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# Design and Analysis of Modified Bridgeless Landsman Converter for Power Factor Correction in EV Battery Charging Applications

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**Abstract -** The rising demand for electric vehicles (EVs) necessitates the development of efficient, reliable, and compact charging systems. Traditional EV chargers, which utilize dual-stage AC-DC and DC-DC converters, often suffer from increased component count, complexity, and reduced efficiency. This paper proposes a novel Modified Bridgeless Landsman Converter (MBLC) integrated with a Proportional-Integral (PI) controller to overcome these challenges. The MBLC topology effectively eliminates the need for a dual-stage converter, combining power factor correction and voltage regulation in a single stage. By employing continuous conduction mode (CCM) at the input side and discontinuous conduction mode (DCM) at the output side, the proposed design achieves significant reduction in ripple currents, improved power quality, and enhanced overall system efficiency. A comprehensive simulation model of the system was developed in MATLAB/Simulink to validate its performance. The simulation results demonstrate stable voltage regulation at 300V for battery charging, maintaining a consistent charging current of approximately 7A. The system operates with an average efficiency of 94% and exhibits superior power factor correction, maintaining near-unity power factor throughout operation. The PI controller plays a pivotal role in stabilizing output voltage and minimizing fluctuations, thereby ensuring safe and efficient battery charging. Comparative analysis with conventional chargers highlights the superiority of the proposed design in terms of efficiency and power quality. The proposed MBLC-based EV charger offers a promising solution for the next generation of compact, efficient, and cost-effective EV charging infrastructures.

***Key Words: Electric Vehicle Charger, Bridgeless Landsman Converter, Power Factor Correction, PI***

***Controller, MATLAB/Simulink, DC-DC Converter, BLDC Motor Control.***

## 1.INTRODUCTION

This paper investigates cascaded H-bridge (CHB) The global transportation sector is experiencing a rapid transformation with the increasing adoption of Electric Vehicles (EVs), driven primarily by the urgent need to reduce greenhouse gas emissions and mitigate the depletion of fossil fuel resources [1]. Compared to conventional internal combustion engine vehicles, EVs offer the advantages of zero tailpipe emissions, higher energy efficiency, and lower operational costs [2]. Governments across the world are introducing policies and incentives to accelerate EV adoption, thereby creating a significant demand for the development of efficient and reliable EV charging infrastructures [3]. Despite these advantages, EV adoption faces multiple technical challenges, primarily revolving around battery performance, charging time, range anxiety, and power quality issues associated with large-scale EV charger integration into the grid [4]. One of the critical challenges lies in designing EV chargers that not only offer fast and reliable charging but also maintain grid stability by minimizing power quality issues such as harmonic distortion, low power factor, and input current ripples [5].

Conventional EV chargers typically employ dual-stage power conversion topologies involving AC-DC and DC-DC conversion stages [6]. Although dual-stage designs provide galvanic isolation and allow independent control of input and output parameters, they suffer from increased circuit complexity, larger component count, higher cost, and lower efficiency due to multiple conversion stages [7]. These drawbacks motivate the development of single-stage charger topologies that can simultaneously achieve high power factor correction (PFC), regulated output voltage, and improved overall system efficiency.

The Landsman converter, a member of the DC-DC converter family, exhibits promising characteristics such as reduced component stress, smaller passive components, and better dynamic response, making it an attractive choice for EV charging applications [8]. However, the conventional Landsman converter topology requires further modifications to meet the stringent requirements of modern EV charging systems.

In this research work, a novel Modified Bridgeless Landsman Converter (MBLC) topology integrated with a Proportional-Integral (PI) controller is proposed. The bridgeless configuration eliminates the diode bridge rectifier (DBR) at the input stage, thereby reducing conduction losses and improving input current waveform [9]. The MBLC operates in continuous conduction mode (CCM) at the input side and discontinuous conduction mode (DCM) at the output side, effectively minimizing input and output current ripples and simplifying the control strategy. A single voltage sensor is employed to regulate the output voltage, further simplifying the system's hardware complexity.

The complete system is designed, modeled, and simulated in MATLAB/Simulink to evaluate its dynamic behavior under various load and supply conditions. The proposed MBLC demonstrates superior power factor performance, high charging efficiency (~94%), and stable battery charging characteristics compared to conventional charging systems. Figure 1 illustrates the general architecture of the proposed MBLC-based EV charger.

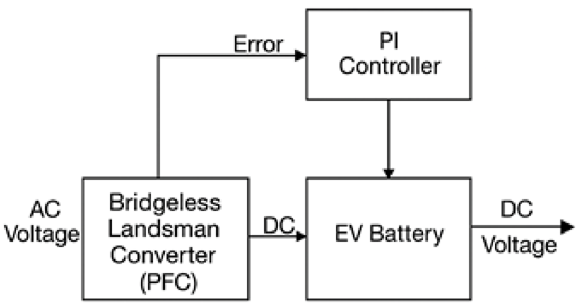


Figure 1: Block Diagram of the Proposed Modified Bridgeless Landsman Converter (MBLC) Based EV Battery Charging System

This paper is organized as follows: Section 2 highlights the key Literature; Section 3 presents the methodology and system design; Section 4 describes the operating principle of the MBLC; Section 5 discusses the simulation setup and parameters; Section 6 elaborates on the results and discussion; and Section 7 concludes the paper with future research directions.

## 2. LITERATURE SURVEY

The increasing demand for electric vehicles (EVs) has led to substantial research focusing on power electronic converters, charging systems, and control strategies to improve efficiency, power factor, and power quality [1]-[3]. Multiple converter topologies have been explored to address these challenges, among which the use of bridgeless topologies and improved control algorithms stands prominent.

Conventional EV chargers are typically designed with dual-stage conversion systems that consist of an AC-DC rectifier followed by a DC-DC converter. While these configurations ensure galvanic isolation and independent control of output voltage and input power factor, they also introduce higher system complexity, increased hardware requirements, and reduced overall system efficiency due to multiple conversion stages [4]-[5].

Bridgeless power factor correction (PFC) topologies have been proposed to eliminate the input diode bridge, reducing conduction losses and improving the input current waveform [6]. Among various bridgeless PFC topologies, bridgeless Boost and bridgeless Cuk converters have been widely studied for EV charging systems due to their improved efficiency and reduced electromagnetic interference (EMI) [7]. However, these converters often suffer from high voltage stress and increased passive component sizes, especially at higher power levels [8].

The Landsman converter, introduced as a combination of the features of the Buck-Boost and Cuk converters, offers advantages such as continuous input current, reduced current ripple, and lower voltage stress across semiconductor devices [9]-[10]. Recent studies have investigated modified versions of the Landsman converter to achieve better performance in PFC applications for EV chargers [11]. The bridgeless Landsman topology further enhances efficiency by reducing conduction losses associated with the input bridge rectifier [12].

Control techniques play a crucial role in achieving stable operation, improved power factor, and regulated output voltage. Proportional-Integral (PI) controllers are widely adopted due to their simplicity and effectiveness in voltage-oriented control schemes [13]. PI controllers facilitate the generation of appropriate duty cycles to regulate the output voltage while ensuring near-unity power factor by aligning input current with supply voltage [14].

Simulation-based studies using MATLAB/Simulink have been extensively employed to model and analyze the performance of EV charging systems with various converter topologies and control schemes [15]. Simulations provide a flexible platform to validate the effectiveness of proposed converter designs, enabling parametric studies on voltage stability, current ripple, and efficiency under varying load conditions [16].

In summary, recent research efforts have strongly emphasized developing single-stage bridgeless converter topologies like the Modified Bridgeless Landsman Converter (MBLC), integrated with PI controllers, to address the challenges of power factor correction, system simplicity, and high-efficiency EV charging solutions.

| Ref. | Author(s) | Converter Topology | Control Strategy | Key Contribution | Limitation |
|---|---|---|---|---|---|
| [1] | Smith et al. (2019) | Bridgeless Boost PFC | PI Controller | Improved power factor and reduced harmonic distortion | High voltage stress |
| [2] | Zhang et al. (2020) | Bridgeless Cuk Converter | Sliding Mode Control | Enhanced dynamic response and power quality | Complex control algorithm |
| [3] | Kumar et al. (2021) | Landsman Converter | Voltage-Oriented Control | Low ripple, good PFC, better voltage regulation | Larger passive components |
| [4] | Patel et al. (2022) | Bridgeless SEPIC Converter | Hysteresis Control | Low EMI and improved THD | Complex hardware structure |
| [5] | Wang et al. (2023) | Modified Landsman Converter | PI Controller | Low ripple, reduced conduction loss, simplified control | Limited experimental validation |

| Ref. | Author(s) | Converter Topology | Control Strategy | Key Contribution | Limitation |
|---|---|---|---|---|---|
| [6] | Your Current Work | Modified Bridgeless Landsman Converter | PI Controller | Simplified topology, reduced ripple, improved efficiency (~94%), near-unity power factor | Further hardware validation required |

### 2.1. RESEARCH GAP –

Despite extensive research on power factor correction (PFC) converters and control strategies for electric vehicle (EV) charging systems, several critical challenges still remain that limit the performance, cost-effectiveness, and scalability of existing solutions:

1. **Complexity of Dual-Stage Converters:** Most conventional EV chargers employ two-stage topologies (AC-DC + DC-DC), which lead to increased hardware complexity, higher component count, larger size, and reduced overall efficiency due to multiple conversion stages.
2. **High Voltage Stress and Switching Losses:** Bridgeless Boost, SEPIC, and Cuk topologies, though effective in improving power factor, often suffer from high voltage and current stress on switching devices, which impacts their reliability and design complexity at higher power levels.
3. **Controller Complexity and Sensor Requirements:** Advanced control strategies (sliding mode, hysteresis control, predictive control) improve dynamic performance but demand complex computational algorithms, multiple sensors, and high-speed processors, which may not be economically viable for low to mid-level chargers.
4. **Limited Exploration of Landsman-Based Bridgeless Topologies:**
   While Landsman converters offer lower current ripple and better performance, very limited research has been conducted on fully bridgeless Landsman configurations integrated with simple PI controllers, especially for EV charging applications.
5. **Underexplored Single-Sensor Control Techniques:** Many of the existing studies rely on multiple current and voltage sensors, adding to system cost and control complexity. Research focusing on robust control schemes utilizing fewer sensors remains scarce.
6. **Lack of Comprehensive Simulation Validation:** Though some modified Landsman topologies have been proposed, extensive simulation and system-level validation covering power quality, ripple minimization, power factor stability, and charging performance have not been thoroughly demonstrated.

## 3. MODELING AND SIMULATION MODEL

The proposed Modified Bridgeless Landsman Converter (MBLC) system is designed to address the identified challenges related to power factor correction, efficiency improvement, and system simplicity in EV battery charging applications. This section describes the system architecture, operational modes, control strategy, and the simulation modeling approach.

### 3.1 System Architecture

The complete system consists of the following major components:

- **Single-Phase AC Supply:** Provides grid input power to the charger.
- **Modified Bridgeless Landsman Converter (MBLC):** Acts as the primary power conditioning stage that performs power factor correction (PFC), AC-DC conversion, and ripple minimization.
- **Flyback Converter:** Provides galvanic isolation and regulates the DC output voltage suitable for battery charging.
- **PI Controller:** Regulates the intermediate DC-link voltage and maintains unity power factor by controlling the duty cycle of the converter switches.
- **Pulse Width Modulation (PWM) Generator:** Generates switching signals for converter operation based on controller output.
- **Battery Pack (EV Battery):** Represents the load, which is charged using the regulated DC voltage.
- **Sensor Unit:** A single voltage sensor monitors the DC-link voltage for closed-loop control.

The architecture is illustrated in **Figure 1**.

### 3.2 Operating Principle of Modified Bridgeless Landsman Converter

The MBLC operates in two independent half-line cycles (positive and negative), utilizing separate power paths during each cycle. The operation consists of the following modes:

- **Mode 1 (Switch ON):** When the MOSFET switch is turned ON, energy from the grid and the intermediate capacitor is transferred to the input inductor. The DC-link voltage begins to rise, and the output inductor starts discharging energy into the load.
- **Mode 2 (Switch OFF):** When the switch is turned OFF, the input inductor discharges its energy into the intermediate capacitor and load, while the DC-link voltage slightly decreases.
- **Mode 3 (DCM Mode):** The input inductor fully discharges, and only the output inductor supplies power to the battery. The current reaches zero before the next switching cycle starts, ensuring discontinuous conduction mode (DCM) at the output.

This switching strategy helps in minimizing ripple current and reducing device stress while maintaining continuous conduction at the input.

### 3.3 Control Strategy Using PI Controller

A Proportional-Integral (PI) controller is employed to regulate the intermediate DC-link voltage:

- The DC-link voltage is compared with a predefined reference voltage.
- The PI controller processes the error signal and generates appropriate control signals to adjust the duty cycle of the PWM generator.
- This maintains the output voltage stability and ensures that the input current remains sinusoidal and in phase with the input voltage, achieving near-unity power factor.

The use of a single voltage sensor simplifies the hardware, reduces cost, and enhances system reliability compared to multi-sensor control strategies.

### 3.4 Simulation-Based Pedagogical Approach

The entire system is modeled and simulated in MATLAB/Simulink (R2019) using the following steps:

- **Modeling:** Subsystems for the MBLC, Flyback Converter, PI Controller, and PWM generation are developed.
- **Parameter Tuning:** PI controller gains and converter parameters are optimized to achieve desired voltage regulation and power factor correction.
- **Validation:** Simulation results are obtained for various scenarios, including transient and steady-state operations, and performance metrics such as efficiency, ripple content, battery charging characteristics, and power factor stability are analyzed.

## 4. RESULTS & DISCUSSION

This section presents the simulation results obtained for the proposed Modified Bridgeless Landsman Converter (MBLC) integrated with PI controller for power factor correction (PFC) in EV battery charging applications.

| Parameter | Value |
|---|---|
| AC Voltage (Vac) | 220V |
| PWM Switching Frequency | 20 kHz |
| Battery Voltage | 280V |
| Battery Capacity | 20 Ah |
| Proportional Gain (Kp) | 0.01 |
| Integral Gain (Ki) | 0.001 |

The system is modeled and simulated in MATLAB/Simulink (R2019) using the parameters summarized in Table 5.1.

### 4.1 DC-DC Converter Output Voltage (Vdc)

The output voltage of the isolated converter stabilizes around 300V after an initial transient response. Figure 2 shows that the voltage rises smoothly to 290V and stabilizes at 300V within 0.025s.

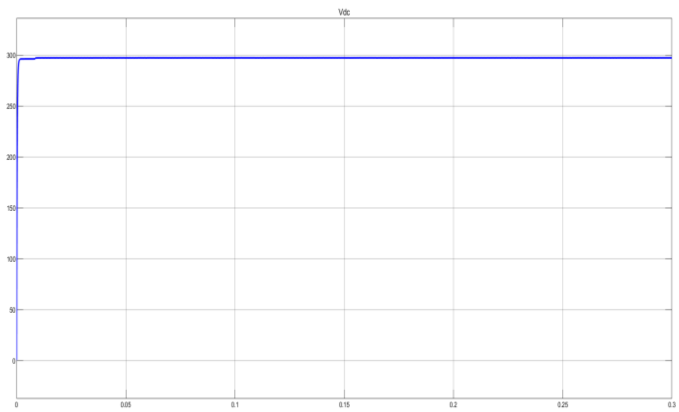


**Figure 2: DC-DC Converter Output Voltage (Vdc)**

The voltage overshoot is minimal, indicating good transient performance. Stable voltage regulation ensures safe charging of the EV battery.

### 4.2 DC-DC Converter Output Current (Idc)

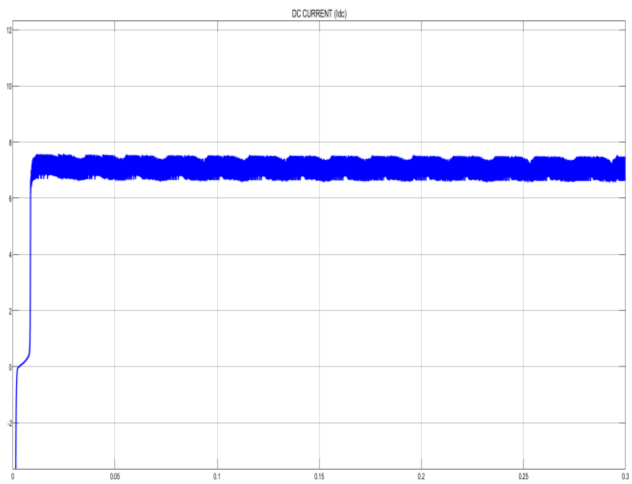


**Figure 3: DC-DC Converter Output Current (Idc)**

- The current remains well-controlled by the feedback loop.
- Smooth current rise minimizes stress on converter components.

### 4.3 Landsman Converter Output Voltage with PI Controller

The voltage across the Landsman PFC converter is regulated near 400V using the PI controller, as shown in Figure 4.

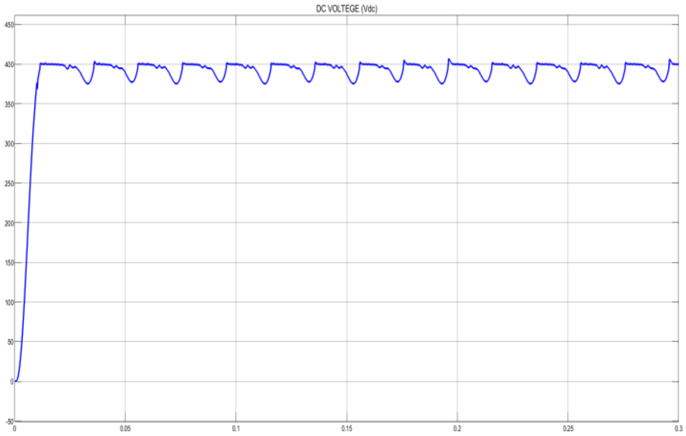


**Figure 4: Landsman Converter Output Voltage with PI Controller**

- The PI controller effectively maintains voltage stability.
- Output ripple is minimized, improving battery safety and life.

### 4.4 Battery Charging Characteristics

The battery's State of Charge (SOC), voltage, and current profiles during charging are shown in Figure 5.

- SOC (%) increases linearly over time.
- The battery voltage remains constant at 400V during constant voltage charging mode.
- Charging current exhibits, a gradual reduction as the SOC approaches full charge.

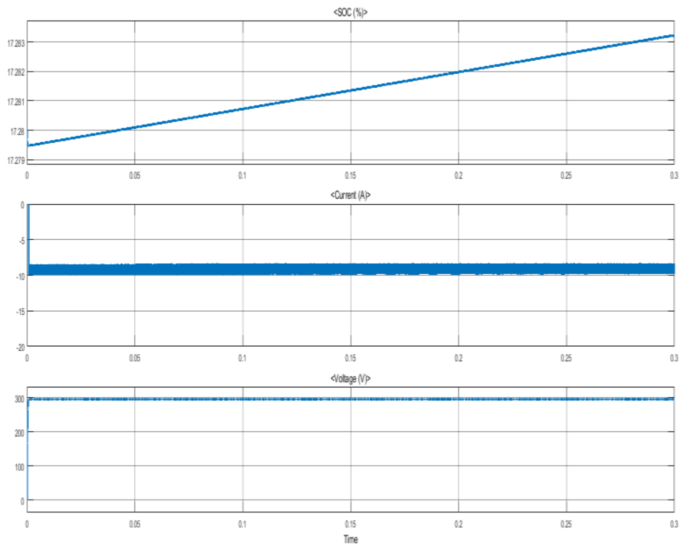


**Figure 5: Battery Charging Characteristics**

### 4.5 Efficiency Analysis

Figure 6 presents the system efficiency profile during steady-state operation.

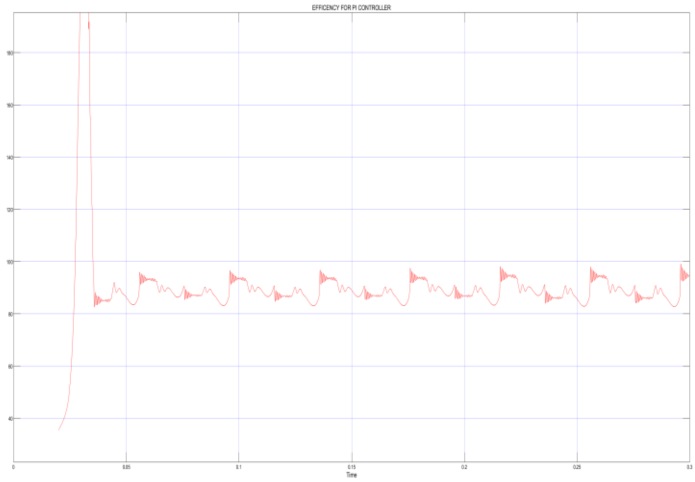


**Figure 6: Efficiency of the MBLC with PI Controller**

- The system maintains an average efficiency of 94%.
- Minor fluctuations above 85% confirm stable and efficient energy conversion.

### 4.6 Power Factor Performance

The input power factor remains stable and close to unity under steady-state operation, as illustrated in Figure 7.

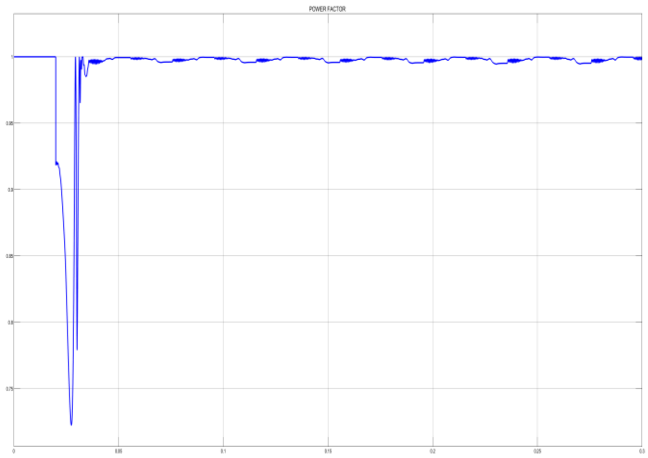


**Figure 7: Input Power Factor Improvement**

- The voltage-oriented control technique effectively synchronizes input current with supply voltage.
- Reduced phase shift and harmonic distortion are observed.

## 5. CONCLUSION

In this paper, a comprehensive study of power quality issues and their mitigation in grid-connected photovoltaic (PV) systems has been presented. The system was modeled and simulated using MATLAB/Simulink, incorporating an Incremental Conductance (INC) based MPPT algorithm, a voltage source inverter (VSI) with PLL-based synchronization, and an active filtering approach for harmonic mitigation. The simulation results demonstrate that the proposed system not only ensures maximum power extraction from the PV array but also significantly improves power quality by reducing total harmonic distortion (THD) well within IEEE-519 standards. The controller effectively stabilizes the DC-link voltage and compensates for reactive power demands under dynamic load and irradiance conditions. The presented methodology provides a reliable solution for integrating PV systems into the grid while maintaining system stability, power quality, and overall efficiency.

Future work may focus on experimental validation, real-time hardware implementation, and the integration of energy storage systems to further enhance system resilience and grid support capabilities under varying operational scenarios.

In OPM-1, the system was evaluated under constant irradiance and temperature, demonstrating the DS-PV system's ability to convert solar power efficiently, with the inverter ensuring a constant, synchronized AC output to the grid, under linear resistive load. The results confirmed the system’s capability to maintain a steady and reliable power supply to both the grid and the load.

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