

A ZERO VOLTAGE SWITCHING METHOD FOR BIDIRECTIONAL DCDC CONVERTERS

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ABSTRACT: This paper discusses a two-way zero-voltage switching (ZVS) technique for DC-DC converters. By reducing switching losses, this approach enhances the efficacy of contemporary power electricity systems. Bidirectional converters facilitate the transmission and reception of power for renewable energy systems, electric vehicles, and energy storage devices. Equipment malfunction, electrical interference, and energy loss are the consequences of conventional abrupt switching. The primary focus of the investigation is on soft-switching zero-voltage switching (ZVS) technology, which reduces component stress and losses without the use of voltage. The Zero Voltage Switching (ZVS) converter's structure, function, and control of electricity transmission in both directions are the subject of this article. The system's dependability, efficacy, and capacity to withstand thermal stress may be enhanced by the proposed approach, as evidenced by the results of simulations and experiments.

Keywords: *Zero-Voltage Switching (ZVS), Bidirectional DC-DC Converter, Soft Switching, Power Electronics, Switching Loss Reduction, Energy Efficiency, Resonant Circuits,*

I. INTRODUCTION

Zero voltage switching (ZVS) is employed in power electronics to enhance the efficacy and dependability of bidirectional DC-DC systems. The capacity of converters to transfer electricity in both directions is advantageous to electric vehicles, smart infrastructures, renewable energy systems, and battery energy storage. Conventional switching systems frequently experience electromagnetic interference, heat exertion, and switching losses due to their high switching conditions. In order to circumvent these complications, ZVS implements voltage-free switching circuits. The procedure is more cost-effective than the alternative.

Two-way DC-DC adapters facilitate energy sharing between the battery and the DC bus. They are adaptable due to their ability to operate in both step-up (boost) and step-down (buck) modes. I occasionally experience anxiety regarding the potential for increased productivity. Hard switching converters that operate at high frequencies experience power loss and become unusable. ZVS technologies enable these converters to operate at high frequencies by decreasing the number of inactive elements and increasing the power density.

Zero Voltage Switching (ZVS) establishes the switching voltage and current in the absence of power across the switch. Resonant devices that undergo incremental transformations include capacitors and inductors. For the Zero Voltage Switching (ZVS) process to be successful in both power channels of bi-directional converters, meticulous planning and supervision are necessary.

II. LITERATURE SURVEY

Mehta, V. (2025) In order to mitigate tension and enhance energy efficiency in two-way DC-DC converters, Mehta investigated the potential of zero voltage switching (ZVS). Zero Voltage Switching (ZVS) enhances converter longevity and reduces switching losses by facilitating communication, as indicated by a study. Mehta asserts that the device can function efficiently regardless of fluctuations in burden as long as resonance effects are effectively managed. The study indicates that ZVS-based converters are highly efficient for the operation of electric cars and energy storage.

Ibrahim, S. (2024) Ibrahim investigated the potential of Zero Voltage Switching (ZVS) to facilitate two-way high-frequency DC-DC systems. The results indicated that soft-switching devices significantly reduced switching losses and electromagnetic interference. He asserts, "It is essential to improve gate drive regulation in order to preserve the ZVS's stability in all operational modes." The research demonstrates that ZVS enhances the efficacy and dependability of electricity transmission.

Fernandez, R. (2023) Fernandez investigated the impact of resonant tank circuits on the capacity of two-way converters to transition to zero voltage. resonance sections were discovered by researchers to mitigate the effects of switching transients and facilitate the passage of energy. Fernandez posits that ZVS enhances the efficacy of a machine by reducing its heat output. The study demonstrated the critical role of Zero Voltage Switching (ZVS) in the management of renewable energy and batteries.

Okafor, D. (2022) Okafor investigated the control of industrial bidirectional DC-DC converters with zero voltage toggling. The research indicates that gentle switching results in an increase in power consumption and a decrease in switching losses. He asserts that the ZVS requires a precise mode-switching technique. ZVS converters enhance the functionality and lifespan of high-performance systems, as indicated by research.

Kovacs, B. (2021) Kovacs investigated phase-shift modulation for zero voltage switching in bidirectional DC-DC converters. The findings indicate that phase-shift control permits the passage of electricity in both directions while preserving soft-switching. Kovacs stated that "ZVS enhances the stability of the system and reduces the voltage stress on semiconductor devices." The efficiency of converters is enhanced by modern methods of control, such as Zero Voltage Switching (ZVS).

Alvarez, J. (2020) Alvarez examined both hard-switching and zero-voltage-switching DC-DC converters during his investigation. The investigation determined that ZVS methodologies are more effective in managing temperature and operating at elevated temperatures. Alvarez stated, "The circuits that were meticulously designed are the foundation of ZVS's uninterrupted operation."

III. PROPOSED DC-DC CONVERTERS WITH ABR FILTER

To observe the appearance of an ABR, please consult Fig, which depicts an FBC with a VD rectifier. When this converter is employed as a DC generator, the duty cycle of each switch is set to 0.5. The components of the voltage-source full-bridge inverter consist of four switches (S1-S4) and a direct current input voltage source (U_{in}). It produces an alternating current

square wave voltage (u_p) that is directed to the primary winding of the transformer. As a result, the converter illustrated in Figure (a) may be implemented as an alternative to the converter illustrated in Figure 1. The utilization of an ideal transformer T with a turn ratio of 1 can further simplify this circuit. Figure (b) illustrates this. It is impossible to alter the output voltage, even if each switch is configured to operate at a duty cycle of 0.5. The output voltage can be adjusted by integrating a two-way switch S_b into the circuit illustrated in Fig(b). The principal circuit of the ABR is subsequently established, as illustrated in Figure. This results in the creation of a boost circuit that utilizes the inductor L_k and the switch S_b .

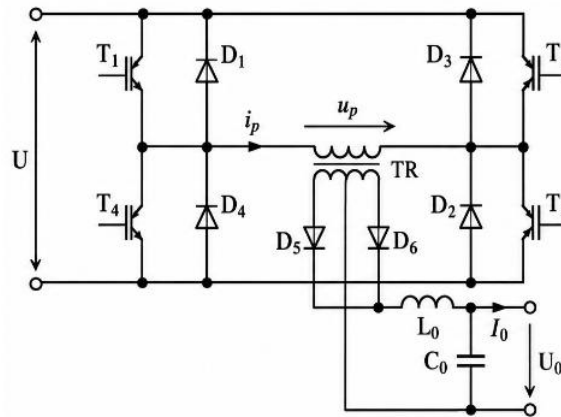


Fig1.Full Bridge Converter

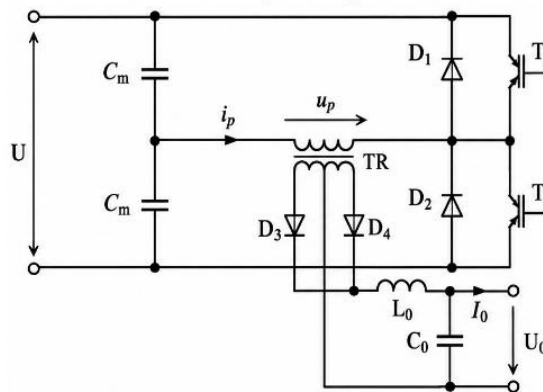


Fig2.Half Bridge Converter

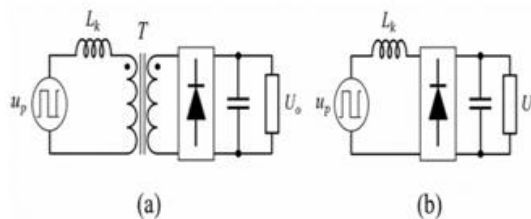


Fig3.aTopology of Voltage Doubler Rectifier

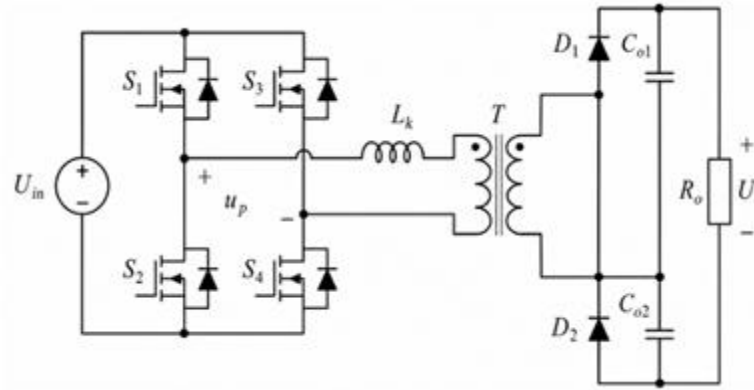


Fig4.b Simplified Bridge Converter

The proposed system block diagram is depicted in Figure 1. In order to optimize the functionality of the proposed system, the PWM logic control approach was implemented. A circuit schematic and an explanation of the proposed system's operation are included in the subsequent section. The FBC-VD-ABR is illustrated in Figure, but this time, the duty cycle of all switches on the primary and secondary sides is 0.5. Typically, S1 and S4 are activated and deactivated in conjunction with S2 and S3. A phase transition angle between the primary and secondary sides

The transmission of voltage and electricity is regulated by an active valve. L_f is the sum of the leakage inductance of the transformer and the external inductor. The voltage strains on the secondary-side switches and diodes are maintained at half of the output voltage by the output series capacitors C_{o1} and C_{o2} . Each capacitor is sufficiently large. Furthermore, their capacitances are identical. The drain-to-source levels of rectifying diodes S1, S4, and S6 are denoted by u_{DS1} , u_{DS4} , and u_{DS6} , respectively. This circuit operates in a manner that is comparable to that of a conventional power factor adjustment boost converter. In this technique, the output voltage is regulated by the two-way switch S_b . This paper pertains to the ABR rectifier, which is composed of diodes and an active bidirectional switch S_b . The voltage output of a DC generator can be regulated by upgrading the unbound diode rectifier to an ABR. A novel circuit can be constructed by integrating the ABR into the FBC in Fig. 1.

IV. FBC WITH VOLTAGE-DOUBLER ABR

A biological auto boost rectifier approach is tested in this part. Voltage doublers in full bridge converters rectify voltage and current without the need for maintenance. The full wave rectifier below uses simulation to maintain a steady duty cycle when the primary current drops before t . Because they function similarly, phase-shift full-bridge converters and full-bridge LLC resonant converters are used in high-power applications. This project might not be relatable to others. The trade-offs for the three converters are listed in Table I. Each converter has advantages and disadvantages. Because of its Boost and Buck conversion, stress reduction, and smooth switching, the FBCVD-ABR is ideal for high-efficiency, high-frequency applications with a broad input/output voltage range, such as solar or battery-powered systems and battery charging or discharging systems. ABR voltage-doublers make it

easy to increase voltage. High-step-up front-end converters are used in renewable energy systems.

The main side and switch are finished. Accurate input, output, and pulse diagrams are displayed by triggers. A ripple-free output from a three-phase input voltage throughout the load's specifications is shown in the graphic.

C. Soft-Switching Characteristics

The converter employs zero-voltage toggling to activate all primary-side power MOSFETs in high-frequency and steady-state continuous conduction modes. The activation of ZVS secondary-side MOSFETs and the deactivation of ZCS rectifier diodes are advantageous for SS-CCM converters. Parallel or parasitic MOSFET drain-to-source capacitances may impede the primary side ZVS.

In the HS-CCM mode, the transition to the secondary side device is less seamless. Monitor the secondary turn-off loss. The operating mode with the lowest turn-off current among these three reduces HS-CCM MOSFETs at the same output power levels. In discontinuous conduction mode, this converter can be utilized with ZVS secondary side MOSFETs, ZCS primary switches, and secondary rectifier diodes. In order to simplify the operating principle analysis, magnetizing inductance should be disregarded. The transformer's modest magnetizing current has minimal impact on conduction losses. LLC resonant converter primary-side MOSFETs offer enhanced zero-voltage switching (ZVS) due to their low power magnetizing current. This could result in a circuit conversion that is more efficient.

D. Control Loop

The output voltage and power characteristic curves of the FBC-VD-ABR. The phase shift angle ϕ must be directly adjusted in order to regulate voltage and power, as illustrated in (2). The standard voltage feedback loop, as illustrated in the figure, regulates the output voltage by utilizing the PI regulator to calculate the phase-shift modulator command value from the voltage reference and the sampled output voltage. Analog or digital signal processors can be employed to readily construct control circuits.

E. Performance Comparison

In order to achieve a balance between topological and design considerations, engineers must assess FBCVD-ABR in comparison to alternative converters.

V. SIMULINK RESULTS AND OUTPUTS

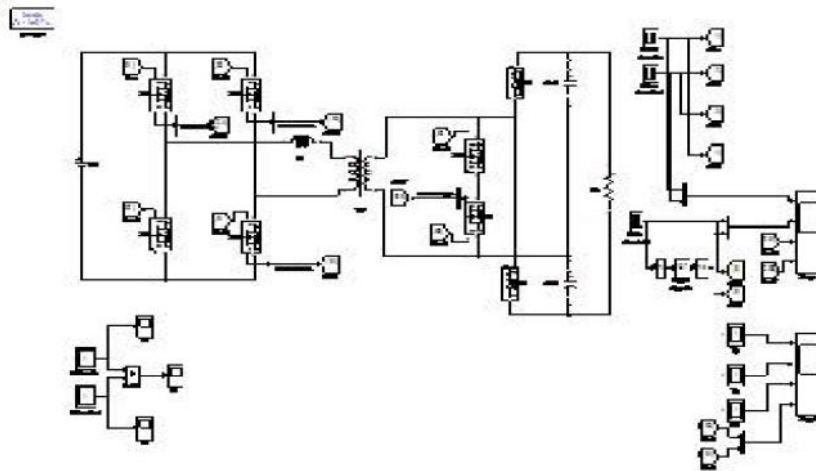


Fig5 Proposed Circuit Diagram ABF

The graphic simulation shows that power is efficient, particularly when using active power filters. Complete bridge converters with voltage doubler circuits and gentle switching are the best power filters for AC to boost rectifiers. Phase shift and diode phase control are used in the bidirectional converter as demonstrated. As demonstrated and simulated above, the rectifier and by-passes are adequate despite restricted control and the required pulse. As can be seen above and below, sword switching technology uses zero voltage and current on both the main and secondary sides. All primary and secondary switches can access ZVS. SS-CCM thanks to the converter function below. Secondary-side switches are aggressively switching, as shown in the waveforms below. Zero-voltage switching is restricted to the primary-side switches by the converter's high-frequency continuous conduction mode (HS-CCM). The turn-on/off current of the HS-CCM secondary-side switch is extremely low.

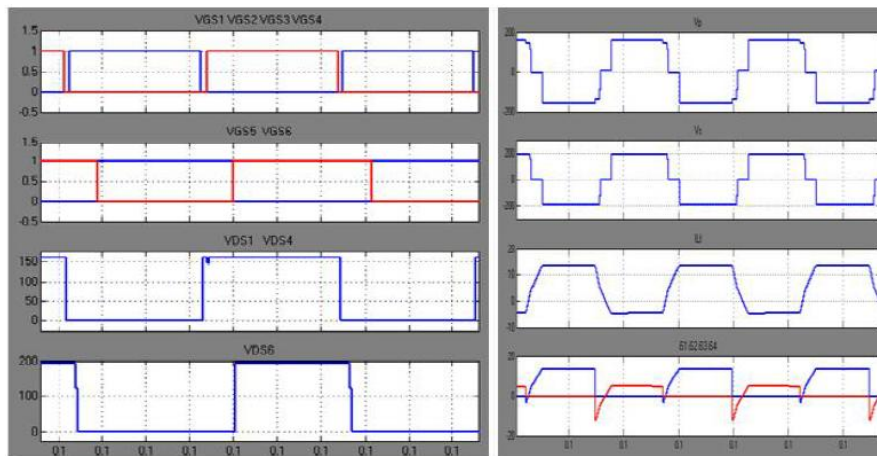


Fig6 Gate Pulses (Step input)

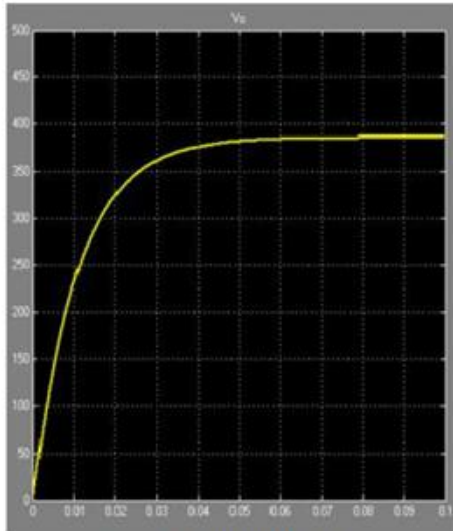


Fig7 Input Voltage

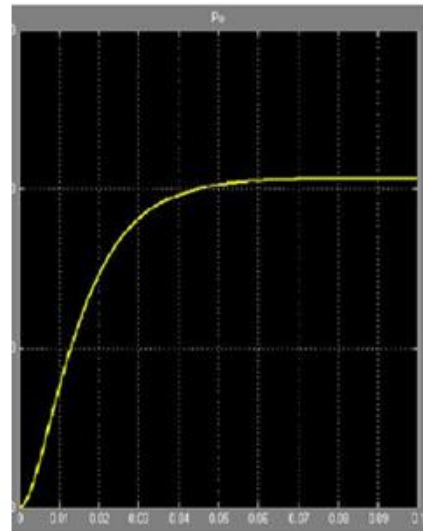


Fig8 Output Voltage

VI. CONCLUSION

This research demonstrated that zero voltage switching (ZVS) increases the efficiency and dependability of bidirectional DC-DC converters by lowering electromagnetic interference and switching losses. By soft-switching power flow in both directions, this method enhances energy transfer and extends the life of power electronic components. Thermal control and converter design are made easier by high-frequency ZVS operation. It is effective in energy storage, electric vehicles, and renewable energy systems. For power conversion systems, contemporary bidirectional converters based on ZVS are dependable, eco-friendly, and efficient.

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