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# Optimizing Power Factor and Efficiency in EV Chargers: Bridgeless Isolated Zeta-Luo Converter Solutions

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**_Abstract_**

*This paper focuses on enhancing the power factor of Electric Vehicle (EV) chargers through the implementation of a Bridgeless Isolated Zeta-Luo Converter. Poor power factor is a common feature of conventional charging systems, which increases energy losses and decreases efficiency. It is critical to address the serious environmental problems that transportation-related hydrocarbon emissions represent in the modern world. Electric car adoption is picking up steam as a means of promoting environmentally friendly transportation. The DC-DC converter is a vital part of these cars since it helps distribute power to auxiliary systems effectively. It guarantees the smooth operation of different vehicle sections by ensuring the efficient transmission of energy between systems operating at different voltage levels. The proposed converter aims to address this issue by employing a bridgeless topology and Zeta-Luo configuration, ensuring improved power factor correction and efficient energy transfer. The isolation feature enhances safety while maintaining a compact design. Through detailed analysis, simulation, this paper aims to demonstrate the effectiveness of the proposed solution in optimizing power factor and overall performance of EV chargers, contributing to the advancement of sustainable and efficient electric transportation infrastructure.*

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**Keywords:** AC-DC Converter, Electric vehicle, Zeta-Luo Converter, Bridgeless topology, Power Quality, Power Factor Pre-Regulation

## INTRODUCTION

The air quality is immediately impacted by emissions from traditional oil-burning automobiles, which in turn impacts the ecology. Fossil fuel burning alone is responsible for 24% of CO2 emissions. According to the International Energy Agency, 37.0 giga tons of CO2 emissions are anticipated by 2035. Electric vehicles are being pushed into the market as an alternative to conventional automobiles in an effort to reduce CO2 emissions and reliance on oil for transportation. Just the introduction of EVs somewhat mitigates pollution indirectly. nations such as India

which burn coal to create energy, charging the EVs will tangentially increase greenhouse gas emissions fumes. Over the next ten years, the traditional IC-based car industry's environmental concerns will allow for a high level of EV market penetration. The EV market has grown dramatically as a result of advancements in battery technology and lower greenhouse gas emissions.

In today's world, addressing the significant environmental challenges posed by hydrocarbon emissions in transportation is of paramount importance. The adoption of electric vehicles are gaining momentum as a strategy to foster sustainable transportation. A critical component in these vehicles is the DC-DC converter, which is essential for the efficient distribution of power to auxiliary systems. It ensures the effective transfer of energy between systems operating at different voltage levels, thereby guaranteeing the seamless performance of various vehicle parts. The electricity infrastructure faces a major issue as electric vehicles (EVs) become widely adopted [1]. Future transportation systems will primarily consist of electric vehicles (EVs) because of growing concerns about global warming and the volatility of the pricing and Oil and gas supply. As the quantity of electric cars If the number of vehicles on the road rises, more electricity will need required, and it's crucial that this strength originates from renewable resources in order to lower our carbon footprint footprint to the greatest extent feasibleConventional EV chargers draw current in a non-sinusoidal form, leading to a low power factor. This inefficiency burdens the grid and increases energy costs. These currents can introduce harmonic distortion, lowering power quality and increasing energy losses. Power Factor Correction (PFC) techniques are crucial to mitigate this issue and ensure efficient power transfer from the grid to the EV battery. The suggested design integrates the use of synchronous rectification along with soft-switching methods, offering a solution that is not only cost-efficient and flexible but also reliable and effective in its operation. : Block Diagram of the EV Charger is shown in Figure 1.

To comprehend the current research on EV charger design and PFC approaches, a thorough literature review will be carried out. Key areas of investigation will includes the existing EV charger topologies and their limitations, different PFC techniques for EV charging, performance analysis of bridgeless isolated converters, control strategies for Zeta-Luo converters in EV charging applications [2]. The literature survey will identify potential research gaps, such as Optimizing the bridgeless isolated Zeta-Luo converter design for specific EV battery charging requirements (voltage, current). Developing advanced control algorithms to achieve high efficiency and fast dynamic response during charging cycles. Investigating the impact of grid voltage variations on the converter performance, Evaluating the cost-effectiveness of the proposed solution compared to conventional EV charger designs. Based on the literature survey and identified research gaps, the paper will focus on Design and simulation of a bridgeless isolated Zeta-Luo converter for EV charging. Developing a control strategy to achieve high power factor, efficiency, and fast transient response [3]. Validate the design performance through experimental testing with a prototype.

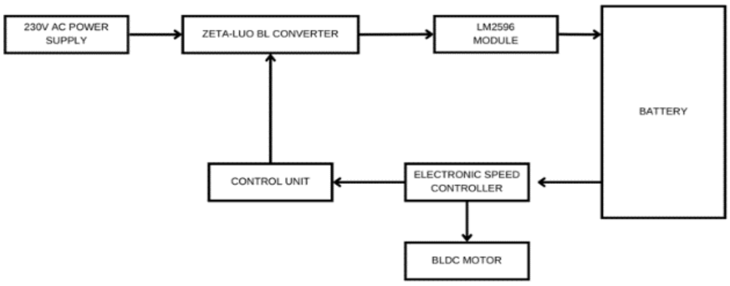

Figure 1. : Block Diagram of the EV Charger

This advancement is achieved through the amalgamation of two distinct converters and the strategic application of a cascaded Proportional-Integral (PI) controller that discerns the different charging states of the EV battery. The implementation of constant current and constant voltage charging strategies results in an optimized charging process, with the PI controller maintaining steady current and voltage levels during these phases. Overall, the BL converter is an innovative approach to achieving efficient and dependable EV battery charging [4].

Precision and stability in charging the EV battery are further reinforced by the cascaded PI controller within the constant current-constant voltage (CC-CV) charging framework, which plays a crucial role in the safety and durability of the system. The incorporation of Zeta-Luo converter technology during alternate half cycles leads to greater efficiency and diminished switching losses, thereby boosting power density and the overall efficacy of the charger. Moreover, the simplification of the converter's design through the use of fewer components contributes to a more streamlined and cost-effective charging solution. The adoption of discontinuous conduction mode (DCM) also plays a part in improving the charger's efficiency, while concurrently shrinking its physical footprint and cost [5]. Circuit Diagram of Bridgeless Isolated Zeta-Luo Converter is shown in Figure 2.

The operation of BIZLC is covered in detail in section 2. Section 3 analyzes the outcomes of the simulation. Section 4 summarizes the key points of conclusion.

## OPERATION OF BRIDGELESS ISOLATED ZETA-LUO CONVERTER

A Bridgeless Isolated Zeta-Luo converter has been developed, offering enhanced efficiency compared to other topologies utilized in Electric Vehicle charger design. This configuration integrates Zeta and Luo converters, each functioning during distinct half cycles of the input supply. The Zeta converter operates in the positive half, while the Luo converter operates in the negative half of the input supply. The resulting BL car charger efficiently combines Zeta-Luo BL converters, operating across two separate half cycles, ensuring continuous pre-PF control at rated voltage and varying power levels. Specifically tailored magnetizing inductance values enable operation in discontinuous conduction mode (DCM), reducing conduction losses and enhancing efficiency. Remarkably, the converter's component count, size, and cost are all reduced because both converters use identical output inductors [6].

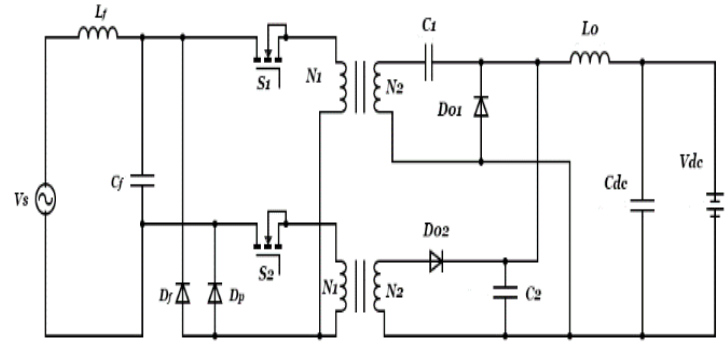

Figure 2. Circuit Diagram of Bridgeless Isolated Zeta-Luo Converter

In constant current and constant voltage (CC-CV) modes, the converter's control mechanism uses a cascaded proportional-integral (PI) controller to ensure efficient battery charging. It delivers reliable performance under steady-state operation, varying line voltage, and diverse load conditions. It also conforms to the specified power quality (PQ) guidelines for the supply current's total harmonic distortion (THD), displacement power factor (DPF), and mains power factor (PF). Switching cycles of isolated Zeta-Luo Converter and Sequence of charging and discharging for various components is shown in Figure 3 and 4 respectively.

By acting as a buck-boost converter during the positive half-cycle of the supply voltage, the Zeta converter turns on switch S1. The magnetizing inductance Lm1 charges the intermediate capacitor C1 while output diode Do1 conducts, enabling current flow to the battery. Meanwhile, the Luo converter remains inactive, and switch S2 stays open. In the negative half-cycle, the Luo converter operates as a boost converter, activating switch S2attracting inductance Current can reach the battery because Lm2 charges the intermediate capacitor C2 and causes the output diode Do2 to conduct. The Zeta converter is not operating at this time, and switch S1 is still open. The voltage across capacitor C1 grows linearly during this period. The Luo converter operates in the negative half-cycle when switch S2 flips ON at time t3, when it achieves its highest value Vp [7].

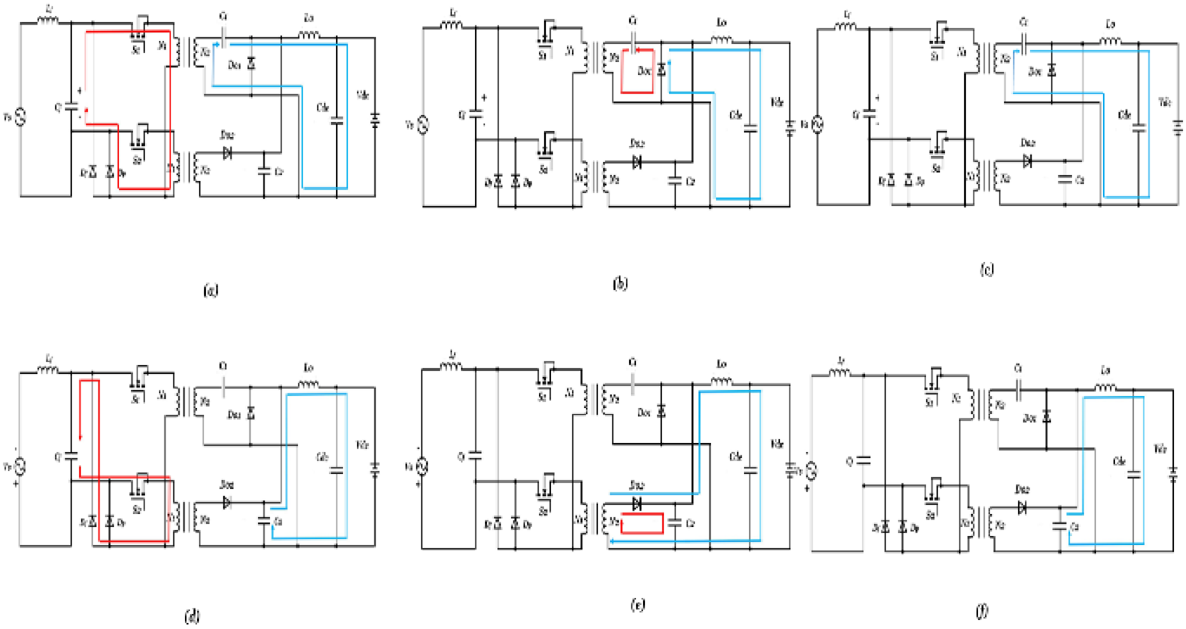
(a)
(b)
(c)
(d)
(e)
(f)

Figure 3. Switching cycles of isolated Zeta-Luo Converter

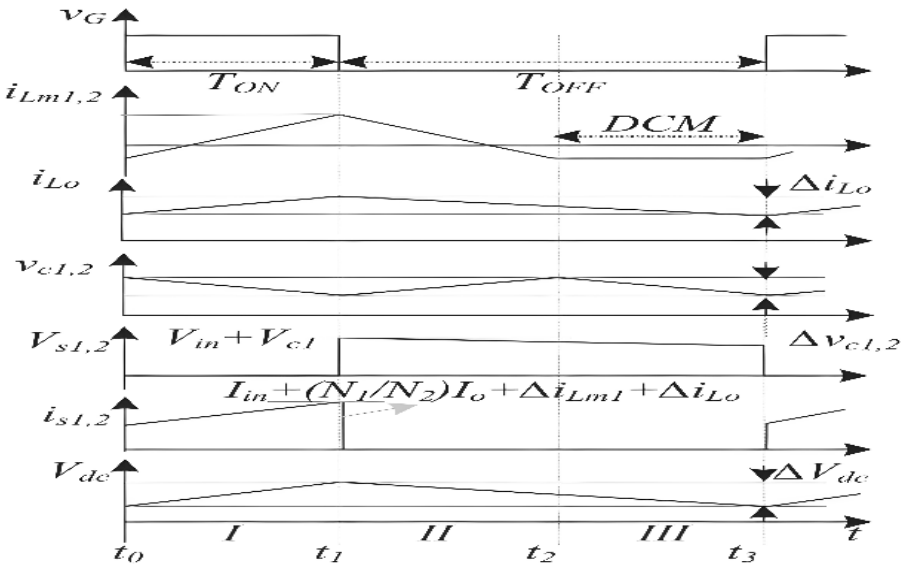

Figure 4 Sequence of charging and discharging for various components

Interval-I [t0–t1]: Switch S2 is conducting and the Luo converter is operational.. Magnetizing inductance Lm2 accumulates energy, and the voltage across capacitor C2 diminishes. At time t4, when switch S2 flips OFF and output diode Do2 stops conducting, this mode comes to an end.

Interval-II [t1 – t2]: Switch S2 is OFF, and diode Do2 conducts. Capacitor C2 allows the stored energy in Lm2 to be released, powering the secondary winding of the transformer and output diode Do2. The output dc-link capacitor charges through inductance Lo, regulating battery current in constant current (CC) mode.

Interval-III [t2 – t3]: Switch S1 remains inactive, leading to the converter entering the discontinuous conduction mode (DCM). Net zero current flows through diode Do1 as a result of combined currents via Lm1 and the output inductor Lo [8, 9]. In the Luo mode during the negative half of the supply, similar operational features are seen; the main difference is in the DCM operation, where the magnetizing inductance shows zero current.

**RESULT AND DISCUSSION:** The simulation results for the Bridgeless Isolated Zeta-Luo Converter in the application of power factor correction for EV chargers have demonstrated its effectiveness and efficiency. The simulation results for the Zeta-Luo Converter based EV charger exhibit stable battery side voltage, current regulation, and SOC progression. Simulink model of isolated Zeta-Luo Converter and Output waveforms of Zeta-Luo Converter is shown in Figure 5 and 6 respectively.

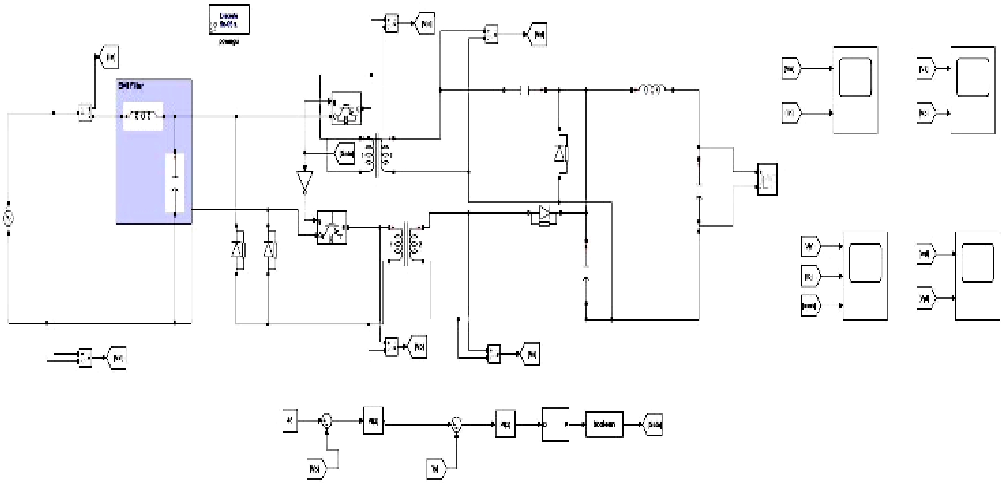

Figure 5. Simulink model of isolated Zeta-Luo Converter

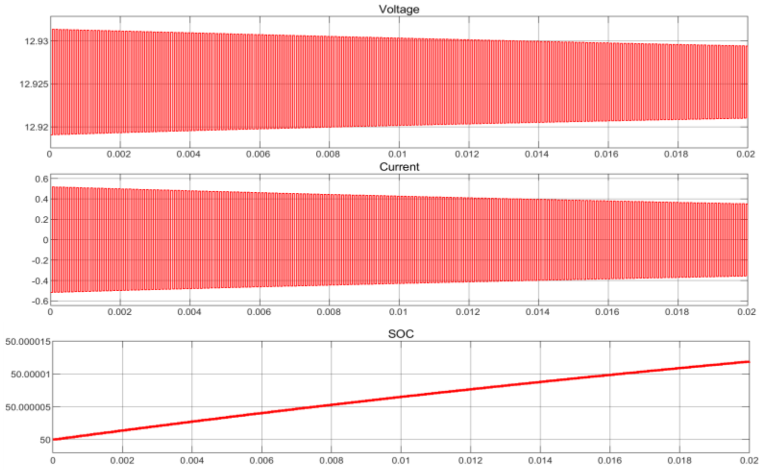

Figure 6**:** Output waveforms of Zeta-Luo Converter

The simulation results for the Bridgeless Isolated Zeta-Luo Converter in the application of power factor correction for EV chargers have demonstrated its effectiveness and efficiency. The simulation results for the Zeta-Luo Converter based EV charger exhibit stable battery side voltage, current regulation, and SOC progression. The voltage levels hovered around 12.93V with minimal fluctuation, signifying a steady output that is essential for maintaining the integrity of the battery charging process. The current measurements oscillated between -0.6A to 0.6A, reflecting the dynamic response of the converter to the charging demands. Notably, the SOC values showed a consistent incremental trend, starting just above 50% and exhibiting a gradual increase. The extended duty cycle intrinsic to the Zeta-Luo converter facilitated a more refined control of the output voltage, accommodating the variable power demands typical of EV charging scenarios. The benefits are fewer components, diminished EMI, and a more compact design. These simulated outcomes strongly indicate that the Bridgeless Isolated Zeta-Luo Converter holds significant potential as a power factor correction solution for future EV charging infrastructure, enhancing both performance and reliability.

## CONCLUSION

A novel EV battery charging system employing discontinuous conduction mode (DCM) has been developed, featuring a bridgeless isolated Zeta-Luo converter that prioritizes power quality enhancement. This cutting-edge approach merges the operational principles of both Zeta and Luo converters, which are activated alternately during the positive and negative cycles of the input voltage, respectively. By utilizing a common output inductor, the system achieves superior efficiency and presents a cost-effective, compact charging solution when compared to earlier designs. The strategic placement of output inductors within the dual converters facilitates a stable charging current, offering a distinct advantage over employing standalone Zeta or Luo converters throughout the charging process. The control and gate drive mechanism benefits from this configuration as well, with both switches being driven by analogous pulse signals. The source current distortion was observed to be negligible and varied according to the mode of charging. In essence, this innovative converter topology marks a significant advancement in EV battery charging technology, delivering improved power quality and performance.

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