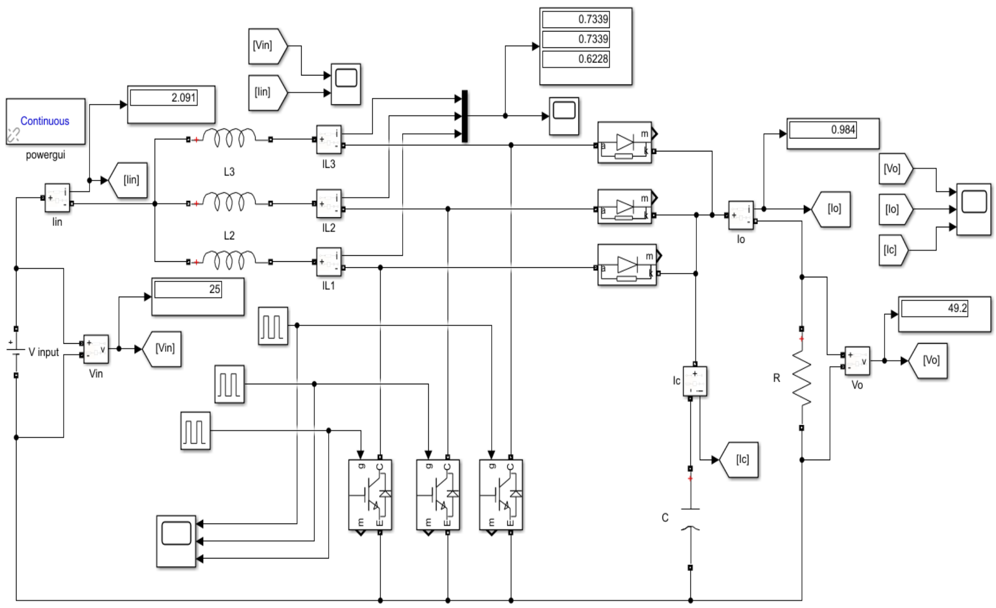

Fig 13: Open loop simulation of interleaved boost converter

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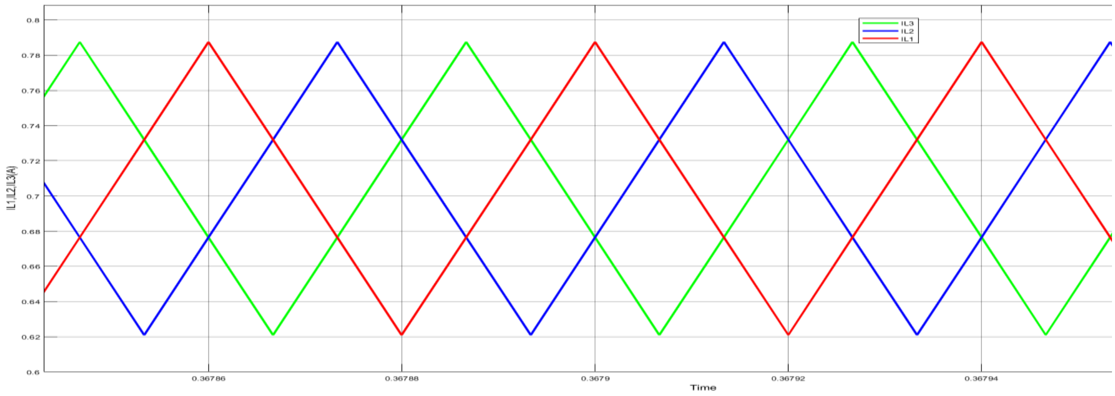

Fig 14: Inductor current of interleaved boost converter

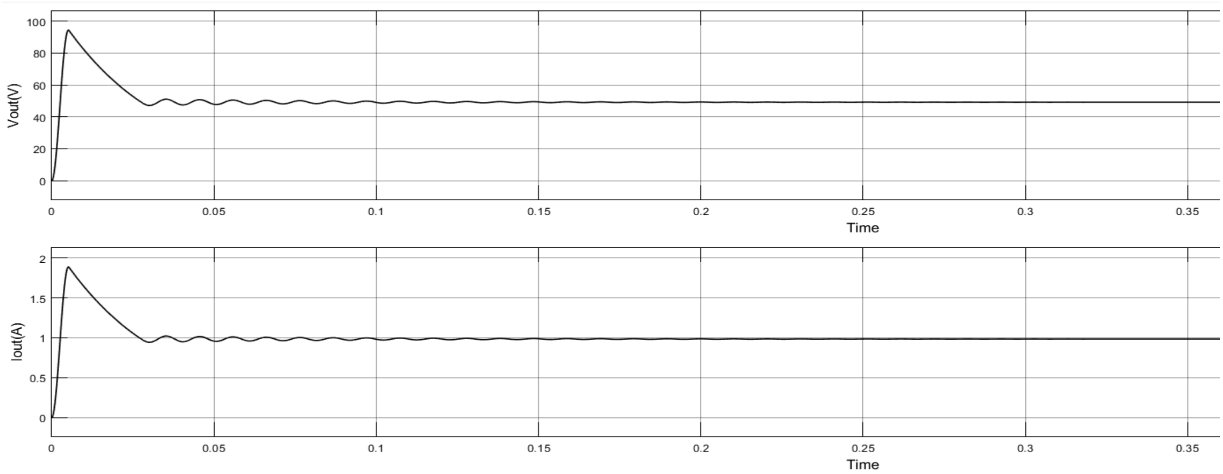

Fig 15: Output voltage and current of interleaved boost converter

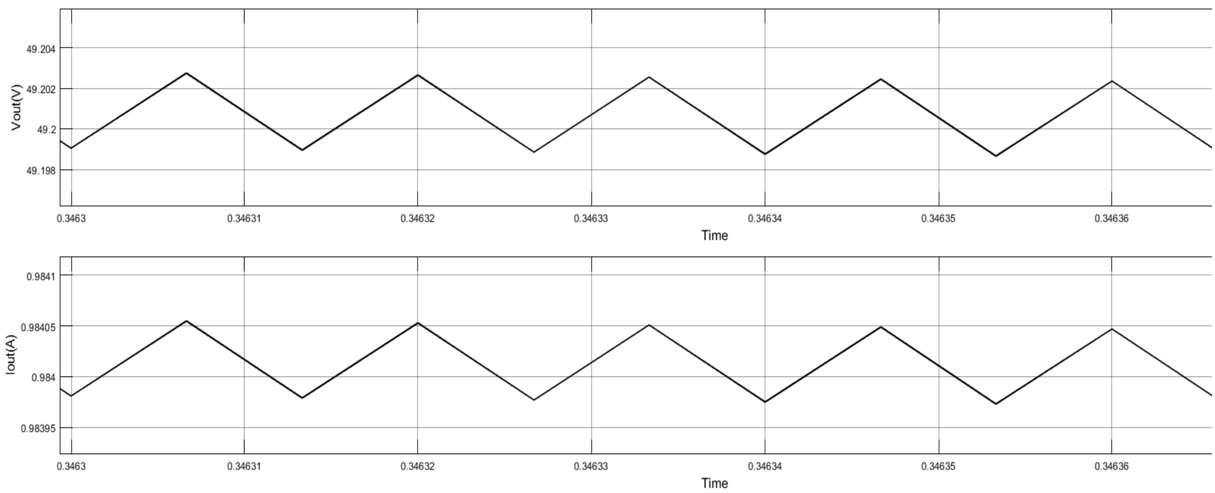

Fig 16: Ripple in voltage, current & capacitor current of interleaved converter

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Table II: Comparison between boost converter and 3-phase interleaved converter

Parameter	Boost converter	3-phase interleaved
Input inductor	10mH	3mH
Filter capacitor	2mF	0.67mF
Output voltage ripple	0.01	0.004

6. CONCLUSION

In this paper, design, analysis and the open loop simulation of an interleaved three-phase dc/dc converter system is presented. Interleaved boost converters have increased efficiency as compared to that of conventional boost converters. It has low input and output ripples. It also has a fast transient response and improved reliability. The steady-state voltage ripples at the output side of capacitors of IBC are reduced.

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