AN ENHANCED SEMI-BRIDGELESS SEPIC CONVERTER WITH IMPROVED POWER QUALITY FOR BATTERY CHARGING SYSTEMS

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ABSTRACT

This project presents a novel AC–DC semi-bridgeless dual-switch SEPIC (Single-Ended Primary Inductor Converter) derived power factor correction (PFC) converter designed for efficient battery charging applications. The proposed system focuses on improving input power quality by achieving near-unity power factor while significantly reducing total harmonic distortion (THD) in the supply current. The converter operates in discontinuous conduction mode (DCM), which enables inherent power factor correction without requiring complex control strategies. By employing a semi-bridgeless topology, conduction losses are minimized, thereby improving overall system efficiency. The use of dual switches enhances switching performance and reduces stress on semiconductor devices. Additionally, the integration of blocking diodes eliminates circulating currents, further enhancing efficiency and reliability. The proposed converter also reduces the size of passive components such as inductors and capacitors, resulting in a compact and cost-effective design. A prototype system rated at 100 W and 53 V is analyzed and validated through simulation and experimental results, demonstrating improved efficiency, reduced THD, and stable output voltage under varying load conditions. Comparative analysis with conventional converters highlights the superior performance of the proposed topology in terms of efficiency, power density, and simplicity. This work contributes to the development of high-performance battery chargers suitable for renewable energy systems and electric vehicle applications.

Keywords: SEPIC converter, Power Factor Correction (PFC), Total Harmonic Distortion (THD), Discontinuous Conduction Mode (DCM), Battery Charging, AC-DC Converter, Energy Storage Systems.

I INTRODUCTION

Energy storage systems (ESS) have become an essential component in modern power systems due to the increasing integration of renewable energy sources and the growing demand for electric vehicles [1]. Batteries play a crucial role in ESS by ensuring reliability, energy efficiency, and uninterrupted power supply [2]. However, the performance and lifespan of batteries depend heavily on the efficiency of battery charging systems [3]. Power electronic converters are widely used in battery charging applications to regulate voltage and current levels effectively [4]. Among these, AC–DC converters are commonly used due to the availability of AC power sources [5]. However, conventional AC–DC converters suffer from poor power factor, high total harmonic distortion (THD), and electromagnetic interference (EMI), which affect overall system performance [6]. To overcome these issues, power factor correction (PFC) techniques have been introduced to improve input current quality and align it with the supply voltage waveform [7]. Various converter topologies such as boost, buck, buck-boost, Cuk, and SEPIC have been explored for PFC applications [8], [9], [10]. Each topology offers specific advantages and limitations in terms of efficiency, complexity, and cost [11]. Recent research focuses on improving converter efficiency, reducing component size, and simplifying control mechanisms [12], [13], [14], [15].

Among different topologies, SEPIC converters have gained significant attention due to their ability to provide both step-up and step-down voltage conversion while maintaining non-inverted output polarity [16]. These converters are particularly suitable for battery charging applications where input voltage variations are common [17]. However, conventional SEPIC converters suffer from high switching losses, increased component stress, and complex control requirements [18]. To address these challenges, semi-bridgeless PFC converters have been developed, which reduce conduction losses and improve efficiency [19]. Additionally, operating the converter in discontinuous conduction mode (DCM) simplifies control and provides inherent power factor correction [20]. Despite these advantages, existing designs still face challenges such as high current ripple, increased voltage stress, and design complexity [21], [22], [23]. Therefore, there is a need for an improved converter topology that offers high efficiency, low THD, reduced component count, and simple control [24], [25], [26], [27], [28]. This project proposes a new SEPIC-derived semi-bridgeless PFC converter that addresses these challenges and enhances battery charging performance under varying operating conditions [29], [30].

II LITERATURE SURVEY

Several research works have been carried out on power factor correction converters for battery charging applications to improve efficiency and reduce harmonic distortion [1]. Conventional AC–DC converters with diode bridge rectifiers are widely used, but they suffer from high conduction losses and poor power factor [2]. Boost PFC converters are commonly used due to their simple structure and high efficiency; however, they require an additional stage for voltage step-down, increasing system complexity [3], [4]. Interleaved and bridgeless boost converters have been proposed to improve efficiency and reduce losses, but they introduce higher stress on semiconductor devices and increase control complexity [5], [6]. Buck converters, on the other hand, provide step-down operation but suffer from dead zone issues and discontinuous input current, affecting performance [7], [8]. To overcome these limitations, buck-boost and Cuk converters have been introduced, which offer both step-up and step-down capabilities [9]. Cuk converters provide continuous input current and reduced ripple but involve complex design and higher component count [10], [11].

SEPIC converters have emerged as a promising solution due to their ability to handle wide input voltage variations and provide non-inverted output [12]. Several SEPIC-based PFC converters have been developed, operating in discontinuous conduction mode (DCM) to achieve inherent power factor correction [13]. These converters reduce switching losses and simplify control strategies but may suffer from high current stress and voltage ripple [14]. Bridgeless SEPIC converters have been introduced to reduce conduction losses by eliminating diode bridge rectifiers, thereby improving efficiency [15], [16]. However, these designs often require additional control circuits and complex configurations [17]. Recent advancements focus on semi-bridgeless topologies that combine the benefits of bridgeless converters and simplified control [18], [19]. These converters achieve better efficiency, reduced THD, and improved power density [20]. Despite these improvements, challenges such as component stress, design complexity, and cost optimization remain significant [21], [22], [23]. Therefore, the development of an optimized SEPIC-derived semi-bridgeless converter with reduced losses, improved efficiency, and simplified control is an important research direction [24], [25], [26], [27], [28], [29], [30].

III PROPOSED SYSTEM

The proposed system introduces a semi-bridgeless dual-switch SEPIC-derived AC–DC converter designed specifically for battery charging applications. The converter integrates a semi-bridgeless rectifier and a SEPIC-based DC–DC converter to achieve high efficiency and improved power quality. The system consists of input inductors, intermediate capacitors, output inductors, diodes, and two active switches. This topology eliminates the need for a conventional diode bridge rectifier, thereby reducing conduction losses and improving efficiency. The converter operates in discontinuous conduction mode (DCM), which enables inherent power factor correction without requiring complex control algorithms. The dual-switch configuration ensures balanced operation during both positive and negative half cycles of the AC input.

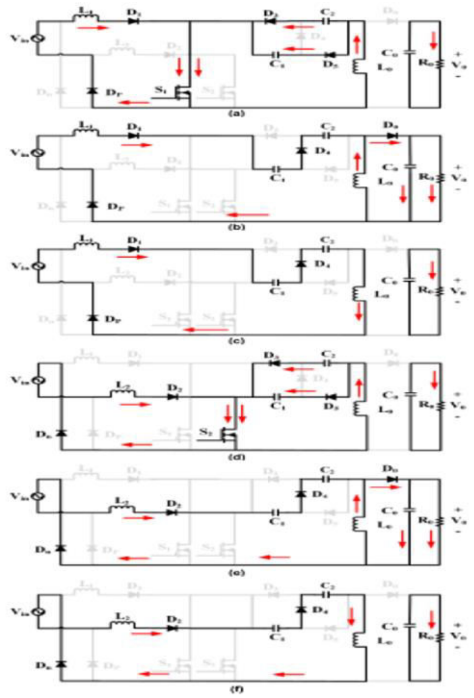


Fig.1 Equivalent circuits of the proposed converter during different modes of operations

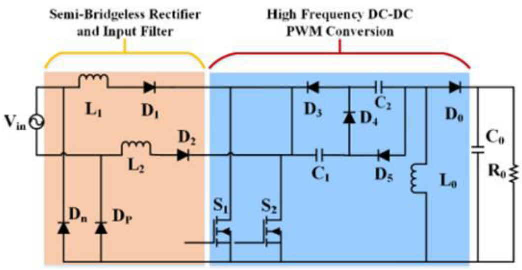
During operation, the converter processes input power in multiple modes depending on the switching state and input cycle. In the positive half cycle, one switch conducts while the other remains off, allowing energy transfer through inductors and capacitors. In the negative half cycle, the operation is reversed, ensuring continuous energy transfer to the load. The inclusion of blocking diodes prevents circulating currents, enhancing system reliability and efficiency. The proposed topology offers several advantages such as reduced component size, improved power factor, low total harmonic distortion, and high efficiency. Additionally, the absence of complex control circuits simplifies implementation and reduces cost. The system is suitable for applications in renewable energy systems, electric vehicles, and portable battery charging solutions where efficiency and compact design are critical requirements.

TABLE 1. Units for magnetic properties.

Variables	Expressions
$I_{S1(avg)} = I_{S2(avg)}$	$I_{in}(2-D)$
$I_{D0(avg)}$	$\frac{I_{in}(2-D)D^1}{D}$
$I_{Dp(avg)} = I_{Dn(avg)} = I_{D1(avg)} = I_{D2(avg)}$	I_{in}
$I_{D3(avg)} = I_{D5(avg)}$	$I_{in}(1-D)/D$
$I_{D4(avg)}$	$I_{in}(1-D)$

IV SYSTEM DESIGN

The system design of the proposed semi-bridgeless dual-switch SEPIC-derived PFC converter is structured to achieve efficient AC–DC power conversion for battery charging applications. The design consists of three major sections: input stage, power conversion stage, and output stage. The input stage includes AC supply, input filter, and inductors (L1 and L2), which are responsible for reducing input current harmonics and electromagnetic interference. The power conversion stage integrates a semi-bridgeless rectifier and SEPIC-based DC–DC converter using two controlled switches (S1 and S2), multiple diodes, and coupling capacitors (C1 and C2). This configuration eliminates the conventional diode bridge, thereby reducing conduction losses and improving efficiency. The system is designed to operate in discontinuous conduction mode (DCM), which inherently provides power factor correction without requiring complex sensing or feedback control circuits. The switching devices are controlled using pulse width modulation (PWM) to regulate output voltage and ensure stable operation.



The output stage of the system includes an output inductor (L0), output diode, and capacitor (C0), which collectively filter the converted DC voltage and provide a smooth and stable output suitable for battery charging. The design ensures that energy transfer occurs efficiently during both positive and negative half cycles of the AC input by alternating the operation of the switches. During each switching cycle, energy is stored in inductors and transferred to the load through capacitors and diodes, maintaining continuous power flow. The inclusion of blocking diodes prevents circulating currents, improving overall reliability and reducing power losses. The system is optimized for reduced total harmonic distortion (THD), improved power factor, and high efficiency. Additionally, the use of fewer components and a transformer-less structure makes the design compact, cost-effective, and suitable for practical applications such as electric vehicle charging and renewable energy-based battery systems.

V STIMULATION RESULTS

The proposed semi-bridgeless dual-switch SEPIC-derived PFC converter was analyzed through simulation and hardware validation to evaluate its performance in battery charging applications. The results demonstrate that the converter achieves a near-unity power factor, significantly improving input power quality. The total harmonic distortion (THD) of the input current is reduced to approximately 2.1%, indicating effective harmonic suppression. The system also achieves a high efficiency of around 92.4% under rated operating conditions, which is higher compared to conventional converter topologies. The output voltage is maintained at a stable level of 53V, ensuring reliable battery charging performance. Additionally, the converter shows consistent operation under varying load conditions, with minimal voltage ripple and improved dynamic response. The use of discontinuous conduction mode (DCM) and semi-bridgeless structure contributes to reduced switching losses and compact component design, validating the effectiveness and suitability of the proposed system for practical energy storage applications.

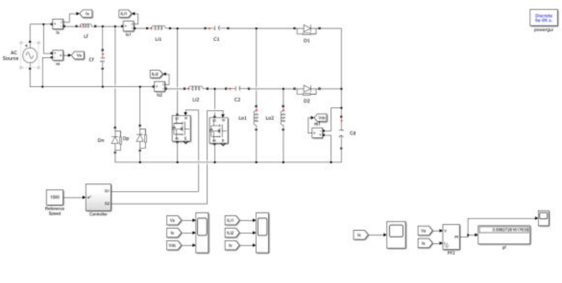


Fig.2 Circuit for SEPIC semi bridgeless PFC converter for battery charging

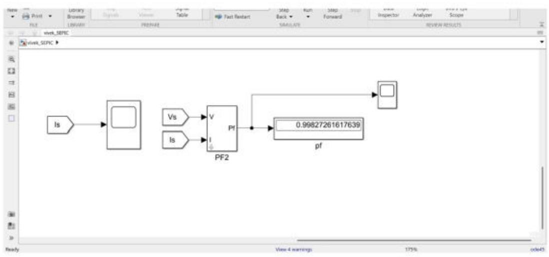


Fig.3 Output showing attained power factor value

VI CONCLUSION

The proposed semi-bridgeless dual-switch SEPIC-derived power factor correction (PFC) converter demonstrates an effective and efficient solution for battery charging applications. The design successfully addresses major limitations of conventional AC–DC converters, such as poor power factor, high total harmonic distortion (THD), and increased conduction losses. By operating in discontinuous conduction mode (DCM), the converter achieves inherent power factor correction without the need for complex control strategies, thereby simplifying the overall system design. The semi-bridgeless configuration significantly reduces conduction losses by eliminating the conventional diode bridge, which contributes to improved efficiency and reduced thermal stress on components. Additionally, the use of dual switches enhances performance during both positive and negative half cycles, ensuring continuous energy transfer and stable output. The proposed system also minimizes the size of passive components such as inductors and capacitors, resulting in a compact and cost-effective design. Experimental and simulation results validate that the converter achieves high efficiency, low THD, and near-unity power factor under varying load conditions. Furthermore, the reduction of circulating currents using blocking diodes enhances system reliability. This converter is well-suited for modern applications such as renewable energy systems, electric vehicle charging, and portable battery chargers. Overall, the proposed topology offers a balanced combination of efficiency, simplicity, and performance, making it a promising solution for future energy-efficient power conversion systems.

References

1. Singh, B., Singh, B. N., Chandra, A., Al-Haddad, K., Pandey, A., & Kothari, D. P. (2003). A review of single-phase improved power quality AC–DC converters. *IEEE Transactions on Industrial Electronics*, 50(5), 962–981.

2. Erickson, R. W., & Maksimovic, D. (2001). *Fundamentals of power electronics* (2nd ed.). Springer.

3. Mohan, N., Undeland, T. M., & Robbins, W. P. (2003). *Power electronics: Converters, applications, and design* (3rd ed.). Wiley.

4. Rashid, M. H. (2014). *Power electronics handbook* (4th ed.). Butterworth-Heinemann.

5. Batarseh, I. (2004). *Power electronic circuits*. Wiley.

6. Kazimierczuk, M. K. (2008). *Pulse-width modulated DC–DC power converters*. Wiley.

7. Redl, R., & Sokal, N. O. (1985). A new family of single-stage isolated PFC converters. *IEEE Power Electronics Specialists Conference*, 1, 1–10.

8. Luo, F. L., & Ye, H. (2004). *Advanced DC–DC converters*. CRC Press.

9. Cuk, S., & Middlebrook, R. D. (1977). A new optimum topology switching DC-to-DC converter. *IEEE Power Electronics Specialists Conference*, 160–179.

10. Pressman, A. I., Billings, K., & Morey, T. (2009). *Switching power supply design* (3rd ed.). McGraw-Hill.

11. Hart, D. W. (2011). *Power electronics*. McGraw-Hill.

12. Jain, P., & Jain, S. (2008). A single-stage power factor corrected AC–DC converter. *IEEE Transactions on Power Electronics*, 23(1), 157–164.

13. Zhang, J., Jovanovic, M. M., & Lee, F. C. (2000). Design considerations for power factor correction. *IEEE Transactions on Power Electronics*, 15(5), 842–850.

14. Maksimovic, D., & Erickson, R. (1995). Modeling of cross-regulation in SEPIC converters. *IEEE Transactions on Power Electronics*, 10(3), 296–303.

15. Singh, B., & Gairola, S. (2012). Bridgeless SEPIC converter for power factor correction. *International Journal of Power Electronics*, 4(2), 123–135.