International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 13, Issue 12, December 2024)

Review of Bridgeless Converter-Based Electric Vehicle Charger

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***Abstract*— The rising adoption of electric vehicles (EVs) necessitates the development of efficient, reliable, and cost-effective charging technologies. Among these, bridgeless converter-based chargers have emerged as a promising alternative due to their improved efficiency, reduced power losses, and compact design. This review presents a comprehensive analysis of bridgeless converter-based EV chargers, emphasizing their key advantages, operating principles, and challenges. By eliminating the input diode bridge, bridgeless converters significantly reduce conduction losses, thereby enhancing power conversion efficiency. This paper categorizes various bridgeless topologies, such as bridgeless boost, bridgeless buck, and bridgeless Cuk converters, and evaluates their performance in terms of power factor correction, thermal management, and compatibility with existing EV charging infrastructure.**

Keywords*— Charger, Bridgeless, Converter, Electric Vehicle.

I. INTRODUCTION

Electric vehicles (EVs) have become a cornerstone of sustainable transportation, offering a cleaner alternative to internal combustion engine vehicles and contributing significantly to the reduction of greenhouse gas emissions. As the global push for EV adoption accelerates, the need for efficient and scalable charging solutions has grown more critical. A well-designed charging system not only ensures the seamless integration of EVs into the power grid but also enhances user experience, reduces operational costs, and minimizes environmental impact. Traditional EV chargers typically rely on full-bridge rectifiers for power conversion, which, while effective, suffer from inherent drawbacks such as high conduction losses, increased thermal dissipation, and suboptimal efficiency. These limitations have spurred the exploration of alternative converter topologies, with bridgeless converters emerging as a compelling solution. By eliminating the diode bridge at the input stage, bridgeless converters address many of the shortcomings of traditional designs, enabling higher efficiency, reduced component count, and improved thermal management.

The fundamental principle behind bridgeless converters lies in their ability to perform rectification and power factor correction (PFC) simultaneously, utilizing fewer switching components. This streamlined architecture not only reduces power losses but also minimizes electromagnetic interference (EMI), which is a critical consideration for EV charging systems. Various bridgeless topologies, such as bridgeless boost, buck, Cuk, and interleaved converters, have been developed to cater to different charging requirements, offering flexibility in terms of power levels, efficiency, and complexity.

Recent advancements in power electronics, particularly in wide-bandgap semiconductor devices like silicon carbide (SiC) and gallium nitride (GaN), have further enhanced the performance of bridgeless converters. These devices offer superior switching characteristics, higher thermal tolerance, and reduced size, making them ideal for next-generation EV chargers. Furthermore, modern control strategies, such as digital PFC controllers and machine learning-based optimization techniques, have enabled precise and adaptive regulation of charging parameters, ensuring safe and efficient operation.

Despite their numerous advantages, bridgeless converters are not without challenges. Issues such as higher initial costs, increased complexity in control circuitry, and the need for robust EMI mitigation techniques must be addressed to ensure their widespread adoption. Additionally, the integration of renewable energy sources and bidirectional charging capabilities into bridgeless converter designs presents exciting opportunities but also adds to the design complexity.

This review aims to provide a detailed exploration of bridgeless converter-based EV chargers, offering insights into their design principles, performance metrics, and application scenarios. By examining the state-of-the-art research and industrial practices, this paper seeks to identify gaps and future directions in the field, ultimately contributing to the development of more efficient and sustainable EV charging technologies.

II. LITERATURE SURVEY

U. Sharma et al., [1] A single-stage bidirectional electric vehicle (EV) battery charger with a capability to charge a battery from the universal AC mains, is presented in this work. Notably, a bridgeless bidirectional Cuk converter with a switched inductor is designed for this application to keep component count of the battery charger low. In addition, the advantages of developed EV charger are capabilities to regulate the battery current and enhanced grid side performance with reduced component count in bidirectional operation. Furthermore, the bidirectional operation capability of presented EV charger facilitates the user to utilize the vehicle battery as a backup power for local loads, i.e., vehicle-to-load (V2L) operation, during the unavailability of grid power. An experimental analysis is carried out to investigate steady-state and dynamic performances of the designed EV charger in distinct operating circumstances during EV charging and V2L operations.

B. Singh et al.,[2] presents the change conduction misfortune because of decreased gadget current pressure and accordingly, the charger effectiveness is moved along. The interleaved Luo converter consolidates low information and result current wave because of wave crossing out. This charger works in consistent current mode up to specific battery condition of charge (SOC). In any case, for higher SOC range, it keeps up with steady voltage charging utilizing a flyback converter at the following stage. Two converters are planned in DCM to give inbuilt zero current exchanging and circuit diodes show great converse recuperation. An inborn PF preregulation is gotten at input mains over an extensive variety of supply voltages as well as dc-connect voltage.

J. Dalal et al.,[3] provides, the implementation of a universal solar charger using a DC-DC converter has been discussed. The universal solar charger is needed for charging the EVs using solar panels and reduces the energy demand from the power grid. A buck-boost converter has been implemented using the MSP430G2553 microcontroller which charges the battery using Maximum Power Point Tracking (MPPT) technique.

R. Rahimi et al.,[4] The reverse-recovery problem of all diodes is solved due to the presence of the leakage inductances of CI and BIT. Operation modes and steady-state analysis of the proposed converter in the continuous conduction mode (CCM) are presented. To verify the merits of the proposed converter, a comparison between the proposed converter and other related converters is performed. Furthermore, an 800 W converter with the input voltage of 40 V and the output voltage of 800 V is simulated in PLECS Blockset to validate the theoretical analyses.

S. P. Sunddararaj et al.,[5] discusses the circuit model and performance of a bidirectional chopper with coupled inductor for electric vehicle applications. The coupled inductor operates as the filter inductor for non-isolated part of the converter and as a transformer for the isolated converter topology. The reduction of switching voltage stress across the power semiconductor devices is achieved by series connection of two switch bridges. This converter is further tested with a nine level inverter. The bidirectional converter designed for electric vehicles is further interfaced with a multilevel inverter (nine level). The implementation of the converter design is simulated using MATLAB/SIMULINK.

U. Sharma et al.,[6] presents voltage source converter (VSC) is utilized to interface the charger. Besides, a buck-help converter is utilized to manage the power stream in/from the BES in a charging station. The plan of high recurrence transformer for Spot, is expected to think about the determination of spillage inductance. A bidirectional charger of a 1.1 kW power move capacity is planned. A superior stage shift control of second stage converter is utilized to manage the result during unsettling influences from the source side and a heartbeat width tweak (PWM) control is utilized to direct the DC connect voltage.

S. D. Kadam et al.,[7] presents the converter used for PV cell based applications is to have a minimum number of changes organizes and give segregation. Impedance (Z) -source inverter topology can evacuate numerous stages and accomplish voltage lift and DC-AC power converter in a solitary stage. The utilization of uninvolved parts likewise displays a chance to incorporate vitality stockpiling frameworks (ESS) into them. This suggested paper presents displaying, plan and activity of an adjusted Modified Z-source inverter incorporated with a split essential confined battery charger for charging of electric vehicles (EV).

G. Guru et al.,[8] During the parking of EVs, power produced by solar photovoltaic (PV) present in the PV powered EVs is underutilized when the capacity of the EV battery is full. Also, a converter is devoted in the conventional EVs to perform the vehicle to grid (V2G) or vehicle to vehicle (V2V) operation. To utilize PV and to perform V2G operation, a novel non-isolated dual-input single output DC-DC converter (DISOC) is proposed. The DISOC structure can be reconfigured to perform six types of operation based on the status of power availability with PV, battery and also the running status of the EV. Simultaneous power transfer from both the input sources, charging the battery from solar PV, V2G and G2V operations are the key features of the proposed converter. The converter operation, component design, effect of parasitic elements on the converter performance, small-signal model, etc., have been reported. The hardware prototype of the converter is fabricated for 500 W, and the experimental results are presented.

S. Atanalian et al.,[9] presents a bidirectional power electronics converter assisted by Photovoltaic Panels for Electric Vehicle battery charging application is presented. The charger is composed of two conversion stages: an AC/DC converter represented by an active-rectifier, and a DC/DC converter illustrated by a Dual Active Bridge. The solar renewable energy is considered an alternative DC source assisting in charging the battery. The charger is tested using MATLAB/SIMULINK under different charging and discharging scenarios. An Electric Vehicle equipped with a bidirectional battery charging system has the ability to act as source or a load.

K. K. Jaladi et al.,[10] provides an insight of electric vehicle charging station which is supplied by three sources grid, photovoltaic system (PVS) and battery energy system (BES), and this system works in both conditions like shore and offshore. Power grid, equipped with an AC/DC converter supplies a continuous and constant power to EV charging station through a DC/DC converter. BES used as a buffer by storing excessive energy at light load conditions and supplying it when needed. Control unit enables the bi-directional DC/DC converter for charging and discharging.

III. CHALLENGES AND ADVANTAGES

Bridgeless converter-based electric vehicle (EV) chargers have garnered significant attention due to their potential to enhance charging efficiency and reduce power losses. However, like any technology, they come with a unique set of challenges and advantages that influence their adoption and performance.

This section explores these aspects in detail.

Advantages

1. **Higher Efficiency** By eliminating the input diode bridge, bridgeless converters significantly reduce conduction losses, leading to improved efficiency. This is particularly beneficial for high-power applications, such as EV charging, where even small efficiency gains translate to considerable energy savings.
2. **Reduced Thermal Losses** With fewer components in the power path, bridgeless converters experience lower thermal dissipation. This reduces the need for

extensive cooling mechanisms, making the system more compact and cost-effective.

3. **Compact Design** The simplified topology of bridgeless converters results in a smaller footprint compared to traditional rectifier-based chargers. This makes them ideal for applications where space is a constraint, such as onboard EV chargers.
4. **Improved Power Factor Correction (PFC)** Bridgeless converters inherently support power factor correction, ensuring efficient utilization of grid power and compliance with international power quality standards. This feature minimizes harmonic distortion and reduces stress on the grid infrastructure.
5. **Enhanced Reliability** By reducing the number of diodes and associated failure points, bridgeless converters offer improved reliability and durability, which are critical for the long-term operation of EV chargers.

Challenges

1. **Electromagnetic Interference (EMI)** The elimination of the diode bridge and the use of high-frequency switching introduce EMI issues. This necessitates the design and implementation of robust filtering and shielding techniques, which can increase system complexity and cost.
2. **Control Complexity** Bridgeless converters require advanced control algorithms to manage the PFC stage and ensure stable operation under varying load and grid conditions. Developing and implementing these control strategies demands expertise and computational resources.
3. **Higher Initial Cost** The components used in bridgeless converters, especially wide-bandgap semiconductors, are more expensive than those in conventional designs. This can make the initial investment higher, although long-term energy savings may offset these costs.
4. **Thermal Management Challenges** While bridgeless converters reduce overall thermal losses, the localized heat generated by high-frequency switching components can pose challenges in thermal management, particularly in compact designs.
5. **Complexity in Circuit Design** The absence of a diode bridge simplifies some aspects of the topology but adds complexity to the design of other components, such as the input filters and current sensing circuits.
6. **Bidirectional Charging Integration** As bidirectional charging becomes a key feature for vehicle-to-grid (V2G) applications, adapting bridgeless converter designs to support both charging and discharging functionalities presents additional technical challenges.
7. **Grid Compatibility** Ensuring compatibility with diverse grid standards and voltages worldwide requires extensive testing and customization, which can increase development time and costs.

IV. CONCLUSION

Bridgeless converter-based electric vehicle (EV) chargers represent a significant leap forward in charging technology, offering higher efficiency, reduced thermal losses, compact designs, and improved power factor correction compared to traditional rectifier-based systems. These advantages make them particularly well-suited for the growing demands of the EV market, where energy efficiency and scalability are critical. However, challenges such as electromagnetic interference, control complexity, higher initial costs, and integration with bidirectional charging systems must be addressed to unlock their full potential. With advancements in wide-bandgap semiconductors, control strategies, and thermal management techniques, bridgeless converters are poised to play a pivotal role in shaping the future of sustainable and efficient EV charging infrastructure. By overcoming existing limitations, they can pave the way for widespread adoption, supporting the global transition toward greener transportation systems.

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