A SOFT SWITCHING DC-DC BOOST CONVERTER WITH PASSIVE SNUBBER

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Abstract- This paper introduces a new soft switching boost converter with passive snubber. In the proposed converter, the main switch turns on under zero current switching (ZCS) and turns off under zero voltage switching (ZVS) without any additional voltage or current stresses. The main diode turns on under ZVS and turns off under ZCS. The proposed converter has features as low cost, simple control, low number of element and high power density. There is no additional voltage stress on any semiconductor power devices. In this study, the operating principle of the proposed converter is presented and its operation is verified for 200 W and 100 kHz model.

Keywords- Passive Snubber Cell, Coupled Inductor, Zero-Voltage Transition, Zero-Current Transition, Soft Switching.

I. INTRODUCTION

DC-DC boost converters are usually used in applications as solar energy, fuel cell, electrical vehicles, power factor correction, etc. due to their perfect dynamic performance, high power density and fast transition response. To obtain high power density, the switching frequency must be increased as possible. But the high switching frequency leads to high switching losses and electromagnetic interference (EMI) noises. Then, the performance and efficiency of the converter decrease. These problems can be solved by using the soft switching (SS) techniques with active or passive snubber cell. SS techniques with passive snubber are Zero Voltage Switching (ZVS), Zero Current Switching (ZCS). Otherwise, SS techniques with active snubber are Zero Voltage Transition (ZVT) and Zero Current Transition (ZCT) techniques [1-10].

In ZVT boost converters from SS techniques with active snubber, main switch turns on with ZVT with the help of an active snubber cell by lossless. Many ZVT converters are suggested in literature [1-6]. In ZCT boost converters, the main switch turns off under ZCT with the help of an active snubber cell. Many ZCT converters are suggested in literature [7-12]. Although the switching power losses are quite eliminated in techniques with active snubber, their controls are more difficult and they have complex structure. So, the cost is higher. In order to solve these problems, the soft switching converters with passive snubber are suggested in [13-].

In this paper, a new soft switching DC-DC PWM boost converter with passive snubber is proposed. The proposed converter is shown in Fig. 1. In this converter, the main switch turns on with ZCS and turns off with ZVS. The main diode turns on with ZVS and turns off with ZCS. The auxiliary diodes operate under SS. There is no additional voltage or current stress on semiconductor devices. The proposed converter decreases EMI noise and operates even under light load conditionals.

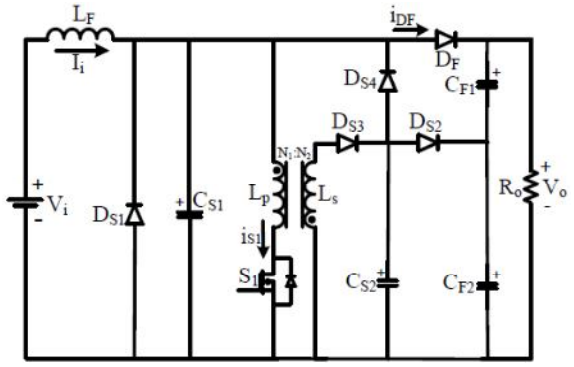


Fig.1 The basic circuit scheme of the proposed converter

II. FEATURES OF THE PROPOSED CONVERTER

The circuit scheme of the soft switching DC-DC PWM boost converter with passive snubber is given in Fig. 1. In this converter, V_i is dc input voltage, V_o is output voltage, L_F is main inductance, C_{F1} and C_{F2} are output capacitors, R_o is output load, S_1 is the main switch and D_F is the main diode. In the snubber cell, L_p and L_s are primer and secondary inductance of coupled resonant inductance, C_{S1} and C_{S2} are the resonant capacitors and D_{S1}, D_{S2}, D_{S3} and D_{S4} are the auxiliary diodes.

The following assumptions are taken into consideration while making theoretical analysis of the proposed converter.

- Output voltage V_o and input current I_i are constant for one switching cycle.
- All semiconductor devices and resonant circuits are ideal.
- The reverse recovery times of all diodes are not taken into account.

Before turning on interval of the main switch, S_1 is at off state and D_F diode is at on state. Then, a gate signal is applied the main switch and it turns on under ZCS because of series inductance L_p. Also, the main diode turns off under ZCS.
Before turning off interval of the main switch, S_1 is at on state and D_F diode is at off state. Then, the gate

signal of the main switch is removed and it turns off under ZVS because of parallel capacitor C_{S2}. Also, the main diode turns on under ZVS.

The other semiconductor devices of converter turn on and off under soft switching. So, the switching power losses are fairly decreased. Especially, this converter introduces an important advantage. This advantage is that the voltage stresses of devices are decreased compared ref []. Also, the converter has features such as simple structure, low cost and easy control.

III. SIMULATION RESULTS

It is realized a prototype of the proposed soft switching DC-DC PWM boost converter with passive snubber for 200 W and 100 kHz in PSIM program. The simulation parameters and the value of the devices are given in Table 1. The simulation circuit scheme of the proposed converter is given in Fig. 2. The simulation results of the converter are shown in between Fig. 3–5. The voltage value of switches is scaled 1/10 ratio in figures.

Table I The Simulation Parameters and The Value of The Device of Proposed Converter

Output Power (P_o)	200 W	**Snubber Primer Inductance (L_p)**	4 µH
Frequency (f)	100 kHz	**Snubber Seconder Inductance (L_s)**	64 µH
Input Voltage (V_i)	50 V	**Snubber Capacitor (C_{S1})**	3.3 nF
Output Voltage (V_o)	100 V	**Snubber Capacitor (C_{S2})**	2.2 nF
Main Inductance (L_F)	500 µH	**Output Capacitors (C_{F1}, C_{F2})**	22 µF

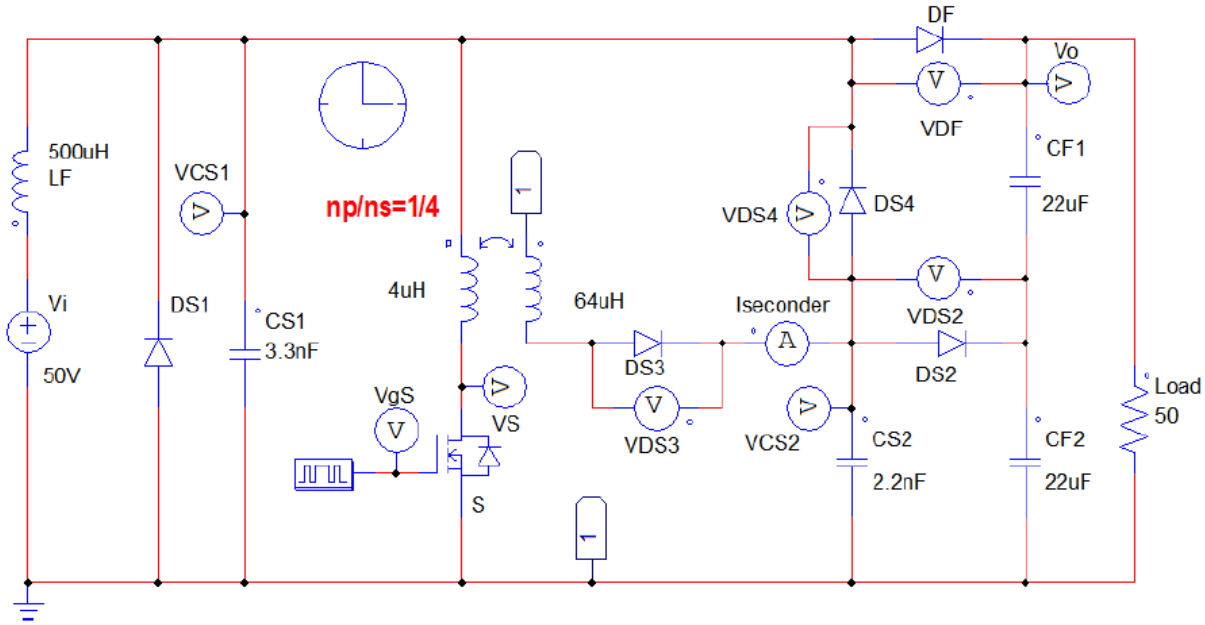


Fig.2 The simulation circuit scheme of the proposed converter

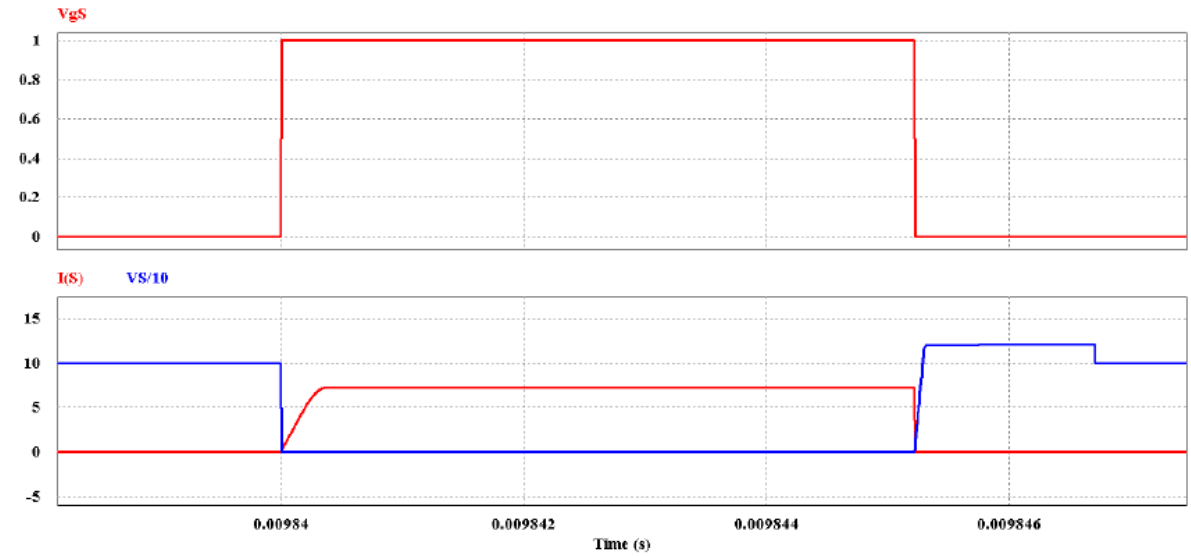


Fig.3 Respectively; the control signals of main switch, the voltage and the current waveforms of main switch

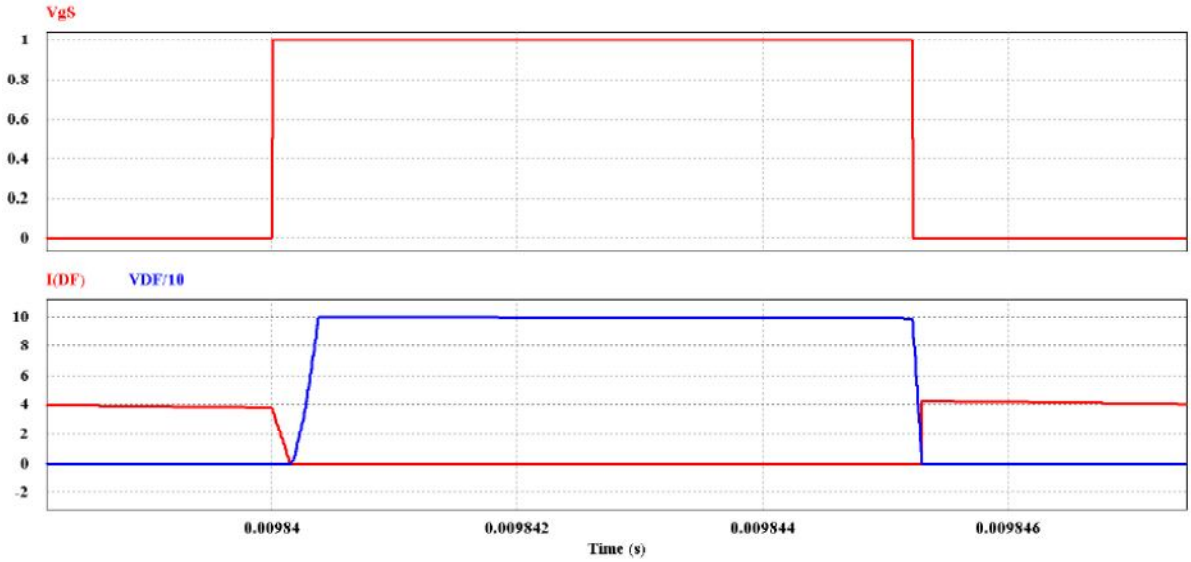


Fig.4 Respectively; the control signals of the main switch, the current and voltage waveforms of the main diode.

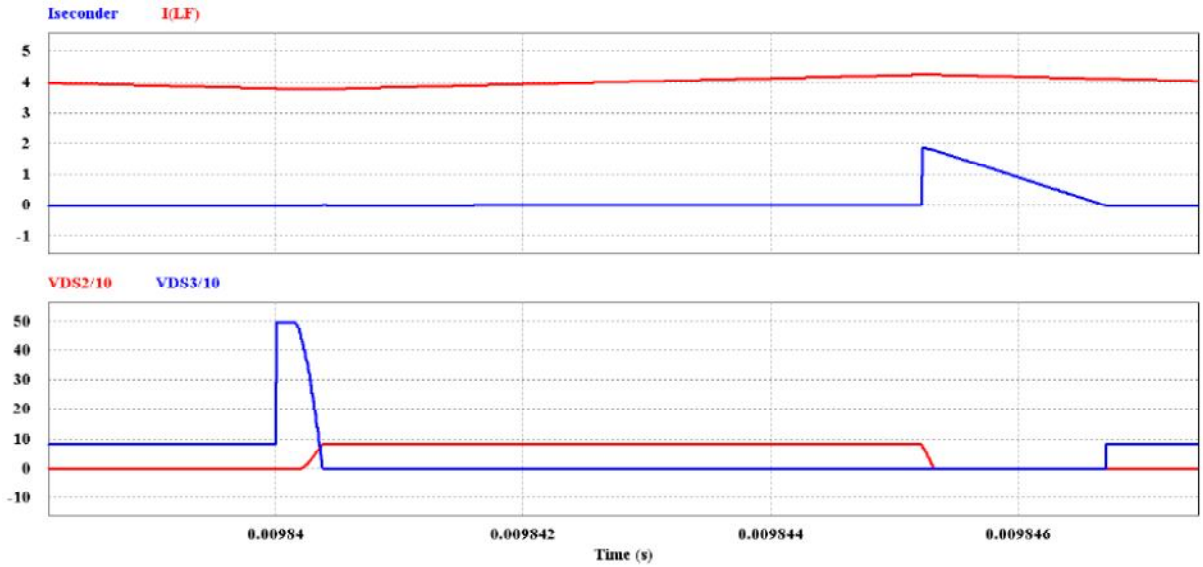


Fig.5 Respectively; the currents of main inductance and secondary resonance inductance, the voltage of auxiliary diodes D_{S2} and D_{S3}.

The conrol signal and current–voltage waveforms of the main switch S_1 are given in Fig. 3. As shown in figure, the current of main switch rises linearly due to series resonant inductance. So, the main switch turns on under ZCS. Also, the voltage of main switch rises slowly due to charging of the parallel resonant capacitors. So, the main switch turns off under ZVS. Besides, there is no additional voltage or current stress on the main switch during this process.

The control signals of the main switch and the current–voltage waveforms of the main diode D_F are given in Fig. 4. As shown in figure, the main diode turns on under ZVS and turns off under ZCS. Also, it is clear that there is not any voltage and current stress on the main diode.

The currents of main inductance and secondary resonance inductance, the voltage of auxiliary diodes D_{S2} and D_{S3} are given in Fig. 5. As shown in figure, the voltage stresses on diodes are low.

CONCLUSIONS

In this paper a new soft switching boost converter with passive snubber is proposed. In this converter, the main switch turns on under ZCS and turns off under ZVS. The main diode turns on under ZVS and turns off under ZCS. The voltage stresses of devices are fairly decreased. The proposed converter decreases EMI noise and operates even under light load conditionals.

In the proposed converter, the passive snubber cell has simple structure and ease of control. Also, this converter has some advantages as low cost, high power density. In here, the switching power losses are eliminated and EMI noises are reduced by the proposed snubber cell. A detailed steady-state analysis of the proposed converter is presented. The

theoretical analysis of the proposed converter is exactly verified by 200 W and 100 kHz prototype.

REFERENCES

[1] G. Hua, C. S. Leu, Y. Jiang and F. C. Y. Lee, "Novel zero-voltage transition PWM converters", *IEEE Trans. on Power Electronics*, vol. 9, pp. 213–219, Mar. 1994.

[2] H. Bodur and A. F. Bakan, "A new ZVT-PWM DC–DC converter", *IEEE Trans. on Power Electronics*, vol.17, pp. 40-47, Jan. 2002.

[3] W. Huang, X. Gao, S. Bassan and G. Moschopoulos, "Novel dual auxiliary circuits for ZVT-PWM converter", Canadian Journal of Elect. and Comp. Eng. Vol. 33, pp. 153-160, Summer/Fall, 2008.

[4] H. Yu, B. M. Song, and J. S. Lai, "A new zero-voltage transition pulse width modulated boost converter", *IET Power Electronics*, vol. 4, pp. 827-834, Marc. 2011.

[5] R. Gurunathan and A. K. S. Bhat, "A zero-voltage transition boost converter using a zero-voltage switching auxiliary circuit", *IEEE Trans. on Aerospace and Electronic Systems* . Vol. 37, pp. 889-897, Jul. 2001.

[6] C. J. Tseng and C. L. Chen, "New ZVT-PWM Converters with Active Snubbers," IEEE Trans. on Power Electron., vol. 13, pp. 861-869, September 1998.

[7] G. Hua, E. X. Yang, Y. Jiang and F. C. Lee, "Novel zero-current-transition PWM converters", *IEEE Trans. on Power Electronics*, vol. 9, pp. 601-606, Nov. 1994.

[8] H. Bodur and A. F. Bakan, "An improved ZCT-PWM DC–DC converter for high-power and frequency applications", *IEEE Trans. on Industrial Electronics*, vol. 51, pp. 89-95, Feb. 2004.

[9] E. Adib and H. Fazenahfard, "Family of Zero-Current Transition PWM Converters," IEEE Trans. Ind. Electron., vol. 55, pp. 3055-3063, August 2008.

[10] D. Lee, M. Lee, D. Hyun, and I. Choy, "New Zero-Current-Transition PWM DC/DC Converters Without Current Stress," IEEE Trans. on Power Electron., vol. 18, pp. 95-104, January 2003.

[11] H. F. Xiao, K. Lan, B. Zhou, L. Zhang, and Z. Wu, "A family of zero current transition transformerless photovoltaic grid-connected inverter," *IEEE Trans. on Power Electron.*, vol. 30, no. 6, pp. 3156–3165, Jun. 2015.

[12] D. Murthy-Bellur and M. K. Kazimierczuk, "Zero-current-transition two switch flyback pulse-width modulated DC-DC converter," *IET Power Electron.*, vol. 4, no. 3, pp. 288–295, 2011.

[13] R. T. H. Li and H. S. Chung, "A passive lossless snubber cell with minimum stress and wide soft-switching range," *IEEE Trans. on Power Electron.*, vol. 25, no. 7, pp. 1725–1738, Jul. 2010.

[14] J. J. Yun, H. J. Choe, Y. H. Hwang, Y. K. Park and B. Kang, "Improvement of power-conversion efficiency of a dc-dc boost converter using a passive snubber circuit," *IEEE Trans. on Industrial Electronics*, vol. 59, pp. 1808-1814, Apr. 2012.

[15] M. Mohammadi, A. Adib and M. R. Yazdani, "Family of soft-switching single-switch PWM converters with lossless passive snubber," *IEEE Trans. on Industrial Electronics*, vol. 62, pp. 3473-3481, Jun. 2015.

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