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Analysis and Design of a Bidirectional Isolated buck-boost DC-DC Converter with duel coupled inductors

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Abstract- ***The main objective of this paper, a bidirectional dc–dc converter with duel coupled inductor is proposed. In the boost mode, two capacitors are parallel charged and series discharged by the coupled inductor. Thus, high step-up voltage gain can be achieved with an appropriate duty ratio. The voltage stress on the main switch is reduced by a passive clamp circuit. Therefore, the low resistance RDS (ON) of the main switch can be adopted to reduce conduction loss. In the buck mode, two capacitors are series charged and parallel discharged by the coupled inductor. The bidirectional converter can have high step-down gain. Aside from that, all of the switches achieve zero voltage-switching turn-on, and the switching loss can be improved. Due to two active clamp circuits, the energy of the leakage inductor of the coupled inductor is recycled. The efficiency can be further improved. The operating principle and the steady-state analyses of the voltage gain are discussed.***

Index Terms—***DC-DC converter, Bidirectional , Duel coupled inductors, switched capacitor.***

Introduction- The demand of renewable energy systems are more and more widely used in the world such as solar and wind energy. However, photovoltaic (PV) solar or wind power cannot provide sufficient power when the load is suddenly increased. Thus, the battery with bidirectional dc–dc converter is needed. Conventionally, the batteries are series strings used to provide a high voltage (HV). Isolated bidirectional dc–dc converters such as half and full-bridge types, can provide high step-up and step-down voltage gains by adjusting the turn ratio of the transformer. The high step-up gain and the high step-down voltage gain can be achieved. The number of switches is usually between four and eight. Also, some isolated bidirectional converters are characterized by a current-fed rectifier on the low voltage (LV) side and a voltage-fed rectifier on the HV side. The leakage inductor of the transformer leads to the HV spike on the main switch during switching transition. Thus, the isolated bidirectional full-bridge dc–dc converter with a flybacksnubber circuit is proposed. A novel soft commutating isolated boost full-bridge zero-voltage-switching (ZVS) pulsewidth-modulation dc–dc converter is proposed. The energy of the leakage inductor is recycled and not dissipated. However, the number of switches is also added. Aside from that, the bidirectional converter based on flyback or forward converters are proposed . The leakage inductor of the transformer also causes HV spike on switches. Thus, an active clamp circuit is applied in the bidirectional converter, which is proposed.

For non-isolated applications, non-isolated bidirectional converters, which include the conventional boost/buck type, the soft-switching technique on conventional boost/buck converter , three levels, multilevel, SEPIC/Zeta, switched-capacitor bidirectional converter, and a coupled-inductor-type bidirectional converter, is proposed where using two auxiliary switches, i.e., ZVS, is provided. For some ZVS purpose, the authors have improved the coupled inductor bidirectional topology with only one auxiliary switch. The authors have modified the two previous converters and proposed a converter without any auxiliary switches.

To achieve a high conversion ratio, two inductors charged in parallel and discharged in series are proposed. In the aforementioned converters, the multilevel type is a magnetic less converter and the conversion ratio based on stack of capacitors, which need 12 switches in this converter. If higher step-up and step-down voltage gains are required, more switches are needed.

The coupled-inductor converters easily achieve a high conversion gain. However, the energy leakage energy needs to recycle. Based on the previous research of the high step-up converter in and, a high-efficiency, high-conversion-ratio, and clamp-mode bidirectional converter is proposed. The initial high step-up converter adds two pairs of additional capacitors and switches on the secondary side of the coupled inductor to achieve an HV ratio.

OPERATING PRINCIPLE OF THE PROPOSED CONVERTER

Fig. 1 shows the circuit topology of the proposed converter. This converter consists of the dc input voltage V_L, the power switch S_1-S_5, the clamp capacitor C_1, two blocking capacitors C_2 and C_3, and the coupled inductors $N_p$and N_s. The equivalent model of the coupled inductor includes the magnetizing inductor L_m, the leakage inductor L_k, and an ideal transformer.

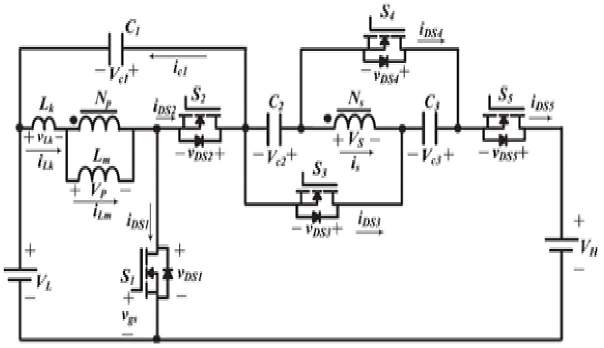

Fig. 1. Circuit configuration of the bidirectional converter.

The switched-capacitor technique in and has proposed that parallel-charged and series-discharged capacitors can achieve high step-up gain. Also, series-charged and parallel-discharged capacitors can achieve high step-down gain. The character of the coupled inductor is that the secondary side can have opposite polarity when the switch is on and off. In the boost-state operation, this character is combined with the switched-capacitor technique. Two capacitors C_2 and C_3 are parallel charged when the switch is on and series discharged when the switch is off. In the buck-state operation, the coupled inductor is used as a transformer. Thus, two capacitors C_2 and $C3$ can be series charged by HV side and parallel discharged through the secondary side.

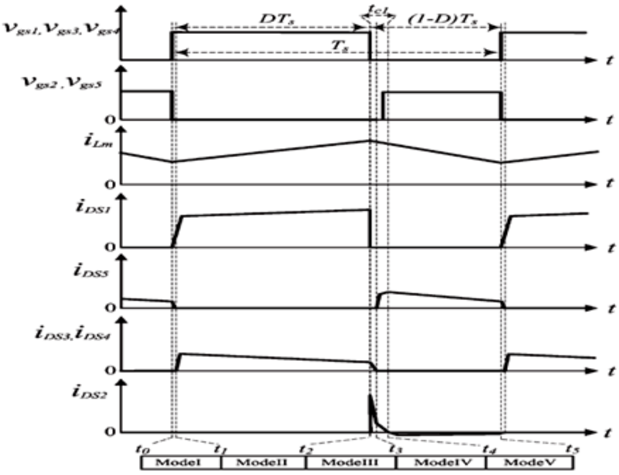

Fig.2. Key waveforms of the bidirectional converter in the boost state at the CCM.

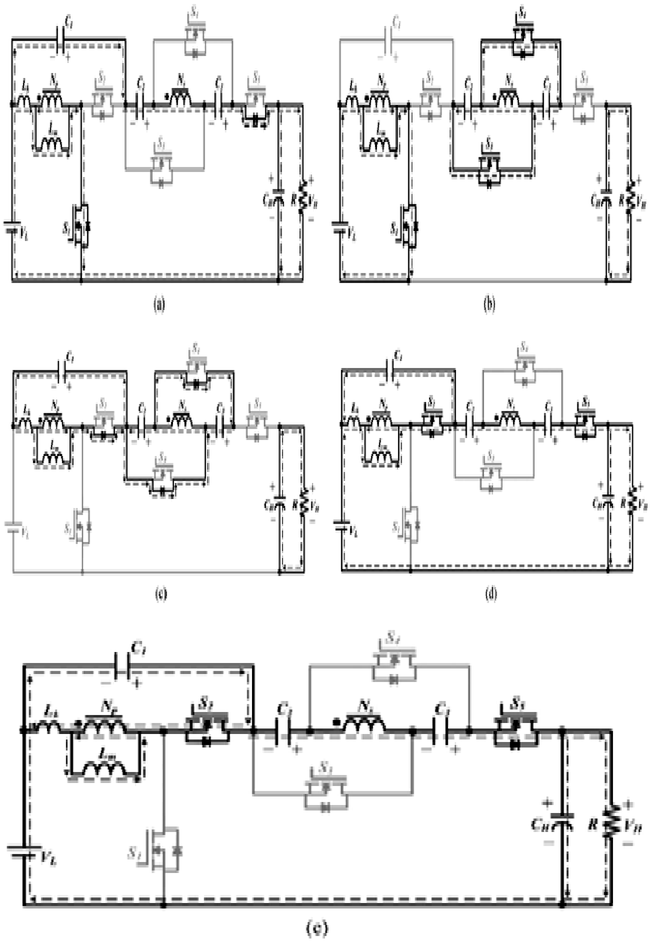

Fig.3. Current-flow path of the operating mode during one switching period in the boost state at the CCM. Modes (a) I, (b) II, (c) III, (d) IV, and (e) V.

In addition, the problem of the energy of the leakage inductor is also solved. In the boost-state operation, S_1 is the main switch, and capacitor C_1 recycles the energy. The voltage across switch S_1 can be clamped. Since switch S_1 has an LV level, the low conducting resistance $R_{DS(ON)}$ of the switch is used to reduce the conduction loss. In the buck-state operation, the main switches are S_2 and S_5. Two capacitors C_2 and C_3 with switches S_3 and S_4 are used as active clamp circuits, recycling the energy of the leakage inductor on the secondary side of the coupled inductor. Capacitor C_1 with switch S_2 is another active clamp circuit that recycled the energy of the leakage inductor on the primary side. Thus, four switches are ZVS turned on. The switching loss is improved; the efficiency can be increased. It is because that the high step-up converter needs a large input current, which results that the conduction loss is larger than the switching loss. Thus, reducing the switch voltage stress for alleviating the conduction loss and the elimination of reverse-recovery current is the key point to improve efficiency. Similarly, the main switch of the high step-up and step-down converters suffers HV stress and low conducting current. The switching loss should be reduced to improve efficiency.

To simplify the circuit analysis, the following conditions are assumed.

1) Capacitors C_2 and C_3 are large enough that V_{c2} and V_{c3} are considered to be constant in one switching period.

2) The power MOSFET and diodes are treated as ideal.

3) The coupling coefficient of the coupled inductor k is equal to $L_m/(L_m + L_k)$, and the turn ratio of the coupled inductor n is equal to N_s/N_p.

STEADY-STATE ANALYSIS OF THE PROPOSED CONVERTER

After the mode analysis of the boost- and buck-state operations, the following equations and voltage gain in the steady state of the proposed converter can be derived. According to the assumptions before the mode analysis, the equations of the turn ratio and the coupling coefficients k of the coupled inductor are defined as

$$n = \frac{N_s}{N_p} \tag{1}$$

$$k = \frac{L_m}{L_m + L_k}. \tag{2}$$

Because the voltage gain is less sensitive to the coupling coefficient and the clamped capacitors C_1, C_2, and C_3 appropriately absorb the leakage inductor energy, the coupling coefficient is set to 1 to obtain the voltage gain.

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SIMULATION CIRCUIT DIAGRAM AND RESULTS

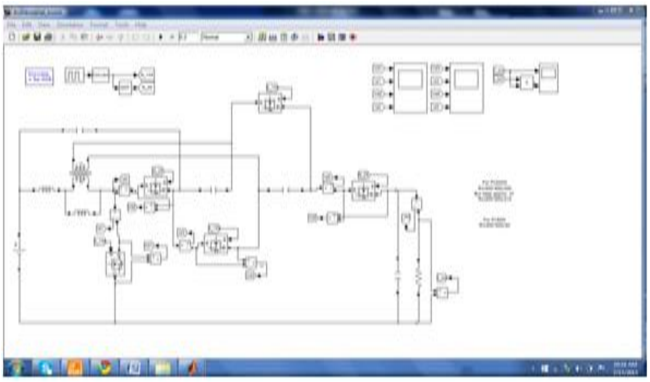

Figure 4 : matlab Circuit of the bidirectional boost converter.

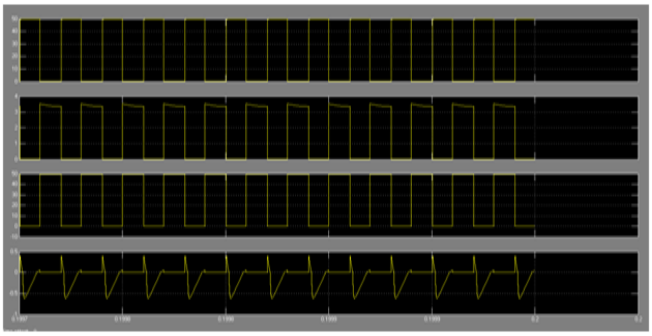

Figure 5 : Vd1,Id1, Vd2 ,Id2

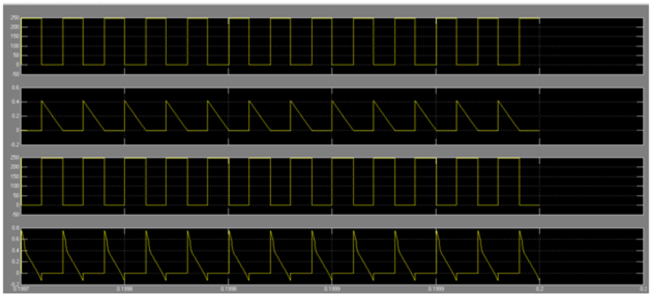

Figure 6 : Vd3,Id3,Vd5,Id5

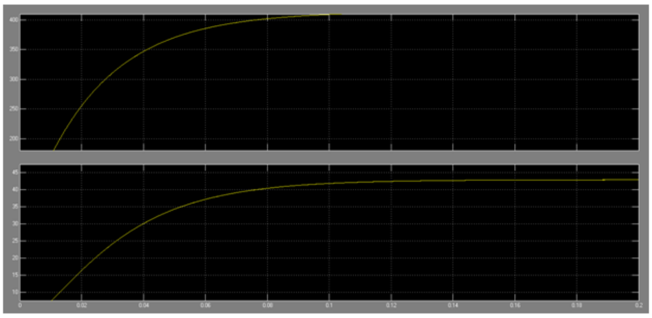

Figure 7 : Vout, Pout

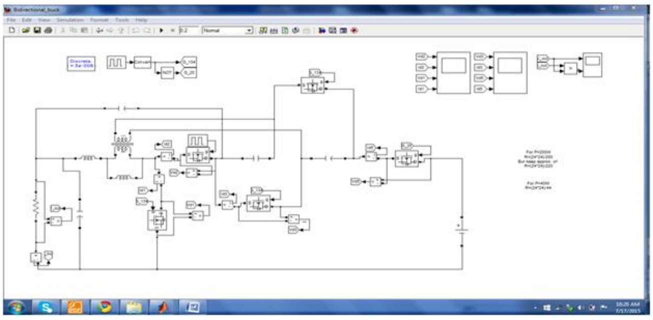

Figure 8 : matlab Circuit diagram of the bidirectional buck converter.

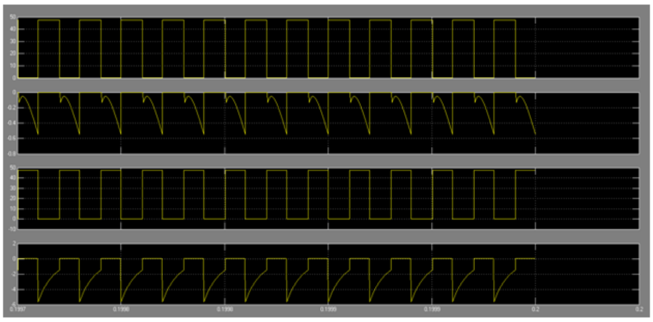

Figure 9 : Vd2,Id2, Vd1 ,Id1

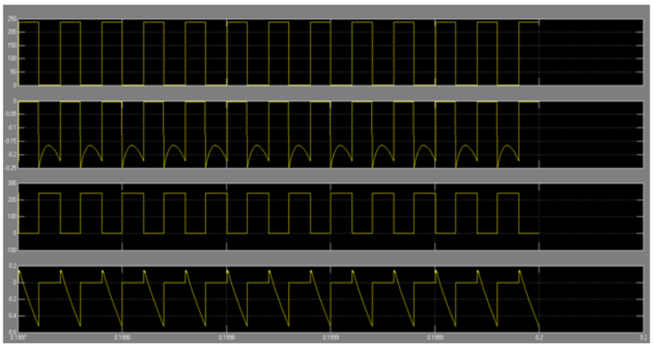

Figure 10 : Vd3,Id3,Vd5,Id5

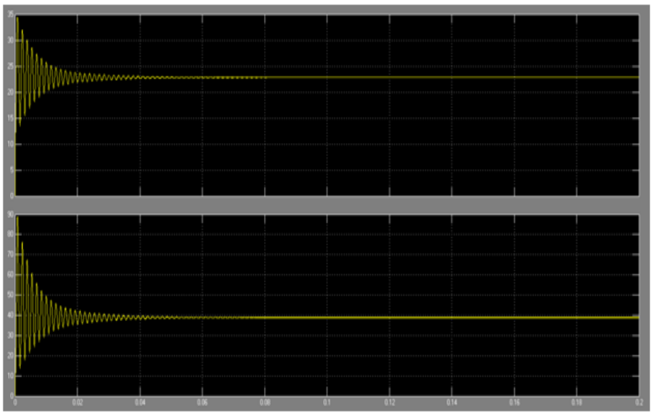

Figure 11: Vout, Pout

CONCLUSION

This paper has proposed a novel, high-efficiency, and high step-up/step-down bidirectional dc–dc converter. By using the capacitor charged in parallel and discharged in series by the coupled inductor, high conversion ratio and high efficiency have been achieved. The steady-state analyses of the proposed converter have been discussed in detail. The voltage gain and the utility rate of the magnetic core have been increased by using a coupled inductor with a low turn ratio. The energy of the leakage inductor has been recycled with the clamp circuit. A prototype circuit has been built in the laboratory. Experimental results show that the maximum efficiency is 97.33% at the boost mode and 96.23% at buck mode. This topology provides efficient conversion of various power sources. This technique can be also applied in different power conversion systems easily.

REFERENCES

[1]R.Gules,J.D.P.Pacheco,H.L.Hey,andJ.Imhoff,“Amaximum power point tracking system with parallel connection for PV stand-alone applications,”IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2674–2683, Jul. 2008.

[2] R. J. Wai, R. Y. Duan, and K. H. Jheng, “High-efficiency bidirectional dc–dc converter with high-voltage gain,”IET Power Electron.,vol.5, no. 2, pp. 173–184, Feb. 2012.

[3] R. Y. Duan and J. D. Lee, “High-efficiency bidirectional dc–dc converter with coupled inductor,”IET Power Electron., vol. 5, no. 1, pp. 115–123, Jan. 2012.

[4] R. J. Wai and R. Y. Duan, “High-efficiency bidirectional converter for power sources with great voltage diversity,”IEEE Trans. Power Electron., vol. 22, no. 5, pp. 1986–1996, Sep. 2007.

[5] M. Jang and V. G. Agelidis, “A minimum power-processing-stage fuelcell energy system based on a boost-inverter with a bidirectional backupbattery storage,”IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1568– 1577, May 2011.

[6] G. Ma, W. Qu, G. Yu, Y. Liu, N. Liang, and W. Li, “A zero-voltageswitching bidirectional dc–dc converter with state analysis and softswitching-oriented design consideration,” IEEE Trans. Ind. Electron., vol. 56, no. 6, pp. 2174–2184, Jun. 2009.

[7] F. Z. Peng, H. Li, G. J. Su, and J. S. Lawler, “A new ZVS bidirectional dc–dc converter for fuel cell and battery application,”IEEE Trans. Power Electron., vol. 19, no. 1, pp. 54–65, Jan. 2004.

[8] H. Li, F. Z. Peng, and J. S. Lawler, “A natural ZVS medium-power bidirectional dc–dc converter with minimum number of devices,”IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 525 535, Mar./Apr. 2003.

[9] B. R. Lin, C. L. Huang, and Y. E. Lee, “Asymmetrical pulse-width modulation bidirectional dc–dc converter,”IET Power Electron., vol. 1, no. 3, pp. 336–347, Sep. 2008.

[10] K. Wu, C. W. de Silva, and W. G. Dunford, “Stability analysis of isolated bidirectional dual active full-bridge dc–dc converter with triple phase-shift control,”IEEE Trans. Power Electron., vol. 27, no. 4, pp. 2007–2017, Apr. 2012.

[11] Z. Wang and H. Li, “A soft switching three-phase current-fed bidirectional dc–dc converter with high efficiency over a wide input voltage range,” IEEE Trans. Ind. Electron., vol. 27, no. 2, pp. 669–684, Feb. 2012.

[12] F. Zhang and Y. Yan, “Novel forward-flyback hybrid bidirectional dc–dc converter,”IEEE Trans. Ind. Electron., vol. 56, no. 5, pp. 1578–1584, May 2009.

[13] S. Jalbrzykowski, A. Bogdan, and T. Citko, “A dual full-bridge resonant class-E bidirectional dc–dc converter,”IEEE Trans. Ind. Electron., vol. 58, no. 9, pp. 3879–3883, Sep. 2011.

[14] T. F. Wu, Y. C. Chen, J. G. Yang, and C. L. kuo, “Isolated bidirectional full-bridge dc–dc converter with a flyback snubber,”IEEE Trans. Power Electron., vol. 25, no. 7, pp. 1915–1922, Jul. 2010.

[15] L. Zhu, “A novel soft-commutating isolated boost full-bridge ZVS-PWM dc–dc converter for bidirectional high power applications,”IEEE Trans. Power Electron., vol. 21, no. 2, pp. 422–429, Mar. 2006.

[16] T. Bhattacharya, V. S. Giri, K. Mathew, and L. Umanand, “Multiphase bidirectional flyback converter

topology for hybrid electric vehicles," IEEE Trans. Ind. Electron., vol. 56, no. 1, pp. 78–84, Jan. 2009.

[17] T. Qian and B. Lehman, "Coupled input-series and output-parallel dual interleaved flyback converter for high input voltage application," IEEE Trans. Power Electron., vol. 23, no. 1, pp. 88–95, Jan. 2008.

[18] W. S. Liu, J. F. Chen, T. J. Liang, R. L. Lin, and C. H. Liu, "Analysis, design, and control of bidirectional cascoded configuration for a fuel cell hybrid power system,"IEEE Trans. Power Electron., vol. 25, no. 6, pp. 1565–1575, Jun. 2010.

[19] G. Chen, Y. S. Lee, S. Y. R. Hui, D. Xu, and Y. Wang, "Actively clamped bidirectional flyback converter,"IEEE Trans. Ind. Electron., vol. 47, no. 4, pp. 770–779, Aug. 2000.

[20] L. R. Chen, N. Y. Chu, C. S. Wang, and R. H. Liang, "Design of a reflexbased bidirectional converter with the energy recovery function,"IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 3022–3029, Aug. 2008.

[21] K. Jin, X. Ruan, M. Yang, and M. Xu, "A hybrid fuel cell power system," IEEE Trans. Ind. Electron., vol. 56, no. 4, pp. 1212–1222, Apr. 2009.

[22] E. F. Vidal, I. E. Colling, and I. Barbi, "A bidirectional PWM threephase step-down rectifier based on the differential-mode power conversion principle,"IEEE Trans. Power Electron., vol. 24, no. 12, pp. 2951–2958, Dec. 2009.

[23] A. S. Samosir and A. H. M. Yatim, "Implementation of dynamic evolution control of bidirectional dc–dc converter for interfacing ultracapacitor energy storage to fuel-cell system,"IEEE Trans. Ind. Electron., vol. 57, no. 10, pp. 3468–3473, Oct. 2010.

[24] L. R. Chen, C. M. Young, N. Y. Chu, and C. S. Liu, "Phase-locked bidirectional converter with pulse charge function for 42-V/14-V dualvoltage powernet,"IEEE Trans. Ind. Electron., vol. 58, no. 5, pp. 2045– 2048, May 2011.

[25] L. Schuch, C. Rech, H. L. Hey, H. A. Grundling, H. Pinheiro, and J. R. Pinheiro, "Analysis and design of a new high-efficiency bidirectional integrated ZVT PWM converter for dc-bus and battery-bank interface," IEEE Trans. Ind. Appl., vol. 42, no. 5, pp. 1321–1332, Sep./Oct. 2006.