ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ANALYSIS OF MULTIPHASE BIDIRECTIONAL NONISOLATED DC – DC CONVERTER FOR HIGH POWER APPLICATIONS

Himanshu* Amit Goriyal
M. Tech Scholar* Dept. of Electrical Engineering, GRD IMT, Dehradun, India
Assistant Professor, Dept. of Electrical Engineering, GRD IMT, Dehradun, India

DOI: 10.5281/zenodo.573524

ABSTRACT
The converter has high efficiency due to soft-switching operation in all Multi bridges. Steady-state analysis of the converter is presented to determine the power flow equations, tank currents and soft-switching region. Dynamic analysis is performed to design a closed-loop controller that will regulate the load-side port voltage and source-side port current. Compared to the traditional full and half bridge bidirectional dc–dc converters for the similar applications, the new topology has the advantages of simple circuit topology with no total device rating (TDR) penalty, soft-switching implementation without additional devices, high efficiency and simple control. These advantages make the new converter promising for medium and high power applications especially for auxiliary power supply in fuel cells and power generation where the high power density, low cost, lightweight and high reliability power converters are required. The operating principle, theoretical analysis, and design guidelines are provided in this thesis. The simulation and the experimental verifications are also presented.

KEYWORDS: DC-DC Converter, Bidirectional, Non Isolated, High Power.

INTRODUCTION
The most of production of energy is from the fossil fuels like coal, oil and natural gas. However these sources are limited and face number of challenges which include rising prices, security concerns over dependence on import of fossil fuels from limited countries in number and also had created environmental problem leading to the change in climatic conditions (Global warming) because of the release of green house gases on its combustion. Because of the limited in nature, fossil fuels they are decreasing very rapidly with high utilization. Also in last few decades the petroleum prices have shown large hike in price and the pollution caused by the nontraditional resources of energy had seek the interest of scientific research scholars towards traditional energy sources. So in order to overcome these problems and reduce the change in climatic conditions, the renewable energy sources are likely to be used for energy generation and storage that have emerged as potential alternatives.

MATERIALS AND METHODS
Power Circuit Topologies and Control
From its origin in early 60's, the field of power processing of power electronics has been considered with solving the challenges pertaining to the processing of electrical power from one form to another while striving for efficiencies approaching100%. To achieve power processing efficiencies approaching 100%, light weight switched mode DC/DC power circuit topologies have been developed. The DC-DC converter presented in[1] is based on MPPT controlled DC-DC converter. The converter presents the high gain in the output and has higher efficiency and is proposed for solar water pumping systems. In this paper the constant voltage maximum power point tracking is applied to obtain the signal of specific duty cycle to operate the switch of DC-DC converter. In[2] the single phase Bi-Directional DC-DC converter (BDC) is developed for solar power application for charging and discharging the battery based on power availability. It operates as boost converter during the sun is not available in order to feed the load and acts as buck during the sun time to store the energy. The small signal analysis is carried out in both modes in MATLAB. By using this small signal analysis the controllers are designed for both modes of operation in order to generate PWM signal for the controlling of switching operation of BDC .

The[9] has presented the three phase transformer isolated DC-DC converter with the phase shift modulation, which features reduced transformer ratio, reduction in the passive components including output filter and input DC bus capacitor using three phase interleaving, eliminate inductor current ripples and operate under soft switching. The propose converter has been analyzed, simulated and implemented in hardware. The achieved efficiency of this converter is above 96%.

[10]Presents the bi directional DC-DC converter with the unified controller is employed with complementary switching between upper and lower switches. Both the buck and boost modes are controlled with the unified current controller. The average current mode is proposed to avoid current sensing related issues. It provides smooth mode transition capability for both charging and discharging.

The paper[13] proposes a single switch three diode DC-DC pulse width modulated converter, which operates in constant frequency and constant duty cycle. The proposed converter posses high voltage gain and small voltage ripples at the output and also is simple in structure and control. Moreover, the reduction in voltage stress on the diodes allows the Schottky diodes to be used for alleviating the problem of reverse-recovery current, as well as decreasing the switching and conduction losses. The results of prototype rated 40W operating at the frequency of 94KHz is provided to verify its performance.

In[16] a bidirectional dual full-bridge dc-dc converter has been developed which is controlled with a unified soft switching scheme and soft start capability shown in Fig.1. The bridge on one side, preferably the lower voltage side, is current-fed, while that on the other side of the bridge is voltage fed. In order to limit the transient voltage across the current-fed bridge circuit and realize zero-voltage-switching in boost mode operation, while achieving hybrid zero-voltage zero-current switching (ZVZCS) for the voltage-fed bridge circuit in buck mode operation, a simple voltage clamp branch, which is composed of an active switch with its anti-paralleled diode and a capacitive energy storage element in series, is placed across the current-fed bridge circuit. In buck mode operation, the voltage-fed bridge is controlled by the well-known phase shift pulse width modulation (PWM). The clamping branch is activated only briefly each time after an on duty cycle is executed and the on-time of the clamp switch is just long enough to reset the transformer leakage current to zero and achieve ZVZCS operation even under maximum load current.

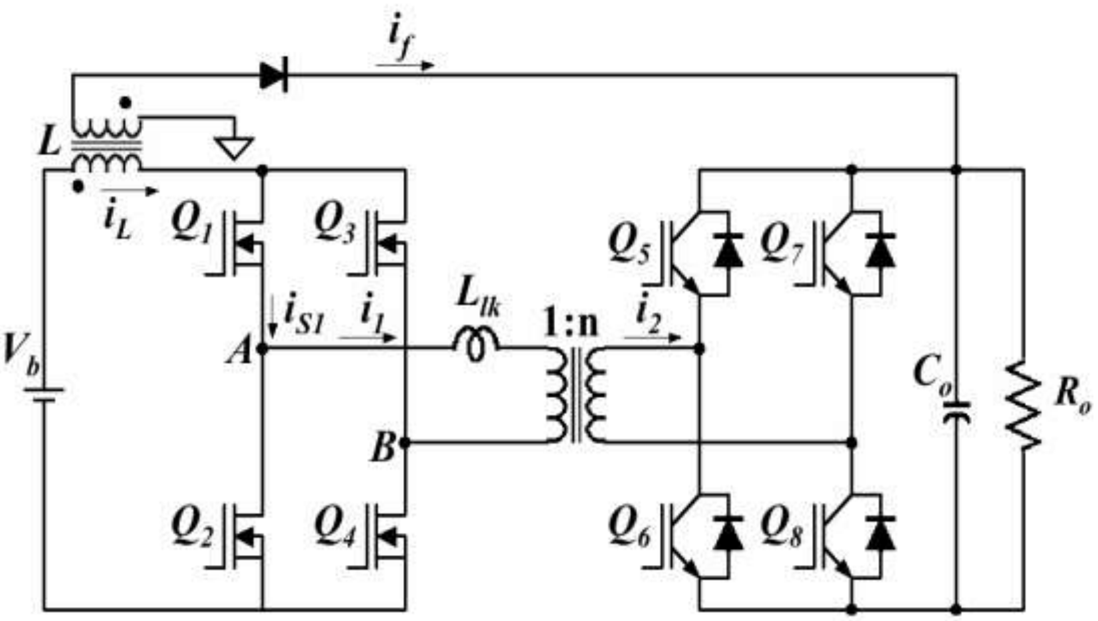

Figure: A bidirectional full-bridge DC-DC converter with unified soft- switching scheme

A novel interleave DC-DC boost converter with high voltage gain and Bi-directional operation is presented in[17]. To obtain high voltage gain using the indicated cell secondary windings are coupled to the inductors. The converter is highly efficient and is having low stress in switches.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

In [18] the synchronous buck converter operates under zero voltage switching ZVS with variable frequency and interleaved control of bidirectional power flow is presented. The method uses slave phase delay control and hysteretic control' which requires instantaneous current to determine the switching action.
The step up switching mode converter with high voltage gain is introduced in [19]. In this paper the switched capacitor circuit can achieve any voltage ratio and is to be operated at low duty cycle. Therefore it avoids the reverse recovery problem

In[10, 21] the proposed full bridge/push pull bi directional DC-Dc converter is able to perform adequate charge and discharge operation between the low voltage, high current side and high voltage low current side. Furthermore conduction losses are reduced. The voltage current surge is drastically reduced by ZVZ operation with loss less snubber capacitor in HV side.

In[22] the half bridge PWM DC-DC converter is proposed provides low and well defined parasitic inductance that makes it useful in large applications. The[23] presents the paper that proposes a dual half bridge DHB ZVS Bi-directional DC-DC converter with high power density. The small signal model of ZVS DHB bi directional DC-DC converter has been described. It offers least component count, wide soft switching operation range and less control demand.

Gap Finding
In[1] the DC-DC boost converter described is applied at low power applications. This proposed converter is not applicable for higher power applications because of more switching stresses and losses faced at higher power applications. The Bi-directional DC-DC converter in[2] is having low gain and is single phase designed. So because of this the proposed converter faces high current ripples at the higher power applications and thus reduces the efficiency of the system.

In[7,14] the addition of transformer implies the additional cost and losses and also makes the system bulky. In the paper[8] as the three phase shift increases the converter losses also increases and the two switch legs require 12 power switches which increases switch losses. The main drawback of the converter in[9] is its complexity and increase in losses due to the circulating currents.

Buck Converter
Buck converter is also called as step down DC to DC converter. This type of converter uses two switches, transistor and a diode, capacitor and inductor as shown in figure

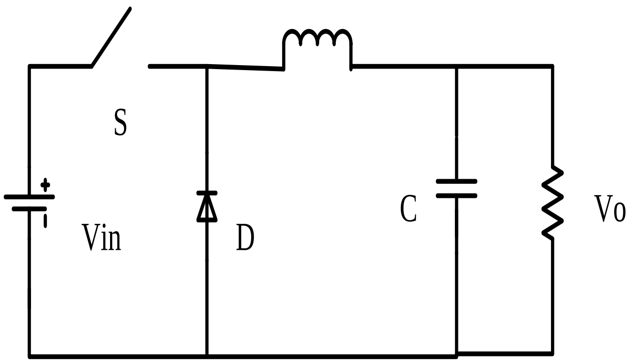

Figure: Circuit diagram of buck converter.

Since the power switch(S) current pulses from the zero to I_o at each switching cycle, thus the input current in the converter is pulsating or discontinuous and because of the output current supplied by inductor/capacitor the output current of the converter is continuous or non pulsating. The D is the freewheeling diode/fly back diode that provides return path for the inductor current. Figure 5.2 shows the waveforms of buck converter.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

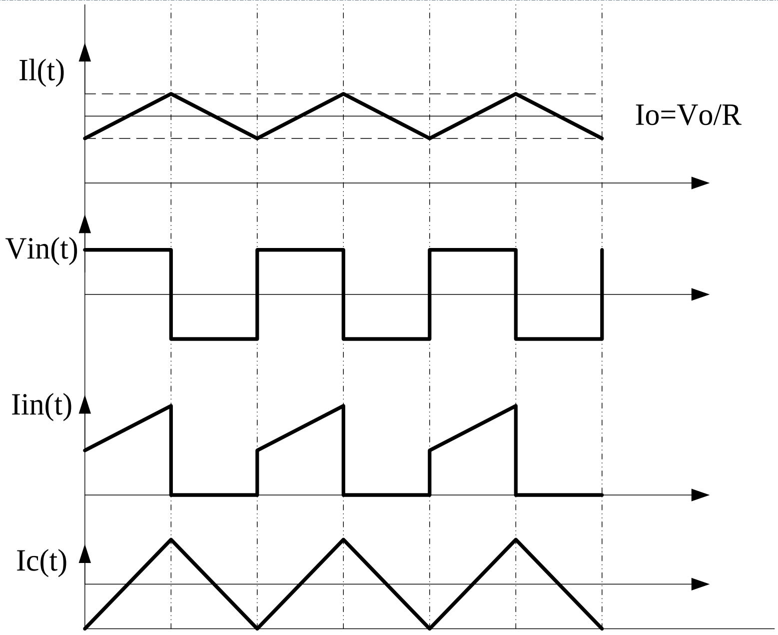

Figure: Voltage and current waveform in buck converter.

Operation of Buck Converter and design equation

Mode I: when the switch is ON: $0 \leq t \leq Dt_s$

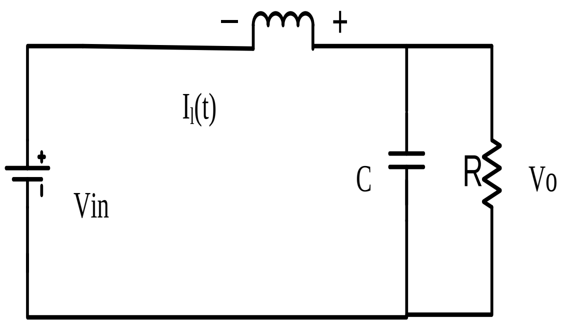

Figure: Buck converter in mode I.

$$\frac{dI_l(t)}{dt} = \frac{V_{in} - V_o}{L}$$

$$I_l(t) = \left[\frac{V_{in} - V_o}{L}\right] t + I_l(0)$$

At the end of the mode-I, $t = Dt_s$

$$I_l(Dt_s) = \left[\frac{V_{in} - V_o}{L}\right] Dt_s + I_l(0)$$

$$I_l(max) = \left[\frac{V_{in} - V_o}{L}\right] Dt_s + I_l(min)$$

Mode II: when the switch is OFF: $Dt_s \leq t \leq t_s$

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

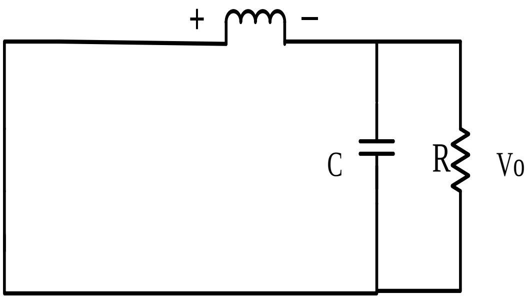

Figure: Buck converter in mode II.

$$\frac{dI_l(t)}{dt} = \frac{-V_o}{L}$$

$$I_l(t) = \left[\frac{-V_o}{L}\right] t + I_l(Dt_s)$$

At the end of mode II;t= t_s

$$I_l(t) = \left[\frac{-V_o}{L}\right](1-D)t_s + I_l$$

$$I_l(min) = \left[\frac{-V_o}{L}\right](1-D)t_s + I_l(max)$$

Adding 1 & 2; we get

$I_l(max) + I_l(min) =$

$$\left[\frac{V_{in}-V_o}{L}\right] Dt_s + I_l(max) + I_l(min) + \left[\frac{-V_o}{L}\right](1-D)t_s$$

$$\left[\frac{V_{in}-V_o}{L}\right] Dt_s = \left[\frac{V_o}{L}\right](1-D)t_s$$

$$DV_{in} - DV_o = V_o - DV_o$$

Therefore for buck converter

$$Gain = \frac{V_o}{V_{in}} = D < 1$$

From the above equation 5.10 it is confirmed that the output voltage will be adjusted by adjusting the duty cycle D.

The input and Output Currents are

During ON period, $I_l(t)=I_{in}$

During OFF period, $I_{in}(t)=0$

$$Average\ input\ current = \frac{1}{t}\left[\frac{I_l(max)+I_l(min)}{2}\right]$$

$$I_{in} = D\left[\frac{I_l(max)+I_l(min)}{2}\right]$$

Average output current =average of inductor current

.

$$I_o = \left[\frac{I_l(max)+I_l(min)}{2}\right]$$

$$I_l(max) + I_l(min) = \frac{2V_o}{R} = \frac{2DV_{in}}{R}$$

$$(max) + I_l(min) = \frac{V_{in}-V_o}{l}Dt = \frac{(1-D)V_{in}(Dt)}{l}$$

$$I_o = \frac{1}{2}[I_l(max) + I_l(min)] = \frac{V_o}{R} = \frac{DV_{in}}{R}$$

$$I_l(max) = \frac{DV_{in}}{R} + \frac{(1-D)V_{in}(Dt)}{2l}$$

$$I_l(min) = \frac{DV_{in}}{R} - \frac{(1-D)V_{in}(Dt)}{2l}$$

Inductor current ripple

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

$$\Delta I = I_l(max) - I_l(min)$$

$$\Delta I = \frac{(1-D)DtV_{in}}{l} = \frac{T_{off}V_o}{l}$$

Therefore current ripple can be minimized by decreasing the switching frequency 'T' and increasing the inductance.

$$\frac{\Delta I}{I_l} = \frac{(1-D)DtV_{in}}{l}\frac{R}{DV_{in}} = \frac{(1-D)t}{l}R$$

$$since, \frac{I_{in}}{I_o} = D \; and \; \frac{V_o}{V_{in}} = D$$

Therefore, assuming the converter is lossless

$$P_o = P_{in}$$

To operate designed buck converter in continuous conduction mode, the load current should be usually above certain level of 5 to 10% of full load. The power stage usually defines the input voltage range, load current and output voltage. This helps in suggesting the value of inductor as a design parameter in order to maintain CCM. Since, I_l (min)=0, therefore

$$DV_{in}\left(\frac{1}{D} - \frac{(1-D)}{RL_{Cri}}\right) = 0$$

$$L_{cri} = \frac{(1-D)TR}{2}$$

The Output Voltage Ripple of the converter are derived as
During turn ON time

$$\Delta I = I_l(max) - I_l(min) = (1-D)T\frac{DV_{in}}{L}, \quad 0 \le t \le Dt$$

$$I_{C_1}(t) = I_l(min) - I_o + \frac{\Delta I}{DT}t$$

$$I_{C_1}(t) = I_l(min) - \left[\frac{I_l(max) + I_l(min)}{2}\right] + \frac{\Delta I}{DT}t$$

$$I_{C_1}(t) = \frac{I_l(min) - I_l(max)}{2} + \frac{\Delta I}{DT}t$$

$$I_{C_1}(t) = \frac{-\Delta I}{2} + \frac{\Delta I}{DT}t = \Delta I\left(\frac{t}{DT} - \frac{1}{2}\right)$$

During turn OFF time, $0 \le t \le Dt$

$$I_{C_2}(t) = I_l(max) - I_o - \frac{\Delta I}{DT}(t - DT)$$

$$I_{C_2}(t) = I_l(max) - \left[\frac{I_l(min) + I_l(max)}{2}\right] - \frac{\Delta I}{DT}(t - DT)$$

$$I_{C_2}(t) = \frac{\Delta I}{2} - \frac{\Delta I}{(1-D)T}(t - DT)$$

Therefore the Capacitor voltage is given by

$$V_{c_1}(t) = \frac{1}{c}\int_0^t I_c(t)\,dt$$

$$V_{c_1}(t) = \frac{1}{c}\int_0^{DT} \Delta I\left(\frac{t}{DT} - \frac{1}{2}\right)dt + V_{c_0}$$

$$V_{c_1}(t) = \frac{\Delta I}{c}\left[\frac{t^2}{2DT}\right]_0^{DT} - \frac{1}{2c}DT + V_{c_0}$$

$$V_{c_1}(t) = \frac{\Delta I}{2c}DT - \frac{1}{2c}DT + V_{c_0} = \frac{DT}{2c}(\Delta I - 1) + V_{c_0}$$

$$V_{c_2}(t) = \frac{1}{c}\int_{DT}^{T}\int_0^t I_{c_2}(t)\,dt + V_c(DT)$$

$$V_{c_2}(t) = \frac{1}{c}\int_{DT}^{T}\left[\frac{\Delta I}{2} - \frac{\Delta I}{(1-D)T}(t - DT)\right]dt + V_c(DT)$$

$V_{c_2}(t) =$

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

$$\frac{1}{c}\left[\frac{\Delta I}{2}(1-D)T-\frac{\Delta I}{(1-D)T}\left(\frac{t^2}{2}-\frac{DT^2}{2}\right)+\frac{\Delta I}{(1-D)T}(1-D)T\right]+V_c(DT)$$

$$V_{c_2}(t)=\frac{\Delta I}{c}\left[\frac{T}{2}-\frac{DT}{2}-\frac{T}{2}-\frac{DT}{2}+DT\right]+V_c(DT)$$

$$V_o=\frac{1}{T}\left[\int_0^{DT}V_{c_1}(t)dt+\int_{DT}^{T}V_{c_2}(t)dt\right]$$

$$V_o=\frac{\Delta I}{Lc2}(1-2D)T+V_c(0)$$

$$V_c(0)=DV_{in}\left[1-\frac{(1-D)(1-2D)}{2LC}T\right]$$

$$V_c(min)=V_{c_1}(t)\Big|,t=\frac{DT}{2}$$

$$V_c(min)=-\frac{\Delta I}{8C}+V_c(0)$$

$$V_c(max)=V_{c_2}(t)\Big|,t=\frac{(1-D)T}{2}$$

$$V_c(max)=\frac{\Delta I}{8C}(1-D)T+V_C(DT)$$

$$\Delta V_o=V_c(max)-V_c(min)=\frac{V_o}{8LCf^2}(1-D)$$

Therefore,

$$Ripple=\frac{\Delta V_o}{V_o}=\frac{(1-D)}{8LCf^2}$$

Boost converter

The boost converter is a power converter also called as step up converter with an output DC voltage greater than input voltage. The circuit diagram of boost converter is shown in figure 5.5 given below.

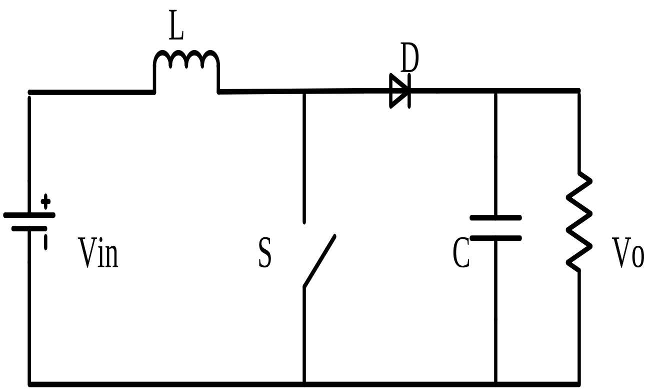

Figure: Circuit diagram of boost converter.

RESULTS AND DISCUSSION

The figure shows the simulink model of the proposed multiphase BDC in which we have used two BDC in parallel operation. The model of the multiphase BDC has been developed in MATLAB 2012a. In this figure the battery is connected to the both converters which supplies power to the load.

The simulation shown in figure 7.2 and 7.3, shows the response of BDC in both directions. In figure 7.3, the transient response of the BDC in multiphase is improved as compared to single BDC in figure 7.2. The rise time of BDC in figure 7.3 is also faster than the single BDC in figure 7.2. From these results we also get that the ripples at the input and output side of converters in different modes are reduced in the multiphase BDC. Therefore due to this reduced current and voltage ripples at the input and output sides, the size of inductor and capacitor filter will be reduced.

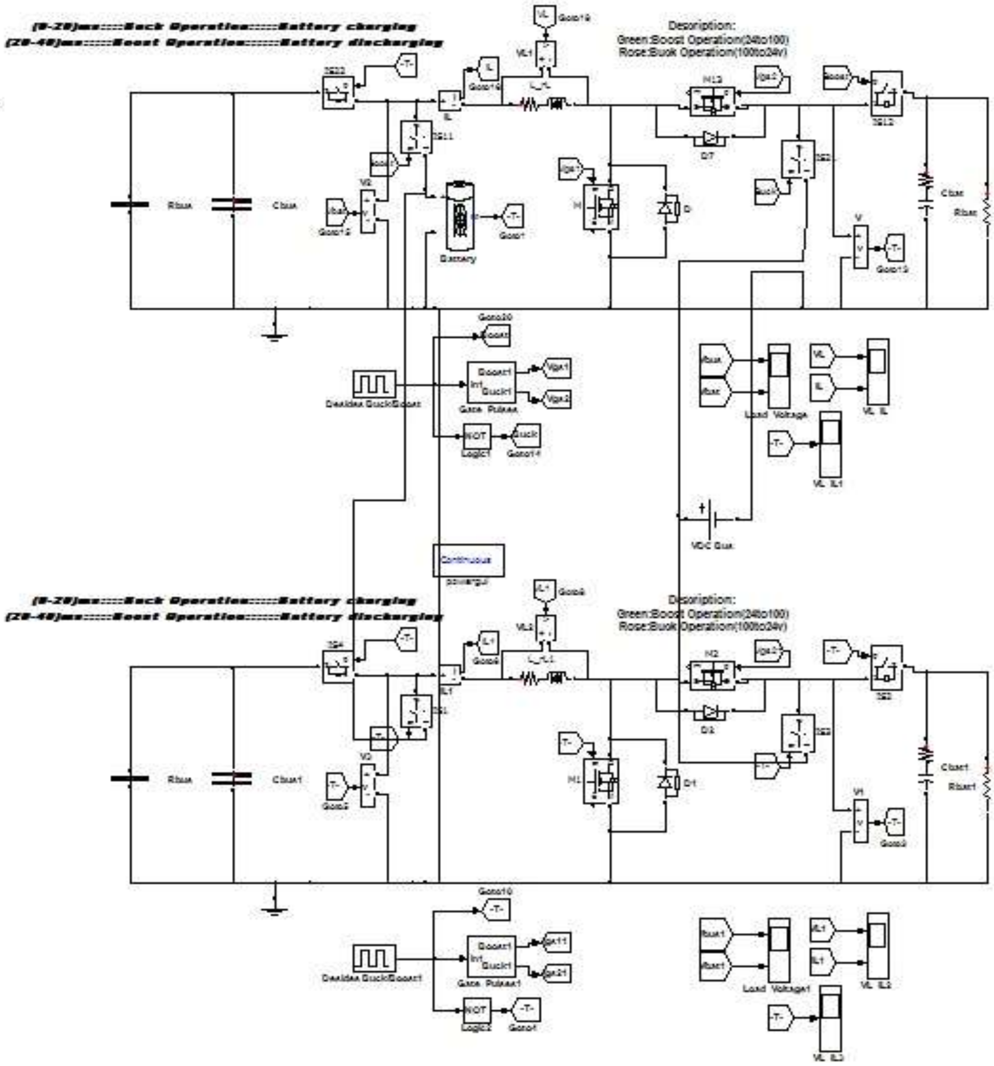

Figure: Simulink model of proposed BDC.

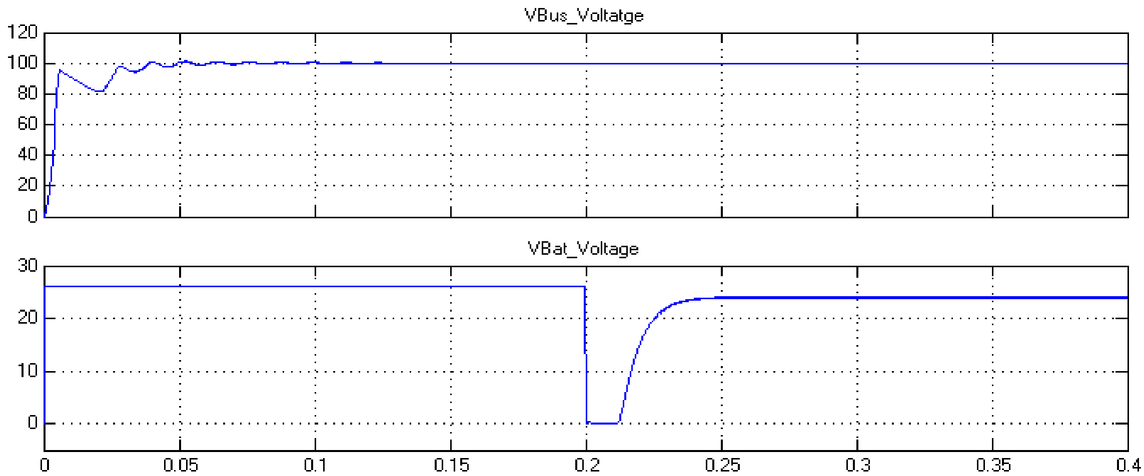

Figure: Voltage waveforms of BDC either sides(Bus side and battery side) in single phase BDC.

CONCLUSION

On the basis of the previous work of short-timescale transient processes in the full bridge DC–DC converter, this paper studied the dead-band effect quantitatively. It also proposed a control strategy to compensate the phase-shift difference caused by the dead-band, thereby avoiding disadvantages of the traditional PI controller and enhancing the preciously proposed phase-shift predictor. With the proposed control algorithm, the dead-band effect can be compensated precisely and the dynamic response of the system can be significantly improved. Preliminary experiments showed good coincidence with the theoretical analysis and simulation. Further work needs to be expanded in the high-voltage and high-power applications.

REFERENCES

1. K.Wang *et al.*, "Bidirectional dc to dc converters for fuel cell systems," in *Proc. IEEE Workshop Power Electron. Transport*, 1998, pp. 47–51.
2. "Design, implementation, and experimental results of bidirectional full-bridge dc-dc converter with unified soft-switching scheme and soft-starting capability," in *Proc. IEEE Power Electron. Spec. Conf.*, 2000, pp. 1058–1063.
3. T. Reimann, S. Szeponik, G. Berger, and J. Petzoldt, "A novel control principle of bidirectional dc-dc power conversion," *Proc. IEEE Power Electron. Spec. Conf.*, pp. 978–984, 1997.
4. R. W. DeDonker, D. M. Divan, and M. H. Kheraluwala, "A three-phase soft- switched high power density dc-dc converter for high power applications," *IEEE Trans. Ind. Applicat.*, vol. 27, pp. 63–73, Jan./Feb. 1991.
5. E. Deschamps and I. Barbi, "A flying-capacitor ZVS 1.5 kW dc-to-dc converter with half of the input voltage across the switches," *IEEE Trans. Power Electron.*, vol. 15, pp. 855–860, Sept. 2000.
6. H. L. Chan, K. Cheng, and D. Sutanto, "An extended load range ZCS-ZVS bidirectional phase-shift dc–dc converter," in *Proc. 8th Int. Conf. Power Electron. Variable Speed Drives*, 2000, pp. 74–79.
7. H. Chung *et al.*, "A ZCS bidirectional flyback dc–dc converter using the leakage inductance of the coupled inductor," in *Proc. IEEE APEC Conf.*, 2000, pp. 979–985.
8. M. Jain, P. K. Jain, and M. Daniel, "A bidirectional dc–dc converter topology for low power application," in *Proc. IEEE Power Electron. Spec. Conf.*, 1997, pp. 804–810.
9. C. Ianello *et al.*, "Full bridge ZCSPWMconverter for high-voltage highpower applications," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 38, pp. 515–526, Apr. 2002.
10. S. Hamada *et al.*, "A novel zero-voltage and zero-current switching PWM dc–dc converter with reduced conduction losses," *IEEE Trans. Power Electron.*, vol. 17, pp. 413–419, May 2002.
11. J. Zhang *et al.*, "A novel ZVS dc–dc converter for high power applications," in *Proc. IEEE APEC Conf.*, 2002, pp. 635–640
12. R. Ayyanar *et al.*, "Novel soft-switching dc–dc converter with full ZVSrange and reduced filter requirement. I. Regulated-output applications," *IEEE Trans. Power Electron.*, vol. 16, pp. 184–192, Mar. 2001
13. R. Torrico-Bascop *et al.*, "A double ZVS-PWM active-clamping forward converter: nalysis, design, and experimentation," *IEEE Trans. Power Electron.*, vol. 16, pp. 745–751, Nov. 2001.
14. R. W. DeDonker and J. P. Lyons, "The auxiliary resonant commutated pole converter," in *Proc. IEEE IAS Annu. Meeting Conf.*, 1990, pp. 1228–1235.
15. A. Fiel *et al.*, "MOSFET failure modes in the zero-voltage-switched fullbridge switching mode power supply applications," in *Proc. IEEE APEC Conf.*, 2001, pp. 1247–1252.
16. H. Watanabe and H. Matsuo, "Analysis of a novel soft-switching dc–dc converter with low output voltage," in *Proc. IEEE PESC*, Galway, Ireland, June 18–23, 2000.
17. H. Watanabe, H. Hatakeyama, and T. Ishikawa, "Boost half-bridge power supply," tech. Rep. IEICE, EE98-17, July 1998.
18. E. Romanello and I. Barbi, "A new isolated phase-shift controlled nonpulsating input-output current converter," in *Proc. IEEE PESC*, 2001, pp. 237–242.
19. "An isolated ZVS-PWM active clamping nonpulsating input and output dc–dc converter," in *Proc. IEEE PESC*, 2000, pp. 205–210.
20. J. Zeng, J. Ying, and Q. Zhang, "A novel DC/DC ZVS converter for battery input applications," in *Proc. IEEE APEC*, vol. 2, 2002, pp. 892–896.
21. C. Choi, C. Kim, F. S. Kang, and S. J. Park, "Zero voltage and zero current switching single-stage power factor correction ac–dc half-bridge converter with low cost," in *Proc. IEEE IECON*, vol. I, 2000, pp. 313–319.

22. J. Y. Lee, G.W. Moon, and M. J. Youn, "Design of high-quality AC/DC converter with high-efficiency based on half-bridge topology," in *Proc. IEEE PESC*, June 1998, pp. 1054–1060.
23. J.-S. Lai and D. J. Nelson, "Energy management power converters in hybrid electric and fuel cell vehicles," in *Proc. IEEE Ind. Electron.,* Taipei, Taiwan, Volume 95, Issue 4, April 2007, pp. 766 – 777.
24. H. Tao, A. Kotsopoulos, J.L. Duarte, and M.A.M. Hendrix, "Multi-input bidirectional dc-dc converter combining dc-link and magnetic-coupling for fuel cell systems," in *Proc. IEEE IAS*, Hong Kong, China, Volume 3, Oct. 2005, pp. 2021 – 2028.
25. H. Tao, J. L. Duarte, and M. A. M. Hendrix, "High-power three-port three-phase bidirectional dc-dc converter," in *Proc. IEEE IAS*, Manchester, UK, Sept. 2007, pp. 2022 – 2029.
26. H.-J. Chiu, H.-M. Huang, L.-W. Lin, and M.-H. Tseng, "A multiple-input dc/dc converter for renewable energy systems," in *Proc. IEEE ICIT*, Hong Kong, China, Dec. 2005, pp. 1304 – 1308.
27. G.-J. Su, J. P. Cunningham, and L. Tang, "A Reduced-part, triple-voltage dc-dc converter for electric vehicle power management," in *Proc. IEEE PESC*, Orlando, FL, June 2007, pp. 1989 – 1994.
28. T. Mishima, E. Hiraki, T. Tanaka, and M. Nakaoka, "A new soft-switched bidirectional dc-dc converter topology for automotive high voltage dc Bus architectures," in *Conf. Rec. of IEEE VPPC*, Windsor, UK, Sept. 2006, pp. 1 – 6.
29. H. Matsuo, W. Lin, F. Kurokawa, T. Shigemizu, and N. Watanabe, "Characteristics of the multiple-input dc-dc converter," *IEEE Trans. Ind. Electron.*, Vol.51, No.3, June 2004, pp. 625-630.
30. Y. Hu, J. Tatler, and Z. Chen, "A bidirectional dc-dc power electronic converter for an energy storage device in an autonomous power system," in *Proc. IEEE IPEMC*, Xi'an, China, Volume 1, August 2004, pp. 171 – 176.
31. J.L. Duarte, M. Hendrix, and M. G. Simoes, "Three-port bidirectional converter for hybrid fuel cell systems," *IEEE Trans. Power Electron.,* March 2007, pp. 480-487.
32. H. Matsuo and F. Kurokawa, "New solar cell power supply system using a Boost type bidirectinal dc-dc converter," *IEEE Trans. Ind. Electron.,* Volume IE-31, Issue 1, Feb. 1984, pp. 51 – 55.

CITE AN ARTICLE

H., & Goriyal, A. (2017). ANALYSIS OF MULTIPHASE BIDIRECTIONAL NONISOLATED DC – DC CONVERTER FOR HIGH POWER APPLICATIONS. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *6*(5), 321-330. doi:10.5281/zenodo.573524