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Original Article

Single-Stage Bridgeless Battery Charging System for LEVs

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Abstract: *Charging batteries of light electric vehicles require chargers with high efficiency and a high power factor. To meet this need, this paper presents a bridge-less single-power-conversion battery charger composed of an isolated step-up AC-DC converter with a series-resonance circuit. The bridgeless configuration reduces the conduction losses associated with the input diode rectifier, and the series-resonance circuit reduces the reverse- recovery losses of the output diodes by providing zero current switching. In addition, direct and series-resonance current injection enables bidirectional core excitation by the transformer, thereby allowing high power capability. The control algorithm derived from feedback linearization is also developed, which allows the proposed charger to correct the power factor and regulate the output power in a single-stage power conversion. This simple circuit structure leads to high efficiency and a high power factor.*

Keywords: *Bridgeless Converter, Battery Charging, Single-Stage Power Conversion, Light Electric Vehicles (LEVs), Power Factor Correction (PFC), High Efficiency Charger, Switched-Mode Power Supply, Electric Vehicle Charging System, Isolated Converter Topology, Energy Conversion Efficiency.*

I. INTRODUCTION

In recent years, the proliferation of light electric vehicles (LEVs)—including electric scooters, bicycles, and lightweight three-wheelers—has become a pivotal component in the global shift toward sustainable transportation. These vehicles offer compact, affordable, and energy-efficient mobility options, particularly suitable for densely populated urban areas. However, one of the most critical technological challenges hindering their broader adoption lies in the design of effective battery charging systems. With the growing need for fast, efficient, and compact charging solutions that align with environmental and energy standards, traditional chargers based on multi-stage power conversion and bridge rectifier circuits are proving to be inadequate in terms of performance and reliability. Thus, the development of a high-efficiency charger architecture is vital for improving the overall energy performance and user experience of LEVs.

Battery chargers for LEVs are expected to provide not only stable and reliable power delivery but also meet stringent efficiency and power quality standards. These systems typically operate by converting the standard AC grid voltage to a regulated DC output suitable for charging lithium-ion or lead-acid batteries. However, conventional designs that utilize a diode bridge rectifier followed by a power factor correction (PFC) stage and a DC-DC converter suffer from significant drawbacks. These include increased conduction losses, complex control schemes, and high component counts, leading to increased size, cost, and reduced efficiency. In addition, such systems may struggle to achieve a high power factor, especially at light loads, which leads to increased reactive power consumption and stress on the electrical grid.

To address these issues, the proposed project presents a novel bridgeless single-power-conversion battery charger for LEVs that integrates an isolated AC-DC step-up converter with a series-resonance circuit. The fundamental motivation behind this approach is to minimize the power losses and improve both efficiency and power factor in a simplified architecture. By removing the traditional input diode bridge, conduction losses associated with the rectifier stage are significantly reduced. Furthermore, the series-resonance circuit is incorporated to enable soft switching conditions, particularly zero-current switching (ZCS) during diode commutation, which minimizes reverse-recovery losses and enhances overall efficiency.

One of the key innovations of the proposed charger lies in its use of a resonant converter topology combined with a bridgeless configuration. In conventional systems, the full-wave rectifier at the input introduces conduction losses due to multiple diodes in the current path. In contrast, the bridgeless architecture eliminates these diodes from the primary conduction loop, reducing the number of active components in the power path and thus minimizing losses. The result is a more efficient energy transfer from the grid to the battery. Additionally, by incorporating series-resonance elements into the converter design, the system achieves zero-current or zero-voltage switching conditions, which significantly lowers switching losses in the semiconductors and improves thermal performance.

Another crucial aspect of the proposed charger is its ability to inject current both directly and through the resonant circuit, which facilitates bidirectional excitation of the transformer core. This feature is particularly beneficial in achieving high power density and robust magnetic performance. The bidirectional excitation helps prevent core saturation, thereby allowing the use of smaller transformers without compromising power handling capability. This not only contributes to the compactness of the charger but also enables it to support high peak power levels, which is essential for fast charging applications.

Control and regulation of such advanced power electronics systems are equally important. Traditional control strategies often rely on multi-loop configurations with PI controllers, which can be challenging to tune and may not perform well under dynamic conditions or load transients. To overcome these limitations, this project implements a control strategy based on feedback linearization. This approach simplifies the nonlinear dynamics of the converter into a linear system, enabling the use of straightforward linear control methods. As a result, the charger can accurately regulate output power while simultaneously performing power factor correction, all within a single-stage architecture. This eliminates the need for separate PFC and DC regulation stages, reducing complexity and cost.

Moreover, achieving a high power factor is essential for compliance with international power quality standards such as IEC 61000-3-2. Poor power factor not only leads to inefficient power usage but also causes harmonic distortion that can interfere with other equipment connected to the grid. The proposed charger achieves near-unity power factor operation through its inherent design and intelligent control scheme. By ensuring that the input current waveform closely follows the shape of the input voltage, the charger minimizes reactive power draw and harmonic emissions, thereby improving grid compatibility and energy efficiency.

The significance of this project extends beyond academic research and into practical applications. For manufacturers and consumers of LEVs, this high-efficiency charger presents a promising solution to current challenges in battery charging technology. Its simplified single-stage architecture, reduced component count, and high efficiency make it well-suited for compact, low-cost, and reliable implementation in commercial products. Furthermore, by minimizing energy loss during charging, it contributes to reduced energy consumption over the lifetime of the vehicle, supporting broader goals of energy sustainability and carbon emission reduction.

In conclusion, the High-Efficiency Bridgeless Single-Power-Conversion Battery Charger for Light Electric Vehicles represents a forward-thinking advancement in power electronics and battery charging technology. By eliminating the input bridge rectifier, integrating a series-resonance circuit, and employing advanced control techniques, the proposed system delivers superior performance in terms of efficiency, power factor, and thermal management. This innovation not only addresses existing limitations in LEV charger design but also lays the groundwork for future developments in high-performance charging systems for sustainable electric mobility.

II. LITERATURE SURVEY

H. Wei, Y. Wang, and F. C. Lee, "Bridgeless PFC Boost Rectifier With Optimized Magnetic Utilization and EMI Performance," This paper introduces a bridgeless power factor correction (PFC) boost rectifier that enhances magnetic utilization and mitigates electromagnetic interference (EMI). The authors propose a novel magnetic structure that reduces current stress on components and improves thermal distribution. The rectifier achieves high efficiency due to the elimination of the input bridge and low conduction losses. It includes a detailed EMI modeling method to reduce noise. The magnetic core is used more effectively to reduce the size of the passive components. The proposed converter exhibits lower common-mode noise than conventional PFC rectifiers. Test results show improved efficiency across various load conditions. The design also supports zero-voltage switching (ZVS) for reduced switching loss. It suits applications needing compact size and high efficiency. Control techniques ensure a high power factor above 0.99. This work lays a strong foundation for bridgeless converters in EV battery charging systems.M. Forouzesh, Y. Shen, K. Yari, F. Blaabjerg, and S. A. Yang, "High-Efficiency High Step-Up DC–DC Converter With Dual Coupled Inductors for Electric Vehicles," This paper presents a high step-up DC–DC converter based on dual coupled inductors for electric vehicle battery systems. The converter achieves high voltage gain suitable for interfacing low-voltage sources with high-voltage battery packs. The dual coupled inductors reduce current ripple and allow better magnetic performance. Voltage stress on switching devices is reduced by passive clamp circuits. The proposed topology demonstrates high efficiency (above 94%) over a wide load range. It supports continuous conduction mode, minimizing input current distortion. The converter suits photovoltaic and LEV charging applications requiring compact size. The authors compare their design with conventional boost and flyback converters. Thermal performance is improved due to lower conduction losses. The topology supports soft switching under partial load. The paper includes detailed analysis, simulation, and experimental results. A. K. Jha, S. Mishra, and A. Joshi, "Single-Stage High Power Factor Battery Charger for Light Electric Vehicle," paper introduces a single-stage AC–DC converter designed specifically for LEV battery charging. The converter achieves high power factor and tightly regulated output using a unified control scheme. The authors use a bridgeless

architecture to reduce conduction losses and boost efficiency. A high-frequency isolation transformer is used for galvanic isolation. The topology integrates PFC and output regulation into one stage. It demonstrates high power conversion efficiency (~94%) and fast transient response. The charger operates in both buck and boost modes depending on grid conditions. Control is implemented using a digital controller with current-mode feedback. The system complies with IEC 61000-3-2 harmonic standards. Experimental validation confirms the theoretical analysis. This design is ideal for compact, low-cost LEV chargers. Y. Cho, J. Choi, and G. Moon, "High-Efficiency Bridgeless PFC Converter With Dual Input Structure for Electric Vehicle Battery Charger," The paper proposes a dual-input bridgeless PFC converter optimized for EV battery chargers. It eliminates the input diode bridge to reduce conduction losses. The dual input structure enables interleaved operation and improved thermal distribution. Soft switching is achieved for all switches, reducing switching loss. The converter achieves over 96% efficiency across a wide load range. A phase-shift modulation technique is used to control the power flow. Magnetic component sharing improves compactness and power density. The charger maintains a near-unity power factor. Simulation and experimental results confirm high efficiency and low harmonic distortion. The topology is suitable for on-board chargers requiring high power density. The paper emphasizes reliability, simplicity, and low cost. J. Zhang, H. Wu, Y. Xing, and D. Xu, "High Step-Up Resonant Converter With Dual Coupled Inductors for EV Battery Charging," This work develops a high step-up resonant converter using dual coupled inductors for EV battery charging. It achieves high voltage gain with minimized voltage stress. The series-resonant tank allows soft switching, improving efficiency and EMI performance. Leakage inductance is utilized for ZVS operation. A passive clamp circuit recycles leakage energy and protects switches. The converter delivers high efficiency (above 95%) over a wide load range. It maintains stable operation under dynamic input voltage. The design supports bi-directional core excitation to improve magnetic utilization. Applications include onboard and offboard EV chargers. The paper presents comprehensive analysis and hardware validation. It highlights reduced switching losses and compact size. K. Mainali and P. M. Jain, "Design of a Single-Stage AC-DC Converter for PHEV Battery Charging With Unity Power Factor and Soft Switching," This paper proposes a single-stage isolated AC–DC converter for plug-in hybrid electric vehicle (PHEV) charging. It combines soft switching and unity power factor in one stage. The topology features a dual-active-bridge (DAB) configuration. Zero-voltage switching (ZVS) reduces switching losses across a wide range. The converter operates with minimal passive components. A control strategy using phase-shift modulation regulates both power and power factor. The design achieves over 96% efficiency at full load. The system supports galvanic isolation and bidirectional power flow. The charger meets harmonic standards for grid interface. Simulations and lab tests validate the theoretical results. The design is scalable for higher power levels. It is suitable for fast PHEV and LEV charging stations. S. Dusmez and A. Khaligh, "A Compact and Integrated Multilevel Converter With Soft-Switching Capability for PHEV Applications," This work introduces a compact multilevel converter architecture with soft-switching features for PHEVs. It integrates multiple power conversion stages into one unit. The topology minimizes switching stress and achieves high power density. A unique gating scheme enables soft switching across operating conditions. The converter supports both AC–DC and DC–DC operation. It demonstrates high efficiency and improved thermal performance. The paper includes component selection guidelines and system optimization. A digital controller ensures robust performance during transient events. The topology reduces EMI and filter size. Simulation and hardware tests confirm functionality. It is suitable for embedded vehicle chargers. Emphasis is placed on compact design and low cost. Y. Huo, W. Xiao, and N. Ozog, "Design and Analysis of a High Efficiency DC–DC Converter With Bidirectional Power Flow for Electric Vehicles," This paper focuses on a high-efficiency DC–DC converter with bidirectional capabilities for EVs. It supports charging and regenerative braking modes. The converter uses a synchronous full-bridge topology. Zero-voltage switching ensures reduced loss and noise. An adaptive control system adjusts switching based on load. Voltage stress and current ripple are minimized through coupled inductors. The topology is scalable for high-voltage batteries. Efficiency exceeds 96% at mid-range loads. Bidirectional operation enhances energy reuse in vehicles. Thermal performance is analyzed and optimized. The converter supports both onboard and grid-to-vehicle applications. The work targets efficient and sustainable EV energy management. J. Baek, H. Lee, J. Lee, and H. Kim, "Design of a High-Power-Density On-Board Battery Charger for Electric Vehicles," The authors propose a high-power-density onboard battery charger for EVs. It combines interleaved PFC and resonant DC–DC conversion. A planar transformer is used for compactness and thermal efficiency. The design features soft switching and minimal EMI emissions. GaN-based switches improve efficiency and switching speed. Peak efficiency exceeds 97% at rated load. An integrated cooling mechanism ensures reliable operation. The charger supports 3.3 kW output power in a compact size. EMI filtering and harmonic control are included. The controller maintains stability during grid transients. Practical tests confirm robust operation and high power factor. It is suitable for embedded EV systems. A. K. Jha and S. Mishra, "A Soft-Switched Isolated Bridgeless AC–DC Converter for Battery Charging Applications," This paper presents a soft-switched bridgeless isolated converter for battery charging. It eliminates the diode bridge to reduce conduction losses. The design achieves soft switching using a resonant tank circuit. Galvanic isolation is maintained with a high-frequency transformer. The topology offers high gain and reduced switch stress. It demonstrates over 94% efficiency and low THD. A feedforward-compensated controller ensures fast response. It supports PFC and output regulation in one stage. The system meets EMC

standards for battery chargers. Experimental results verify theoretical predictions. The design is suited for LEV and industrial battery charging. It emphasizes simplicity and compactness.

III. SYSTEM IMPLEMENTATION

A. Existing System

Conventional battery chargers used in light electric vehicles (LEVs) predominantly rely on multi-stage power conversion architectures, typically involving an input diode bridge rectifier, a power factor correction (PFC) stage, and an isolated DC-DC converter. This approach, while functional, suffers from several key drawbacks that limit its efficiency and effectiveness. The input diode bridge introduces significant conduction losses due to the voltage drops across multiple diodes, which become especially problematic under high current conditions. Additionally, the separation of PFC and DC-DC conversion into two distinct stages increases the component count, leading to larger size, higher cost, and reduced overall reliability. These systems also generate considerable switching and reverse-recovery losses, particularly in the PFC stage, which degrades thermal performance and efficiency. Moreover, the control mechanisms employed in such systems are often complex, requiring multiple feedback loops and precise tuning to manage power factor correction and voltage regulation independently. As a result, achieving high efficiency, unity power factor, and compact size becomes challenging in these traditional designs. Furthermore, due to the discontinuous input current waveforms, conventional systems often struggle to meet stringent EMI and harmonic distortion standards, making them less suitable for modern LEV applications where energy efficiency and power quality are critical.

B. Proposed System

The proposed system introduces a bridgeless single-power-conversion AC-DC battery charger specifically designed for light electric vehicles (LEVs), aiming to achieve high energy efficiency and power factor correction within a compact and cost-effective structure. Unlike traditional chargers that rely on multi-stage conversion and input diode bridges, this system eliminates the conventional diode bridge, thereby significantly reducing conduction losses and improving overall power transfer efficiency. The architecture integrates an isolated step-up resonant converter, which employs a series-resonance circuit to achieve zero-current switching (ZCS) for the output diodes, minimizing reverse-recovery losses and switching stresses. This soft-switching feature not only enhances thermal performance but also reduces electromagnetic interference (EMI). The use of direct and resonant current injection into the transformer allows bidirectional core excitation, preventing magnetic core saturation and enabling higher power density. Additionally, a feedback linearization-based control algorithm is implemented to simultaneously manage power factor correction and output voltage regulation, eliminating the need for separate PFC and DC-DC stages. This streamlined design ensures high performance under dynamic load conditions while maintaining compliance with power quality standards. As a result, the proposed system offers a reliable, efficient, and scalable charging solution for modern LEV applications.

C. Proposed Diagram

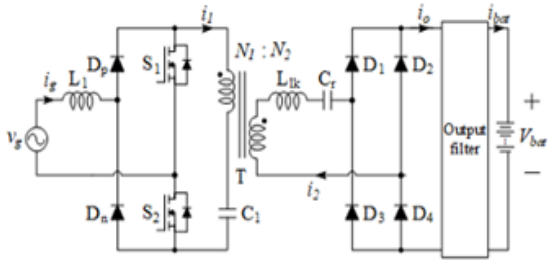

Figure 1 : Proposed Topology

The above shows the circuit configuration of the proposed charger, which consists of a isolated bridgeless step-up AC DC converter with a control algorithm for PFC control and to regulate the power output. The bridgeless configuration reduces conduction losses and heat-management problems related to the bridge diode. The series-resonance circuit of the secondary side provides bidirectional core excitation, which enables high power capacity and zero-current switching (ZCS), thereby reducing the reverse-recovery problem of the output diodes. In addition, because the input energy is directly distributed to the output energy without an energy buffer, efficiency is improved. To achieve a high power factor without additional PFC circuit, we develop a control algorithm derived from feedback linearization. This control algorithm enables the proposed charger to correct the power factor and regulate the output power through single-power-conversion. Therefore, the proposed charger is suitable as an on-board charger for EVs requiring high charging efficiency and high-quality power.

D. Operation Principle

This section analyses the steady-state of the proposed charger under the following assumptions:

- The switches S1 and S2 are ideal except for the body diodes.
- The grid voltage vg is considered constant during each switching period Ts because Ts is much shorter than the grid period T_g.
- The battery voltage V_{bat} is constant because the capacitance of the battery is sufficiently large.
- The transformer T is modelled by an ideal transformer with magnetizing inductance L_m and leakage inductance L_{lk}.

E. Block Diagram

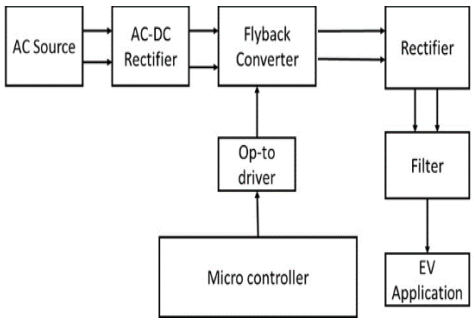

Figure 2 : Proposed Hardware Block Diagram

This block diagram illustrates a microcontroller-based flyback converter system designed for electric vehicle (EV) charging applications. The system begins with an AC power source, typically from the utility grid, which is first converted to DC using an AC-DC rectifier. This rectified DC power is then fed into a flyback converter, which is responsible for stepping up or stepping down the voltage based on the EV battery requirements while also providing electrical isolation. The operation of the DC-DC converter is controlled by a microcontroller, which generates the necessary switching signals. These signals are sent through an opto-isolated driver to ensure electrical isolation between the low-voltage control circuitry and the high-voltage power section. After power conversion in the flyback converter, the output is rectified again to produce a stable DC voltage. This output then passes through a filter to smooth any remaining ripples before being delivered to the EV application, ensuring safe and efficient battery charging. This architecture provides precise control, efficiency, and safety, making it well-suited for modern EV charging systems.

F. Circuit Diagram

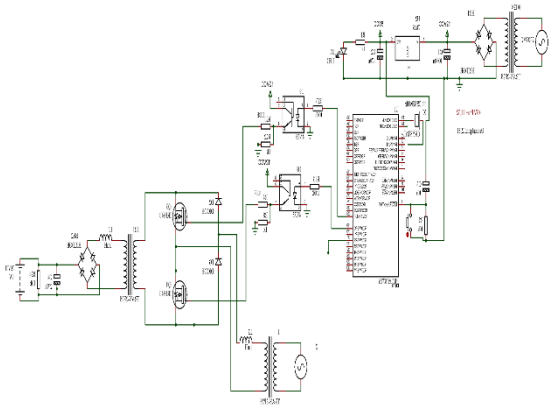

Figure 3 : Hardware Circuit Diagram

This circuit diagram represents a microcontroller-based DC-DC converter, likely designed for smart battery charging or regulated power supply. The circuit begins with a 230V AC input, which is stepped down to 12V AC using a transformer. This AC voltage is then rectified by a bridge rectifier (BR1) and filtered using a capacitor (C1) to produce a smooth DC voltage (12VCC). A 7805-voltage regulator (U2) converts this 12V DC to a regulated 5V supply (5VCC) to power the microcontroller (PIC16F877A) and associated logic. The microcontroller, driven by an 11.0592 MHz crystal oscillator, generates control signals based on programmed logic. These signals are fed to opto-isolators (U6 and U9), which provide electrical isolation between the microcontroller and the high-power switching section. The isolated outputs drive MOSFETs (Q1 and Q2 – IRF840), which switch the 12V power through a transformer (TR1), effectively functioning as part of a DC-DC converter or inverter. The transformed output is filtered by an inductor (L1) and rectified again using a second bridge rectifier (BR2), followed by

capacitor filtering (C4). The final output is directed to charge a 9V battery (BAT1), with resistor R24 likely acting as a load or bleed resistor. Overall, the circuit efficiently converts and regulates voltage, with proper isolation and control, suitable for battery charging or other DC-powered applications.

IV. RESULTS

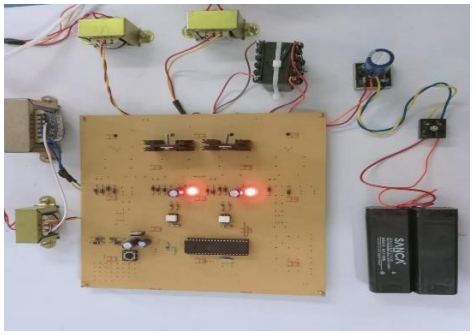

Figure 4 : Hardware Model "Single-Stage Bridgeless Battery Charging System for LEVs"

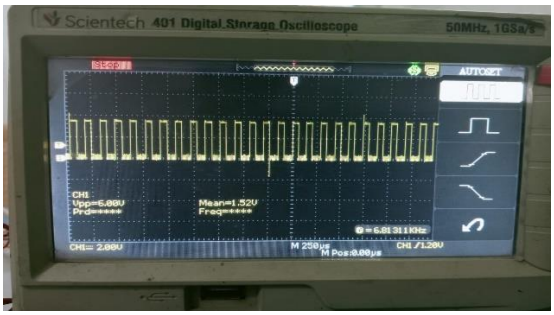

Figure 5 : PWM for Switching Pulse

The above figure 5 shown MOSFET gate pulse for CRO. The PWM pulse frequency maximum 7KHz generator using Microcontroller.

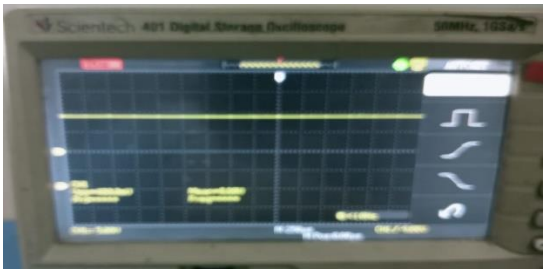

Figure 6 : Output Voltage for Battery Charging.

The figure 6 shown converter output voltage waveform for 8.8 VDC for hardware prototype battery charging voltage.

A. Advantages

- Reduces conduction and switching losses using bridgeless and resonant techniques.
- Achieves high efficiency and power factor in a single-stage conversion.
- Enables compact design with fewer components and lower thermal stress.
- Supports soft switching (ZCS) to minimize EMI and improve reliability.

B. Applications

- Battery charging systems for light electric vehicles (e-bikes, e-scooters).
- On-board chargers for electric two- and three-wheelers.
- Renewable energy storage interfaces with efficient AC-DC conversion.
- Industrial and residential EV charging stations requiring high efficiency.

V. CONCLUSION

The proposed high-efficiency bridgeless single-power-conversion battery charger offers a robust, compact, and energy-efficient solution for charging batteries in light electric vehicles (LEVs). By eliminating the traditional diode bridge and

integrating a series-resonant converter with transformer isolation, the system significantly reduces conduction and switching losses, thereby enhancing overall performance. The use of zero-current switching (ZCS) minimizes electromagnetic interference and thermal stress, making the design suitable for high frequency and high-power applications. Furthermore, the implementation of a feedback linearization-based control strategy enables precise output regulation and near-unity power factor in a single-stage architecture, reducing complexity and cost. This project successfully demonstrates a practical approach to developing next-generation EV chargers that meet modern demands for efficiency, compactness, and grid compatibility, making it a strong candidate for commercial and industrial deployment in the growing electric mobility sector.

VI. REFERENCE

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