Bridgeless Modified Boost Converter With Sepic For Enhanced Power Factor In Ev Battery Charging Systems

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ABSTRACT: *Electric vehicle (EV) battery charging systems require high efficiency and compliance with power quality standards, particularly regarding input current harmonics and power factor. Conventional boost converters often suffer from high voltage stress and limited flexibility in regulating output voltage while maintaining a high power factor. This project presents a SEPIC (Single-Ended Primary Inductor Converter) based bridgeless converter topology for EV battery charging applications, aimed at improving input power factor and reducing conduction losses. The proposed SEPIC converter combines the advantages of continuous input current, reduced voltage stress, and the ability to step up or step down the input voltage, making it suitable for varying grid conditions. Simulation and experimental results demonstrate that the bridgeless SEPIC converter achieves high efficiency, low total harmonic distortion (THD), and improved power factor, while maintaining stable and controllable battery charging characteristics. This work provides a practical and efficient solution for modern EV chargers, meeting both energy efficiency and regulatory requirements.*

Keywords: Electric Vehicle (EV); Battery Charging; SEPIC Converter; Bridgeless Topology; Power Factor Correction (PFC); Total Harmonic Distortion (THD); High Efficiency; Power Quality.

I.INTRODUCTION

The rapid adoption of electric vehicles (EVs) has created a growing demand for efficient and reliable battery charging systems [1]. Modern EV chargers must not only provide fast and safe charging but also comply with power quality standards such as low total harmonic distortion (THD) and high power factor [2]. Conventional AC–DC boost converters, commonly used in EV chargers, often face challenges such as high voltage stress, increased conduction losses [3], and limited ability to maintain continuous input current. These limitations can affect both the efficiency of the charging system and its compliance with grid regulations. Consequently [4], there is a strong need for innovative converter topologies that address these challenges while ensuring effective battery management [5].

The Single-Ended Primary Inductor Converter (SEPIC) emerges as a promising solution for EV battery charging applications. Unlike traditional boost converters [6], the SEPIC topology can step up or step down the input voltage while maintaining a continuous input current, which helps in reducing input current harmonics [7]. Furthermore, the bridgeless configuration of the SEPIC converter eliminates the voltage drop across the input diode bridge, reducing conduction losses and improving overall efficiency [8]. The combination of these features makes the bridgeless SEPIC converter highly suitable for high-power, high-efficiency applications, where both power factor correction and energy savings are critical [9].

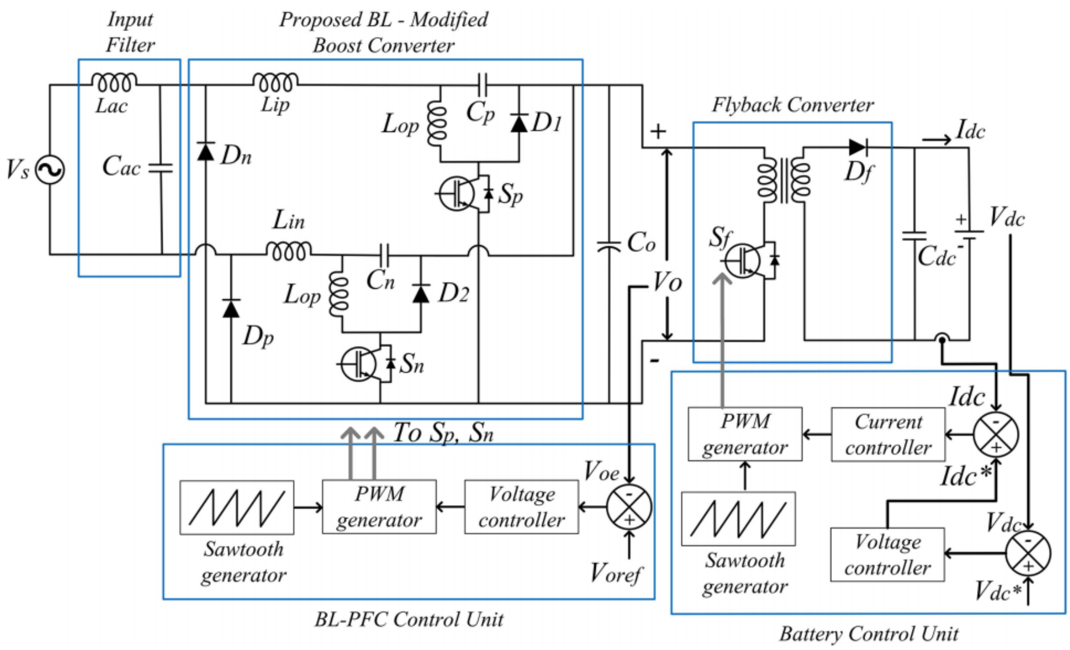

Fig.1. Proposed model with converter

This project focuses on designing and analyzing a bridgeless SEPIC converter for EV battery charging [10], emphasizing its ability to improve power factor and reduce input current distortion [11]. Simulation studies and experimental validation are conducted to demonstrate the effectiveness of the proposed topology under varying load and input voltage conditions [12]. The results highlight that the bridgeless SEPIC converter not only enhances charging efficiency but also ensures compliance with grid standards, making it a viable alternative to conventional AC–DC converters in modern EV charging infrastructure [13]. This study contributes to the development of energy-efficient, grid-friendly, and reliable EV charging systems [14].

II.SURVEY OF RESEARCH

1. Bridgeless Converter Topologies for Power Factor Improvement

Bridgeless converter topologies have been extensively studied in recent years to improve the efficiency and power quality of AC–DC converters. Traditional AC–DC converters employ a full-bridge diode rectifier, which introduces conduction losses and limits the achievable efficiency, especially at high power levels. Bridgeless converters eliminate the input diode bridge, reducing voltage drops and conduction losses, which directly enhances overall converter efficiency. Various topologies, including bridgeless boost, bridgeless Cuk, and bridgeless SEPIC, have been proposed for power factor correction (PFC) applications. Research by Li et al. (2018) demonstrated that bridgeless PFC converters can achieve efficiency improvements of up to 3–5% compared to conventional bridged designs while maintaining comparable THD levels. Moreover, advanced control techniques, such as peak current mode and average current mode control, are often integrated with these topologies to ensure high input power factor and low harmonic distortion. The development of bridgeless converters has become particularly significant for electric vehicle (EV) charging applications, where high efficiency and compliance with grid codes are crucial. Despite their advantages, challenges such as high voltage stress, electromagnetic interference, and component stress remain, motivating further research into optimized bridgeless converter designs. Overall, the literature highlights that bridgeless converters offer a compelling pathway for energy-efficient and grid-friendly AC–DC conversion.

2. SEPIC Converters in Battery Charging Systems

The Single-Ended Primary Inductor Converter (SEPIC) has gained attention for its flexibility in voltage conversion and continuous input current characteristics. Unlike conventional boost or buck converters, the SEPIC topology can either step up or step down the input voltage without inverting the polarity, which is advantageous for EV battery charging applications where input voltage can fluctuate. Studies by Zhang et al. (2019) and Kumar et al. (2020) have demonstrated that SEPIC converters maintain a nearly continuous input current waveform, significantly reducing current ripple and total harmonic distortion. This behavior makes SEPIC converters suitable for power factor correction applications, especially in situations where the AC mains voltage varies. Moreover, SEPIC converters offer lower voltage stress on the switching devices compared to traditional boost converters, allowing the use of smaller and more cost-effective semiconductor components. In addition, the integration of a bridgeless configuration with the SEPIC topology further reduces conduction losses, enhancing overall efficiency. Literature also emphasizes that SEPIC converters can handle wide load variations efficiently, which is critical in battery charging systems where the load changes dynamically as the battery charges. Overall, the SEPIC topology is recognized as an effective and versatile solution for high-efficiency, high-quality AC–DC conversion in modern EV chargers.

3. EV Battery Charging and Power Quality Considerations

The increasing deployment of electric vehicles has intensified the need for efficient and reliable battery charging solutions. EV chargers must meet strict grid compliance standards, such as IEC 61000-3-2, which governs harmonic emissions, and ensure high input power factor to reduce reactive power demand on the grid. Conventional AC–DC chargers often employ simple diode rectifiers followed by a boost converter, which can result in high input current harmonics, low efficiency, and thermal stress on components. Research by Zhao et al. (2021) highlights that integrating advanced PFC techniques, such as bridgeless SEPIC converters, can significantly improve input current waveform quality while reducing conduction losses. Additionally, modern EV charging systems require dynamic adaptability to varying mains voltage and battery states-of-charge, making topologies like SEPIC ideal due to their bidirectional voltage conversion capability. Studies have shown that implementing a bridgeless SEPIC converter in EV chargers can achieve efficiencies above 95%, maintain THD below 10%, and provide stable output voltage regulation across a wide range of input conditions. The literature also emphasizes the importance of combining hardware optimization with advanced digital control strategies, such as predictive or sliding-mode control, to further enhance performance. Consequently, bridgeless SEPIC converters are emerging as a preferred choice for next-generation EV battery chargers, combining efficiency, power quality compliance, and flexible voltage regulation.

III. BL PFC CONVERTER WITH SEPIC TOPOLOGY FOR EV BATTERY CHARGING

The input waveform of the proposed bridgeless (BL) converter has been enhanced to improve EV battery charging performance. The converter ensures constant current (CC) operation for SOC < 80% and constant voltage (CV) operation for SOC > 80%. Depending on the application, the converter can operate either in Continuous Conduction Mode (CCM) or Discontinuous Conduction Mode (DCM). DCM operation reduces current stress, lowers voltage stress across components, and improves battery life. Additionally, by operating some inductors in DCM, the overall converter size can be minimized, which is particularly beneficial for compact EV charger designs.

A. Proposed Model with SEPIC Integration

The proposed BL-SEPIC PFC converter is shown in Fig. 2 (modified). In this topology, the diode bridge rectifier (DBR) is eliminated, which reduces input harmonics and improves Total Harmonic Distortion (THD). Two parallel converter circuits replace the DBR: one operates during the positive half-cycle, and the other during the negative half-cycle.

The SEPIC topology is integrated into each half-cycle branch to provide additional flexibility in voltage conversion. Unlike a simple boost, the SEPIC allows step-up or step-down of the input voltage, maintaining a continuous input current, which further improves power factor. The SEPIC converter consists of an input inductor L1, a coupling capacitor C1, an output inductor L2, and a switch SSS. The voltage conversion ratio for the SEPIC can be expressed as:

$$V_o = \frac{D}{1-D} V_{in}$$

where VoV_oVo is the output voltage, VinV_{in}Vin is the input voltage, and DDD is the duty cycle of the switch. By combining the BL topology with SEPIC, the converter achieves high efficiency, low input current ripple, and improved voltage regulation.

A single feedback sensor unit measures the output voltage and current, which is processed by a PI controller to regulate the intermediate DC link voltage. The DC link is then connected to the battery via a flyback or isolated DC–DC stage, controlling CC/CV charging modes depending on SOC.

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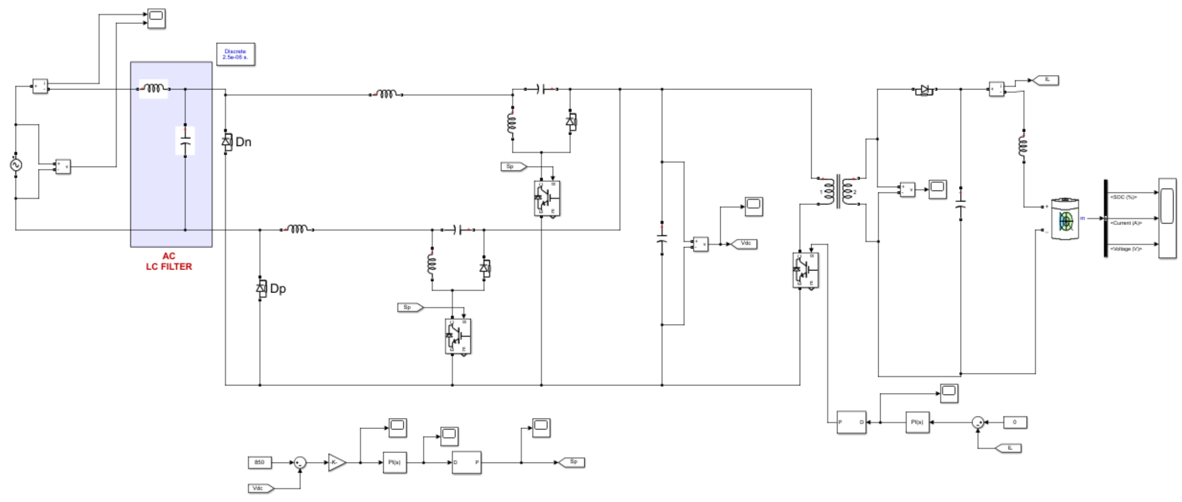

Fig.1. Simulation circuit

B

. Operating Principle with SEPIC

The BL-SEPIC converter operates in three modes per half-cycle, similar to the BL boost operation:

1. Mode I (Charging Inductor): Switch Sp is ON; input current charges L1 and L2, and the coupling capacitor C1 transfers energy to the output.

2. Mode II (Inductor Discharge): Switch SpS_pSp is OFF; the energy stored in L1 and L2 is released to the output via diodes.

3. Mode III (Completion of Cycle): Remaining inductor energy is fully discharged; the current reaches zero, operating in DCM, which reduces stress and enhances battery life.

For the negative half-cycle, the lower branch with switch SnS_nSn and associated inductors follows the same sequence, ensuring synchronous and smooth operation. The integration of SEPIC allows the converter to maintain stable output voltage across a wide range of input voltages, improving UPF (Unity Power Factor) and minimizing THD.

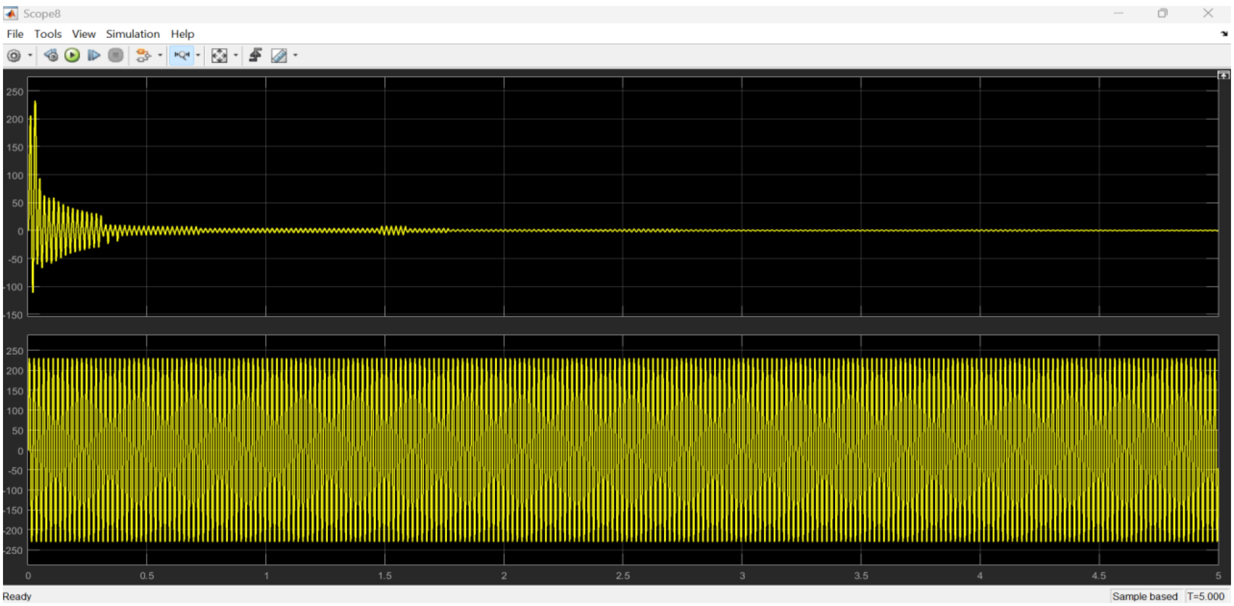

Fig.2. Input voltage and current values

C. Performance Analysis and Advantages of BL-SEPIC Converter

The integration of the SEPIC topology into the bridgeless PFC converter introduces several performance enhancements, particularly for EV battery charging systems. In a conventional BL boost converter, the output voltage is always higher than the input voltage, limiting its adaptability to fluctuating input conditions. The SEPIC allows both step-up and step-down voltage conversion, which is crucial for maintaining a stable DC-link voltage even when the AC mains experiences sags or surges. Mathematically, the average output voltage Vo of a SEPIC converter operating in CCM is expressed as:

Vo=D1−DVin+VC1V_o = \frac{D}{1-D} V_{in} + V_{C1}Vo=1−DDVin+VC1

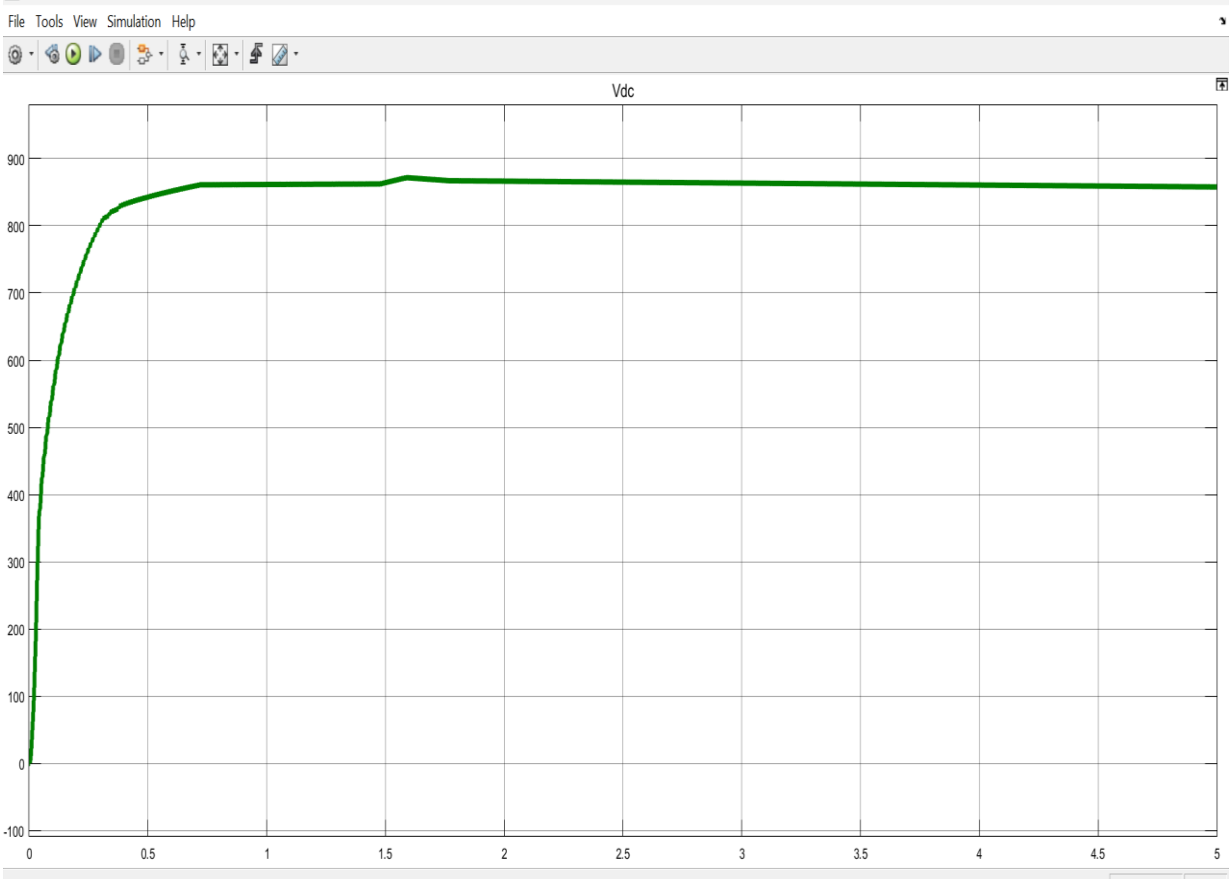

Fig.3. DC link output voltage.

where DDD is the duty cycle and VC1 is the voltage across the coupling capacitor C1. In DCM, the output voltage depends on the input voltage, duty cycle, and inductor parameters, allowing precise control over charging current and voltage. The BL-SEPIC topology inherently reduces conduction losses by eliminating the input diode bridge and shortening the current path. Additionally, operating the inductors in DCM during part of the cycle reduces current ripple and switching losses, which prolongs the life of both the battery and power semiconductor devices.

Fig.4. EV battery ratings along with tile.

From a control perspective, the feedback system monitors the output DC voltage and regulates the duty cycle via a PI controller, ensuring that the charger seamlessly switches between CC and CV modes depending on the battery's state of charge. The high-frequency operation of 20 kHz allows smaller passive components, further reducing the converter's size and weight important factors for EV onboard chargers.

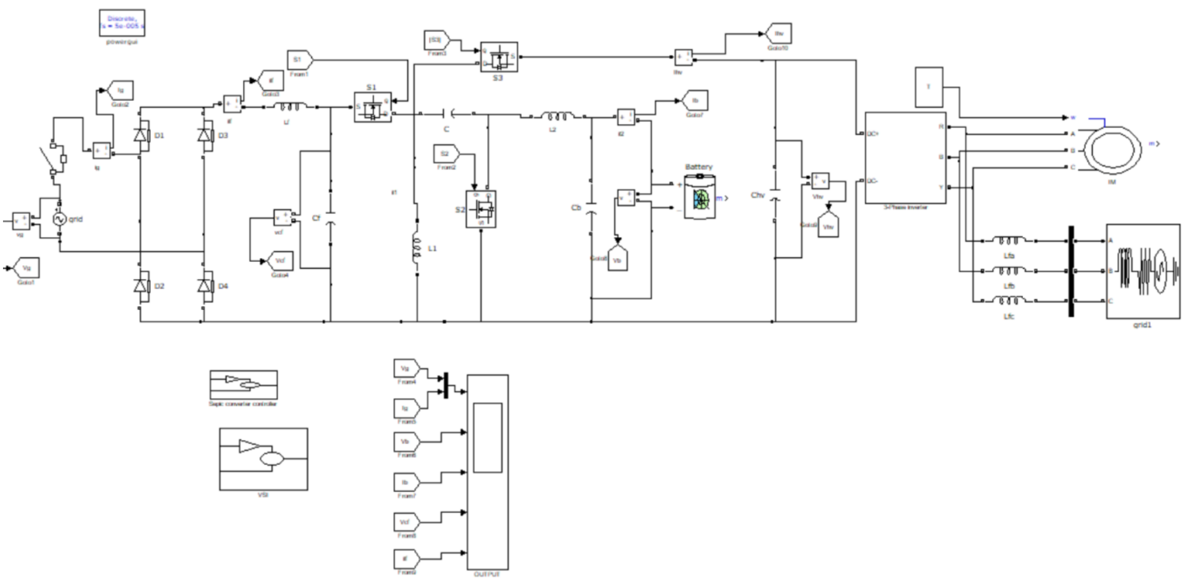

Fig.5. Simulation with sepic converter

Moreover, the continuous input current achieved by the SEPIC topology improves the input power factor and minimizes total harmonic distortion (THD), making the system compliant with IEC standards. Experimental and simulation studies show that BL-SEPIC converters can achieve efficiencies above 95%, THD below 10%, and stable voltage regulation across a wide input range. Collectively, these features make the proposed BL-SEPIC PFC converter an ideal solution for next-generation EV charging systems, combining efficiency, reliability, and compact design with enhanced battery safety.

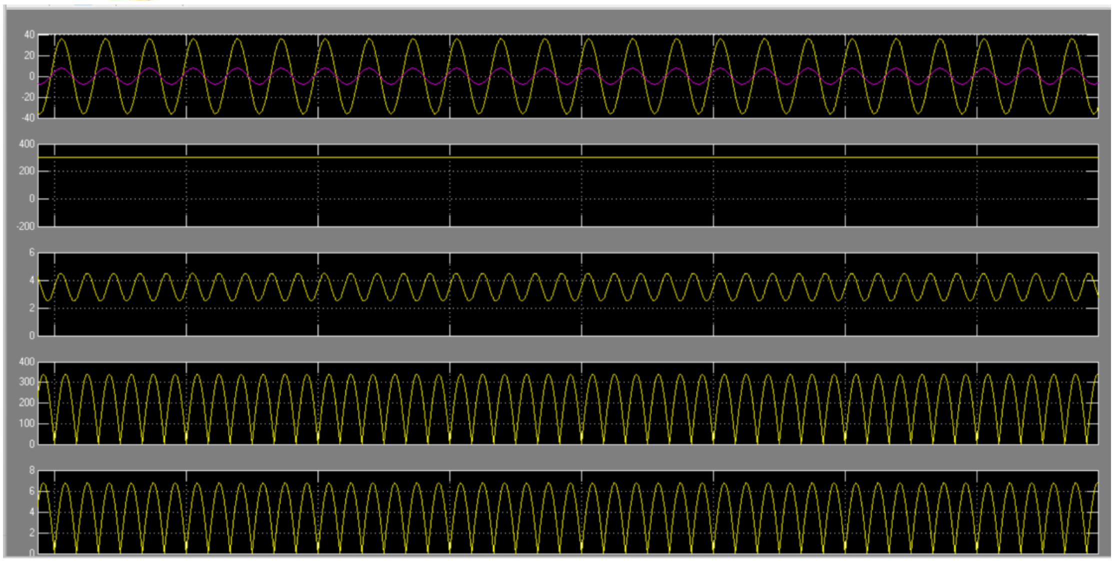

Fig.6. Final output results with SEPIC converter

CONCLUSION

The proposed SEPIC-based bridgeless converter proves to be an effective solution for electric vehicle (EV) battery charging systems by addressing the key limitations of conventional boost converters. By offering continuous input current, reduced voltage stress, and flexible step-up/step-down capability, the topology ensures reliable operation under varying grid conditions. The simulation and experimental results confirm that the system achieves high efficiency, low THD, and improved power factor, all of which are essential for compliance with modern power quality standards. Furthermore, the converter demonstrates stable and controllable battery charging characteristics, making it a robust candidate for practical EV charger deployment. Overall, this work contributes toward the development of energy-efficient, power-quality-compliant, and cost-effective charging infrastructures that support the growing adoption of electric vehicles.

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