Advanced Research and Development Journal
ISSN: Applied | Volume 1 Issue 1 | October-December 2025 | Inaugural Edition | ARD-007
www.ardjournal.com | DOI:

AN EFFICIENT SNUBBER-BASED SOFT-SWITCHING STRATEGY FOR BIDIRECTIONAL ISOLATED FULL-BRIDGE CONVERTERS

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ABSTRACT: The bidirectional isolated full-bridge converter (BIFBC) is extensively utilized in energy storage systems, electric vehicles, and renewable energy interfaces because to its capability to transfer power in both directions while maintaining galvanic isolation. However, typical converters experience significant switching losses, electromagnetic interference, and component stress due to hard-switching, particularly at elevated switching frequencies. This paper examines the utilization of active and inactive snubber circuits to facilitate soft-switching in BIFBC topologies, hence addressing these issues. Passive snubbers consist of capacitors and inductors. Their resonance components modify the converter's operation, facilitate energy recovery, and reduce voltage stress. Active snubbers enhance the soft-switching range and improve system efficiency across diverse load circumstances by recovering all energy dissipated through regulated switches. The study examines the impact of many factors, including design characteristics, switching transitions, and loss mitigation measures, on the overall performance of the converter. Passive snubbers remain attractive for straightforward and cost-effective designs. Simulations and comparative analyses indicate that active snubbers perform more effectively and induce reduced switching stress. To optimize soft-switching techniques in contemporary bidirectional isolated full-bridge converters, the findings illustrate the trade-offs among dynamic performance, efficiency, and complexity.

Index Terms: *Bidirectional, snubbers, soft switching.*

1. INTRODUCTION

When the power goes out, it's crucial to have batteries that use green direct current (DC) sources to keep electronics running.

Modern energy systems rely on bidirectional isolated full-bridge converters (BIFBCs) for a variety of tasks, such as powering electric vehicles, storing energy in batteries, integrating renewable sources, and providing uninterrupted power. They can handle high power levels, allow power to flow in both directions, and offer galvanic isolation, making them very versatile. Increased switching losses, electromagnetic interference (EMI), and device stress are some of the major problems with traditional full-bridge converters when they operate in hard-switching conditions. As switching rates rise in an effort to shrink designs, these problems become more pressing. To work around these problems and make converters more efficient and reliable, engineers often use soft-switching techniques like Zero-Voltage Switching (ZVS) and Zero-Current Switching (ZCS).

It is common for the DC bus voltage to be much greater than the voltage of the battery. When charging or discharging a battery, a bidirectional adaptor is necessary. Fuel cell and electric

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vehicle propulsion systems once made extensive use of bridge-type bidirectional isolated converters. It is common practice to increase output power using a tandem full-bridge layout that has high- and low-side boost and buck designs. Component stress, switching losses, and electromagnetic interference noise are all increased when diode reverse-recovery current and MOSFET drain-source voltage are applied simultaneously, which decreases the device's reliability. A large voltage spike will occur during the switching shift because of the isolation transformer's leakage inductance. The voltage spike can be mitigated by pre-exciting the faulty inductance to coincide with the current sent by the inductor.

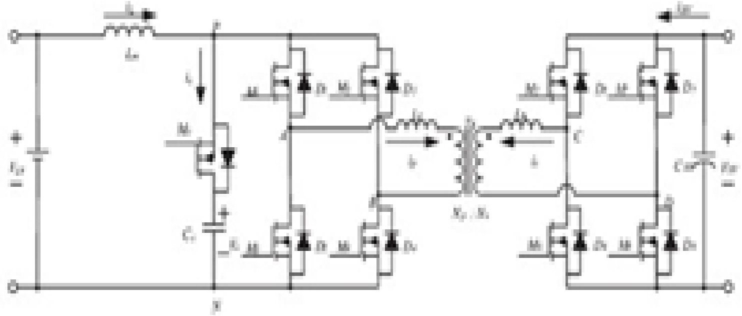

Fig.1. An active clamp snubber, bidirectional operation, and electrical separation characterize this DC-DC converter.

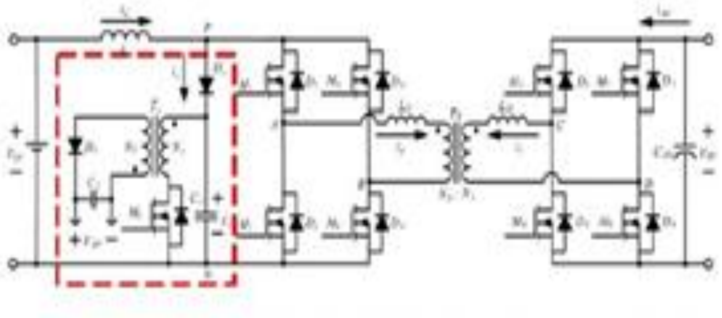

Fig.2. A separated DC-DC converter that is bidirectional and has a type A flyback snubber built in.

2. EXISTING SYSTEM

As shown in Figure 4, there is a full-bridge converter that can switch smoothly in both directions. An active flyback circuit and two capacitor-diode snubbers make up the system. You can apply two types of modifications: step-up and step-down. A voltage-fed switch bridge is shown in Figure 4. In terms of flyback snubbers, one is operational on the low voltage side and two are inoperable on the high voltage side. Here, the process of decreasing the strength of an electrical current is called "step-down conversion." This technique uses Lm inductors to filter the output. But the step-up version does the exact opposite.

When the isolation transformer (TP) is turned on and off, the current differential between the current-fed inductor current (iL) and the leakage inductance current (iP) is reduced by the snubber capacitor (CC) and the diode DC. Activating the flyback snubber transfers the energy stored in the snubber capacitor CC to the storage capacitors Cb1 and Cb2.

This causes the voltage VC to go down to zero. This means that by keeping the voltage demands on switches M1-M4 low, a ZCS turnoff can be accomplished. The suggested snubber stops the spike current flow, which gives it soft-switching characteristics. It must be

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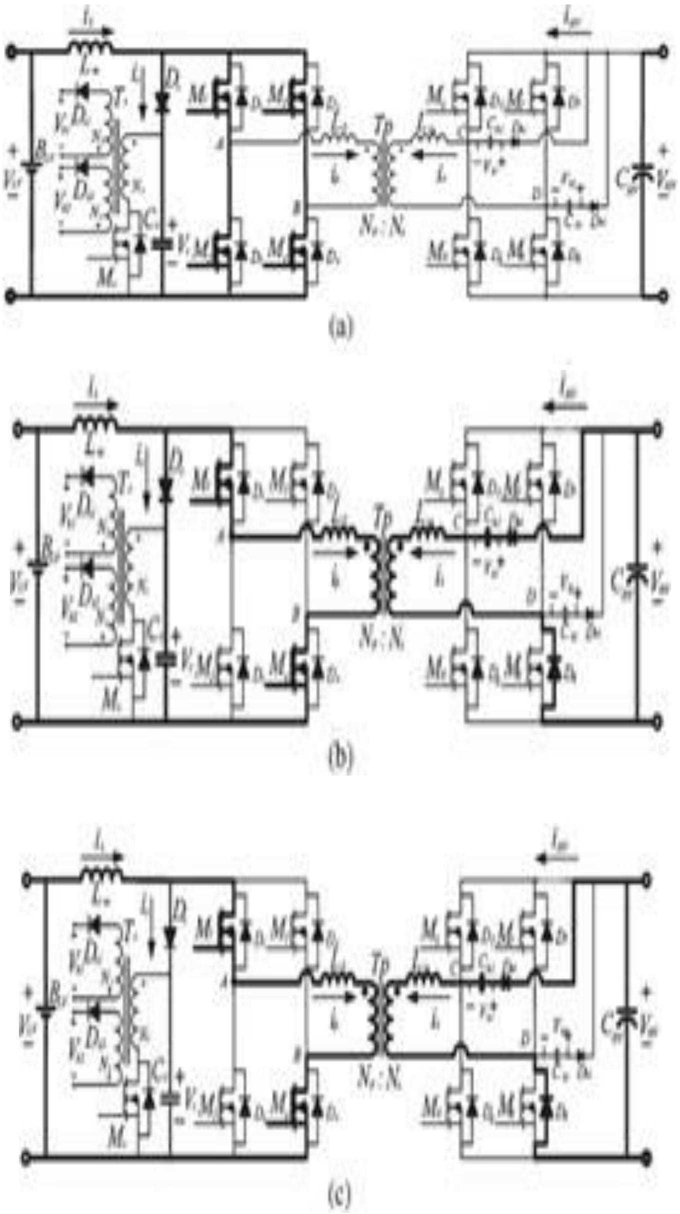
kept in mind that a spike in current might cause charge to flow, current density to rise, and magnetic force to intensify. The conducting resistance of the MOSFET rises due to a lack of carriers, improperly linked wires, and an excessively small channel.

3. PROPOSED SYSTEM

The suggested system incorporates improved active and passive snubber circuits to create a bidirectional isolated full-bridge converter that soft-switches, which improves converter performance overall, prevents voltage surges, and minimizes switching losses. During switching times, the design alters resonant transitions using a passive snubber network. Because of this, primary-side switches are never overloaded, regardless of the demand. The integration of an active snubber circuit allows for the recovery of energy lost due to leaky inductance and the prevention of excessive voltage jumps. Because of this, a wider operational range may be reliably served by switching to zero voltage or zero current. For improved reliability, high-frequency performance, and suitability for use in renewable power conversion, electric car charging systems, and current energy storage, it is recommended to combine two different types of snubbers.



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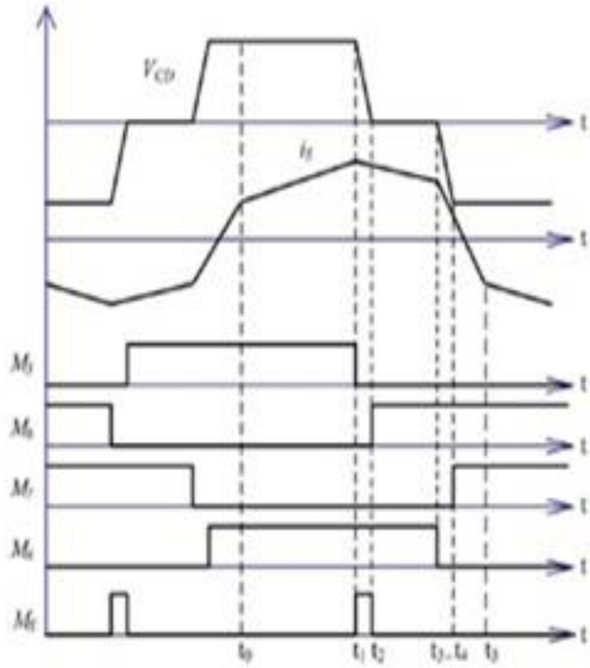

Fig. 3. The step-down conversion made use of the main current and voltage patterns from the chosen converter.

4. EXPERIMENTAL RESULTS

The proposed converter was tested using three experimental prototypes, each with a 1.5 kW power output, to ensure its effectiveness and capabilities. The A, B, and C converters are shown in Figures 2, 3, and 4, respectively. Disregarding the necessity. At its lowest point, the voltage is 42–54 volts. Db1 and Db2 are two snubber diodes needed to stop the current from bouncing. A Type B current and voltage graph backs up this finding. It was expected and seen that the current waveforms iP with an active clamp circuit in the converter would show that the snubbers retrieve the energy stored in the CC and stop it from crossing the main switches upon current release.

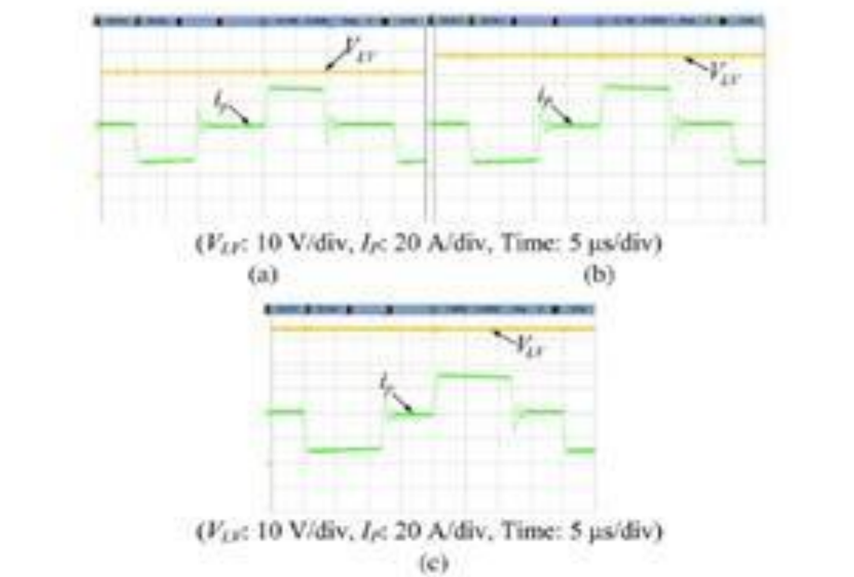

Fig. Measured waveforms of voltage V_{LV} and current i_P from input voltages (a) 42, (b) 48, and (c) 54 V under step-up conversion.

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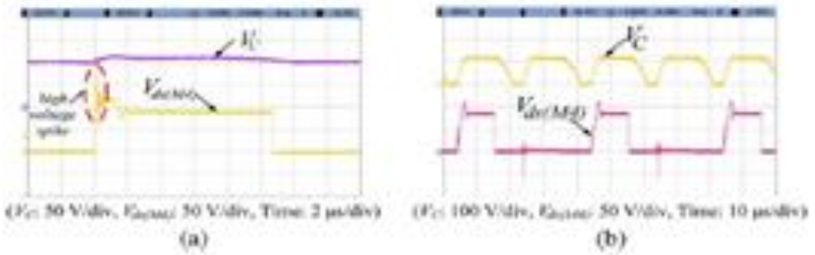

Fig. 11. Measured voltage waveforms of V_C and $V_{ds(M4)}$ from (a) type A, and (b) the proposed one of which V_C is discharged completely in each switching cycle, under step-up conversion and with 1.5-kW power rating.

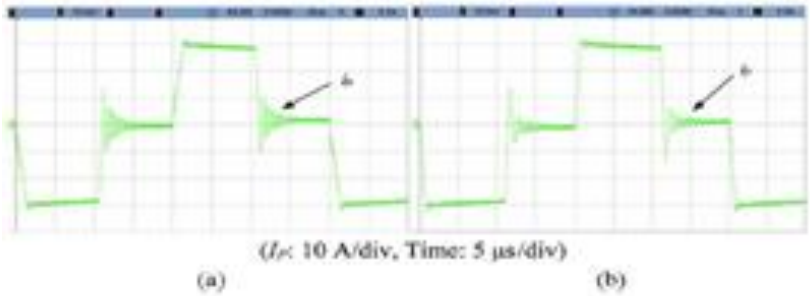

Fig. 12. Measured current i_p waveforms from (a) type A and (b) the proposed one under step-up conversion and with 1.5-kW power rating.

During the M4 turnoff phase, Figures 13(a) and (b) show the ID(M4) values with 1.5 kW loads. The values of ID(M4) with 500 W loads are shown in Figure 13(c). Based on statistical analysis, Type A can achieve a voltage spike peaking at 197 V. The high capacitance of switches M1 through M4 and the circuit's increased inductance cause this to happen. The suggested approach achieves a voltage surge reduction to 107 V and a ZCS turnoff via soft-switching, as shown in Figure 13(b).

In addition, the quick switching feature is shown in Figures 13(b) and (c) to be versatile and applicable in both light-load and heavy-load settings. Type A can be used to test the patterns of current Ids(M8) and voltage Vds(M8). Figure 14 shows the expected waveform at the M8 turnoff phase. Switching power loss (voltage across transistor M8 times current through transistor M8) and voltage across drain-source terminal of transistor M8 both grow more slowly when Cb1 and Cb2 rise in the suggested converter. The next step is for it to enter a zero crossing state. Figure 15 also shows type B voltage patterns, such as Vds(M5) and Vds(M6), in addition to the step-down conversion pattern. The voltage drop across the type B ring as shown in Figure 15(a). At the root of the problem are the large buffer capacitors Cb1 and Cb2. You can see the current Ids (M5) and the step-down voltages for type B and the suggested alternative in Figure 16.

5. CONCLUSION

A two-way, isolated full-bridge converter with soft-switching is suggested in this study for charging and discharging batteries with an input voltage range of 42 to 54 V. Both Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS) are built into the suggested converter, and they work together to mitigate current spikes caused by diode reverse recovery, voltage spikes caused by the disparity between leakage and current-fed inductor currents, and other related voltage and current stresses. Raising the diP/dt slew rate while holding Vb1 or Vb2 constant can decrease duty loss. At low loads, step-down converters are unable to use the ZVS turn-on shift, which involves switching voltages close to zero. We looked at three different kinds of 1.5 kW bidirectional isolated full-bridge dc-dc converters and rated them. It is recommended that individuals utilize the Type C converter due to its improved efficiency, less ringing, and reduced voltage and current spikes. Its galvanic isolation makes it suitable for use in high-power applications.

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