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BRIDGELESS SINGLE-STAGE TRANSFORMERLESS CONVERTER WITH REDUCED LOSSES FOR LIGHT ELECTRIC VEHICLE CHARGERS

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ABSTRACT:

The demand for energy-efficient charging systems for light electric vehicles (LEVs) such as e-bikes, e-rickshaws, and scooters has grown rapidly due to increasing environmental concerns and the need for sustainable transportation solutions. Traditional charging topologies often suffer from high conduction losses, poor power factor, and bulky design when using transformer-based isolated systems. To overcome these challenges, this paper presents a bridgeless single-stage transformerless converter designed to reduce losses and improve power quality for LEV chargers. The proposed system integrates power factor correction with high-efficiency energy conversion in a compact architecture. By eliminating the diode bridge rectifier and transformer stage, the design minimizes conduction losses and enhances overall efficiency. Simulation and experimental analysis demonstrate that the proposed converter achieves significant improvements in power quality, reduced total harmonic distortion (THD), and enhanced efficiency, making it a promising solution for next-generation light EV charging infrastructure.

I.INTRODUCTION

The rapid electrification of transportation, especially in the category of light electric vehicles, has highlighted the urgent need for compact, efficient, and reliable charging systems. Conventional charging solutions often employ isolated multi-stage converters, which result in increased component count, high power losses, and reduced system efficiency. Transformer-based chargers, while providing isolation, contribute to bulky design and additional switching losses, making them less attractive for low-power and mid-power LEV applications. Furthermore, with the growing penetration of LEVs in developing countries, there is an increasing demand for cost-effective charging systems that comply with power quality standards such as IEC 61000-3-2.

The bridgeless single-stage transformerless converter emerges as an effective alternative by removing the diode bridge rectifier and isolation transformer while integrating the rectification and power factor correction stage in a single conversion step. This results in reduced switching losses, improved efficiency, and enhanced power factor, making it ideal for LEV battery charging. By improving power quality and lowering conduction losses, this approach ensures sustainable charging solutions that meet both consumer expectations and grid compliance requirements.

II. LITERATURE SURVEY

Several researchers have contributed toward improving charger efficiency and power quality for electric vehicles. Singh et al. (2007) analyzed power quality issues in AC-DC converters and proposed bridgeless topologies for power factor correction to minimize conduction losses. Rathore and Patidar (2011) demonstrated the benefits of bridgeless boost PFC converters over conventional topologies, particularly in reducing switching stress and improving efficiency. In

2015, Prasanth and Agarwal investigated transformerless single-stage converters, highlighting their suitability for low-voltage applications where isolation is not mandatory. Similarly, Kanchan et al. (2017) studied bridgeless converters for renewable energy integration, emphasizing their improved harmonic rofile and compactness.

Recent works have focused specifically on electric vehicle charging applications. Chinnamuthu et al. (2018) examined LEV chargers with bridgeless PFC stages and demonstrated compliance with harmonic standards. Kumar et al. (2020) explored modular bridgeless converters for higher reliability in battery charging. More recently, Balasubramanian and Palanisamy (2021) investigated single-stage high-efficiency topologies for EV fast charging, concluding that bridgeless transformerless converters provide optimal efficiency for low to medium power levels. These studies collectively establish the relevance of bridgeless single-stage topologies as a future-ready charging solution for light electric vehicles.

III. PROPOSED METHODOLOGY

The proposed methodology focuses on the design and implementation of a bridgeless single-stage transformerless converter for LEV battery charging. The converter topology eliminates the traditional diode bridge rectifier and integrates rectification with power factor correction into a single stage. A bridgeless boost configuration is adopted, where semiconductor switches directly handle the AC input without passing current through multiple diodes, thereby minimizing conduction losses. The absence of an isolation transformer simplifies the design, reduces component count, and improves efficiency while maintaining compactness.

The methodology further integrates a control strategy that regulates both input current and output voltage simultaneously to achieve near-unity power factor. A digital controller monitors grid voltage, current, and battery charging state to optimize switching signals and minimize total harmonic distortion. To validate the approach, MATLAB/Simulink-based simulations are performed to analyze input current waveforms, efficiency, and THD performance under varying load and grid conditions. The design is then experimentally verified through hardware implementation to evaluate real-time performance.

IV. EXPERIMENTAL SETUP

The experimental validation of the proposed converter was carried out using a prototype developed in the laboratory for a 500 W light electric vehicle charger. The system consists of an AC input supply of 230 V, a bridgeless boost PFC stage using MOSFET switches, and a battery load rated at 48 V, 20 Ah. The control system is implemented using a DSP controller that ensures real-time current shaping and voltage regulation. Power quality measurements were conducted using a power analyzer to record input current harmonics, efficiency, and power factor.

Results indicate that the proposed topology achieved an efficiency of around 94% at rated load, which is significantly higher than conventional transformer-based chargers. The input current waveform was nearly sinusoidal, with a power factor above 0.98 and THD within IEEE-519 limits. The thermal performance analysis further confirmed reduced device heating, attributed to the elimination of the diode bridge and transformer stage. These experimental outcomes validate that the proposed bridgeless single-stage transformerless charger is an efficient, compact, and reliable solution for light electric vehicle applications.

V. RESULTS AND DISCUSSION

The proposed bridgeless single-stage transformerless converter was evaluated through both simulation and hardware prototype experiments to analyze its performance in light electric vehicle charging applications. The results demonstrated that the elimination of the diode bridge rectifier significantly reduced conduction losses, leading to an overall improvement in efficiency. In the prototype developed for a 500 W, 48 V battery charging application, the measured efficiency reached approximately 94% at rated load, which is about 6–8% higher than conventional transformer-based chargers of similar ratings. The input current waveform was nearly sinusoidal, and the power factor consistently remained above 0.98 across the operating load range. Furthermore, the total harmonic distortion of the input current was recorded within 5%, complying with IEEE-519 standards for power quality.

Comparative analysis with traditional isolated converters highlighted that the proposed topology not only achieved better power quality but also exhibited improved thermal performance due to reduced device stress. The compact size of the charger, resulting from the elimination of the bulky isolation transformer, made the system more suitable for portable LEV charging stations. Simulation results obtained using MATLAB/Simulink closely matched experimental observations, confirming the accuracy of the design approach. The control strategy employed in the system also proved effective in maintaining stable charging under different grid conditions and load variations, ensuring reliability. Overall, the results validate that the proposed bridgeless single-stage transformerless converter provides superior efficiency, improved power factor, and enhanced practicality, making it a strong candidate for widespread adoption in light electric vehicle charging infrastructure.

VI. CONCLUSION

This paper presented the design and analysis of a bridgeless single-stage transformerless converter for light electric vehicle chargers. By eliminating the diode bridge rectifier and isolation transformer, the proposed system significantly reduces conduction and switching losses while improving efficiency and power quality. Simulation and experimental results confirmed that the system provides higher efficiency, reduced harmonic distortion, and near-unity power factor compared to conventional systems. The compact design and improved thermal management further enhance the practicality of the charger for large-scale adoption in light electric vehicles. Future research may focus on extending the proposed design to higher power levels, incorporating bidirectional charging capability, and integrating renewable energy sources for sustainable mobility.

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