A Novel Bidirectional Soft Switching Dc-Dc Converter

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Abstract: The Bidirectional DC-DC (BDC) Converter topologies plays major role in HEV, RES based system etc., As the demand for BDC is increasing, it should be made more compact with high efficiency. Keeping this in view, this work proposed an efficient BDC using coupled Inductor with reduced switching losses. Further, to improve the dynamic performance of the converter, Fuzzy controller is integrated. The performance of the proposed topology is studied using MATLAB simulation. From the results, it is concluded that the proposed topology exhibits higher voltages gain with reduced switching loss.

Keywords: Bidirectional converter, Proportional Integral Controller, coupled inductor.

1. Introduction

Increase in demand for fuel and environmental protection control have made it necessary to move towards the Renewable Energy Sources (RES). This leads to the transition of internal combustion engine (ICE) vehicles to electric vehicles (EVs) or hybrid electric vehicles (HEVs) is very attractive and desirable, but there are still some serious issues with regard to energy storage technology. In these applications, the combination of batteries and ultra- capacitors are used as an energy storage unit. The battery is connected with the ultra-capacitor through a bidirectional dc/dc converter [1-3]. Thus the designed bidirectional DC-DC converter should accomplish a high power density with low current/voltage ripple. At the same time, the converter should have high efficiency, low cost, low EMI, and compact component size. However, the converter efficiency is reduced at high frequencies due to switching losses. The switching loss can be reduced by soft switching. This soft switching eliminates the losses by limiting the current or voltage at the switching moment and improves efficiency of the converter [4-10].

Hence, this work proposed a new bidirectional converter with reduced switching loss. Thus the proposed converter comprises a half bridge topology with coupled inductor. In this work, the steady state analysis of the proposed topology is explained. From the analysis, it is proven that that the proposed converters possess increased efficiency then the conventional converter.

However, a BDC must provide a regulated DC output voltage under varying input / load condition. Hence, to improve the dynamic performance of the system, this work proposed a robust AI controller namely fuzzy to control the proposed BDC.

2. Proposed Bidirectional Converter

Fig. 2 depicts circuit diagram of the proposed converter. The auxiliary circuit of this BDC comprises coupled inductor and resonant capacitors. This will carry out ZVS condition and hence, the ripple present in the inductor current cancels automatically irrespective of the direction of power flow [11, 12].

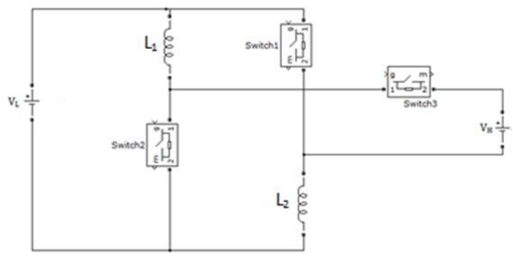

Fig.2 Proposed DC-DC Boost/Buck converter

Proposed converter has two operation modes.

- ✓ Boost mode
- ✓ Buck mode.

Boost Mode of Operation

During boost mode, switch S_2 remain off and S_1 turns on.

Buck Mode of Operation

In step down, Condition of switches are interchanged.

3. Result And Discussion

To validate the performance of the proposed converter, simulations were carried in MATLAB environment and the obtained results are discussed below.

Open Loop Analysis

i. Boost Mode:

Under open loop control, a step change of 5V is applied at the input as shown in Fig.3a.

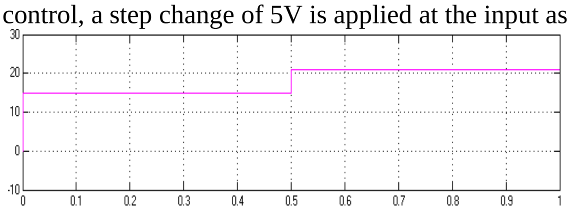

Fig. 3a : Input Voltage

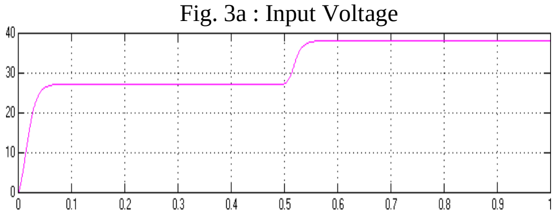

Fig. 3b: Output Voltage

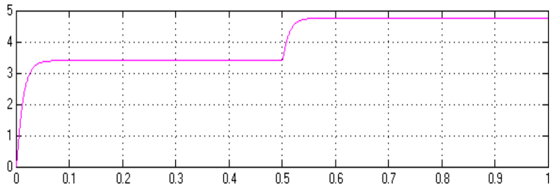

Fig. 3c: Output Current

Fig 3. Analysis under Boost mode of operation

Thus, the obtained output voltage and current during boost operation is depicted in figure 3b and 3c. Similarly, the open loop controlled DC-DC converter operating in buck mode is shown in Fig.4. The variation of input voltage, output voltage and output power are shown in figures 4a, 4b & 4c.

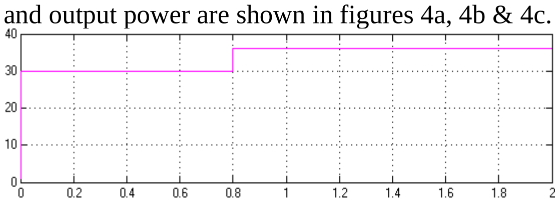

Fig.4a. Input Voltage

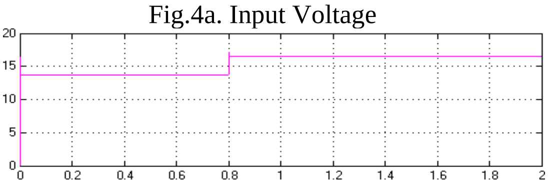

Fig. 4b. Output Voltage

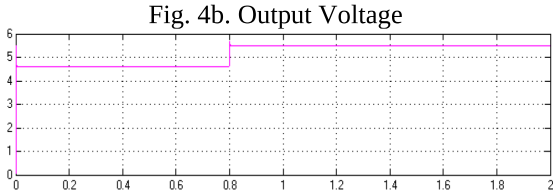

Fig. 4c. Output Current

Fig 4. Analysis under Buck mode of operation

Analysis Under Closed Loop Control

In order to enhance the performance of the proposed converter, controllers are implemented. In this topology, Fuzzy controller is adopted for as a controller for proposed BDC.

Thus, the designed FLC is characterized with

- 5 Triangular MFs using mamdani fuzzy reasoning method.
- Centroid for defuzzification process.

Thus, the output obtained from the fuzzy controller controls the modulating pulses applied to the switches of the converter. Thus, the designed MF for proposed FLC is depicted in fig. 5

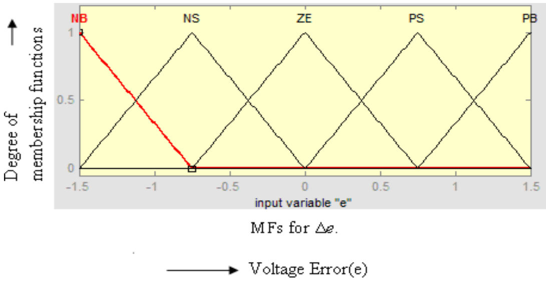

Figure 5a MF (*e*)

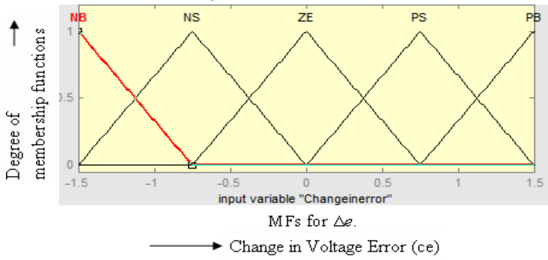

Figure 5b MF (Δ*e)*

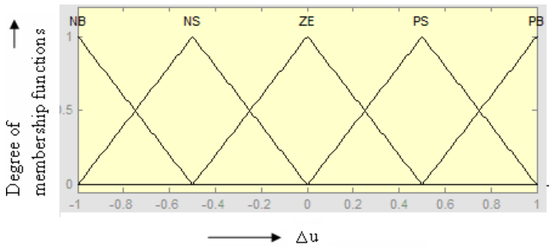

Figure 5c MF (Δu)

Fig 5. Designed MF of proposed FLC

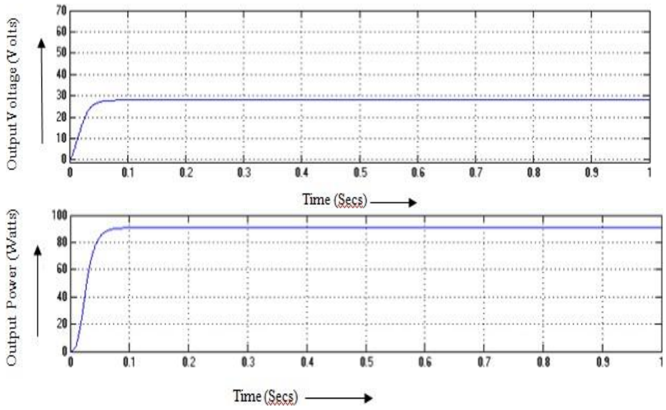

Fig. 6. Analysis of proposed BDC with FLC (Boost Mode)

Figure 5 depicts the output voltage and of the BDC with FLC controller. From the waveform, it is concluded that the proposed FLC controller regulates the output without any overshoot and the time taken for its steady state response is also less when compared to conventional controller.

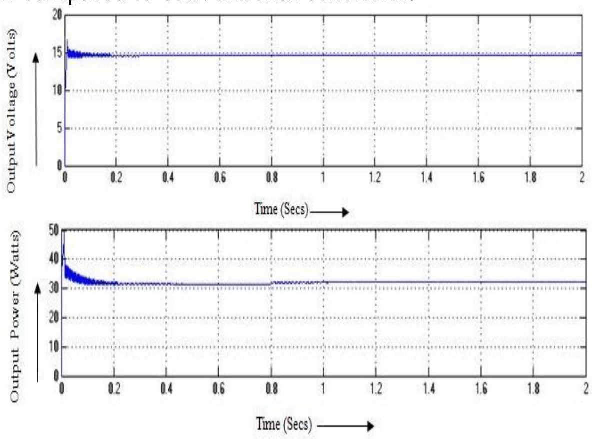

Fig.7 Analysis of proposed BDC with FLC (Buck Mode)

Similarly, the output obtained during buck mode is depicted in figure 7. In the buck mode also, the controller proved its efficiency. Hence, it is concluded that proposed FLC enhances the dynamic performance of the proposed efficiency.

Comparative analysis

Table 1 Measured efficiency in the proposed converter and conventional Bidirectional boost/buck converter.

Converter Type	Mode	Efficiency
Conventional	Boost	90.7%
	Buck	86%
Proposed	Boost	93%
	Buck	90%

Thus the efficiency of the proposed DBC with conventional one is tabulated in Table 1. From the table, it is proven that the proposed BDC exhibits 93% and 90% in boost and buck mode which is higher than that of the conventional one. Hence, it is proven that the proposed converter shows higher efficiency in all modes of operation with less switching loss.

4. Conclusion

A BDC suitable for EV application is designed in this work. It comprises half bridge topology with coupled inductor. In this topology, as ZVS switching is obtained, the loss due to switching gets reduced. similarly, when compared to conventional topology, the proposed controller exhibits higher efficiency. Finally to enhance to dynamic behaviour of BDC, FLC is implemented. From the results, it is evident that this proposed BDC is suitable for EV application.

References

1. A.Amalin Rishma,P.Raja Rajeswari, M.Sasikumar, “High Efficiency Modified Pulse Width Modulation Bidirectional Converters for Medium Power Drives,”IJAIEM, vol. 1, no. 2, pp. 94–100, 2012.
2. Amin Mirzaei, Awang jusoh, Zainal Salam, “Design and Implementation of High Efficiency Non Isolated Bidirectional Zero Voltage Transition Pulse With modulated DC-DC converters,” 2012,Elsevier, Energy 47, pp. 358–369.
3. Baburaja.C and J.Jayakumar, “Transformer less soft switching bi-directional DC-DC Chopper”, International journal of Engineering and Advanced Technology, 2013, vol. 2, pp.391-395.
4. Chuan-Kuei Huang, Hsiau-Hsian Nien,Koan-Yuh Chang and Wen-Jer Chang,,“An Optimal Designed RCD Snubber for DC-DC Converters,” Journal of Marine Science and Technology, Vol. 18, No. 6, pp. 901-906, 2010
5. D.-Y. Lee, M.-K. Kee, D.-S. Hyun, and I. Choy, “New zero-current-transition PWM DC/DC converters without Current Stress,” IEEE Trans. Power Electron., 2003,vol. 18, no. 1, pp. 95–104.
6. Doo-Yong Jung, Sun-Hee Hwang, Young- Hyok Ji, Jung-Hyo Lee, Yong-Chae Jung and Chung-Yuen Won,“Soft-Switching Bidirectional dc-dc Converter with a LC Series Resonant Circuit,” IEEE Trans.Power Electron ,vol. 28, no. 4, pp. 1680– 1690,2013.
7. G. Hua, C. Leu, Y. Jiang, and F. C. Lee, “Novel zero-voltage transition PWM converters,” IEEE Trans.Power Electron., vol. 9, no. 2, pp. 213– 219, Mar. 1994.
8. Ho-Sung Kim, Myung-Hyo Ryu, Ju-Won Back and Jee-Hoon Jung, “High-Efficiency Isolated Bidirectional AC-DC Converter for a dc Distribution System,” IEEE Trans. Power Electron., 2013, vol. 28, no. 4, pp.1642–1654.
9. Hua Han, Yonglu Liu, Yao Sun,Hui Wang and Mei Su, “A Single Phase Current Source Bidirectional Converter for V2G Applications” Journal of Power Electronics, 2014,vol. 14, no. 3, pp. 458-467.
10. Huiqing Wen and BinSu, “Reactive Power and Soft-Switching Capability Analysis of Dual -Active –Bridge DC-DC Converters with Dual-Phase-Shift Control” Journal of Power Electronics, vol. 15, no. 1, pp.18–30, 2015
11. Hyung-Min Ryu , “High Efficient High- Volatge MOSFET Converter with Bidirectional Power Flow Legs”, Journal of Power Electronics, Vol. 14, No. 2, pp. 265- 270, 2014.
12. Jeong-il Kang, Sang-Kyoo Han and Jonghee Han, “Lossless Snubber with Minimum Voltage Stress for continuous Current Mode Tapped-Inductor Boost Converters for High Step-up Applications,” 2014,Journal of Power Electronics, vol. 18, no. 4, pp. 621–631.