A NON ISOLATED BIDIRECTIONAL DC-DC CONVERTER WITH SOFT SWITCHING

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***Abstract*—*Power electronic converter systems for applications such as telecom, automotive, and space can have dc voltage buses that are backed up with batteries or super-capacitors. These batteries or super-capacitors are connected to the buses with bidirectional dc–dc converters which allow them to discharged or charged, depending on the operating conditions. Bidirectional dc–dc converters may be isolated or Non-Isolated depending on the application. A new soft-switched bidirectional dc–dc converter will be proposed in this paper. The proposed converter can operate with soft switching, a continuous inductor current and the switch stresses of a conventional pulse-width modulation converter regardless of the direction of power flow. These features are due to a very simple auxiliary active clamp circuit that is operational regardless of the direction of power flow. In the paper, the operation of the converter will be discussed and its feasibility will be confirmed with simulation result.*

Keywords*—*DC–DC power conversion; energy conversion; switch stresses

1. INTRODUCTION

Power electronic converter systems for applications such as telecom, automotive, and space can have dc voltage buses that are backed up with batteries or super capacitors. These batteries or super capacitors are connected to the buses with bidirectional dc–dc converters that allow them to be discharged or charged, depending on the operating conditions. Bidirectional dc–dc converters may be isolated.

It is not difficult to implement soft switching in isolated bidirectional dc–dc converters as they tend to be based on conventional half-bridge and full-bridge structures that can use inductive energy stored in the main power transformer to discharge the capacitance across the converter switches. It is more challenging to do so for Non-Isolated converters as there is no such transformer.

2. CIRCUIT DIAGRAM

The auxiliary switch S_a , capacitor C_r, and inductors L_{r1} and L_{r2} have been added. These four components make up a simple circuit that is based on well-established active clamp technology and that can be used to ensure that the main power switches S_1 and S_2 operate with ZVS regardless of whether the converter is operating in a boost or buck mode. The proposed converter shown in fig 1 can operate with a continuous inductor current, fixed switching frequency, and the switch stresses of a conventional PWM converter regardless of the direction of power flow.

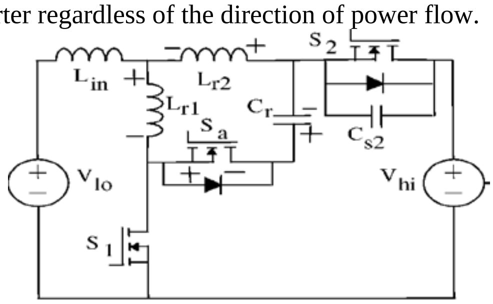

Fig 1.Circuit Diagram

3. MODES OF OPERATION

The inductor current $I_{Lr\,1}$ is positive if it enters the inductor through its positive terminal, the currents through switches S_1 and S_2 are considered positive if they flow into a switch through its drain, and the current through $S_a$is considered positive if it flows through the switch source. Any current flowing into the positive terminal of the capacitor C_r is considered to be positive

A. Boost Mode

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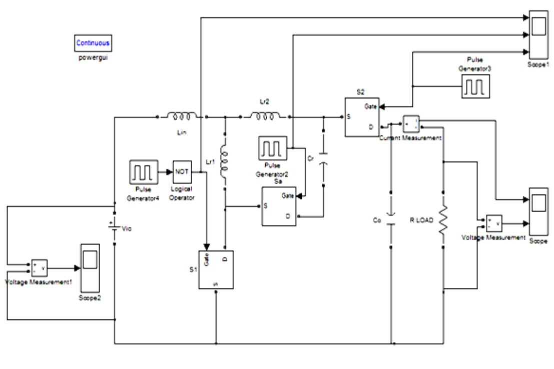

Fig. 2 Boost mode

B. Buck mode

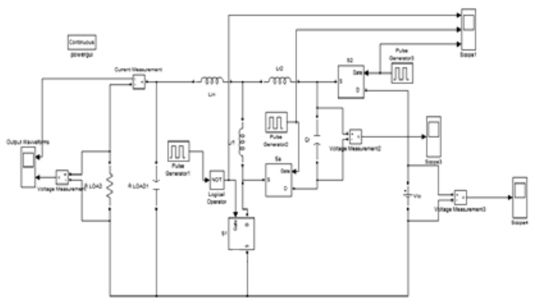

Fig. 3 Buck mode

4. SIMULATION RESULTS

The selection of the active clamp components was done by considering the high- and low-side voltages and the load range (which affects the current flowing in the converter). It was determined that the ZVS operation range is not dependent on whether the converter operates in the boost or buck mode of operation as the voltages and the currents to be considered in the design of this range are the same. This is true as long as L_{r1} and L_{r2} are also the same so that the symmetry of the two modes is kept. If the converter is designed to operate with ZVS for the boost mode, it can therefore operate with ZVS for the buck mode.In order to reduce the circulating current losses of the converter under light-load conditions, it was decided to design the ZVS range to be from 40% load to 100% load. The duty cycle of S_a was kept fixed for all operating conditions.

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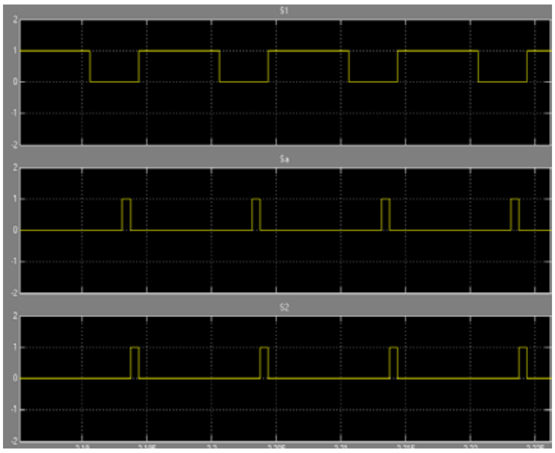
A. Pulse Generation for boost mode

Typical converter waveforms are shown in Fig.4(b) of voltage waveforms of S1 when it is turning on and the converter is operating in boost mode. Fig. 5(b) shows similar waveforms of S2 when the converter is operating in the buck mode. It can be seen that in both cases, the converter switches can operate with a ZVS turn-on. It can be seen that the auxiliary active circuit is ON for a short time and that Sa is off before S1 or S2 is turned on. The turning on of Sa allows energy to be stored in the auxiliary circuit inductors, which is then used to discharge the *appropriate switch capacitance*



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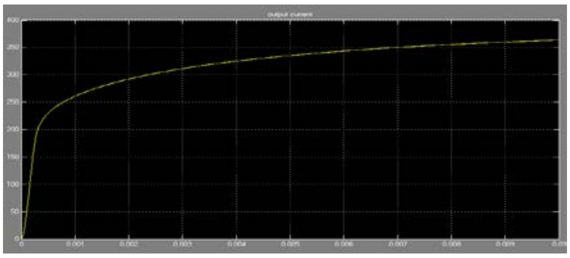
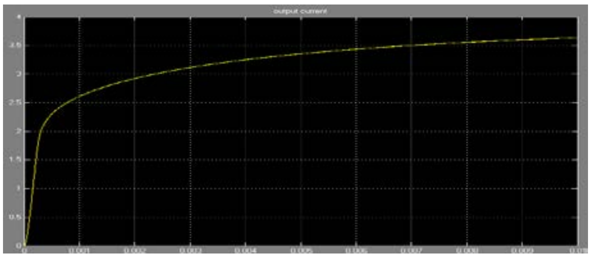
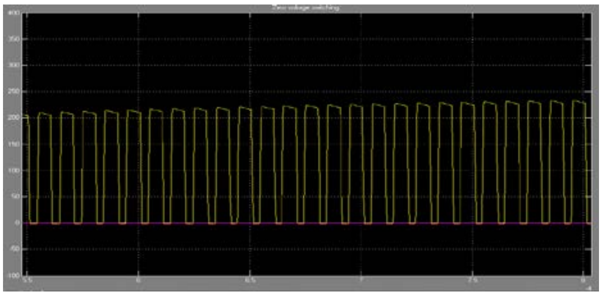
a.Pulse generated



b.Output voltage waveform



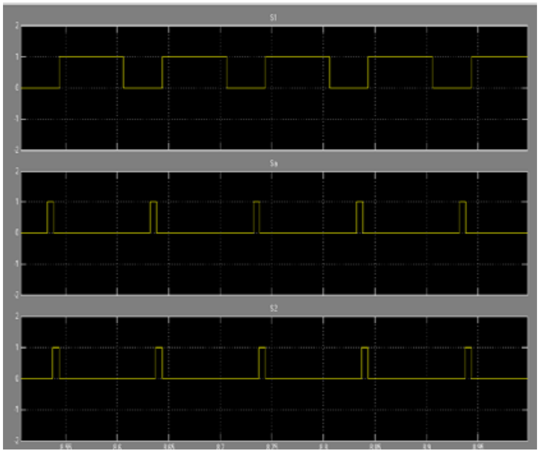
c.Output current waveform



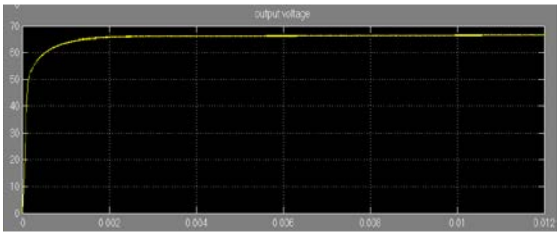
d.Zero Voltage Switching of S1

Fig.4 Output waveforms of boost mode

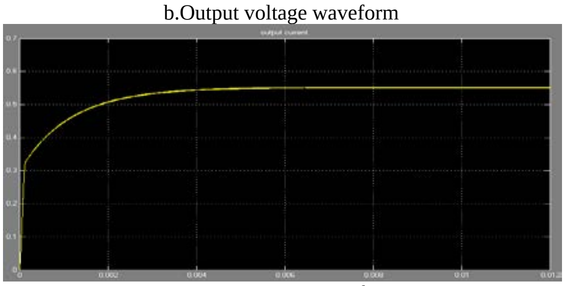
B. Pulse Generation for buck mode



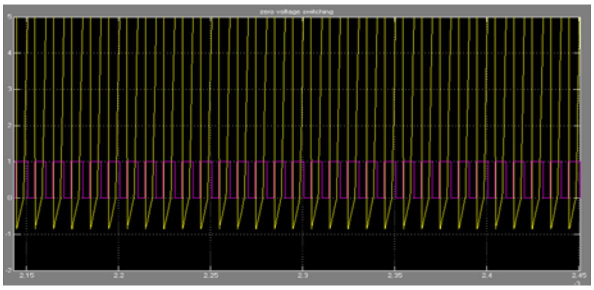
a.Pulse generated for buck mode



b.Output voltage waveform



c.Output Current waveform



d.Zero Voltage Switching Of S2
Fig.5 Output waveforms of boost mode

5. CONCLUSION

A new Non-Isolated bidirectional PWM converter was presented in this paper. The outstanding features of the proposed converter are that it can operate with continuous inductor current, fixed switching frequency, and the switch stresses of a conventional PWM converter regardless of the direction of power flow. These features are due to a simple and inexpensive auxiliary circuit that is based on well-established active clamp technology. The feasibility of the proposed converter was con-firmed with simulation results.

REFERENCES

[1] M. Jain, M. Daniele, and P. K. Jain, "A bidirectional DC– DC converter topology for low power application," IEEE Trans. Power Electron., vol. 15, no. 4, pp. 595–606, Jul. 2000.
[2] H. Li, F.-Z. Peng, and J. S. Lawler, "A natural ZVS medium-power bidi-rectional DC–DC converter with minimum number of devices," IEEETrans. Ind. Appl., vol. 39, no. 2, pp. 525–535, Mar. 2003.
[3] P. Jose and N. Mohan, "A novel ZVS bidirectional cuk converter for dual voltage systems in automobiles," in Proc. IEEE IECON Conf. Rec., 2003, pp. 117–122.
[4] R. Li, A. Pottharst, N. Frohleke, and J. Bocker, "Analysis and design of improved isolated full-bridge bidirectional DC–DC converter," in Proc.IEEE PESC Conf. Rec., 2004, pp. 521–52
[5] S. Inoue and H. Akagi, "A bidirectional isolated DC–DC converter as a core circuit of the next-generation medium-voltage power conversion system," IEEE Trans. Power Electron., vol. 22, no. 2, pp. 535–542, Mar. 2007.
[6] K. Zhiguo, Z. Chunbo, Y. Shiyan, and C. Shukang, "Study of bidirectional DC–DC converter for power management in electric bus with supercapac-itors," in Proc. IEEE VPPC Conf. Rec., 2006, pp. 1–6.
[7] C. P. Henze, H. C. Martin, and D. W. Parsley, "Zero voltage switching in high frequency power converters using pulse width modulation," in Proc.IEEE APEC Conf. Rec., 1988, pp. 33–40.
[8] D. M. Sable and F. C. Lee, "A zero-voltage-switching bidirectional battery charger/discharger for NASA EOS satellite," in Proc. IEEE APEC Conf.Rec., 1992, pp. 614–621.
[9] Z. R. Martinez and B. Ray, "Bidirectional DC/DC power conversion using constant frequency multi-resonant topology," in Proc. IEEE APEC Conf.Rec., 1994, pp. 991–997.
[10] C.-E. Kim, S.-K. Han, K.-H. Yi, W.-J. Lee, and G.-W. Moon, "A new high efficiency ZVZCS bi-directional DC/DC converter for 42 V Power System of HEVs," in Proc. IEEE PESC Conf. Rec., 2006, pp. 792–797.
[11] C.-E. Kim, S.-K. Han, K.-H. Yi, W.-J. Lee, and G.-W Moon, "A new high efficiency ZVZCS bi-directional DC/DC converter for 42 V Power System of HEVs," in Proc. IEEE PESC Conf. Rec., 2006, pp. 792–797.
[12] K. T. Chau, T. W. Ching, and C. C. Chan, "Bidirectional soft-switching converter-fed DC motor drives," in Proc. IEEE PESC Conf. Rec., 1998, pp. 416–422.
[13] H. Shiji, K. Harada, Y. Ishihara, T. Todaka, and G. Alzamora, "A zero-voltage-switching bidirectional converter for PV systems," in Proc. IEEEINTELEC Conf. Rec., 2003, pp. 14–19.
[14] E. Sanchis-Kilders, A. Ferreres, E. Maset, J. B. Ejea, V. Esteve, J. Jordan, Garrigos, and J. Calvente, "Soft switching bidirectional converter for battery discharging–charging," in Proc. IEEE APEC Conf. Rec., 2006, pp. 603–609.
[15] I.-D. Kim, S.-H. Paeng, J.-W. Ahn, E.-C. Nho, and J.-S. Ko, "New bidi-rectional ZVS PWM Sepic/Zeta DC–DC converter," in Proc. IEEE ISIEConf. Rec., 2007, pp. 555–560.