Retraction

Retraction: Experimental Validation with FPGA Controller to A Switched-Capacitor Interleaved Bidirectional DC-DC Converter for A Renewable Energy Storage Systems (J. Phys.: Conf. Ser. 1916 012012)

Published 23 February 2022

This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

Retraction published: 23 February 2022
Experimental Validation with FPGA Controller to A Switched-Capacitor Interleaved Bidirectional DC-DC Converter for A Renewable Energy Storage Systems

Ramu Bhukya¹, KalyanSagar Kadali², Asapu Siva³, Y T R Palleswari¹, S Pragaspathy² and S Saravanan³

¹ Department of Electrical & Electronics Engineering, Shri Vishnu Engineering College for Women, Bhimavaram, Andhra Pradesh A.P India,
² Department of EEE, Vishnu Institute of Technology, Bhimavaram, A.P India,
³ Department of EEE, B.V.Raju Institute of Technology, Narsapur, Telangana, India
¹ramu1632@gmail.com

Abstract. A Switched-Capacitor Interleaved Bidirectional DC-DC Converter is used to increase the voltage gain and to decrease the voltage gain to a renewable energy storage system is illustrated with an experimental setup using FPGA controller. This interleaved construction is accepted on this converter of the less-voltage side to decrease the content of the ripple which flows through the side which is low-voltage of this converter. This type of series-connection structure is accepted to achieve the more voltage gain on the higher voltage side/less voltage gain on the high-voltage side of this converter structure. Also, this type of structure is need in a bidirectional synchonic rectification performance are carried out without requiring any additional experimental setup for the same operation, and with this type of converter’s structure its performance is improved. Besides, with this structure, here we can analyze the converter's current ripple characteristics and also, the operating principles of voltage, and current stresses. Finally, a power rating of kW experimental setup was constructed to analyze this converter's performance for different ranges under various voltage gain ranges in between the voltage ranges of 50V to 120V on the low-voltage side of this converter while other voltage 400V is kept constant. Under this condition, this converters' efficiency obtained maximum value is 95.21% in the increase mode whereas when the converter is operating in the decrease mode of operation, the efficiency obtained value is 95.30%. The investigational validation values are verified for increase and decrease modes of performance.

1. Introduction
At present days, universally energy disaster and global warming is the biggest crisis for pollution of environmental degradation. Also, day by day the fossil fuels are decreasing drastically which leads to energy crisis. So, in view of this situation, the alternate energy systems which are not harmful to the environment and non-pollutant systems are like solar, wind, tidal etc., are play the vital role to overcome this crisis. With these energy systems, energy storage and maintaining a constant voltage at the output side is a big task. To meet this point, there are several topologies are proposed to analyzethe
characteristics of the energy storage systems in the absence of regular power supply. In this paper, with a experimental setup is made to analyze the performance of a switched capacitor interleaved dc–dc bidirectional converter for a renewable systems of energy storage system with FPGA controller. [1] discussed on current & voltage stress, also about auto-current-sharing mechanism illustrated. In [2] the discussion on two capacitors which are connected in series that are used for division of voltage on highvoltage side. These voltages that are divided then charged from and on the low-voltage side these voltages are discharged by a modified interleaved two-phase buck-boost converter, respectively. In [3], a energy storage unit is used in a power flow controlling of a bidirectional dc–dc converter is illustrated. In paper [4], to obtain more power conversion with parallel connection of an interleaved structure with a bi-directional three-level DC–DC converter is illustrated. However, [5] The stress of voltage on the converter switches on H.V.side is half and then, dc voltage ratios of conversion of the converter is half and twice that of the conventional bidirectional boost/buck in boost and buck modes, respectively. In [6], about energy storage system which is connected in a parallel-resonant of a bidirectional isolated DC-DC converter (PR-IBDC) for less ripple content in current is discussed. In [7], bidirectional DC-DC converter has a higher gain for Base Transceiver Stations (BTS) of the grid integration of telecommunication is illustrated. [8] In renewable energy systems, current is unstable compared to convention power system. So, battery is an important device to store the energy and is transfer from lower voltage side to higher voltage is discussed. In [9], about low voltage stress on power semiconductor switch, less ripple content for a bidirectional non-isolated DC-DC converter with high voltage-gain to a interleaves structure is discussed. In [10], an autonomous vehicles auxiliary power in bidirectional in 400V to 12V with a power rating of 6kw is discussed. In [11], management of energy with a dynamic control in ANN inverter with a hybrid renewable system connected from a Zsource switched converter.

2. Proposed Topology
To study the performance characteristics of this converter topology, some practical conventions are made in their working performance, which are illustrated as: (a) the power devices of all switches of the semiconductors and components of capacity to store the energy which type of devices are considered for this converters are preserved as perfect model, and this converter is operating in the continuous conduction mode (CCM) and; (b) Every capacitance is hefty sufficient that each voltage of capacitor in each switching cycle is assumed to be constant. Figure 1 shows the Circuit diagram

![Circuit diagram](image)

Figure 1. Circuit diagram.

2.1. Operation Modes
When the power streams to the lower voltage side to the higher voltage side of the converter, the yield \( V_{\text{high}} \) is increased from \( V_{\text{low}} \) to power semiconductor switches are \( Q_1 \) & \( Q_2 \), then the counter equal diodes are \( Q_3 \), \( Q_4 \) & \( Q_5 \). The connection lies for \( d_1 \) & \( d_2 \) is composed is \( d_1 = d_2 = \text{d}_{\text{boost}} \), here the duty cycles of \( Q_1 \) and \( Q_2 \) are \( d_1 \) and \( d_2 \) respectively. The path for the current flow in the proposed topology when working in the increase mode.
2.2. Increase Mode of operation

State-I

In this state of operation, the switch of power semiconductor $Q_1$ is, in on condition, then $Q_2$ is, in off condition. Then diode $Q_3$ of counter-parallel is in on condition; during this period of time the counterparallel diodes $Q_4$ and $Q_5$ are in off state. The working condition of the converter in this state of operation is shown in below Figure 2. In this state of operation of the converter, the power is transferred from the lower side of source $V_{low}$ to the inductor $L_1$. During this time, $C_1$ is being charged by inductor $L_2$, at the same time, $C_2$ & $C_3$ are discharging. These $C_2$ & $C_3$ are linked in series to supply, then the power for the load is transferred to the higher voltage side of the converter.

![Figure 2. Equivalent Circuit of state-I.](image)

State-II

Here, the operation of state-II is, the switches $Q_1$ & $Q_2$ power semiconductors are in off state condition. Then, the diodes are $Q_3$ & $Q_4$ are connected in the counter-parallel connection are switched to on condition; during this period of time, the anti-parallel diode is $Q_5$ in the condition off. The state-II of the projected topology current directions in this converter is shown in below Figure 3. Then $L_1$ and $L_2$ Inductors are starts discharging. At the same time, the capacitor $C_1$ is charging from inductor $L_2$, while capacitor $C_3$ is discharging. Then, from the DC source $U_{low}$, through Inductor $L_1$ and capacitor $C_3$, output power flows to the higher side of load.

![Figure 3. Equivalent Circuit of state-II.](image)

2.3. Step-Down Mode State-I

The power switch semiconductor $Q_1$ is in conduction on, during this time $Q_4$ & $Q_5$ are in conduction off. The parallel counter diode of $Q_1$ is conducted, and the counter-across diode of $Q_2$ is switched off. The path flow of current the projected converter is shown in Figure 4. $C_2$ & $C_3$ are DC source charged $U_{high}$ in series. During this time, inductors $L_1$, $L_2$ & $C_1$ are discharging to transfer power to the load which is connected in the l.v.side. Figure 5 shows the Experimental setup. Figure 6 shows the Simulink model of boost converter.
3. Experimental setup

3.1 Simulink circuit for boost converter in step-up mode operation

3.1.1 Output waveform. The result of boost mode obtained in the projected converter in the simulation execution is shown in below figures 7 and 8. Here on X-axis voltage is expressed in volts and on Y-axis time is expressed in seconds. When the input voltage 120V is applied in the l.v.side and we received the output in the h.v.side as 388.1V. This output voltage is approximate more than 3.3 times the applied voltage in the low voltage side.
3.2 Simulink circuit of buck converter in the decrease mode of operation

3.2.1 Output waveform. Here the output waveform of the buck converter model is presented in the simulation is shown in the below figure 9. Where on the X-axis, voltage expressed as in volts and on Y-axis time is expressed as in seconds. When 400 V is applied as an input in the higher voltage side and the voltage output obtained is 150.2V. This voltage is measured on the low voltage side as output voltage, nearly 2.6 times the applied voltage at the input voltage side.

![Figure 7. Simulation results for boost converter.](image)

**Figure 7.** Simulation results for boost converter.

![Figure 8. Simulink model of buck converter.](image)

**Figure 8.** Simulink model of buck converter.

![Figure 9. Simulation results for buck converter.](image)

**Figure 9.** Simulation results for buck converter.
3.3 Experimental validation in step-up mode

The hardware kit/experimental setup of this proposed converter is tested under step-up mode as well as step-down mode with different conditions of duty cycles for various input voltages.

3.3.1 Boost mode (<0.5). Here, as the converter is connected to function in the boost mode of operation with the voltage input is given at lower voltage side and output is collected at higher voltage side when circuit is operating under <0.5 as duty cycle. When we apply various voltages like 5V, 7.5V, 10V are given as input voltages at lower side, and we measure the output voltages at the higher side of voltage as nearly five times the respected given input voltage. Figure 11 shows the hardware output waveform for 5V.

For the given input voltage = 5V, the obtained output voltage = 23.6V is shown in figure 10.

![Figure 10. Experimental results for boost converter measured in DSO.](image)

3.3.2 Experimental Execution

![Figure 11. hardware output waveform for 5V.](image)
3.3.3 Buck mode (<0.5). Here when the converter is connected in the buck mode operation for the voltage input is given at the side of higher voltage and output is taken at low voltage side when the converter is operated under <0.5 as duty cycle. When the various voltages are like 10V, 20V, 30V are given as input voltages at the higher side of voltage and at the lower side of voltage, the obtained output voltages are nearly half of the respected given voltage input.

For the given input voltage = 10V, the obtained output voltage = 4.2V is shown in below figure 12.

![Figure 12. Experimental result for a buck converter with 10V measured in DSO.](image)

4. Conclusion

Here we have been illustrated a switched-capacitor with an interleaved bidirectional DC-DC converter topology by an experimental setup with FPGA controller is validated under boost mode and buck mode for various duty cycle ranges for different input voltage values. This experimental setup is performed in the increased (boost) mode, decreased (buck) and in between the ranges of 0 to 0.5 duty cycles to achieve an extensive voltage-gain range in buck mode of operation and for more than 0.5 duty cycles to achieve an extensive voltage-gain range in boost mode of operation. In adding to this performance, this converter topology has the benefits of the stress in voltage on power semiconductor devices and capacitors is low, and in the low-voltage side, there current ripples are present. Hence, to improve the power quality with reduced ripple content, here a bidirectional an interleaved structure with a switched-capacitor DC-DC Converter topology is illustrated to achieve a higher step-up/stepdown gain in voltage on the either side of the converter with FPGA controller. With this experimental setup converter, we get voltage gain is more at the given input voltage is nearly five times.

References

[1] Wang Y F, Xue L K, Wang C S, Wang P and Li W Aug 2016 Interleaved High-Conversion-Ratio Bidirectional DC–DC Converter for Distributed Energy-Storage Systems—Circuit Generation, Analysis and Design, *IEEE Transactions on Power Electronics* 31(8), pp 5547–61.

[2] Liao S H, Teng J H and Chen S W Dec 2016 Bidirectional DC–DC converter with high step-down and step-up voltage conversion ratio, 2016 *IEEE 2nd Annual Southern Power Electronics Conference (SPEC)*.

[3] Lee Y S, Ko Y P, Cheng M W and Liu L J Aug 2013 Multiphase Zero-Current Switching Bidirectional Converters and Battery Energy Storage Application, *IEEE Transactions on Power Electronics* 28(8) pp 3806–15.

[4] Kan Z, Li P, Yuan R and Zhang C April 2018 Interleaved three-level bi-directional DC-DC converter and power flow control, 2018 3rd *International Conference on Intelligent Green Building and Smart Grid* (IGBSG).

[5] Molavi N, Esteki M, Adib E and Farzanefar H Feb 2015 High step-up/down DC-DC bidirectional converter with low switch voltage stress, The 6th *Power Electronics, Drive Systems & Technologies Conference (PEDSTC2015).*
[6] M. Suganya and H. Anandakumar, Handover based spectrum allocation in cognitive radio networks, 2013 International Conference on Green Computing, Communication and Conservation of Energy (ICGCE), Dec. 2013. doi:10.1109/icgce.2013.6823431. doi:10.4018/9781-5225-5246-8.ch012

[7] Haldorai and A. Ramu, An Intelligent-Based Wavelet Classifier for Accurate Prediction of Breast Cancer, Intelligent Multidimensional Data and Image Processing, pp. 306–319.

[8] Lu Y J, Liang T J, Lin C H and ChenK H Oct 2017 Design and implementation of a bidirectional dc-dc forward/flyback converter with leakage energy recycled, 2017 Asian Conference on Energy, Power and Transportation Electrification (ACEPT).

[9] Zhang Y, Gao Y, Li J and Sumner M May 2018 Interleaved Switched-Capacitor Bidirectional DC-DC Converter with Wide Voltage-Gain Range for Energy Storage Systems, IEEE Transactions on Power Electronics 33(5) pp. 3852–69.

[10] Zhu L, Bai H, Brown A and McAmmond M Jun 2020 Two-stage vs One-stage Design for A Bidirectional 400V/12V 6kW Auxiliary Power Module in Electric Vehicles, 2020 IEEE Transportation Electrification Conference & Expo (ITEC).

[11] Santhoshi B K, Mohanasundaram K and Kumar L A Feb 2021 ANN-based dynamic control and energy management of inverter and battery in a grid-tied hybrid renewable power system fed through switched Z-source converter, Electrical Engineering.