INTERNATIONAL JOURNAL OF TECHO-ENGINEERING

ISSN: 2057-5688

PHOTOVOLTAIC AS WELL AS ENERGY STORAGE EQUIPMENT BASED SHUT LOOPHOLE CONTROL OF BIDIRECTIONAL BUCK-BOOST CONVERTER IN A WISE GRID

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ABSTRACT:

This thesis proposes a new closed loop control bidirectional buck-boost converter, which is a key component in a photovoltaic and energy storage system (PV-ESS). Conventional bidirectional buck-boost converters for ESSs operate in discontinuous conduction mode (DCM) to achieve zero-voltage-switching turn-on for switches. However, operation in DCM causes high ripples in the output voltage and current, as well as low power-conversion efficiency. To improve on the performance of the conventional converter, the proposed converter has a new combined structure of a cascaded buck-boost converter and an auxiliary capacitor. The combined structure of the proposed converter reduces the output current ripple by providing a current path and the efficiency is increased. The proposed closed loop control converter has a maximum efficiency of 98%, less than 5.14 Vp.p of output voltage ripple, and less than 7.12 Ap.p of output current ripple. These results were obtained at an input voltage of 160 V, switching frequency of 45 kHz, output voltage of 80 ~ 320 V, and output power of 16 ~ 160 W. The experimental results show that the proposed converter has improved performance compared to the conventional converter.

Keywords: DCM, ESS, capacitor, PV, Boost & Buck converter.

1. INTRODUCTION:

Smart grid is future electric energy system that has been studied to reduce mismatching between sources of electricity (such as renewable energy and power plants) and electricity consumers (homes, vehicles, factories, etc.). However, the energy production of renewable energy depends on environmental conditions. Therefore, an energy storage system (ESS) is needed in a smart grid to provide stability and efficiently manage the renewable energy. An ESS consists of a battery that stores electric energy and a bidirectional DC-DC converter that transfers energy from the battery and renewable energy source in both directions [4-9]. A conventional bidirectional DC-DC converter uses a half-bridge converter with two switches based on a buck or boost DC-DC converter. In the buck mode of the converter, electric energy is transferred from a high voltage (HV) port to the low voltage (LV) port. In boost mode, the electric energy is transferred from the LV port to the HV port. The conventional bidirectional converter has a limitation in that it can only be operated in buck mode in one direction and boost mode in the other direction. Therefore, when the input is a photovoltaic (PV) module and the output is battery cells in a smart grid, a half bridge converter based on a buck or boost converter cannot be used because of the following reasons:

1) The battery cells repeatedly perform charging and discharging operations, resulting in large voltage variation.

2) The PV module has a large voltage variation that depends on the

ISSN: 2057-5688

module temperature and the solar irradiance. Thus, the ranges of the input voltage and output voltage can overlap.

2. SURVEY OF RESEARCH

Bidirectional buck-boost converters were introduced for use in cases of overlapping input and output voltages. They can operate in both buck and boost modes in both directions. A combined half-bridge (CHB) converter is the most basic bidirectional buck-boost converter and has a symmetric structure with respect to the storage capacitor CS. There is one inductor at the input port and one at the output port, which results in low voltage ripples in the input and output. However, because the CHB converter uses two inductors of the same size, it is large and has a low power-conversion efficiency ηe due to the DC-offset current of each inductor. Cascaded buck-boost (CBB) converter, along with the CHB converter, has been commonly used in ESSs. Compared with the CHB converter, CBB converter is smaller and has higher ηe because it uses only one inductor L. Recently, research has been actively conducted on bidirectional buck-boost DC-DC converters in discontinuous conduction mode (DCM) because this mode can achieve zero-voltage-switching (ZVS) turn-on of the switches. However, operation in DCM increases the current ripple of L, which affects the output current ripple and increases the output voltage ripple.

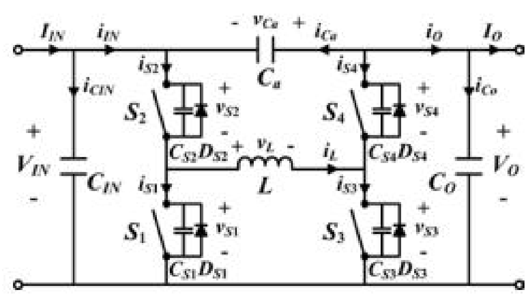

Fig.2.1. Proposed block diagram.

3. PROPOSED SYSTEM

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The proposed converter consists of a conventional CBB converter and an auxiliary capacitor (Ca), and has a symmetric structure with respect to Ca and L. The CBB converter consists of two capacitors (CIN, CO), four switches (S1, S2, S3, S4), and an inductor (L). Four switches (S1, S2, S3, S4) and an inductor (L) control the direction of energy transfer and the ratio between the input voltage and output voltage. Four switches are turned on in the ZVS condition by operating in DCM. Two capacitors (CIN, CO) reduce the output voltage ripple and noise, and an auxiliary capacitor (Ca) reduces the output current ripple by providing a current path.

The proposed converter operates with a fixed switching period TS and controls the voltage gain by changing the duty ratio D of the switches (S1, S2, S3, S4) from 0 to 1. Each switch has four states in six operating conditions created by the energy transfer directions between VIN and VO and the types of operation (buck, boost, and buck-boost), as shown in Table I. Due to the symmetric structure with respect to Ca and L, the operations are separated by only the types of operation in one direction of energy transfer (VIN → VO).

To simplify the analysis of the operation, the following assumptions are made: 1) the inductor and all capacitors are lossless, 2) the voltage ripples of CIN, Ca, and CO are small enough to assume that VIN, VCa, and VO are constant voltage sources, and 3) the converter operates in steady state.

(1) Buck mode When the proposed converter operates in buck mode, it has four distinct operating modes (Mode 1 ~ 4). The equivalent circuits and

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operating waveforms are shown in Fig. 5 and Fig. 6.

Mode 1 (Fig. 5(a), t0 ≤ t ≤ t1) starts when S2 is turned on. At t = t0, S2 achieves ZVS turn-on because the body diode DS2 of S2 is turned on before t = t0. Then, the voltage vL of L becomes VIN – VO, and the current iL of L is expressed as

$$i_L(t)=i_L(t_0)+\frac{V_{IN}-V_O}{L}(t-t_0). \quad (1)$$

The current i_{S2} of S_2 is equal to i_L, so i_{S2} is expressed as

$$i_{S2}(t)=i_L(t_0)+\frac{V_{IN}-V_O}{L}(t-t_0).$$

In this mode, the current iCa of Ca, the current iCo of CO, the output current iO, and the load current IO have the following relations: iO = iCo + IO, iCo = iCa ·CO/Ca, and iO = iL - iCa. Therefore, iCa and iO can be derived as

$$i_{Ca}(t)=\frac{C_a}{C_a+C_O}[i_L(t)-I_O]$$

$$i_O(t)=\frac{C_O}{C_a+C_O}i_L(t)+\frac{C_a}{C_a+C_O}I_O. \quad (2)$$

The voltage v_{Ca} across the auxiliary capacitor C_a is expressed as

$$v_{Ca}(t)=V_{Ca}+\Delta v_{Ca,AC}(t)$$

where V_{Ca} and $\Delta v_{Ca,AC}$ represent the DC voltage and the AC ripple voltage across the C_a, respectively. Because $V_{Ca} >> \Delta v_{Ca,AC}$, v_{Ca} can be approximated as

$$v_{Ca}(t)\approx V_{Ca}=V_O-V_{IN}.$$

Mode 2 (Fig. 5(b), t1 ≤ t ≤ t2) starts when S2 is turned off. At this time, S1 remains in the off state to prevent a shoot-through problem with S1 and S2. In this mode, the output capacitor CS1 of S1 discharges from VIN to 0, and the output capacitor CS2 of S2 charges from 0 to VIN. Shortly after the discharging of CS1 and charging of CS2 are finished, the body diode DS1 of S1 is turned on.

4. SIMULATION RESULTS

Hysteresis control and the switch selector are used to solve this problem. The hysteresis control uses different gains (GL1, GL2, GH1, GH2) for smooth transition between modes, and the switch selector determines the main switch that controls the operation and voltage gain G (= VO / VIN) of the converter in each mode (Fig. 12). The hysteresis control is explained in the following for operating mode transitions. 1) Transition from buck mode to buck-boost mode The transition from buck mode to buck-boost mode occurs at G = GL2 (@ D = Dmax2,bck). For buck-boost mode, S1, S2, S3, and S4 have duty ratios of 1-D, D, D, and 1-D, respectively, and S2 becomes the main switch. The duty ratio D of S2 is decreased from Dmax2,bck to Dmin2,bb so that the proposed converter has a voltage gain G of GL2 in buck-boost mode. 2) Transition from buck-boost mode to boost mode The transition from buck-boost mode to boost mode occurs at G = GH2 (@ D = Dmax2,bb). For boost mode, S1, S2, S3, and S4 have duty ratios of 0, 1, D, and 1-D, respectively, and S3 becomes the main switch. The duty ratio D of S3 is decreased from Dmax2,bb to Dmin2,bst so that the proposed converter has a voltage gain G of GH2 in the boost mode. 3) Transition from boost mode to buck-boost mode The transition from the boost mode to the buck-boost mode occurs at G = GH1 (@ D = Dmin1,bst). For buck-boost mode, S1, S2, S3, and S4 have duty ratios of 1-D, D, D, and 1-D, respectively, and S3 becomes the main switch. The duty ratio D of S3 is increased from Dmin1,bst to Dmax1,bb so that the proposed converter has a voltage gain G of GH1 in the buck-boost mode. 4) Transition from buck-boost mode to buck mode The transition from the buck-boost mode to the buck mode occurs at G = GL1 (@D =Dmin1,bb). For buck mode, S1, S2, S3, and S4 have duty ratios of 1-D, D, 0, and 1, respectively, and S2 becomes the main switch. The duty ratio D of S2 is increased from Dmin1,bb to Dmax1,bck so that the proposed

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converter has a voltage gain G of GL1 in the buck mode. In the opposite energy transfer direction (VO → VIN), the transitions between different operating modes are controlled by the same method.

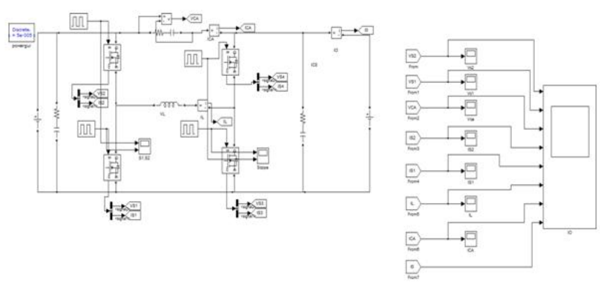

Fig.4.1. Simulation circuit.

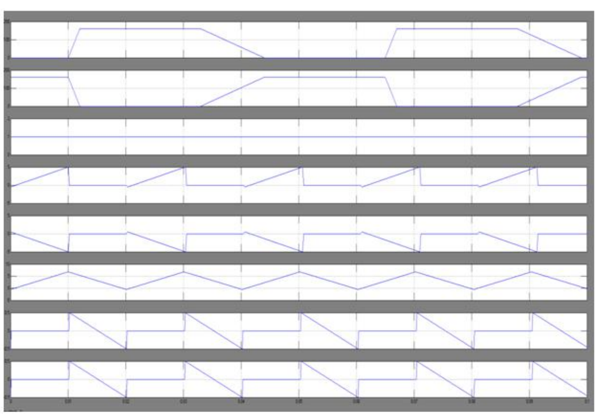

Fig.4.2. Boost converter output results.

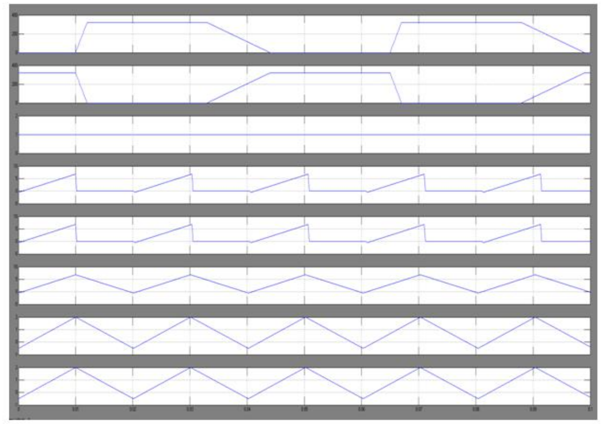

Fig.4.3. Buck converter output results.

CONCLUSION

A new closed loop control of bidirectional buck-boost converter was proposed in this paper. The proposed converter effectively had lower output current ripple than the conventional CBB converter, which was achieved by providing a bypass path for the output current. The reduced output current ripple enabled lower output voltage ripple and higher power-conversion efficiency compared to the conventional converter. The proposed converter had a maximum efficiency of 98% at VIN = 160 V, VO = 80 ~ 320 V, PO = 16 ~ 160 W, and fS = 45 kHz, and the output voltage ripple was less than 5.14 Vp.p. These results show that the proposed converter is suitable for PV-ESS in a smart grid, which requires a closed loop control of bidirectional buck-boost converter with high efficiency and low ripples in the output voltage and current.

FUTURE SCOPE:

The Fuzzy based bidirectional buck-boost converter enhances the stability of the system and improves the dynamic response of the system operating in a better way and it has also effectively enhanced the damping of bidirectional buck-boost converter simulation results.

REFERENCES:

[1] M. Sechilariu, W. Baochao, and F. Locment, “Building integrated photovoltaic system with energy storage and smart grid communication,” IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1607–1618, Apr. 2013.

[2] B. K. Bose, “Power electronics, smart grid, and renewable energy systems,” in Proc. IEEE, vol. 105, no. 11, Nov. 2017.

[3] L. Park, Y. Jang, S. Cho, and J. Kim, “Residential demand response for renewable energy resources in smart grid systems,” IEEE Trans. Ind. Informat., vol. 13, no. 6, pp. 3165–3173, Dec. 2017.

[4] C. S. Lim and K. J. Lee, “Nonisolated two-phase bidirectional DC-DC converter with zero-voltage-transition for battery energy storage system,” Journal of Electrical Engineering & Technology, vol. 12, no. 6, pp. 2237-2246, Nov. 2017.

[5] M. Glavin, P. Chan, S. Armstrong, and W. Hurley, “A stand-alone photovoltaic supercapacitor battery hybrid energy storage system,” in Proc. 13th Power Electron. Motion Control Conf., 2008 (EPE-PEMC 2008), pp. 1688–1695.

[6] J.-J. He, K.-W. Hu, and C.-M. Liaw, "On a Battery/Supercapacitor Powered SRM Drive for EV with Integrated On-board Charger," in IEEE Industrial Technology Conference, Seville, 2015.

ISSN: 2057-5688

[7] S. H. Moon, S. T. Jou, and K. B. Lee, "Performance improvement of a bidirectional DC-DC converter for battery chargers using an LCLC filter," Journal of Electrical Engineering & Technology, vol. 10, no. 2, pp. 742-755, Mar. 2015.

[8] Y. Du, X. Zhou, S. Bai, S. Lukic, and A. Huang, "Review of nonisolated bi-directional DC–DC converters for plug-in hybrid electric vehicle charge station application at municipal parking decks," in Proc. IEEE Appl. Power Electron. Conf., Feb. 2010, pp. 1145–1151.

[9] S. Vazquez, S. M. Lukic, E. Galvan, L. G. Franquelo, and J. M. Carrasco, "Energy storage system for transport and grid application," IEEE Trans. Ind. Electron., vol. 57, no. 12, pp. 3881–3895, Dec. 2010.

[10] M. Ahmadi, M. R. Mohammadi, E. Adib, and H. Farzanehfard, "Family of non-isolated zero current transition bi-directional converters with one auxiliary switch," IET Power Electron., vol. 5, no. 2, pp. 158–165, 2012.