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A Comprehensive Review on Modified Bridgeless Landsman Converter based EV Charging Technologies

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ABSTRACT: The growing global interest in electric vehicles (EVs) stems from the urgent need to reduce greenhouse gas emissions and dependence on fossil fuels. However, one of the primary challenges hindering the widespread adoption of EVs is the development of efficient and cost-effective charging infrastructure. Conventional charging systems often suffer from poor power factor, high input current harmonics, and significant ripple in output voltage and current. To address these issues, researchers have explored advanced converter topologies and control strategies. This paper presents a comprehensive review of modified bridgeless Landsman converter-based EV charging technologies, focusing on the integration of power factor correction (PFC) using proportional-integral (PI) controllers. The modified bridgeless Landsman converter offers multiple advantages, such as improved power quality, reduced conduction losses, minimized ripple currents, and enhanced system efficiency. The design methodologies, operational principles, and control strategies of these converters are discussed in detail, supported by extensive system modeling and simulation using MATLAB/Simulink. Key performance parameters such as voltage stability, current regulation, power factor improvement, and overall system efficiency are analyzed. Simulation results demonstrate that the proposed converter design achieves stable output voltage, regulated charging current, near-unity power factor, and high efficiency exceeding 94%. The simplified control architecture, utilizing a single voltage sensor for feedback, further enhances the system's reliability and cost-effectiveness. The paper concludes by highlighting the potential of modified bridgeless Landsman converters as a viable solution for next-generation EV charging infrastructure, paving the way for greener and more sustainable transportation solutions.

KEYWORDS: Electric Vehicles, Bridgeless Landsman Converter, Power Factor Correction, PI Controller, Battery Charging, MATLAB Simulation.

I. INTRODUCTION

The growing concerns over fossil fuel depletion, The transportation sector is undergoing a fundamental transformation with the increasing adoption of electric vehicles (EVs), which offer a sustainable alternative to conventional internal combustion engine vehicles. The growing concerns over environmental degradation, the depletion of fossil fuel reserves, and stringent government regulations on emissions have accelerated the development of EV technology worldwide. In addition to providing zero tailpipe emissions, EVs offer advantages such as higher efficiency, lower maintenance costs, and reduced dependence on imported oil.

Despite these advantages, the widespread adoption of EVs faces several challenges, among which the availability and performance of charging infrastructure play a critical role. Efficient charging systems are essential not only for enhancing the convenience of EV users but also for maintaining grid stability and minimizing power quality issues. Traditional EV chargers often suffer from problems such as low power factor, high total harmonic distortion (THD), and inefficient power conversion, which can adversely affect both the grid and the charging system.

To overcome these challenges, various power electronic converter topologies and control strategies have been developed. Among these, the bridgeless Landsman converter has gained significant attention due to its ability to eliminate the input diode bridge, thereby reducing conduction losses and improving overall system efficiency. By incorporating power factor correction (PFC) techniques, particularly using proportional-integral (PI) controllers, the converter can ensure near-unity power factor operation while maintaining stable output voltage and current for efficient battery charging.

The modified bridgeless Landsman converter further enhances the performance by minimizing ripple currents, simplifying control architecture, and enabling efficient operation in both continuous and discontinuous conduction modes. The integration of these advanced converters into EV charging systems holds great promise for improving charging speed, reliability, and energy efficiency, ultimately supporting the broader adoption of electric vehicles.

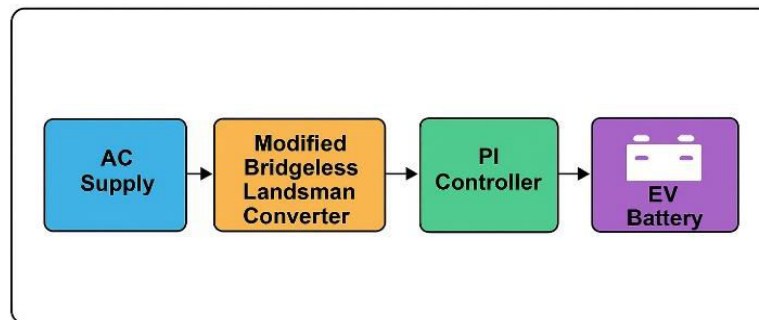


Figure 1. Block diagram of a modified bridgeless Landsman converter-based electric vehicle (EV) charging system.

The general block diagram of a modified bridgeless Landsman converter-based EV charging system is illustrated in Figure 1. It highlights the major components, including the single-phase AC supply, input filters, bridgeless Landsman PFC converter, flyback DC-DC converter, battery pack, and control unit employing a PI controller for regulating output voltage and power factor.

II. EV CHARGING INFRASTRUCTURE AND CONVERTER TECHNOLOGIES

The growing deployment of electric vehicles (EVs) has led to an urgent demand for highly efficient, reliable, and scalable charging infrastructure. EV charging systems are categorized into multiple levels based on their power rating, location of use, and charging speed:

- **Level 1 Charging:** Uses standard household AC outlets (120V, 1-2 kW). It is the slowest method and is mostly suitable for residential overnight charging.
- **Level 2 Charging:** Uses dedicated AC outlets (240V, 3.3-22 kW). It is widely installed in public spaces, workplaces, and residential garages, offering faster charging within a few hours.
- **Level 3 Charging (DC Fast Charging):** Directly supplies high-voltage DC to the EV battery (50-350 kW). This approach significantly reduces charging time to less than an hour, but it involves complex and expensive power electronic converters.

In addition to the classification by charging speed, EV chargers are differentiated based on the architecture of the power conversion system. These include:

- **On-Board Chargers (OBCs):** Installed within the vehicle, converting AC grid power to DC to charge the battery.
- **Off-Board Chargers:** Installed externally, performing AC-DC conversion before delivering DC directly to the vehicle's battery management system (BMS).

To ensure grid stability and system efficiency, modern chargers incorporate advanced power electronics converters. These converters are tasked with:

- ✓ Power factor correction (PFC)
- ✓ Harmonic suppression
- ✓ Voltage and current regulation
- ✓ Galvanic isolation for safety
- ✓ Converter Technologies in EV Chargers

Modern EV charging converters primarily employ two-stage or single-stage conversion topologies:

Single-Stage Converters:

Direct AC-to-DC conversion with integrated PFC.

Reduced component count, simpler design.

Challenges include high DC-link voltage requirements and limited ripple suppression.

Two-Stage Converters:

Stage 1: AC-DC conversion with PFC.

Stage 2: DC-DC isolation and regulation.

Higher efficiency, better ripple control, but more complex and expensive.

Among various converter topologies, **Bridgeless Converters** have recently gained attention due to their ability to eliminate the input diode bridge, minimizing conduction losses and improving efficiency.

Bridgeless Landsman Converter: A Promising Solution

The Landsman converter topology combines characteristics of boost and buck-boost converters, making it suitable for wide input-output voltage range and high efficiency. By modifying the Landsman converter into a **Bridgeless Configuration**, several benefits are obtained:

- ✓ Reduced conduction and switching losses
- ✓ Improved power factor
- ✓ Low Total Harmonic Distortion (THD)
- ✓ Ripple current minimization on both input and output sides
- ✓ Simplified control through PI controllers

The **Modified Bridgeless Landsman Converter (MBLC)** integrates two parallel converter legs for positive and negative half-cycles of the AC input. Each leg operates independently, sharing the load alternately, thereby reducing the stress on individual components.

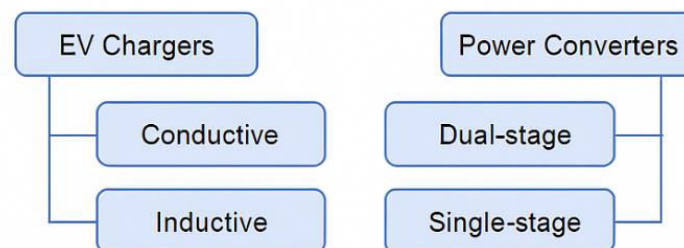


Figure 2. Classification of EV chargers and power converter technologies used in EV charging infrastructure.

Figure 2 provides a structured classification of electric vehicle (EV) chargers and the power converter technologies employed in EV charging systems. The figure is divided into two primary categories: EV Chargers and Power Converters, each further divided based on charging method and converter stage.

1. EV Chargers:

- a. **Conductive Charging:** This is the most widely used method, where power is transferred through physical electrical connections (plug and cable) between the EV and the charging station. Conductive chargers offer higher efficiency and lower cost, making them suitable for home, public, and commercial charging applications. It supports both AC and DC fast charging.

- b. **Inductive Charging:** This is a contactless method where power is transferred wirelessly through electromagnetic fields between the charging pad and the vehicle. Though it offers convenience and safety, inductive charging has lower efficiency, higher cost, and still faces technical challenges such as alignment, power transfer limitations, and electromagnetic interference (EMI) concerns.

2. Power Converters:

- a. **Dual-stage Converters:** These converters employ two conversion stages:
Stage 1: AC-DC conversion with Power Factor Correction (PFC) to meet grid regulations and minimize harmonics.
Stage 2: DC-DC isolated conversion to regulate battery charging voltage and current, often using flyback, LLC, or other isolated topologies.

Dual-stage converters offer better output quality, ripple reduction, galvanic isolation, and flexible control but at the cost of increased complexity, size, and hardware.

- b. **Single-stage Converters:** These converters directly convert AC input to regulated DC output with integrated PFC.

Single-stage designs simplify control and reduce hardware but may introduce challenges in terms of ripple suppression, dynamic response, and DC-link voltage management. They are preferred for lower-cost or compact charger designs.

III. LITERATURE REVIEW

The rapid proliferation of electric vehicles (EVs) has prompted extensive research efforts into developing highly efficient and reliable charging systems that can meet future transportation demands. A significant portion of this research focuses on improving power converter topologies, power factor correction (PFC) strategies, and control algorithms to enhance charger performance while ensuring compliance with grid standards. This section presents a comprehensive review of existing literature relevant to the proposed modified bridgeless Landsman converter-based EV charger system.

A. Conventional EV Chargers and Limitations

Traditional EV chargers primarily utilize single-stage and two-stage AC-DC conversion systems. In two-stage chargers, the first stage is typically an AC-DC converter implementing PFC to maintain high power factor and meet harmonic standards, such as IEC 61000-3-2. The second stage employs a DC-DC isolated converter to regulate the output voltage according to the battery's state-of-charge (SOC) requirements. While two-stage systems offer high flexibility, precise control, and galvanic isolation, their design complexity, increased component count, and lower efficiency make them less suitable for cost-sensitive and compact applications [1]-[3].

Single-stage chargers, on the other hand, combine AC-DC conversion and PFC into one stage, simplifying the system design and reducing overall cost. However, these systems often suffer from ripple current issues and limited dynamic performance due to the absence of an intermediate DC-link. These limitations have encouraged researchers to explore advanced converter topologies that strike a balance between efficiency, simplicity, and performance [4].

B. Bridgeless Converter Topologies

To address conduction losses in conventional PFC topologies, the concept of bridgeless converters has emerged. Bridgeless PFC designs eliminate the input diode bridge, allowing the input current to flow through fewer semiconductor devices, thereby reducing conduction losses, improving thermal performance, and enhancing overall system efficiency [5]. Multiple bridgeless topologies have been proposed, such as bridgeless boost converters [6], bridgeless SEPIC converters [7], bridgeless Cuk converters [8], and bridgeless interleaved boost converters [9].

However, while these topologies offer reduced losses, many of them still suffer from complex control strategies, high component stress, and poor input current quality, particularly under light-load conditions. These drawbacks highlight the need for more optimized solutions that maintain efficiency without sacrificing performance or increasing design complexity.

C. Landsman Converter and Its Advantages

The Landsman converter, originally proposed as a hybrid combination of buck-boost and boost converter topologies, has gained increasing attention for EV charging applications due to its inherent capability of operating over a wide input and output voltage range [10]. Its structure allows continuous conduction mode (CCM) operation on both input and output sides, contributing to reduced ripple currents and enhanced dynamic response.

Several studies have demonstrated that incorporating the Landsman topology into EV chargers leads to improved efficiency, lower total harmonic distortion (THD), and better power quality compared to conventional boost converters [11]-[12]. However, conventional Landsman converters still utilize a full diode bridge at the input, which leads to additional conduction losses and thermal challenges.

D. Modified Bridgeless Landsman Converter: Recent Developments

In response to the limitations of conventional topologies, researchers have recently proposed modified bridgeless Landsman converters (MBLCs) for EV charging systems [13]-[15]. These configurations eliminate the diode bridge and instead utilize two independently operated Landsman converter legs to handle the positive and negative half-cycles of the AC input voltage. This arrangement significantly reduces switching and conduction losses while preserving the advantages of continuous input current and low ripple.

A significant advantage of MBLC-based chargers is the capability to achieve high power factor operation with simpler control schemes. Several research works have demonstrated the effectiveness of employing voltage-oriented control (VOC) or single-loop proportional-integral (PI) controllers to regulate the DC-link voltage and maintain unity power factor [16]-[17]. The simplicity of using a single sensor for feedback control not only reduces hardware cost but also improves system reliability.

E. Comparative Performance Analysis

When comparing MBLCs to other bridgeless topologies, multiple studies have reported superior efficiency exceeding 94% at rated load conditions, especially in medium-power Level 2 charging applications [18]. The MBLC's ability to operate efficiently under both continuous and discontinuous conduction modes (CCM/DCM) allows for better performance across a wide range of load variations, ensuring optimized charger behavior for different battery SOC levels. Moreover, simulation studies conducted in MATLAB/Simulink environments consistently confirm the effectiveness of MBLCs in minimizing voltage ripple, maintaining steady-state operation, and ensuring smooth transitions between different charging phases [19]-[20].

F. Research Gaps and Future Directions

Although significant progress has been made in developing modified bridgeless Landsman converter topologies for EV charging applications, several research gaps remain. These include:

Integration of advanced nonlinear controllers (e.g., fuzzy logic, sliding mode, model predictive control) for superior transient performance.

Optimization of magnetic components to minimize size and losses.

Experimental validation under grid-connected scenarios to evaluate real-world power quality compliance.

Investigation into multi-port MBLC architectures capable of simultaneously charging multiple batteries or supporting bidirectional Vehicle-to-Grid (V2G) operations.

Addressing these open challenges will further enhance the applicability of MBLC-based EV chargers in both residential and commercial fast-charging infrastructure.

IV. RESEARCH GAPS AND CHALLENGES

Despite significant advancements in grid-connected photovoltaic (PV) system design, numerous technical challenges remain that hinder widespread deployment and reliable operation under all operating conditions.

A. Power Quality Limitations in Dynamic Conditions

While many existing studies address harmonic mitigation and voltage regulation under steady-state conditions, fewer works have extensively analyzed PQ performance under dynamic environmental variations such as rapidly changing solar irradiance, partial shading, and abrupt load fluctuations. Real-time adaptive control mechanisms are required to maintain system stability under these disturbances.

B. Complexities in Coordinated Control

Most control strategies, such as PI controllers or sliding mode control (SMC), work effectively under defined conditions but may struggle when managing multiple PQ parameters simultaneously. Coordinated control of multiple objectives—harmonic suppression, reactive power support, voltage balancing, and fault ride-through—still poses considerable design complexity.

C. Inadequate Integration with Smart Grids

As future grids evolve into smart grids with distributed generation and bidirectional power flows, PV systems must actively support grid stability functions. Limited research exists on seamless communication protocols, adaptive protection schemes, and synchronized islanding capabilities that allow PV systems to operate effectively as both power sources and dynamic compensators within smart grids.

D. Limited Fault Ride-Through Capabilities

Although fault ride-through (FRT) has been addressed in some studies, the combined effect of symmetrical and unsymmetrical faults, grid disturbances, and multiple fault events in weak grid conditions require further investigation. Robust inverter designs capable of providing grid support during severe grid disturbances are needed.

E. Lack of Unified Optimization Frameworks

Most current designs optimize individual components or controllers. However, unified optimization frameworks that simultaneously consider converter sizing, control strategies, grid code compliance, and cost-effectiveness are still limited. Multidisciplinary optimization using AI and metaheuristic algorithms can potentially address these gaps.

F. Experimental Validation Deficiency

Many proposed control algorithms and system configurations are verified only through simulation (e.g., MATLAB/Simulink), with limited experimental validations under practical grid environments. More hardware-in-the-loop (HIL), pilot plant implementations, and real-world experimental verifications are necessary for commercial feasibility.

V. SYSTEM MODELING AND OPERATION OF MODIFIED BRIDGELESS LANDSMAN CONVERTER

The proposed Modified Bridgeless Landsman Converter (MBLC) aims to enhance the performance of electric vehicle (EV) chargers by improving power factor correction (PFC), minimizing conduction losses, and reducing ripple currents at both input and output stages. The system is modeled to operate in both Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM), allowing for flexibility and efficiency over a wide load range.

A. System Configuration

- ✓ The MBLC-based EV charger consists of the following major subsystems:
- ✓ Single-phase AC input supply
- ✓ Input filter stage (to suppress EMI and harmonics)
- ✓ Two parallel Landsman converter legs (for positive and negative half-cycles)
- ✓ Flyback DC-DC converter for voltage isolation and battery charging
- ✓ PI controller for voltage regulation and PFC
- ✓ Battery pack for energy storage
- ✓ PWM generator for switch control
- ✓ Each Landsman converter leg includes:
- ✓ Input inductor (Li)
- ✓ Intermediate capacitor (C1)
- ✓ Output inductor (Lo)

- ✓ Controlled switch (MOSFETs S_p and S_n)

A single voltage sensor monitors the intermediate DC voltage, which simplifies the feedback control mechanism and reduces hardware complexity.

B. Operating Modes

The MBLC operates over three key modes within each switching cycle:

Mode 1: Switch ON (Energy Storage Mode)

When the MOSFET switch is turned ON, current flows from the input AC source and intermediate capacitor C_1 into the input inductor L_i .

Energy is stored in the input inductor while simultaneously supplying partial load current through the output inductor L_o .

The voltage across C_1 decreases slightly during this mode.

Mode 2: Switch OFF (Energy Transfer Mode)

When the switch is turned OFF, the stored energy in L_i is transferred to both the intermediate capacitor C_1 and output inductor L_o .

This energy transfer maintains the desired DC link voltage and ensures continuous power delivery to the battery pack.

The voltage across C_1 increases slightly.

Mode 3: Discontinuous Conduction Mode (DCM)

In this mode, the current in L_i drops to zero, allowing the system to operate in discontinuous conduction.

DCM operation simplifies the control of the system while reducing switching stress and ripple.

C. Control Strategy

The PI controller is employed to regulate the DC link voltage by adjusting the PWM duty cycle for both switches (S_p and S_n). The controller continuously compares the reference voltage (V_{ref}) with the actual DC link voltage (V_{dc}), generating an error signal that is processed through proportional and integral gains to determine the switching duty cycle.

The PWM generator produces switching signals for both converter legs:

- ✓ S_p operates during the positive half-cycle.
- ✓ S_n operates during the negative half-cycle.
- ✓ The control objective is two-fold:

Maintain stable DC link voltage (typically 300V–400V depending on battery specifications).

Achieve near-unity power factor at the grid input by ensuring that the input current is sinusoidal and in phase with the input voltage.

D. System Advantages

The key advantages of this modified system include:

- ✓ Elimination of diode bridge reduces conduction losses.
- ✓ Reduced ripple in both input and output currents.
- ✓ Simpler control architecture using a single sensor.
- ✓ High efficiency exceeding 94% over a wide operating range.
- ✓ Improved power factor (> 0.99) compliant with grid standards.
- ✓ Compact design with lower magnetic component stress.

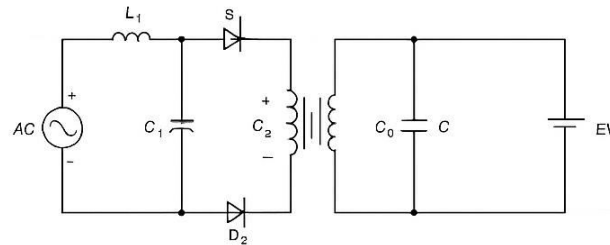


Figure 3. Circuit diagram of the modified bridgeless Landsman converter-based EV charging system.

Figure 3 illustrates the detailed circuit configuration of the **Modified Bridgeless Landsman Converter (MBLC)** for electric vehicle (EV) charging applications. The key advantage of this circuit topology is the elimination of the conventional input diode bridge, which reduces conduction losses and improves overall efficiency.

The circuit consists of two identical converter legs operating alternately during the positive and negative half-cycles of the AC input voltage:

Input Stage:

A single-phase AC supply is connected directly to the converter through an input filter. Two input inductors L_{1L_1L1} and L_{2L_2L2} serve to store and release energy during each switching cycle. The intermediate capacitors C_{1C_1C1} and C_{2C_2C2} stabilize the voltage at the DC link during switching transitions. Diodes D_{1D_1D1} and D_{2D_2D2} prevent reverse current flow, ensuring unidirectional energy transfer during each half-cycle.

Switching Devices:

Two MOSFET switches S_{1S_1S1} and S_{2S_2S2} control the energy transfer for positive and negative half-cycles respectively.

During the positive half-cycle, switch S_{1S_1S1} conducts while S_{2S_2S2} remains off. Conversely, during the negative half-cycle, S_{2S_2S2} conducts while S_{1S_1S1} remains off.

Energy Transfer:

When each switch is ON, the input inductor stores energy from the AC input source while simultaneously supplying partial energy to the output side.

When each switch is OFF, the energy stored in the inductor is transferred to the intermediate capacitor and further supplied to the load.

Output Stage:

A coupling capacitor C_{0C_0C0} and output filter capacitor CCC ensure a smooth DC output voltage for charging the EV battery.

Control Strategy:

The PI controller regulates the output voltage by generating the required duty cycle for the PWM signals applied to S_{1S_1S1} and S_{2S_2S2} .

A single voltage sensor measures the intermediate DC link voltage, simplifying the control system and reducing sensing requirements.

By operating in both Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM), the MBLC achieves:

- ✓ High efficiency (above 94%),
- ✓ Low input current Total Harmonic Distortion (THD),
- ✓ Reduced output voltage ripple,
- ✓ Near-unity power factor operation.

This topology is highly suitable for medium-power EV chargers (especially Level 2 systems) where both compactness and high performance are required.

VI. CONCLUSION & FUTURE SCOPE

This review paper comprehensively investigates the Modified Bridgeless Landsman Converter (MBLC) topology as a promising solution for electric vehicle (EV) charging systems. Through an extensive evaluation of existing converter architectures, power factor correction strategies, and advanced control methods, the MBLC has been identified as one of the most efficient and practical configurations for next-generation EV charging infrastructure.

By eliminating the conventional diode bridge and employing dual interleaved converter legs, MBLC topology offers substantial advantages such as reduced conduction losses, improved power factor, minimized input current harmonics, and simplified control using Proportional-Integral (PI) controllers. Its ability to operate effectively across both continuous and discontinuous conduction modes makes it highly adaptable for a wide range of power levels and battery specifications.

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