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# ACTIVE AND PASSIVE SNUBBER-ASSISTED SOFT-SWITCHING FOR BIDIRECTIONAL ISOLATED FULL-BRIDGE DC–DC CONVERTERS

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**ABSTRACT:** This paper introduces a nine-fold direct current-direct current converter that features bidirectional isolation and gentle switching to continuously charge and discharge batteries. The converter employs two passive capacitor diode snubbers and an active flyback to facilitate gentle switching with reduced voltage and current. This mitigates stresses and surges. The investigation commences with a concise explanation of the converter's operation, followed by an analysis and enhancement of the electronic device.
***Index Terms:*** *Bi directional, snubbers, softswitching*

## 1. INTRODUCTION:

The demand for high-efficiency bidirectional DC–DC converters has increased as a result of the proliferation of intelligent microgrids, battery energy storage systems (BESS), electric vehicles (EVs), and renewable energy systems. These converters guarantee high power density and electrical isolation to facilitate the regulation of power transfer between energy sources and storage devices. The bidirectional isolated full-bridge (BIFB) DC–DC converter is the most widely used converter topology due to its ability to regulate voltage, support medium- and high-power applications, and facilitate bidirectional power flow. Additionally, it provides galvanic isolation. Nevertheless, the efficiency and reliability of converters are diminished as a result of the increased switching losses, EMI, and thermal stress of semiconductor devices that result from standard hard-switching operation.

The limitations of soft-switching approaches and hard-switching converters have been investigated. Soft-switching ensures that semiconductor devices operate under ZVS or ZCS conditions, thereby reducing switching losses and voltage and current stressors. Current stress is reduced by soft-switching. Soft-switching converters can operate at higher switching frequencies, which enhances efficiency, dependability, electromagnetic emissions, and efficiency. Passive component sizes are reduced as a result of increased switching frequencies, which results in more compact and power-efficient converter designs.

Delicate switching is facilitated by snubber circuits. Recycle or dissipate parasitic inductance energy, reduce switching transients, and mitigate voltage spikes. Inductors, capacitors, and resistors are employed in passive snubber circuits. The switching stress is reduced and semiconductor devices are protected in a simple and cost-effective manner by these circuits. Nevertheless, passive snubbers may dissipate a greater amount of power, particularly when power is required. Active snubber circuits reduce power loss by enabling zero-voltage or zero-current switching and recovering leakage energy through the use of resonant components and auxiliary switches. Active snubbers enhance the efficiency and dynamic

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performance of complex power electronic applications, despite the growing complexity of the circuit and control system.

The performance of converters is enhanced by the combination of active and passive snubbers. This is accomplished by integrating the energy recovery potential of active snubbers with the ease of use of passive snubbers. This hybrid approach is effective in reducing switching losses, voltage overshoots, electromagnetic interference, and converter reliability in a diverse range of load conditions. These characteristics are essential for industrial DC distribution networks, aerospace power supplies, battery management systems, renewable energy interfaces, and electric vehicle charging systems that necessitate high efficiency and reliable bidirectional power conversion.

The design and performance evaluation of a bidirectional isolated full-bridge DC–DC converter is described in this paper, which employs active and passive snubber-assisted soft-switching. The objective of a recommended converter is to enhance system reliability, reduce switching stress, and increase conversion efficiency. A comprehensive evaluation is achieved by comparing the switching characteristics, voltage and current waveforms, converter efficiency, and power loss in a variety of operating conditions. The results demonstrate that snubber-assisted soft-switching can be employed to fabricate bidirectional isolated DC–DC converters for contemporary power electronics. Energy-efficient, dependable, and high-performance converters.

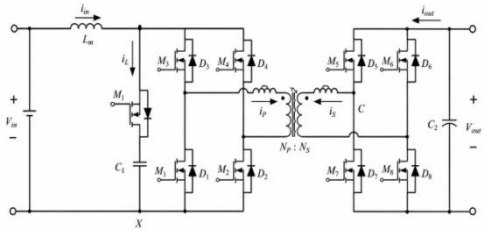


Fig.1. DC-DC converter that operates in both directions, is isolated, and has an active clamp snubber.

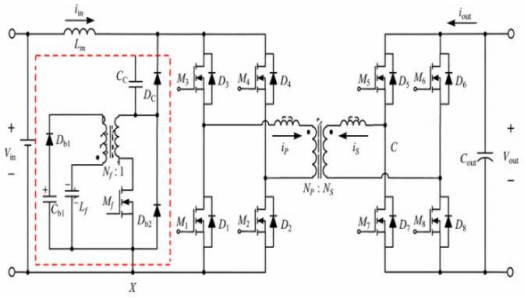


Fig.2. A two-way, full-bridge, separated DC-DC converter with a flyback snubber (type A).

## 2. EXISTINGSYSTEM:

Soft-switching is implemented in the current bidirectional isolated full-bridge DC–DC converter. In this configuration, there are two passive capacitor–diode snubbers and an active flyback snubber. Using this design, power transmission between low-voltage and high-voltage DC buses is enhanced, and switching losses are reduced. The converter is suitable for applications such as battery energy storage systems, electric vehicle charging, renewable energy interfaces, and DC microgrids, as it can operate in both step-down (buck) and step-up (boost) functions. Transformer leakage inductance-induced voltage surges are mitigated by passive snubbers on the converter's high-voltage side. Nevertheless, the active flyback snubber located on the low-voltage side of the converter is capable of recovering energy that has been stored as a result of leakage.

The voltage-fed full-bridge inverter

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converts high-voltage direct current (DC) into high-frequency AC, which the high-frequency isolation transformer transmits during step-down. Before secondary-side rectifiers convert alternating current to regulated direct current, transformers provide galvanic isolation and voltage transformation. An output filter inductor (Lm) is required to eliminate current ripple and sustain output current. The energy transfer from low to high voltage is facilitated by the reversal of power flow in a step-up operation. With appropriate switching management, the identical converter concept can operate in reverse. Modern energy storage and electric car systems require bidirectional capabilities.

The isolation transformer's switching transition produces transient energy as a result of the current differential between the current-fed inductor (iL) and the transformer's leakage inductance. The capacitor-diode snubber temporarily absorbs excess energy. The passive snubber safeguards semiconductor devices from excessive voltage stress by reducing voltage overshoots across MOSFET switches. The energy stored in the CC is subsequently transferred to the buffer capacitors (Cb1 and Cb2) by the active flyback snubber. The efficacy of the converter is enhanced as a result of the snubber capacitor's voltage decreasing to nearly zero during the recycling of stored energy.

The active flyback snubber enables the converter switches (M1–M4) to operate at nearly Zero-Current Switching (ZCS) during turn-off. Soft-switching mitigates switching losses by decreasing voltage-current overlap during switching transitions. The converter enhances its performance by decreasing switching stress, EMI, heat production, and efficiency. By preventing high-frequency spike currents from transformer leakage inductance and parasitic circuit parts, the passive snubber enhances the reliability of converters and the lifespan of switching devices.

Although these advantages exist, the existing framework contains numerous deficiencies. The construction of a converter becomes more challenging after the addition of an active flyback snubber. Auxiliary valves, control circuits, and additional magnetic components are necessary for converter architecture. The design of the controller is more complex due to the necessity of precise synchronization between the principal switches and the active snubber for optimal functionality. Passive snubber circuits result in power losses by wasting leakage energy. This is particularly true when the switching frequencies and loads are high. MOSFET performance can be compromised by abrupt current transients as a result of charge migration, increased current density, and magnetic pressures. Conduction resistance is elevated as a result of the reduction in wire bonding, channel constriction, and carrier mobility. Converter efficiency, thermal stress, and long-term reliability are all adversely affected by these constraints. In high-power applications, the performance of bidirectional isolated full-bridge DC–DC converters can be enhanced by the use of improved soft-switching approaches with snubbers, which can reduce switching stress and increase efficiency.

## 3. PROPOSEDSYSTEM:

The proposed system employs a bidirectional isolated full-bridge DC–DC converter with active and passive snubber

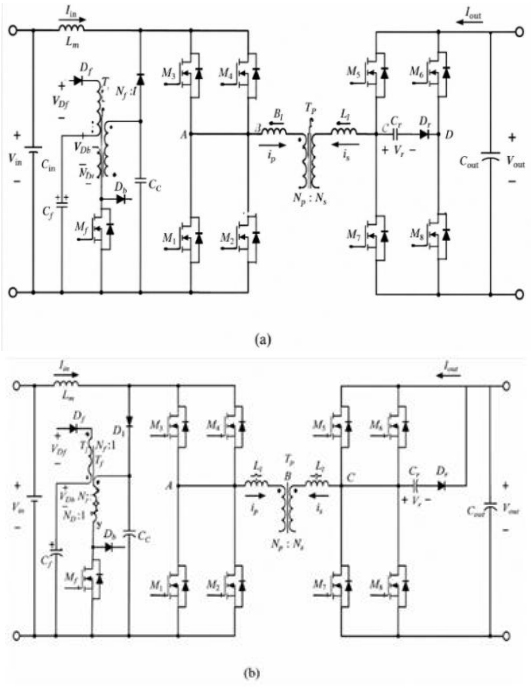

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assistance for soft-switching to enhance the efficiency of power conversion, reduce switching losses, and enhance converter reliability.. In addition to the passive capacitor–diode snubber, an active flyback snubber is employed to recover transformer leakage energy during switching transitions. Active flyback snubbers effectively transfer energy from the snubber capacitor (CC) to the buffer capacitors (Cb1 and Cb2). This minimizes the loss of energy in the form of heat. This energy recovery technology significantly reduces power switch voltage overshoots and optimizes converter operation in the vicinity of Zero-Current Switching. This significantly decreases switching losses, electromagnetic interference (EMI), and thermal stress, thereby enhancing the efficiency and lifespan of semiconductor devices.

The flyback snubber operates in Discontinuous Conduction Mode (DCM), which ensures that all transformer leakage inductance energy is transmitted prior to the subsequent switching cycle. This mode safeguards the primary MOSFET switch (MS) from high-voltage transients induced by parasitic circuit component inductance and transformer leakage. The snubber capacitor absorbs transient energy during the switching process. The active flyback circuit then transfers energy to the buffer capacitors through the flyback transformer. The voltage across the snubber capacitor approaches zero prior to the subsequent transition interval. This enables the implementation of soft switching in primary switches. This method maintains power conversion efficiency while reducing switching stress, heat emission, and device stability at higher switching frequencies.

The converter that is recommended enhances converter performance by combining the energy recuperation potential of active flyback snubbers with the simplicity of passive snubber circuits. The proposed architecture enhances converter dependability in step-up and step-down modes, reduces switching losses, enhances voltage control, and increases power density. These advantages are comparable to those of modern hard-switching converters. The reduction of switching stress enables the integration of smaller cooling systems and compact passive components, thereby reducing the size and cost of the system. Due to these advantages, the soft-switching bidirectional isolated full-bridge converter that is recommended is optimal for high-performance applications. Examples include industrial power conversion systems, DC microgrids, battery energy storage systems, renewable energy systems, and electric vehicle battery chargers. These applications necessitate exceptional reliability, efficiency, and bidirectional power flow.



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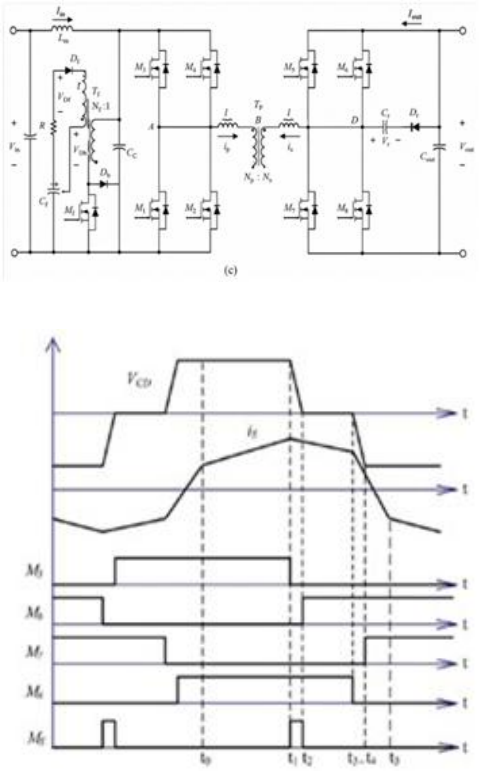


Fig. 3. For the step-down conversion, the principal voltage and current patterns from the indicated converter were employed.

## 4. EXPERIMENTALRESULTS

The proposed active and passive snubber-assisted soft-switching bidirectional isolated full-bridge DC–DC converter was tested under consistent working conditions. Three 1.5 kW experimental prototypes were designed, manufactured, and tested. In order to assess the switching behavior, voltage stress, current characteristics, and conversion efficiency of a variety of snubber designs, prototypes of Type A, Type B, and Type C were developed. The converters functioned satisfactorily when operating at a low-side DC voltage of 42 V to 54 V, which is consistent with the operating conditions of electric cars and battery energy storage systems. In order to assess soft-switching and verify theoretical calculations, voltage and current waveforms were assessed using digital oscilloscopes and current instruments. The waveforms that were captured demonstrated effective voltage spike suppression in step-up and step-down operational modes, outstanding transformer performance, and constant power transfer in both directions.

The experiments demonstrate that the snubber-assisted converter that was recommended outperforms hard-switching converters. The oscillation currents of parasitic circuit components and transformer leakage inductance are diminished by the use of snubber diodes Db1 and Db2. This mitigates MOSFET switching stress and EMI. The voltage and current waveforms of the Type B prototype exhibit seamless switching transitions and performance that is nearly equivalent to Zero-Current Switching. The active flyback snubber effectively recovers the energy stored in the snubber capacitor (CC) during current commutation, as evidenced by the simulated and observed primary current (iP) waveforms of the transformer. This energy is not routed through the main switches. Switching losses, device temperature, converter efficiency, and system reliability are all reduced by this energy recycling method. The recommended converter's efficacy in high-efficiency bidirectional power conversion in renewable energy systems, battery charging applications, and DC microgrids is demonstrated by the striking correlation between theoretical predictions and experimental observations.

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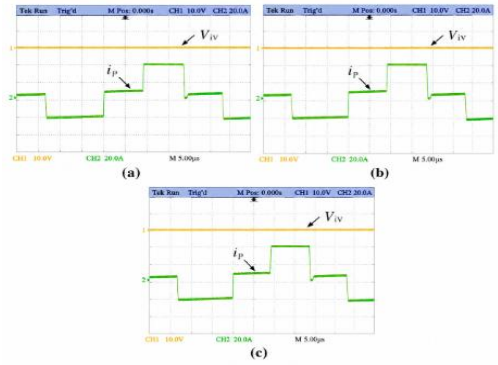


Fig. Measured voltage (ViVV_{iV}ViV) and primary current (iPi_PiP) waveforms at input voltages of (a) 42 V, (b) 48 V, and (c) 54 V during step-up operation.

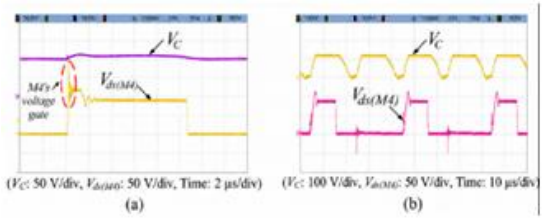


Fig. 11. Measured voltage waveforms of snubber capacitor voltage (VCV_CVC) and switch voltage (VdsV_{ds}Vds) during step-up operation for (a) Type A converter and (b) the proposed converter.

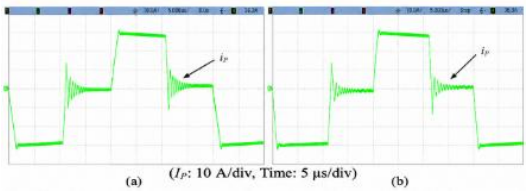


Fig. 12. Measured primary current (iPi_PiP) waveforms for (a) Type A converter and (b) the proposed converter under step-up operation at a 1.5-kW power rating.

The ID(M4) values for loads of 1.5 kW are shown in Figures 13(a) and (b) as they change from M4 to off, while the values for loads of 500 W are shown in Figure 13(c). Statistics indicate that Type A experiences a voltage spike of 197 V. This occurs as a result of the increasing capacitance of the switch M1–M4 and the circuit inductance. The proposed method is capable of achieving nearly zero-current switching (ZCS) turnoff with soft-switching, thereby reducing the voltage surge to 107 V, as illustrated in Figure 13(b). Additionally, the simple switching capability is applicable to both lower and heavier loads, as illustrated in Figures 13(b) and (c). M8 current and voltage waveforms can be assessed by Type A circuits. The predicted waveform of the M8 turnoff is depicted in Figure 14. The voltage across the drain-source terminal of transistor M8 and the switching power loss of the recommended converter increase at a slower rate as Cb1 and Cb2 increase. The switching power loss of transistor M8 is determined by multiplying its current by the voltage of its drain-source terminal. It transitions to a state of zero crossing. The voltage patterns in Figure 15 are Type B, including Vds(M5), Vds(M6), and the step-down conversion pattern. The Vds voltage of a type B ring switching system is illustrated in Figure 15(a). This is a result of the significantly large buffer capacitors Cb1 and Cb2. Type B step-down voltages and current Ids (M5) are illustrated in Figure 16, in addition to the voltage.

## 5. CONCLUSION

A soft-switching bidirectional isolated full-bridge converter for 42–54 V battery charging and discharge is introduced in this investigation. The proposed converter is capable of achieving Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS), which mitigates voltage spikes induced by leakage and current-fed inductor currents, diode reverse recovery current spikes, and current and voltage stressors. The diP/dt slew rate is increased while the passive snubber maintains Vb1 or Vb2. It concurrently mitigates duty loss. The near-zero voltage

switching (ZVS) turn-on shift is not feasible for step-down conversions owing to the presence of low loads. Three kinds of 1.5-kW bidirectional isolated full-bridge dc-dc converters were evaluated. Evaluations and investigations were conducted on an individual basis. The Type C converter is intended to mitigate voltage and current spikes, enhance efficiency, and mitigate ringing. It is optimal for high-power applications due to its galvanically separated nature.

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