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ZVT Interleaved Boost Converter

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Abstract: ZVT interleaved boost DC/DC converter is a converter in which all the power semiconductor devices operate in soft switching with the help of a secondary switch. Zero voltage soft switching technique is used for the interleaved boost and secondary circuit is operated in zero current switching. The secondary circuit does not impose any extra voltage and current stresses on the converter. The reverse recovery problem of the diodes is also alleviated. The implemented system is validated with MATLAB/Simulink.

Keywords: Coupled inductor, interleaved boost converter, zero current switching, zero voltage switching.

I. INTRODUCTION

Power DC-DC converters (step up/ step down) are gaining importance due to their enormous advantages. The boost converter is one kind of step up DC-DC converter which provides higher output dc voltage from low input voltage. It is one of the most frequently used non-isolated topology in various applications [1]. Single phase boost converter has low conversion efficiency and it has high ripple in input current and output voltage. Therefore, we use multi-phase interleaved converter which have better efficiency, reduced harmonics, better thermal performance, high power density, reduced ripple in input current and lower voltage stress [2].

Furthermore, to reduce the size and weight of electronic products, the switching frequency of interleaved boost converters can be increased. Unfortunately, this also increases the switching losses; turn-on loss caused by output capacitance and the turn-off loss caused by of the current tail characteristics and the reverse recovery characteristics of diodes. Moreover, the electromagnetic interferences (EMI), also cause severe problems. Soft switching techniques can diminish the EMI problems and eliminate switching losses. To eliminate the switching losses and improve the efficiency of an interleaved boost converter, soft switching technique can be used. There are two techniques namely active switching and passive switching.

Passive snubber circuits can achieve soft switching by using only passive components such as inductors, capacitors, and diodes without auxiliary switches. Compared with active snubber circuits, passive snubber circuits are generally simpler to design and have fewer components. Therefore, they are less expensive, more reliable, and smaller in size. In [3], role of the auxiliary switch is played by the synchronous rectifiers. Hence this method can only be used in converters with synchronous rectifiers and there is an extra current on switches and circulating losses. In active switching technique we use the power switches instead of passive components. Usually, switching technique can be divided into Zero Voltage Transition (ZVT) and Zero Current Transition (ZCT) cells, according to the switching characteristic of the main switch in the converter. An active soft switching circuit based on interleaving two boost converters and adding two simple auxiliary commutation circuits is proposed in [4]. The main switches operate in ZCS at turn-on transition and ZVS at turn-off transition. In [5], a novel interleaved boost converter with both characteristics of zero-voltage turn-on and zero-current turn-off for the main switches to improve the efficiency with a wide range of load is introduced. The auxiliary unit is simple but it requires two circuit for the two main switches. The duty cycle can be increased to more than 50%. The disadvantage of this converter is that axillary circuit is hard switching so there will be an increase in losses.

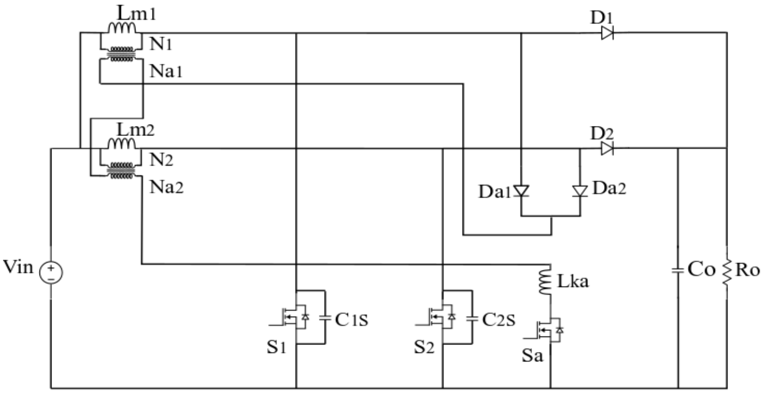

Fig. 1. ZVT interleaved boost converter

In this paper we are using a two phase interleaved boost converter as shown in Fig.1. All devices operate in soft switching condition. Only one secondary switch is used to achieve soft switching. Main switches operate in zero-voltage switching and zero current switching is used for secondary switches. Here instead of inductors two coupled inductors are used. The coupled inductor regulates the current falling rate and forces secondary circuit current to zero after the zero-voltage switching of the main switches. The required snubber capacitance for ZVT cell is obtained from the MOSFET parasitic capacitors energy and also absorbs the leakage inductance of the two coupled inductors. Hence the size weight and cost are reduced.

II. WORKING

The interleaved ZVT boost converter contains two coupled inductors, where L_1 & L_2 are primary windings and L_{a1} & L_{a2} are secondary windings. Primary windings are connected to the input and secondary windings of coupled inductor are in the secondary circuit. S_1 and S_2 are main switches and Sa is the secondary switch. D_1 & D_2 and D_{a1} & D_{a2} are the two output diodes and secondary diodes respectively. Snubber capacitors for the switches S_1 and S_2 are represented as C_{S1} & C_{S2} respectively. N_1 & N_2 and N_{a1} & N_{a2} are the number of turns in primary and secondary coils. L_{m1} and L_{m2} are the magnetizing inductances and L_{ka} is equivalent leakage inductance of the two coupled inductors. Primary turns of coupled inductor are assumed to be equal to N and secondary turns to be N_a.

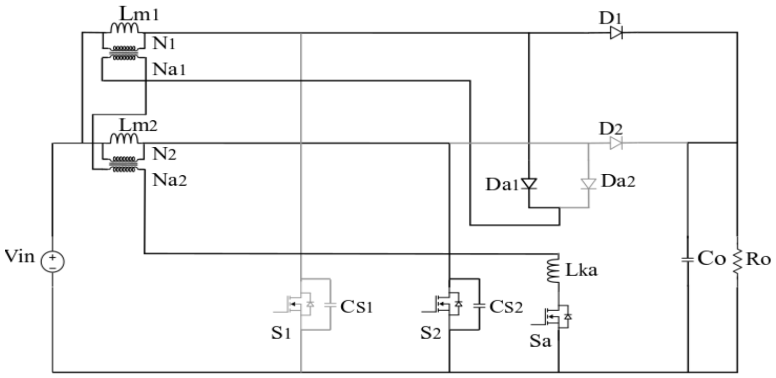

Fig. 2. Mode 1 [$t_0 - t_1$].

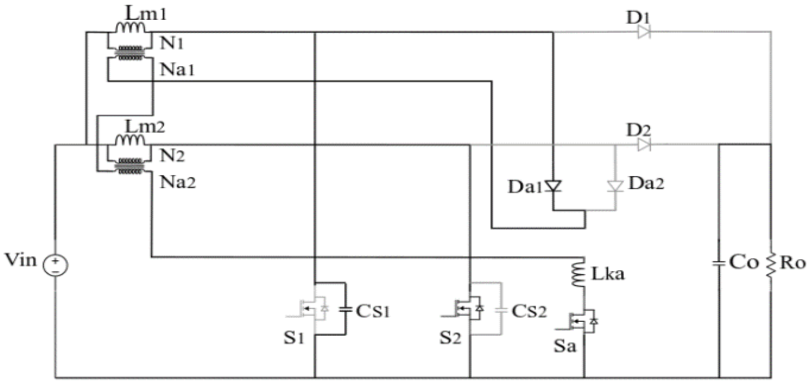

Fig. 3. Mode 2 [$t1 - t2$].

The turns ratio n is defined as N_a/N. There are fourteen modes of operation during each switching period. Here only seven modes of operation related to main switch is discussed. It is considered that S_2 and D_1 are conducting with all other switches and diodes at OFF state and capacitor C_{S1} charged to output voltage.

A. Mode 1: In this mode switch S_1 is turned on at ZCS, for that capacitor C_{S1} should be discharged. To discharge C_{S1} just before turning on S_1, the secondary circuit must be activated. S_a is turned on. Because of the series leakage inductance, L_{ka}, S1 is turned on at ZCS. So D_{a1} also turns on at ZCS. Current through L_{ka} starts to increase. Therefore, current through output diode start to decrease linearly.

B. Mode 2: In this mode, current through D_1 becomes zero and it turns off at ZCS. Since the diode is turned off a resonance begins between C_{S1} and L_{Ka}. C_{S1} start to discharge and at the end of this mode C_{S1} voltage, V_{CS1} decreases to zero.

C. Mode 3: The antiparallel diodes of S_1 and S_2 turn on and current I_{Lka} ramps down. When current through the diode becomes zero, antiparallel diodes of both main switches turn off at ZCS. In this mode, S_1 can be turned on at ZVS.

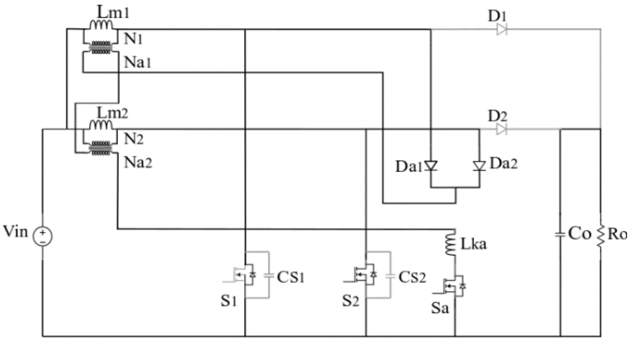

Fig. 4. Mode 3 [t2 − t3].

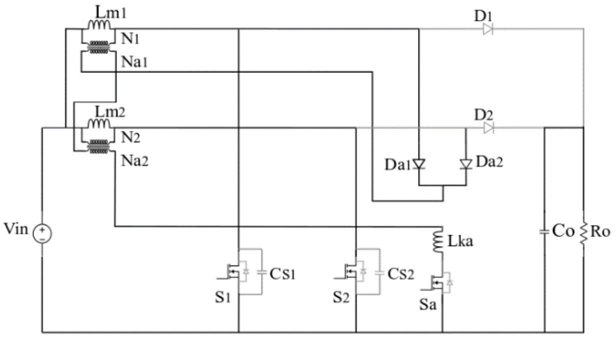

Fig. 5. Mode 4 [t3 − t4].

D. Mode 4: The switch S_1 is turned on. Current I_{Lka} continues to decrease linearly until it becomes zero and S_a turn off. So it can be turned off at ZCS.

E. Mode 5: In this mode, S_1 and S_2 switches are conducting and the secondary circuit is turned off. Input voltage source, V_{in} linearly charges the inductor L_{m1} and L_{m2}. The load is supplied by the output capacitor C_o.

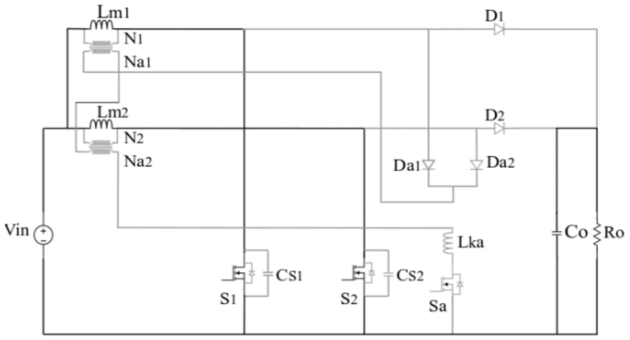

Fig. 6. Mode 5 [$t_4 - t_5$].

F. Mode 6: Voltage across the snubber capacitor C_{S2} is zero. So S_2 can turned off at ZVS. afterwards capacitor C_{S2}, start to charge linearly from L_{m2}. when the C_{S2} voltage equals V_{out} the diode D_2 start conducting.

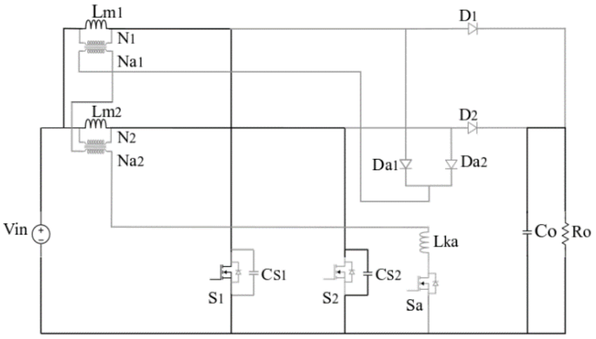

Fig. 7. Mode 6 [$t_5 - t6$].

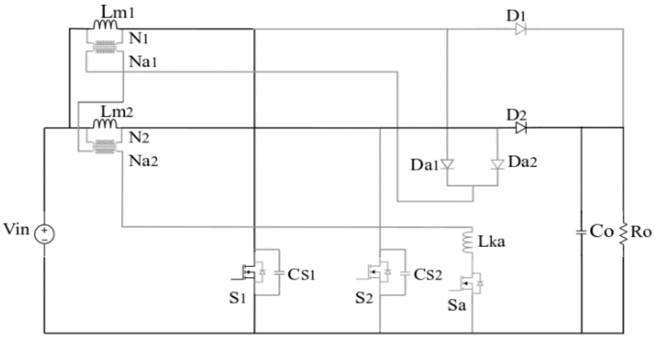

Fig. 8. Mode 7 [t6 − t7].

G. Mode 7: In this mode, L_{m2} transfers the stored energy to the output. and V_{in} charges L_{m1} linearly. After mode 7, again the secondary circuit is turned on to give the ZVS condition for S_2.

III. SIMULATION AND RESULTS

TABLE I SPECIFICATIONS

	Specification
Input voltage V_{in}	100 V
Output voltage V_{out}	400 V
Output Power P_{out}	200 W
Output capacitor C_o	2 µF
Magnetizing inductance L_m	1.58 mH
Leakage inductance L_{ka}	5 µH
Snubber capacitance C_{S1}, C_{S2}	1 nF
Turn ratio n	0.3

The Fig.9 shows the MATLAB/Simulink simulation diagram of the ZVT interleaved converter. Here the converter is designed for the 200W and 100KHz frequency. The converter, step-up the voltage from 90V to 400V.

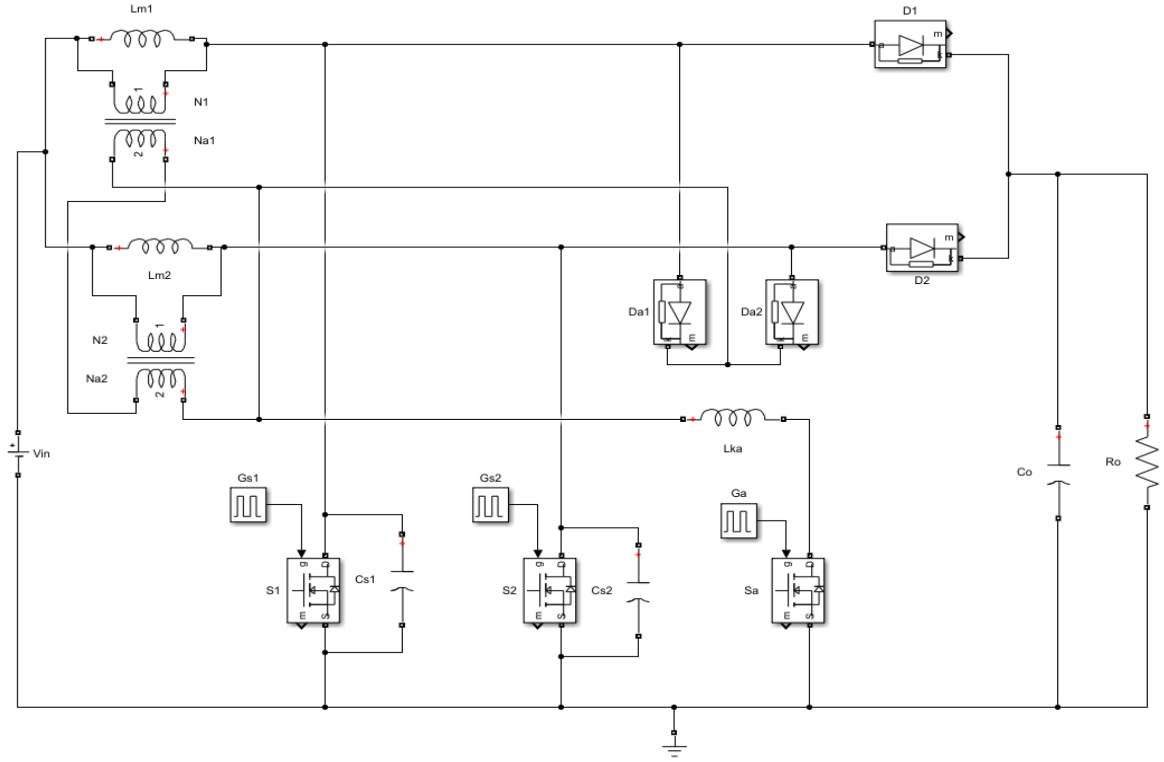

Fig. 9. Simulation Diagram.

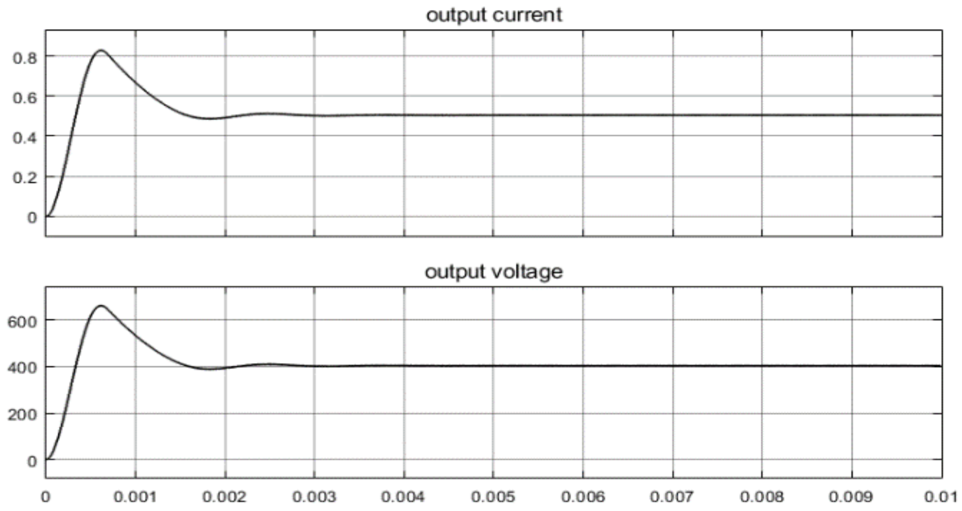

Fig. 10. Output Current and Voltage Waveform.

The Fig. 10 shows the output voltage and current waveform. By using the interleaved converter topology ripples in the output is reduced. Fig.11 clearly illustrates how the main switch turns on and off under ZVS condition. G_{S2} and G_{S1} are the gate pulse to the main switches S_1 and S_2.

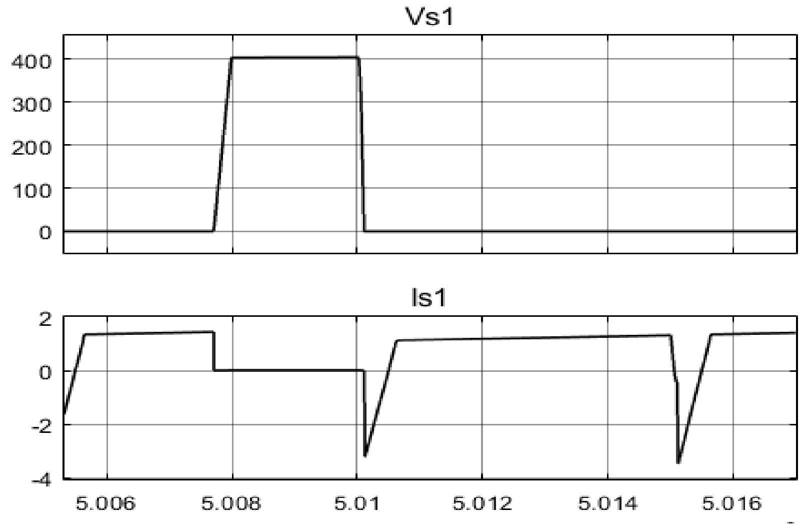

Fig. 11. Voltage and Current Waveform of S_1

G_{sa} is the gate pulse to the secondary switch. G_{S1} & G_{S2} are turned on with 180-degree phase shift, with duty ratio greater than 50%.

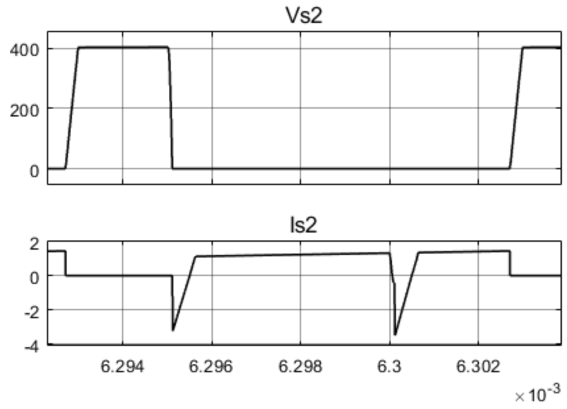

Fig. 12. Voltage and Current Waveform of S_2

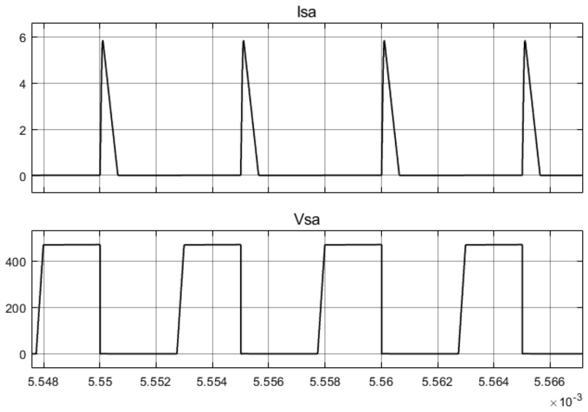

Fig. 13. Voltage and current Waveform of S_a

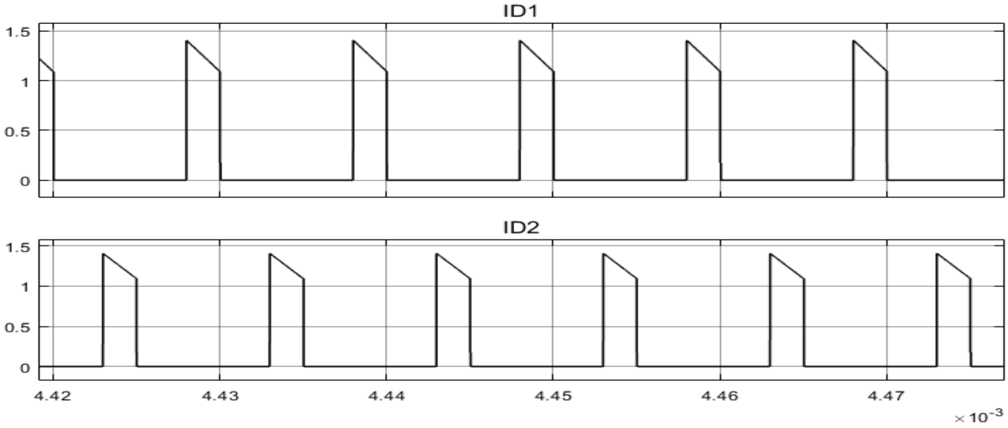

Fig. 14. Current through D_1 and D_2

From the voltage and current waveforms of the main switches Fig.11 and Fig.12 it is clear that no extra stresses on the switch Also the voltage and current waveforms of the secondary switch, S_a is given in Fig.13. From this figure, ZCS turn on and turn off of S_a can be seen. D_1 and D_2 are turned off at ZCS therefore its reverse recovery problem is alleviated.

IV. CONCLUSION

This converter provides soft switching for all semiconductor devices by using only a secondary circuit with one by using only a secondary circuit with one switch and no extra inductor. The main switches can be turned on and turned off at ZVS with the help of a secondary circuit. The secondary switch is also soft switched. They are turned on and turned off at ZCS condition. Converter diodes are turned off at zero voltage, therefore the reverse recovery problem of the diodes are alleviated. This converter is validated with MATLAB/Simulink.

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