Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 7 April-June (2015) pp. 79-82
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Effective Utilization of PV System by using Interleaved Boost Converter

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Abstract—*Solar energy is one of the most promising renewable resources that can be used to produce electric energy through photovoltaic process. But PV system hinder their widespread use due to high cost, low efficiency and intermittent nature of the of the output power of PV. DC-DC Boost Converters serves many purposes and usually required in many applications which has a low output voltage such as Photo-voltaic cells. Interleaved Boost converter has a better performance characteristics when compared to a conventional boost converter due to its increased efficiency, reduction in size and greater reliability. This paper focuses on the design aspects of two phase interleaved boost converter. The various parameters of the IBC are compared to a conventional boost converter. Simulation studies have been carried out using MATLAB/SIMULINK. Theoretical analysis is done to emphasis the benefits of the interleaved boost converter.*

Keywords: *Interleaved Boost Converter , MATLAB /SIMULINK, ripple and efficiency.*

1. INTRODUCTION

Renewable energy is derived from natural resources that are replenished constantly. The commonly used renewable energy systems include photovoltaic cells and fuel cells and received a worldwide great attention in research fields there is renewed focus on the power electronic converter interface for DC energy sources. These power sources have quite low voltage output and require series connection of voltage booster to provide enough voltage output. DC-DC boost converter is generally used to further boost the voltage to the required level. Large input current and high output voltage are the two major concerns for high step up converters. The high step up DC – DC converters can be non isolated but they should operate at high efficiency while taking high currents from low voltage dc sources at their inputs. In conventional boost converter, the duty ratio increases as the output to input voltage ratio increase. Therefore the conventional boost converter will require extreme duty ratios to meet the high voltage step-up requirement. Under such condition, it is a major challenge to operate the boost converters at high efficiency because the low level input voltages cause large input currents to flow through the switches and the extreme duty cycle operation drives short pulsed currents with high amplitude to flow through the output diodes and the capacitors, which cause severe diode reverse recovery problem and increases in conduction losses which limit the power level of the conventional boost converters.

Interleaved boost converter can be a good solution to the previously discussed problems of the conventional boost converter. This is because turns ratio of the primary inductor to the secondary inductor of the coupled inductor can be effectively used to reduce the duty ratio and the voltage stress of the switch. Therefore for high voltage step applications the two phase chopper can be more efficient than the conventional single phase boost converter. The switching and conduction losses are less in interleaved boost converter than the conventional boost converter. The cancellation of low frequency harmonics eventually allows the reduction in size and losses of the filtering stages. Simulation results show that the current ripple in the input and output circuits is less and also minimizes the size of input filter and output power is more in case of interleaved boost converter. The frequency of the current ripple is twice for two phase than the conventional boost converter. Due to a phase shift of 180 degrees ripple cancellation takes place. This paper concentrates on the various design aspects, steady state and transient response, device selection, operating principle, gating pattern and the various waveforms which compares with the conventional boost converter.

2. OPERATION PRINCIPLE OF BOOST CONVERTER

i) Boost converter

The power sources such as PV system has quite low voltage output and require series connection of voltage booster to provide enough voltage output. DC-DC boost converter is generally used to further boost the voltage to the required level. Fig.1 shows conventional boost converter.

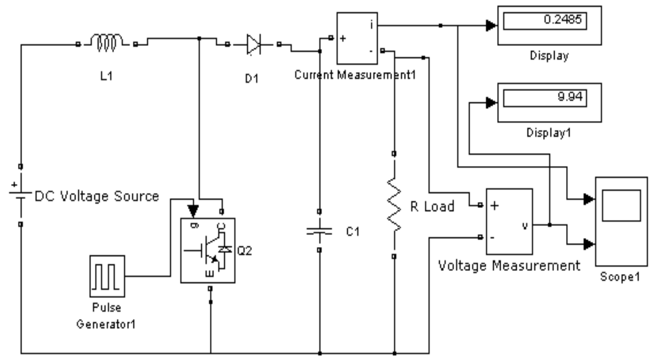

Fig. 1: Boost converter

ii) Interleaved Boost converter

Interleaved boost converter mainly used for renewable energy sources. Interleaved Boost converter has a number of boost converters connected in parallel which have the same frequency and phase shift. These Interleaved Boost converters are distinguished from the conventional boost converters by critical operation mode, discontinuous conduction mode (DCM) and continuous conduction mode (CCM) so that the devices are turned on when the current through the boost rectifier is zero. The design becomes tedious as the critical point varies with load in case of critical conduction mode. In the DCM, the difficulties of the reverse recovery effects are taken care but it leads to high input current and conduction losses and it is not best suited for high power applications. CCM has lower input peak current, less conduction losses and can be used for high power applications. So by dividing the output current into 'n' paths higher efficiency is achieved by reducing the copper losses and the inductor losses.

Here the operation of Two phase interleaved boost converter is explained which is shown in the fig.2.Firstly when the device Q_1 is turned ON, the current i_{L1}in the inductor L_1 increases linearly. During this period energy is stored in the inductor L_1. When Q_1 is turned OFF, diode D_1 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 Q_1, Q_2 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. This advantage makes this topology very attractive for the renewable sources of energy.

The gating pulses of the two devices are shifted by a phase difference of 360/n, where n is the number of parallel boost converters connected in parallel. For a two-phase interleaved boost converter n=2, which is 180 degrees. In the fig.2 it can be seen that the input current i, for two phase interleaved boost converter is sum of each channels inductors currents. As the two devices are phase-shifted by 180 degrees, the input current ripple produced is the smallest.

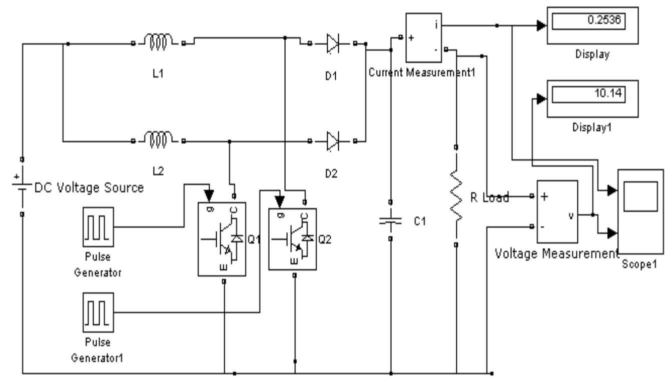

Fig. 2: Two Phase Interleaved Boost Converter

3. DESIGN ASPECTS OF IBC

The design aspects of IBC are discussed in this section:

1. 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

$$\frac{V_{dc}}{V_{in}} = \frac{1}{1-D} \quad (1)$$

Where V_{dc} is the output voltage, V_{in} is the input voltage and D is the duty ratio.

2. Input current :

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

$$I_{in} = \frac{P_{in}}{V_{in}} \quad (2)$$

Where P_{in} is the input power, V_{in} is the input voltage.

3. Inductor current ripple peak-to-peak amplitude:

The inductor current ripple peak-peak amplitude is given by

$$\Delta I_{L1,L2} = \frac{V_{in} D}{f_{sw} L} \quad (3)$$

Where f_{sw} is the switching frequency, D is the duty cycle, V_{in} is the input voltage and L is the inductance.

4. Relationship between input current ripple peak-to-peak amplitude and inductor current ripple peak-to-peak amplitude :

Mostly in IBC the minimum input ripple occurs at a duty ratio of 0.5, this is due to the 180 degrees phase difference between the two devices. There are two operating modes which can be defined by the inductor:

(i) Mode 1, D>0.5: over a particular period of time the current in both the inductors rises.

(ii) Mode2, D<0.5: over a specified period of time both the inductors discharge

A. Selection of inductor and capacitor:

In the operation of Interleaved Boost Converter 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 shown in the fig.2. 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 formulae

$$L = \frac{V_{in} D}{\Delta i_L f}$$

Where Vs represents the source voltage and Δi_L represents the inductor current ripple, D represents the duty ratio.

The value of the capacitor is given by the formulae

$$C = \frac{V_o D f}{R \Delta V_o}$$

Where Vo represents the output voltage (V), D represents the duty ratio, f represents the frequency, R represents the resistance and ΔVo represents the change in the output voltage (V).

B. Choosing the number of phases
The factor which decides in choosing the number of phases is that the ripple content reduces with the increases in the number of phases. There is a restriction to the increase in number of phases because if the number of phases is increased further without much reduction in ripple content the size of the components increases and hence increases the cost of performance. Therefore the number of phases is chosen to be two. It is to be noted that the number of inductors, switches and diodes are same as the number of phases and the switching frequency should be same for all the phases

C. Duty ratio
The duty ratio selection is based on the number of phases. The ripple is minimum at a certain duty ratio. In the two phase interleaved boost converter ripple is minimum at duty ratio in the range of 0.5.

4. SIMULATION RESULTS

Using MATLAB / Simulink the various parameters such as the value of the inductor, capacitor and the gating pattern are designed. Simulation results for Interleaved Boost Converter and the Conventional Boost Converter are obtained in the form of current and voltage waveforms are shown below. After Comparison it has been seen that the THD of the Conventional boost converter and Interleaved Boost converter are 65.55% and 57.20% which shows increased efficiency of Interleaved Boost Converter. The simulation parameters of two phase interleaved boost converter are shown in Table-I.

Table I: Simulation Parameters of Two Phase Interleaved Boost Converter

PARAMETERS	VALUES
Input Voltage(Vi)	5V
Output Voltage(Vo)	10.14V
Output Current	0.2536A
Switching Frequency (f)	2000Hz
Duty Ratio (D)	5.5
Inductance L1,L2	5.2 mH
Capacitance	1800µF

The results shown below are for a duty cycle of 0.55. From the simulation results, the transient and steady state response of the conventional boost converter and the interleaved boost converter have been shown in fig.3 and 5. The difference between the two is well understood by observing the simulated waveforms.

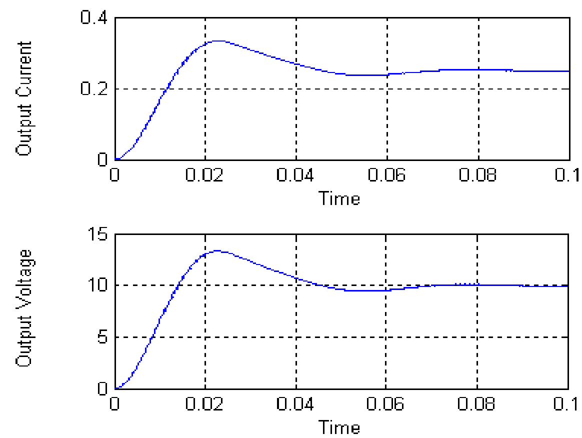

Fig. 3: Transient and steady state response of conventional Boost Converter

The output voltage and current ripple of the conventional Boost converter has been shown in Fig.4.The obtained results shows output Voltage 9.94V and current 0.2485A

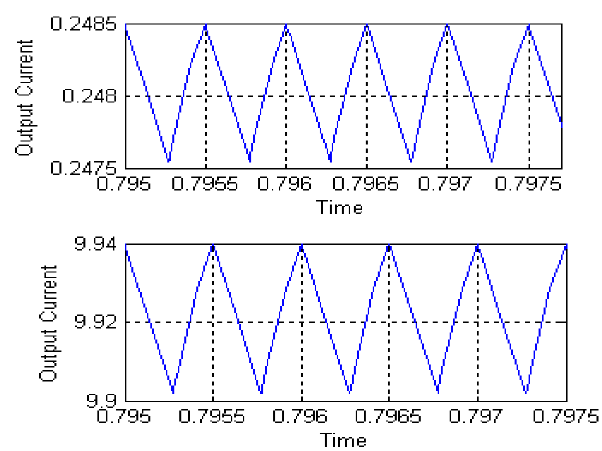

Fig. 4: Output voltage and current ripple of the conventional boost converter

The output voltage and current ripple waveforms of Interleaved Boost Converter has been shown in Fig.6.The obtained results shows output voltage of 10.14V and 0.2536 A.

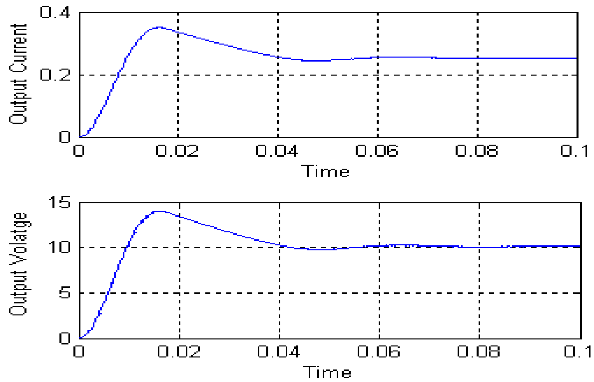

Fig. 5: Transient and steady state response of Interleaved Boost Converter

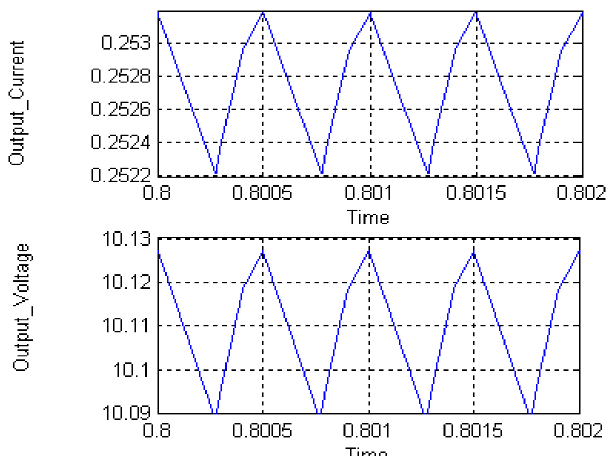

Fig. 6: Output voltage and current ripple of the Interleaved Boost converter

From the results shown in fig.7 and 8 , Total harmonic distortion obtained is 65.55 % in case of Conventional Boost converter and 57.20 % in case of Interleaved Boost Converter.

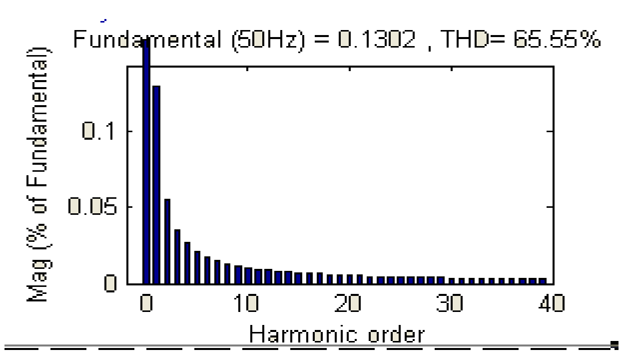

Fig. 7: Total harmonic distortion obtained from boost converter

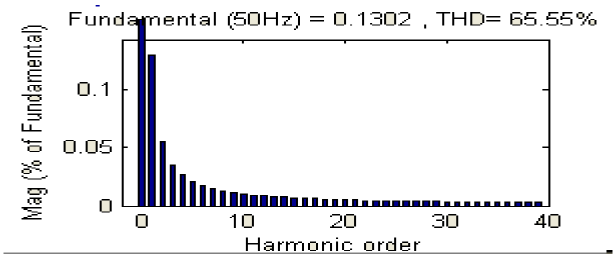

Fig. 8: Total harmonic distortion obtained from Interleaved Boost converter

5. CONCLUSION

Interleaved boost converter has so many advantages and is a suitable converter for renewable energy applications. In this paper the principle and operation of Interleaved boost converter and various design parameters have been presented.Using MATLAB/Simulink, various waveforms in form of output voltage and current have been obtained for Interleaved Boost Converter and Conventional Boost converter. The comparison between Interleaved Boost converter and conventional Boost Converter has been done on the basis of obtained results. Total Harmonic Distortion is also obtained for both the converter and from these results it is come to know that THD of Interleaved Boost Converter is less as compared to Conventional Boost Converter. So Interleaved Boost Converter is having higher efficiency.

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