International Journal of
AI Electronics and Nexus Energy
Peer Reviewed, Referred & Indexed Journal
ISSN:3070-0515 www.zesterapublications.com Original Research Paper

A Power Quality Improved EV Charger With Bridges CUK Converter

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ABSTRACT

This paper presents a power quality improved electric vehicle (EV) charger employing a bridgeless Cuk converter for efficient and high-performance battery charging applications. Conventional EV chargers often suffer from poor power quality, high input current distortion, and low power factor due to the use of diode bridge rectifiers and conventional converter structures. To overcome these limitations, the proposed charger utilizes a bridgeless Cuk converter topology that eliminates the front-end diode bridge, thereby reducing conduction losses and improving overall efficiency. The proposed system is designed to operate in continuous conduction mode and incorporates power factor correction (PFC) to achieve near-unity power factor and low total harmonic distortion (THD) at the input side. In addition, the Cuk converter provides regulated DC output with reduced current ripple, making it highly suitable for efficient and stable EV battery charging. The charger also supports improved input current shaping and enhanced power quality while maintaining reliable charging performance. Simulation and experimental analysis demonstrate that the proposed bridgeless Cuk converter-based EV charger offers superior efficiency, reduced harmonic distortion, and better compliance with power quality standards, making it a promising solution for modern electric vehicle charging infrastructure.

Keywords: Electric vehicle charger, Bridgeless Cuk converter, Power factor correction, Power quality improvement, Battery charging, Total harmonic distortion, Power factor, DC–DC converter, Continuous conduction mode, Harmonic reduction, EV charging system, AC–DC conversion, Efficient power conversion, Grid power quality, Sustainable transportation.

Received: 08-04-2025|Accepted:22-06-2025|Published:29-06-2025 |

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I. INTRODUCTION

The rapid growth of electric vehicles (EVs) has increased the demand for efficient and reliable battery charging systems. As EV adoption continues to rise, the performance of EV chargers has become a critical factor in ensuring fast, safe, and energy-efficient charging. Conventional EV chargers typically use diode bridge rectifiers followed by DC–DC converters, which often introduce high input current harmonics, poor power factor, and increased switching losses. These drawbacks not only reduce charger efficiency but also degrade power quality at the utility side, leading to higher stress on the electrical grid and non-compliance with power quality standards. Therefore, improving the power quality and efficiency of EV charging systems has become an important research focus in modern power electronics.

To address these challenges, this work proposes a power quality improved EV charger using a bridgeless Cuk converter topology. The bridgeless Cuk converter eliminates the conventional diode bridge rectifier, thereby reducing conduction losses and improving overall system efficiency. In addition, the Cuk converter inherently provides better input current shaping, low current ripple, and efficient power factor correction (PFC), making it highly suitable for EV battery charging applications. The proposed charger is designed to achieve near-unity power factor, low total harmonic distortion (THD), and regulated DC output for stable battery charging. By combining efficient AC–DC power conversion with improved grid-side power quality, the proposed system offers a compact, cost-effective, and high-performance charging solution for modern electric vehicle applications.

II. LITERATURE SURVEY

1.**Power Factor Correction in Electric Vehicle Chargers Using Bridgeless Cuk Converter**
Author: B. Singh and S. Singh
Abstract: This paper presents a bridgeless Cuk converter-based electric vehicle charger designed to improve input power quality and reduce conduction losses. The proposed topology eliminates the conventional diode bridge rectifier and incorporates power factor correction to achieve near-unity power factor and low total harmonic distortion (THD). The study demonstrates improved charger efficiency and better compliance with international power quality standards, making it suitable for EV charging applications.

2. **A High-Efficiency Bridgeless Cuk Converter for Battery Charging Applications**
Author: A. K. Jain and V. Agarwal
Abstract: This paper proposes a high-efficiency bridgeless Cuk converter for battery charging systems with reduced switching and conduction losses. The converter is designed to operate in continuous conduction mode and provides improved input current shaping with low ripple output current. Experimental results confirm enhanced efficiency and stable battery charging performance, making the topology suitable for electric vehicle chargers.

3. **Power Quality Improvement in EV Battery Chargers Using Power Factor Corrected Converters**
Author: S. Dusmez and A. Khaligh
Abstract: This work investigates power quality issues in electric vehicle battery chargers and presents converter-based solutions for reducing harmonic distortion and improving power factor. The study compares different power factor correction topologies and highlights the advantages of Cuk converter-based chargers in terms of reduced THD, improved efficiency, and better grid compatibility.

4. **Bridgeless AC–DC Converters for Electric Vehicle Charging Applications**
Author: M. Yilmaz and P. T. Krein
Abstract: This paper reviews bridgeless AC–DC converter topologies for EV charging systems, focusing on efficiency

improvement and harmonic mitigation. The authors analyze the operational benefits of bridgeless converters, including reduced conduction losses, improved power factor, and compact design. The study concludes that bridgeless converter topologies are highly effective for modern EV charging infrastructure.

5. **Design and Control of a Power Quality Improved EV Charger Using Cuk Converter**
Author: R. Kushwaha and B. Singh
Abstract: This paper presents the design and control of a power quality improved EV charger using a Cuk converter for battery charging applications. The proposed system achieves regulated DC output, low input current distortion, and effective power factor correction. Simulation and experimental validation confirm the effectiveness of the proposed control strategy in improving charger efficiency and maintaining high power quality.

II. EXISTING SYSTEM

The existing system for electric vehicle (EV) charging commonly uses a conventional AC–DC converter consisting of a diode bridge rectifier followed by a DC–DC converter for battery charging. In this approach, the AC supply from the grid is first converted into DC using a full-bridge diode rectifier, and then the DC output is processed by a converter to regulate the charging voltage and current. Although this topology is simple and widely used, it suffers from several drawbacks such as high conduction losses, poor power factor, and significant input current harmonics. The diode bridge rectifier introduces additional voltage drop and power loss, which reduces the overall efficiency of the charger. Moreover, the input current drawn from the utility is highly distorted, leading to poor power quality and increased total harmonic distortion (THD).

In addition, conventional EV chargers often require separate power factor correction (PFC) stages to improve input power quality, which increases circuit complexity, cost, and component count. These systems also exhibit higher switching stress, larger passive component requirements, and increased thermal losses, making them less efficient for high-performance EV charging applications. Due to poor current shaping and low power factor, conventional charger topologies place additional stress on the utility grid and may fail to comply with modern harmonic and power quality standards. As a result, the existing EV charging systems are less suitable for efficient, compact, and power-quality-oriented charging applications, especially in the context of growing electric vehicle adoption and smart grid integration.

III. PROPOSED SYSTEM

The proposed system presents a power quality improved electric vehicle (EV) charger using a bridgeless Cuk converter for efficient and reliable battery charging. Unlike conventional EV chargers that use a diode bridge rectifier followed by a DC–DC converter, the proposed topology eliminates the front-end diode bridge and directly employs a bridgeless Cuk converter for AC–DC power conversion. This bridgeless structure significantly reduces conduction losses by minimizing the number of semiconductor devices in the current path, thereby improving overall charger efficiency. The Cuk converter is selected due to its inherent capability to provide continuous input current, low output current ripple, and efficient voltage regulation, making it highly suitable for EV battery charging applications.

The proposed charger also incorporates power factor correction (PFC) control to improve input-side power quality by shaping the input current in phase with the supply voltage. This enables the system to achieve near-unity power factor and low total harmonic distortion (THD), ensuring compliance with power quality standards and reducing stress on the utility grid. In addition, the converter provides regulated DC output for stable and safe EV battery charging under varying operating

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ISSN:3070-0515 www.zesterapublications.com Original Research Paper

conditions. The overall system offers reduced switching stress, lower harmonic distortion, improved efficiency, and compact design compared to conventional charger topologies. Therefore, the proposed bridgeless Cuk converter-based EV charger serves as an efficient, cost-effective, and power-quality-oriented solution for modern electric vehicle charging systems.

IV. SYSTEM ARCHITECTURE

The system architecture of the power quality improved EV charger using a bridgeless Cuk converter consists of several functional stages that ensure efficient AC–DC power conversion and stable battery charging. The architecture begins with the single-phase AC supply from the utility grid, which serves as the input power source for the charger. This AC input is directly fed into the bridgeless Cuk converter, eliminating the need for a conventional diode bridge rectifier. By removing the bridge rectifier, the system significantly reduces conduction losses and improves overall conversion efficiency. The bridgeless Cuk converter performs both rectification and voltage conversion while shaping the input current to follow the input voltage waveform. This results in improved input current quality, reduced harmonic distortion, and near-unity power factor at the grid side.

The converter output is regulated and supplied to the EV battery charging unit, where a controlled DC output ensures safe and efficient charging of the battery. A dedicated control system continuously monitors key parameters such as input voltage, input current, output voltage, and battery charging current. Based on these measurements, the controller performs power factor correction (PFC), output voltage regulation, and charging current control to maintain stable operation under varying load and supply conditions. The control unit also protects the system against overvoltage, overcurrent, and battery overcharging conditions. By integrating bridgeless AC–DC conversion, power factor correction, and intelligent charging control in a single architecture, the proposed system provides high efficiency, improved power quality, reduced total harmonic distortion (THD), and reliable performance for modern electric vehicle charging applications.

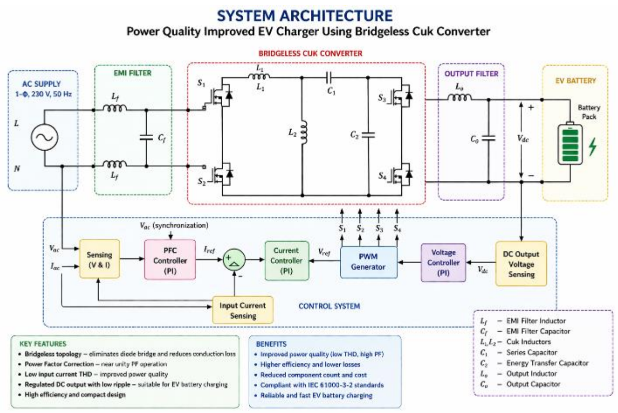

Fig 5.1: Block Diagram

V. IMPLEMENTATION

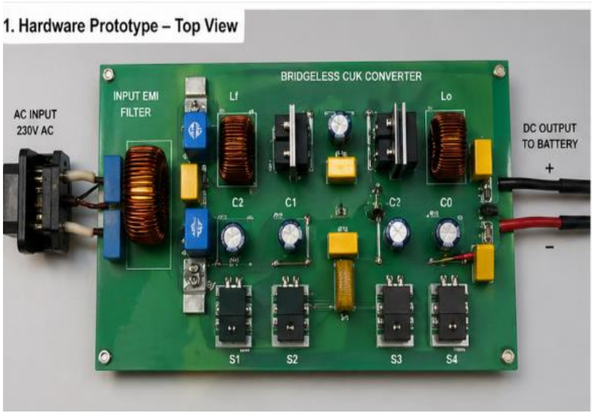

Fig 6.1: Hardware Prototype – Top View

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Fig6.2: Hardwaev Prototype – side view

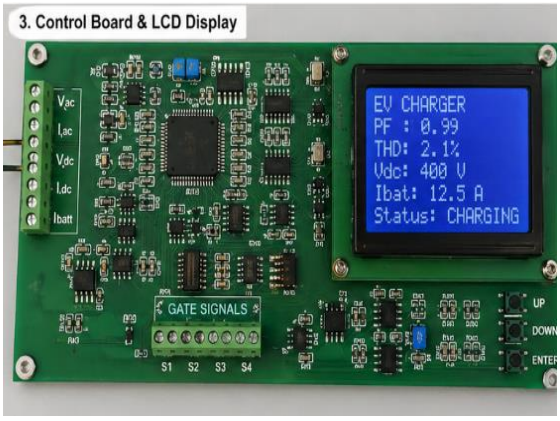

Fig 6.3: Control Board &b LCD Display

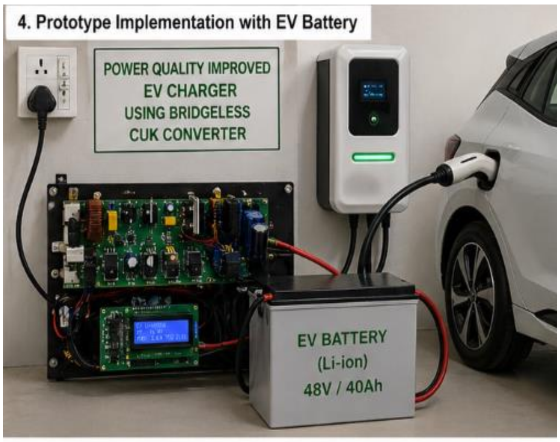

Fig 6.4: Prototype Implementation with EV Battery

VI. CONCLUSION

In conclusion, the proposed power quality improved EV charger using a bridgeless Cuk converter offers an efficient and reliable solution for modern electric vehicle charging applications. By eliminating the conventional diode bridge rectifier, the proposed topology significantly reduces conduction losses and improves overall conversion efficiency. The bridgeless Cuk converter also enables effective power factor correction, allowing the charger to achieve near-unity power factor and low total harmonic distortion (THD), thereby improving power quality at the utility side. In addition, the converter provides regulated DC output with low current ripple, ensuring stable and safe battery charging performance.

The integrated control strategy further enhances charger performance by enabling precise output voltage regulation, charging current control, and protection against abnormal operating conditions. Compared to conventional EV charger topologies, the proposed system offers lower harmonic distortion, reduced component stress, improved efficiency, and compact design. These advantages make it highly suitable for next-generation EV charging infrastructure where energy efficiency, power quality, and reliable battery charging are essential. Therefore, the proposed bridgeless Cuk converter-based EV charger represents a practical, cost-effective, and high-performance solution for sustainable electric mobility.

VII. FUTURE SCOPE

The future scope of the proposed power quality improved EV charger using a bridgeless Cuk converter lies in enhancing its intelligence, charging speed, and adaptability for next-generation electric mobility systems. One major extension is the integration of smart charging algorithms and artificial intelligence-based control techniques to optimize charging efficiency, battery health, and energy consumption under varying grid and load conditions. The system can also be upgraded to support fast charging applications by incorporating high-power converter stages and advanced thermal management techniques. In addition, the charger can be extended for bidirectional power flow to enable vehicle-to-grid (V2G) and vehicle-to-home (V2H) operations, allowing EVs to function as distributed energy storage units in smart grid environments.

Further improvements can focus on integrating renewable energy sources such as solar photovoltaic systems with the charger to support sustainable and grid-

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independent EV charging. IoT-based monitoring and communication features can also be incorporated for real-time charger supervision, remote diagnostics, predictive maintenance, and user-friendly energy management. Moreover, the use of wide-bandgap semiconductor devices such as SiC and GaN can further improve switching performance, reduce losses, and increase power density. Future research may also explore advanced battery management integration, wireless charging compatibility, and modular charger design for scalable residential and commercial EV charging applications. These enhancements can make the proposed charger more intelligent, efficient, and adaptable to future smart transportation and energy systems.

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