Design and Analysis of Zero Voltage Transition Interleaved Boost Converter for High Power Applications

K.M. Namitha and R. Divya

Abstract- *This paper presents the design and performance of a dc to dc interleaved boost converter with zero voltage transition. A soft-switched interleaved boost converter composed of two-cell shunted boost conversion units and an auxiliary inductor is presented and simulations are done in Matlab/simulink. The converter is able to turn on both the active power switches of the shunted boost units at zero voltage to reduce their switching losses and raise the conversion efficiency. The circuit is operated at different power outputs to evaluate its efficiency. The efficiency at different power outputs was found to be between 90% to 95% due to its zero voltage switching characteristics.*

Keywords- *Interleaved Boost Converter, Zero Voltage Transition, Soft Switching*

I. INTRODUCTION

THE boost topology is used in numerous applications with battery-powered input to generate a high output voltage from a relatively low battery voltage. Boost converters are usually applied as pre -regulators or even integrated with the latter-stage circuits or rectifiers into single-stage circuits. Most renewable power sources, such as photovoltaic power systems and fuel cells, have quite low-voltage output and require series connection or a voltage booster to provide enough voltage output [6].Several soft-switching techniques, gaining the features of zero-voltage switching (ZVS) or zero-current switching (ZCS) for dc/dc converters, have been proposed to substantially reduce switching losses, and hence, attain high efficiency at increased frequencies [3].

In conventional interleaved boost converters the voltage stresses on the semiconductor devices is high. High voltage rated devices have generally poor characteristics such as high cost, high on-resistance, high forward voltage drop, and severe reverse recovery, etc. In addition, the converter operates under hard switching condition. Thus, the cost becomes high and the efficiency becomes poor. And, for higher power density and better dynamics, it is required that the converter operates at higher switching frequencies. However, higher switching frequencies increase the switching losses associated with turn-on, turn-off and reverse recovery. Consequently efficiency is further deteriorated. Converters with interleaved operation are fascinating techniques nowadays. In the field of power electronics, application of interleaving technique can be traced back to very early days, especially in high power applications. In high power applications, the voltage and current stress can easily go beyond the range that one power device can handle. Multiple power devices connected in parallel and/or series could be one solution. However, voltage sharing and/or current sharing are still the concerns. Instead of paralleling power devices, paralleling power converters is another solution which could be more beneficial. Furthermore, with the power converter paralleling architecture, interleaving technique comes naturally. Benefits like better efficiency, better thermal performance, and high power density can be obtained.

The soft-switching interleaved boost converter has two shunted elementary boost conversion units and an auxiliary inductor. This converter is able to turn on both the active power switches at zero voltage to reduce their switching losses and evidently raise the conversion efficiency. Since the two parallel operated boost units are identical, operation analysis and design for the converter module becomes quite simple. A soft switched interleaved boost converter is simulated in MATLAB/simulink and the waveforms are analysed. Efficiency measurements are done in matlab and efficiency as high as 95% is obtained.

II. INTERLEAVED BOOST CONVERTER

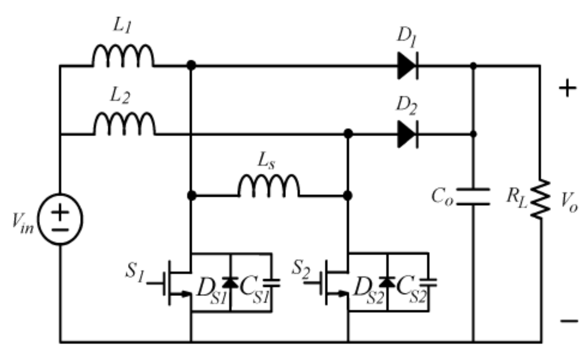

Fig.1 Interleaved boost converter

It consists of Inductor L_1,MOSFET active switch S_1 and diode D_1 and it comprises of one step up conversion units. Similarly Inductor L_2,MOSFET active switch S_2 and diode D_2 form antiparallel diode and output capacitance of MOSFET S_1,respectively.The voltage source V_{in},via the two paralleled

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converters, replenishes the output capacitor C_o and the load R_1.The inductor $L_S$is shunted with the two active MOSFET switches to release the charge stored within output capacitor C_{Sx} prior to the turn-ON of S_x to fulfill zero voltage turn-ON(ZVS), and therefore, raises the converter efficiency. To simplify the analysis L_1,L_2 and C_O are replaced by current and voltage sources respectively.

III. Circuit Operation Analysis

The following assumptions are made before the analysis of the circuit.

1) Inductors L_1 and L_2 have large inductance values and their currents are identical.
2) The output capacitor C_o is large enough to neglect output voltage ripple.
3) The forward voltage drops on the MOSFETS S_1 andS_2 and diodes $D_1$and D_2 are neglected.
4) The output capacitances of C_{S1} and C_{S2} are identical.

The interleaved boost converter is gated with PWM control signals. The two switches are gated with identical duty ratios and frequencies. In order to turn-ONS_2 at ZVS condition, switch S_1 has to keep conducting current so as to allow the current through the auxiliary inductor to flow through antiparallel diode D_{S2}.While D_{S2} clamps the switch voltage at zero, the gating signal V_{GS2} should shift to high state before V_{GS1} goes low. For ZVS and symmetrical operations of both the switches, the duty ratios of both the switches should be greater than 0.5.The operation of the converter can be divided into eight modes and it is explained in detail in [1].

IV. Simulation Parameters

TABLE 1

Parameter	Value
Inductors L_1 and L_2	600µH
Inductor L_S	270µH
Capacitor C_o	330µF
Input voltage V_{in}	120V
Output voltage V_O	300V
Output power P_o	500W

The switching frequency is 100 kHz. In the simulation closed loop control is provided for voltage regulation. The PWM duty cycle signals are generated by comparing a level control signal with a constant peak repetitive triangle signal. The frequency of the repetitive triangle signal establishes the switching frequency.120V input voltage is boosted to 300V.A regulated dc voltage output is obtained. The output voltage ripple is very small near to 0.2V.The inductor currents are measured and the zero voltage switching characteristics are also analysed.500W power output is obtained from the interleaved boost converter. So this converter is the right choice for high power applications. The simulink diagram of the interleaved boost converter is shown below.

Figure 2 shows the dc to dc interleaved boost converter with soft switching characteristics. The 120V input voltage is boosted to 300V.Due this particular circuit configuration zero voltage transition is possible. The two MOSFET switches are supplied with PWM signals. The PWM gating signals are phase shifted for achieving soft switching. The losses in the switches are reduced considerably. The input and output power are measured by changing the load values and efficiency is calculated. The circuit efficiency varied from 90 to 95% for different load values.

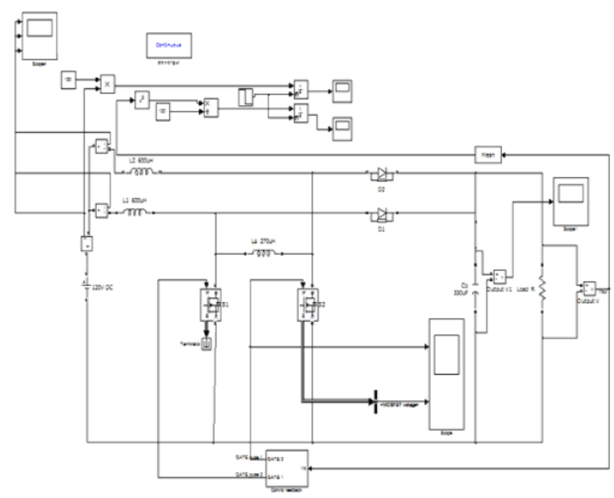

Fig.2 Simulink diagram of dc to dc interleaved boost converter

V. Results of Simulation

The simulation results of the interleaved boost converter as follows.

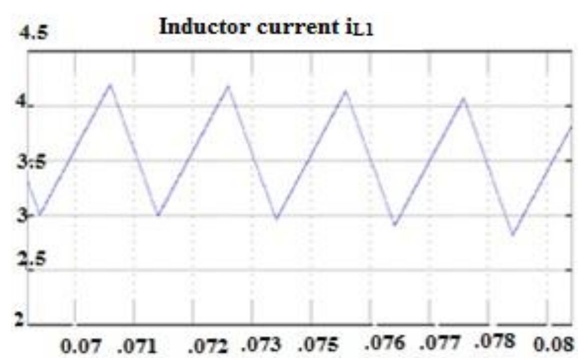

Fig.3Inductor current I_{L1}

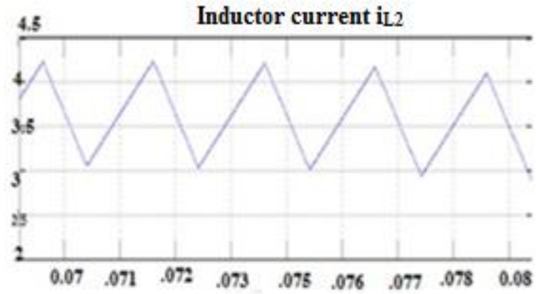

Fig.4 Inductor current I_{L2}

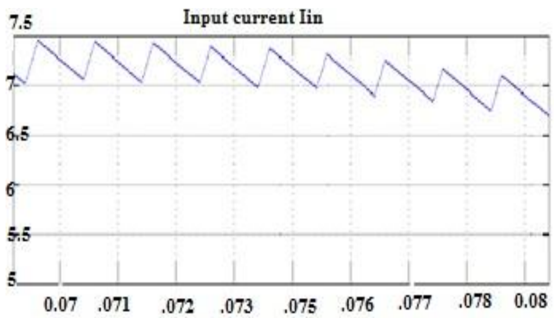

Fig.5 Input current I_{in}

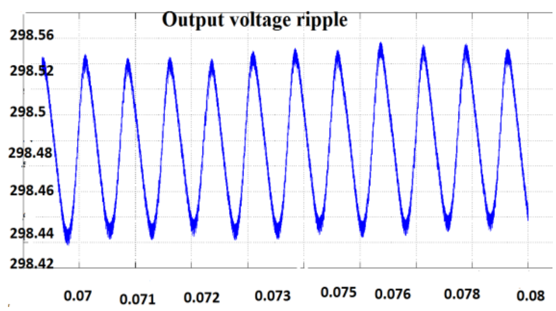

Fig.6 Output voltage ripple

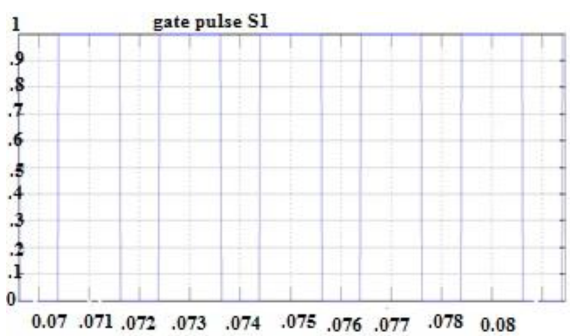

Fig.7 Gate pulse of switch S_1

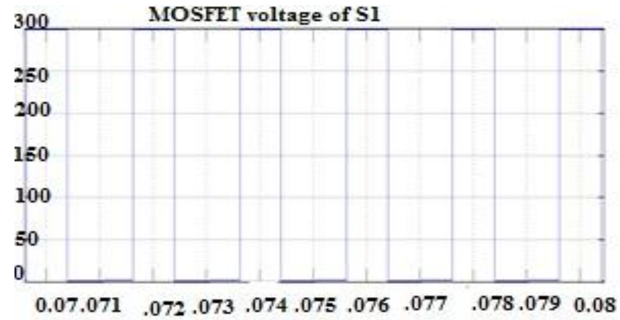

Fig.8 MOSFET S_1 voltage

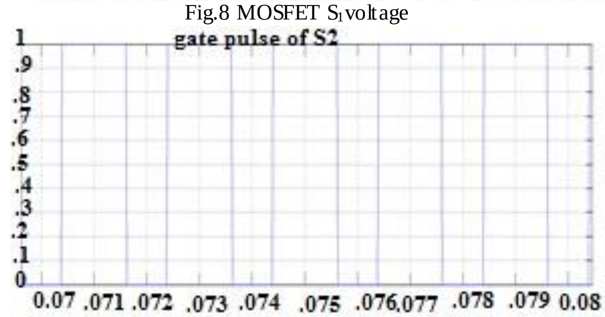

Fig.9 Gate pulse of switch S_2

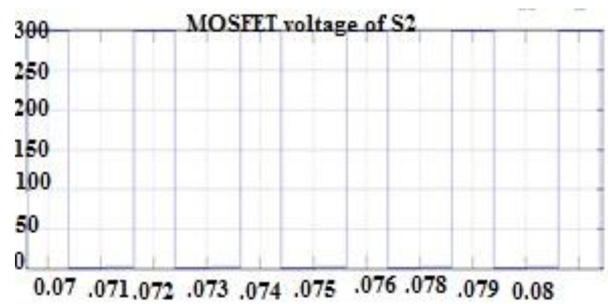

Fig.10 MOSFET S_2 voltage

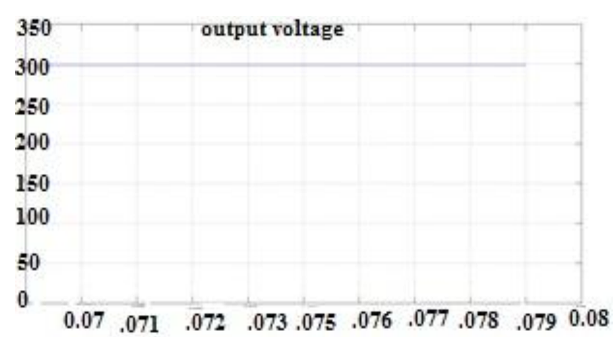

Fig.11 Interleaved boost output voltage

The simulation results shows inductor currents, input current, output voltage ripple, Gate pulseof switch $S_1$and S_2,voltage across switch S_1 and $S_2$and boost output voltage. The input current shown in figure 5 is the sum of inductor currents I_{L1} and I_{l2} shown in figures 3 and 4 respectively. The output voltage ripple in figure 6 is measured to be 0.2V.Figures 7 and 8 shows zero voltage turn-ON of switch S_1 and figures 9 and 10 shows the zero voltage turn-ON of

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switch S_2. When the voltage across Switch is zero gating signal is imposed and this facilitates the ZVS turn-ON of the switch.When the gating signal goes low the voltage across the switch increases to the output voltage.The dc to dc interleaved boost output voltage 300V is measured in figure 11.The output voltage is regulated and hence it can be used for applications that require constant output voltage of 300V.

VI. APPLICATION

Further this dc to dc interleaved boost converter can be powered from a solar panel. This saves energy as it is renewable energy source. Maximum power point trackers (MPPTs) play a vital role in photovoltaic (PV) systems because they increase the efficiency of the solar photovoltaic system by increasing the power output. There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc.

VII. CONCLUSIONS

The dc to dc interleaved boost converter is simulated in Matlab/simulink. The results shows that the soft switching characteristics have been achieved.300V regulated output voltage is obtained. The output power was calculated to be 500W. Through simulation it is observed that the output voltage ripple is reduced. This dc to dc interleaved boost converter is attractive in applications in which high output voltage with low ripple, higher power density and low cost are required.

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