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Design and Analysis of Modified Bridgeless AC–DC Landsman Converter for EV Charger Applications

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Abstract:** The rapid growth of electric vehicles (EVs) has increased the demand for efficient and high-power quality battery charging systems. Conventional EV chargers typically use diode bridge rectifiers followed by DC–DC converters for AC–DC power conversion; however, these rectifier-based systems suffer from high conduction losses, poor power factor, increased total harmonic distortion (THD), and reduced overall efficiency. These drawbacks not only degrade charger performance but also introduce harmonics into the utility grid, resulting in additional losses and reduced reliability. To address these issues, this paper presents the design and analysis of a modified bridgeless AC–DC Landsman converter for EV charging applications. The proposed topology eliminates the conventional diode bridge rectifier, thereby reducing conduction losses and improving efficiency. The converter operates as a power factor correction (PFC) stage and provides a regulated DC output suitable for EV battery charging. The modified bridgeless configuration reduces the number of conducting devices in each switching cycle, which improves power quality and minimizes input current ripple. A PI controller is employed to regulate the DC-link voltage and maintain a constant output voltage. The proposed converter is modeled and simulated in MATLAB/Simulink using a 230 V single-phase AC input with a switching frequency of 20 kHz, and the output voltage is regulated to 48 V. Simulation results demonstrate improved power factor, reduced harmonic distortion, and stable output voltage. The input current waveform becomes nearly sinusoidal, and conduction losses are significantly reduced compared to conventional rectifier-based chargers. Therefore, the proposed modified bridgeless Landsman converter provides improved efficiency, reduced THD, better voltage regulation, and enhanced power quality, making it suitable for EV battery charging applications.
***Keywords:** Modified Bridgeless Converter, Landsman Converter, Electric Vehicle Charger, Power Factor Correction, AC–DC Converter, Harmonic Reduction, MATLAB/Simulink, High Efficiency, PI Controller, EV Battery Charging*

I. INTRODUCTION

This document is a template.For questions onpaper guidelines, please contact us via e-mail. The increasing demand for electric vehicles (EVs) has led to the development of efficient and reliable battery charging systems. EV chargers must provide high efficiency, improved power quality, and reduced harmonic distortion to ensure proper integration with the electrical grid. Conventional EV battery chargers generally employ diode bridge rectifiers followed by DC–DC converters for AC–DC power conversion. Although these converters are simple and widely used, they suffer from significant drawbacks such as high conduction losses, poor input power factor, and increased total harmonic distortion (THD). These issues reduce overall system efficiency and negatively impact the utility grid.

Power factor correction (PFC) converters are widely used to improve input current quality and reduce harmonic distortion. Among various PFC topologies, bridgeless converters have gained significant attention due to their reduced conduction path and improved efficiency. By eliminating the conventional diode bridge rectifier, bridgeless converters reduce the number of semiconductor devices conducting during each switching cycle. This results in lower conduction losses, improved efficiency, and better thermal performance.

The Landsman converter is a non-isolated DC–DC converter derived from SEPIC and Cuk converter topologies. It offers advantages such as reduced input current ripple, continuous input current, and improved voltage regulation. By implementing a modified bridgeless Landsman converter, the input current waveform can be improved and harmonic distortion can be minimized. This makes the topology suitable for EV battery charging applications where high efficiency and improved power quality are required.

In this work, a modified bridgeless AC–DC Landsman converter is proposed for EV charger applications. The converter is designed to operate with a single-phase 230 V AC input and regulate the output voltage to 48 V. A PI controller is used to maintain constant output voltage and improve system stability. The proposed system is modeled and simulated using MATLAB/Simulink, and performance is evaluated in terms of output voltage regulation, harmonic distortion, and power factor improvement.

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II. EXISTING SYSTEM

An Conventional electric vehicle (EV) battery chargers generally use a diode bridge rectifier followed by a DC–DC converter for AC–DC power conversion. In this configuration, the AC input supply is first rectified using a full-bridge diode rectifier, and the resulting DC voltage is processed using a DC–DC converter to obtain the required output voltage for battery charging. Although this method is simple and widely used, it suffers from several limitations such as high conduction losses, poor power factor, and increased harmonic distortion. The presence of multiple diodes in the current path increases voltage drop and power loss, which reduces overall system efficiency.

In addition, the input current drawn by the diode bridge rectifier is highly non-sinusoidal, which results in low power factor and high total harmonic distortion (THD). These harmonics propagate into the power system and may cause overheating of equipment, increased losses, and poor power quality. Moreover, the rectifier stage requires additional filtering components to reduce ripple and improve performance, which increases system size and cost. The reduced efficiency and poor power quality of conventional rectifier-based EV chargers make them less suitable for modern electric vehicle charging applications.

Therefore, there is a need for improved converter topologies that can reduce conduction losses, improve power factor, and minimize harmonic distortion. Bridgeless converter configurations offer an effective solution by eliminating the diode bridge rectifier and reducing the number of conducting components. This motivates the use of a modified bridgeless Landsman converter for efficient EV battery charging applications.

III. PROPOSED SYSTEM

The proposed system consists of a modified bridgeless AC–DC Landsman converter designed for electric vehicle battery charging applications. The conventional diode bridge rectifier used in traditional EV chargers is eliminated to reduce conduction losses and improve efficiency. The modified bridgeless configuration operates during both positive and negative half cycles of the input AC supply using two switches and inductors. This reduces the number of conducting semiconductor devices in each switching cycle and improves overall power quality.

The input to the proposed converter is a single-phase 230 V AC supply. The AC input is directly processed by the modified bridgeless Landsman converter, which performs both rectification and power factor correction. During the positive half cycle, one set of switch and inductor operates, while during the negative half cycle, the other set conducts. This symmetrical operation ensures continuous input current and reduced harmonic distortion. The converter also minimizes input current ripple due to the presence of inductors in both half cycles.

A DC-link capacitor is used to maintain a stable intermediate voltage. The output voltage is regulated using a PI controller that senses the output voltage and compares it with a reference voltage of 48 V. The error signal generated by the controller is used to produce PWM pulses for switching operation. The switching frequency of the converter is maintained at 20 kHz to balance efficiency and harmonic reduction. The regulated DC output is suitable for EV battery charging applications.

The proposed converter offers several advantages such as reduced conduction losses, improved power factor, reduced total harmonic distortion, and better voltage regulation. The modified bridgeless Landsman converter also reduces component count and improves overall efficiency, making it suitable for electric vehicle charger applications.

A. *Circuit Description*

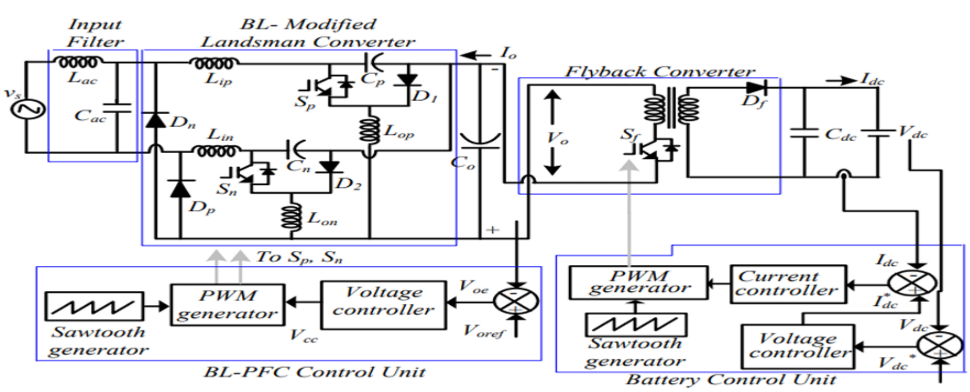

Fig. 1 Circuit Diagram of Proposed Method

The proposed converter consists of an input filter followed by a modified bridgeless Landsman converter. The input filter is formed by inductor L_{ac} and capacitor C_{ac}, which reduces input current harmonics and smooths the AC supply. The filtered AC voltage is then applied to the modified bridgeless Landsman converter. The converter eliminates the conventional diode bridge rectifier and uses two switches S_p and S_n operating during positive and negative half cycles of the input voltage.

During the positive half cycle of the input voltage, switch S_p, inductor L_i, coupling capacitor C_p, and output inductor L_{op} participate in power transfer. The diode D_1 provides the current path when the switch is turned OFF. The energy stored in the inductors is transferred to the output capacitor C_o and load. Similarly, during the negative half cycle, switch S_n inductor L_{in}, coupling capacitor C_n, and output inductor L_{on}operate. The diode D_2 conducts during the OFF period of the switch and transfers energy to the output stage.

Diodes D_p and D_n provide current paths corresponding to the polarity of the input voltage. The output capacitor C_o maintains a constant DC output voltage and reduces voltage ripple. The inductors L_{ip}, L_{in}, L_{op}, and L_{on} ensure continuous input current and reduce harmonic distortion. This bridgeless configuration reduces conduction losses by minimizing the number of conducting devices in each switching cycle.

The converter is controlled using a PI controller that regulates the output voltage to 48 V. The sensed output voltage is compared with a reference value, and the error signal is processed to generate PWM pulses. These pulses drive switches S_p and S_n at a switching frequency of 20 kHz. The proposed circuit provides improved power factor, reduced harmonic distortion, and regulated output voltage suitable for EV battery charging applications.

B. Operating Modes of Modified Bridgeless Landsman Converter

The modified bridgeless Landsman converter operates in three modes during the positive half cycle of the input voltage. The operation depends on the switching state of switch S_p and energy transfer through inductors and capacitors. The converter operates in discontinuous conduction mode for simplified control and improved power factor.

1) Mode 1 (t_o – t_1): Switch S_p ON – Inductor Charging

During the positive half cycle, switch S_p is turned ON. The input inductor L_{ip} and output inductor L_{op} start charging through the input supply. The coupling capacitor C_p transfers energy, while diode D_1 remains reverse biased. The output capacitor C_o supplies energy to the load during this interval. The inductor current increases linearly and energy is stored in the inductors. This mode represents the energy storage interval of the converter.

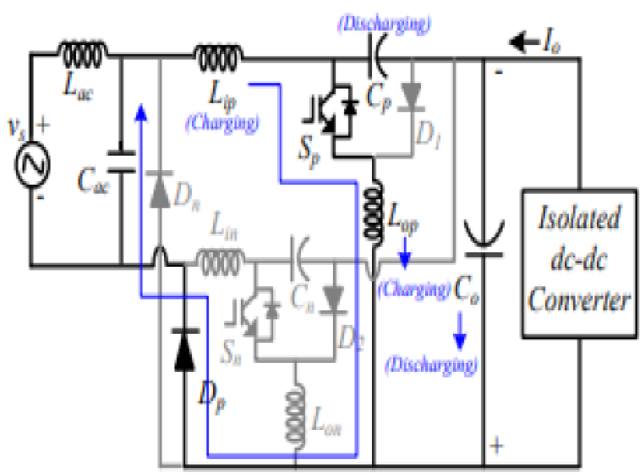

Fig. 2 Circuit Diagram of Mode 1 (t_0 – t_1): Switch Sp ON – Inductor Charging

2) Mode 2 (t_1 – t_2): Switch Sp OFF – Energy Transfer

When switch S_p is turned OFF, diode D_1 becomes forward biased. The stored energy in inductors L_{ip} and L_{op} is transferred to the output capacitor C_o and load. The coupling capacitor C_p also participates in energy transfer. The output capacitor starts charging, and the inductor current decreases gradually. This mode represents the power transfer interval of the converter.

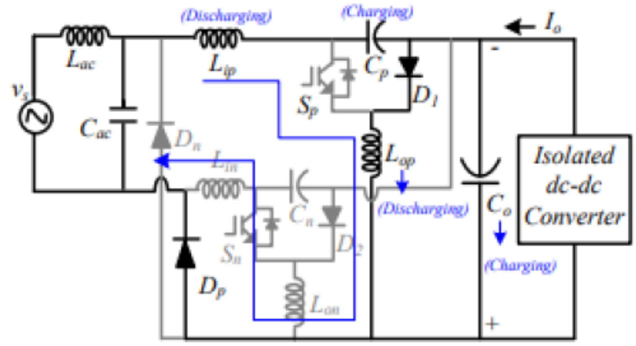

Fig. 3 Circuit Diagram of Mode 2 ($t_1 - t_2$): Switch Sp OFF – Energy Transfer

3) Mode 3 ($t_2 - t_3$): Discontinuous Conduction Mode

In this mode, the energy stored in inductors is completely discharged. The inductor current reaches zero before the next switching cycle begins. The diode D_1 becomes reverse biased, and the load is supplied only by the output capacitor C_o. The converter operates in discontinuous conduction mode during this interval. This mode helps in achieving improved power factor and simplified control of the converter.

The same operating modes repeat for the negative half cycle using switch S_n, inductors L_{in} and L_{on}, and diode D_2. This symmetrical operation ensures continuous input current and reduced harmonic distortion.

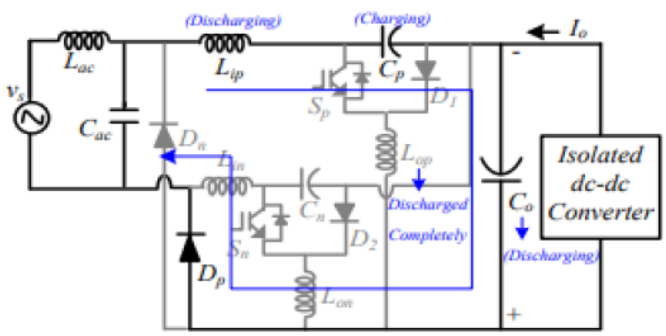

Fig. 4 Circuit Diagram of Mode 3 ($t_2 - t_3$): Discontinuous Conduction Mode

C. Design Calculations

The design parameters of the modified bridgeless Landsman converter are calculated based on the required output voltage, input voltage, and switching frequency. The converter is designed for a 230 V AC input supply and regulated 48 V DC output.

$$V_{in} = 230V, V_o = 48V, P_o = 1000W, f_s = 20kHz$$

1) Peak Input Voltage

$$V_{s,peak} = \sqrt{2}V_{in}$$

$$V_{s,peak} = \sqrt{2} \times 230 = 325\ V$$

2) Output Current

$$I_o = \frac{P_o}{V_o}$$

$$I_o = \frac{1000}{42} = 25.83\ A$$

3) Duty Cycle

$$D = 1 - \frac{V_o}{V_{s,peak}}$$

$$D = 1 - \frac{42}{325} = 0.65$$

4) Input Inductor

$$L_{in} = \frac{V_{s,peak}^2}{2P_o f_s}$$

$$L_{in} = \frac{325^2}{2 \times 1000 \times 20000}$$

$$L_{in} = 2.4\ mH$$

5) Output Inductor

$$L_{out} = \frac{V_o(1-D)^2}{2f_s I_o}$$

$$L_{out} = \frac{48(1-0.65)^2}{2 \times 20000 \times 25.83}$$

$$L_{out} = 0.2\ mH$$

6) Output Capacitor

$$C_o = \frac{I_o D}{f_s \Delta V_o}$$

Assume ripple = 2%

$$\Delta V_o = 0.02 \times 48 = 0.96V$$

$$C_o = \frac{25.83 \times 0.65}{20000 \times 0.66}$$

$$C_o = 62\mu F$$

7) Load Resistance

$$R_{load} = \frac{V_o}{I_o}$$

$$R_{load} = \frac{42}{25.83} = 1.6$$

IV. SIMULATION RESULTS AND DISCUSSION

The proposed modified bridgeless AC–DC Landsman converter is simulated using MATLAB/Simulink to evaluate its performance. The simulation is carried out with a single-phase 230 V AC input supply and switching frequency of 20 kHz. A PI controller is used to regulate the output voltage to 48 V. The performance of the converter is analysed using output voltage, input current, PWM pulses, inductor current, and harmonic analysis.

1) Input Voltage and Input Current

The input voltage waveform is sinusoidal, and the input current follows the input voltage waveform. The input current is shaped by the inductors in the converter, resulting in reduced distortion. The nearly sinusoidal input current indicates improved power factor and better power quality. The input filter further reduces switching harmonics and smooths the current waveform.

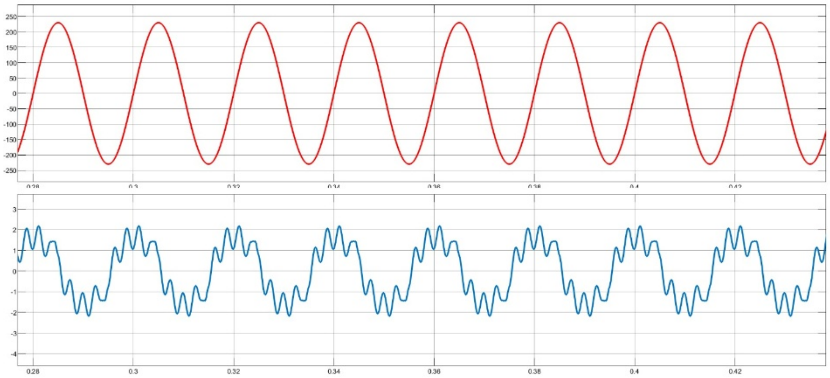

Fig. 6 Waveform of Input Voltage and Input Current

2) Output Voltage:

The output voltage waveform is regulated to 48 V using the PI controller. Initially, the output voltage rises from zero and settles at the reference value. The output capacitor reduces voltage ripple and maintains a constant DC output. The regulated output voltage confirms proper operation of the modified bridgeless Landsman converter for EV battery charging applications

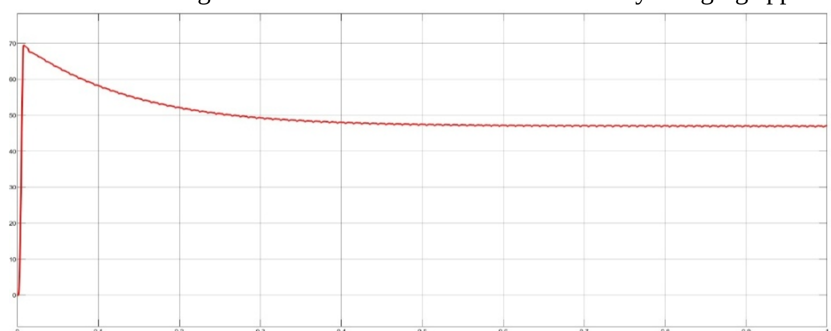

Fig. 7 Waveform of Output Voltage

3) PWM Pulses and Inductor Current

The PWM pulses are generated at a switching frequency of 20 kHz. These pulses control the switching operation of the converter. The inductor current waveform shows charging and discharging behavior corresponding to switching intervals. The current operates in discontinuous conduction mode, which simplifies control and improves power factor. The ripple in the inductor current is limited due to proper selection of inductance values.

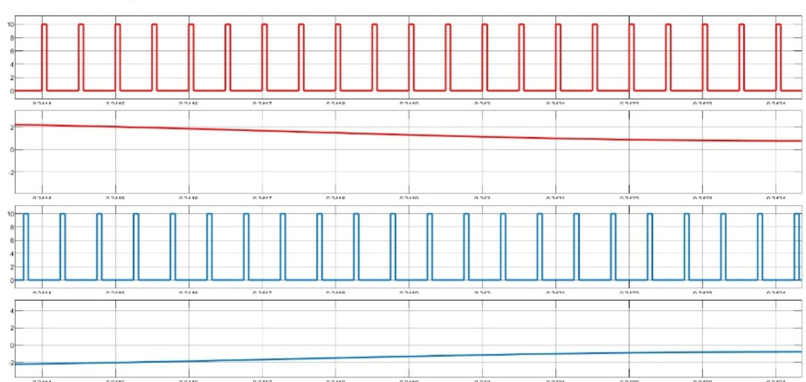

Fig. 8 Waveform of PWM Pulses and Inductor Current

4) Harmonic Analysis

FFT analysis of the input current is performed to evaluate harmonic distortion. The total harmonic distortion (THD) is observed to be approximately 37% without using an LC filter. The dominant harmonics are 5th and 7th order components. The inclusion of an input filter reduces harmonic distortion and improves input current waveform. The reduction in THD demonstrates improved power quality of the proposed converter.

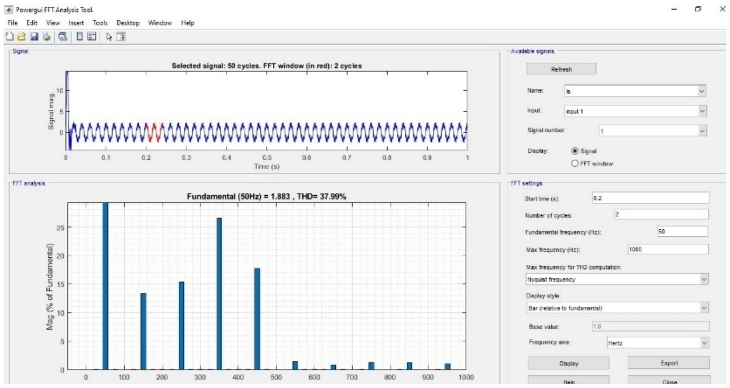

Fig. 9 Waveform of Harmonic Analysis

The simulation results confirm that the modified bridgeless Landsman converter provides regulated output voltage, improved power factor, and reduced harmonic distortion. The converter operates efficiently and is suitable for EV battery charging applications.

V. HARDWARE IMPLEMENTATION

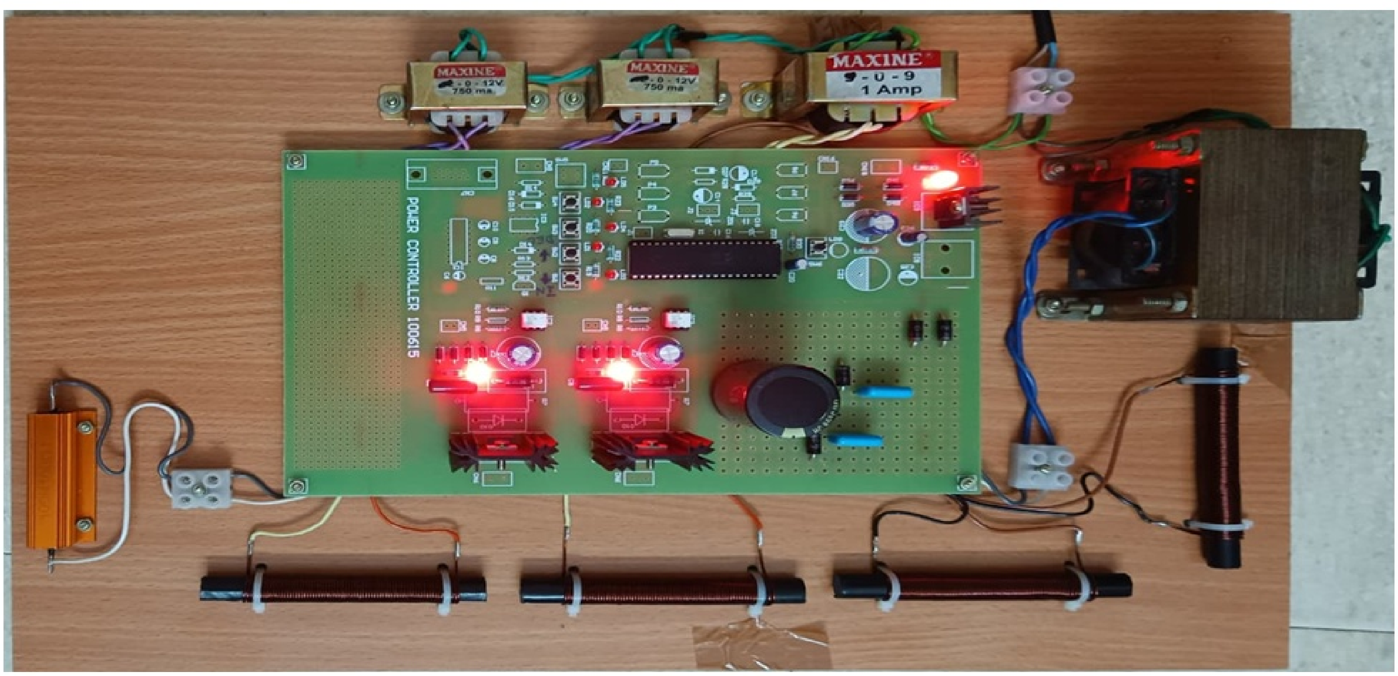

Fig. 10 Waveform of Harmonic Analysis

A hardware prototype of the modified bridgeless AC–DC Landsman converter is developed to validate the performance of the proposed system. The hardware setup consists of power switches, inductors, diodes, capacitors, control circuit, and power supply unit. The inductors used in the converter are designed to maintain continuous input current and reduce ripple. The switching pulses required for the converter operation are generated using a controller-based PWM circuit.

The input AC supply is stepped down using a transformer and rectified to obtain the required DC supply for the control circuit. The gate driver circuit is used to drive the power switches. Proper heat sinks are provided for switching devices to reduce thermal stress.

The output capacitor is used to maintain a constant DC output voltage, and resistive load is connected at the output to verify converter operation.

The hardware kit demonstrates the charging and discharging behaviour of inductors during switching operation. LEDs are used for indication of switching states. The implemented prototype validates the operation of the modified bridgeless Landsman converter. The experimental setup confirms proper switching, regulated output voltage, and improved performance of the proposed converter.

The hardware results closely match the simulation results, demonstrating the effectiveness of the proposed topology. The developed hardware prototype verifies that the modified bridgeless Landsman converter is suitable for EV battery charging applications with improved efficiency and reduced harmonic distortion.

VI. CONCLUSION

In this paper, a modified bridgeless AC–DC Landsman converter for electric vehicle charging applications has been designed, simulated, and experimentally validated. The proposed converter eliminates the conventional diode bridge rectifier, thereby reducing conduction losses and improving overall efficiency. The modified bridgeless configuration allows the converter to operate during both positive and negative half cycles of the input voltage, resulting in improved input current waveform and reduced harmonic distortion.

The converter is simulated using MATLAB/Simulink with a 230 V AC input and switching frequency of 20 kHz. A PI controller is implemented to regulate the output voltage to 48 V. Simulation results demonstrate improved power factor, reduced input current harmonics, and stable output voltage. The input current waveform becomes nearly sinusoidal, indicating improved power quality. The converter also operates in discontinuous conduction mode, which simplifies control and enhances performance.

A hardware prototype of the modified bridgeless Landsman converter is developed to validate the simulation results. The hardware implementation confirms proper switching operation and regulated output voltage. The experimental setup verifies the effectiveness of the proposed converter in reducing conduction losses and improving efficiency.

Therefore, the modified bridgeless Landsman converter provides improved efficiency, reduced total harmonic distortion, better voltage regulation, and enhanced power quality. The proposed converter is suitable for electric vehicle battery charging applications and can be considered as an effective alternative to conventional rectifier-based EV chargers.

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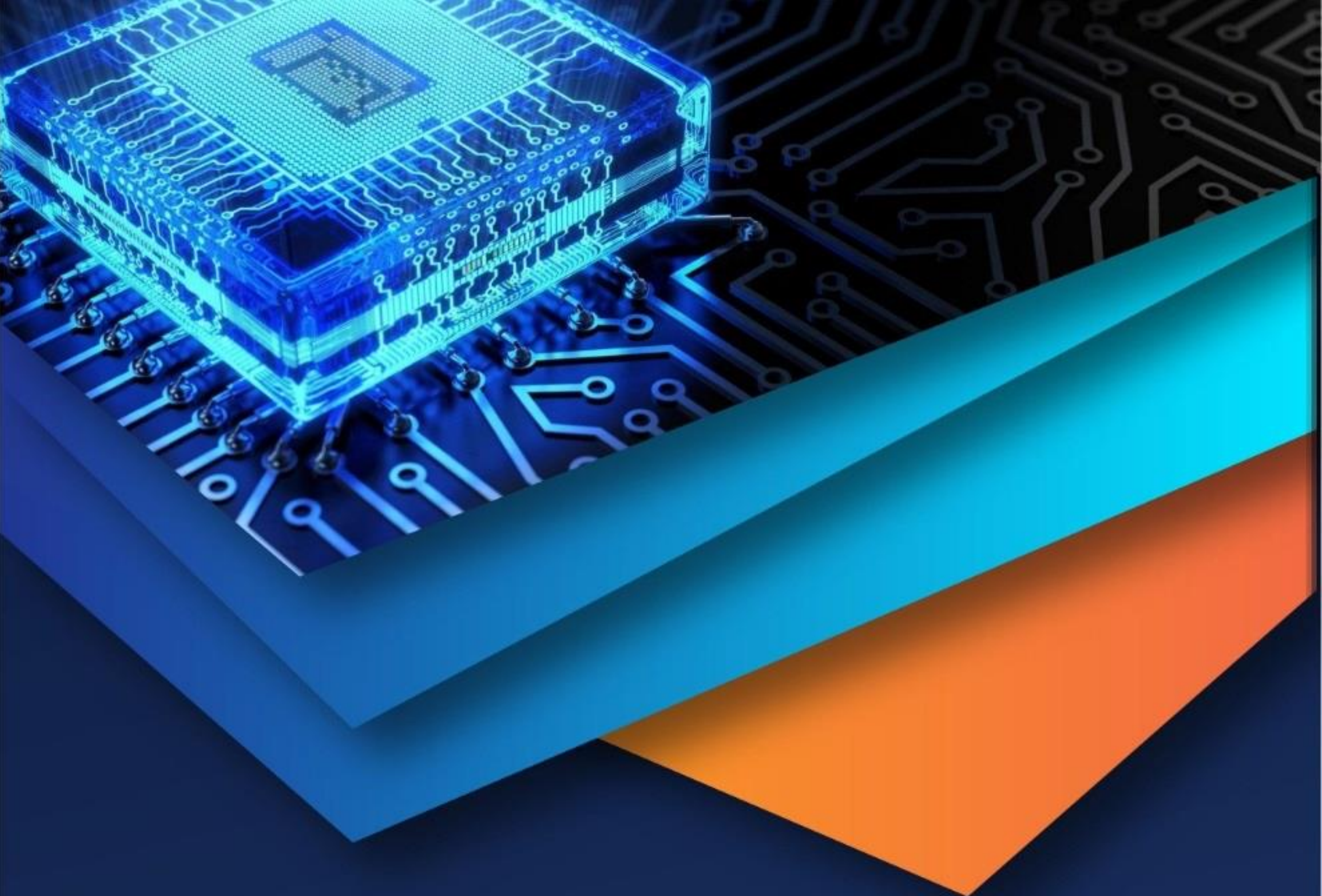

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