

An Isolated SEPIC DC-DC Converter for EV Charging Systems: Design, Simulation, and Feasibility Studies

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ABSTRACT- This paper presents the design and simulation-based performance assessment of an isolated single-ended primary-inductor converter (SEPIC) for electric vehicle (EV) battery-charging applications. The proposed topology allows adjustable step-up/step-down voltage conversion with galvanic isolation to ensure excellent operational safety and grid-to-vehicle system reliability. The detailed design procedures are established for the passive elements, crucial coupling capacitors, and the high-frequency isolation transformer working at 50kHz to maintain tight output voltage regulation under wide input voltage changes. The performance of the converter is extensively assessed in open-loop and closed-loop proportional-integral (PI) control schemes using MATLAB/Simulink. Additionally, a passive input filter is incorporated to improve the power quality and to decrease the grid current's total harmonic distortion (THD) successfully to 6.89%. In closed-loop operation, the architecture can achieve a highly stabilized output voltage with a low ripple of 2.14% and a peak simulated efficiency of 95.49%. A CC-CV battery-charging profile and supply-voltage variation analysis are also presented to evaluate the simulated charging and regulation performance. Experimental verification is performed only on a scaled conventional SEPIC prototype rated at 168 W (56 V, 3 A), serving as a proof of concept for the component-sizing approach and SEPIC energy-transfer principle. The conventional SEPIC experimental results do not constitute experimental validation of the proposed isolated SEPIC converter. Future work will include experimental validation of the complete isolated converter. The proposed isolated SEPIC converter is verified by MATLAB/Simulink simulations. The simulation results reveal that the isolated SEPIC arrangement offers minimal output ripple, increased power quality, and high efficiency, proving its appropriateness for medium power on-board EV charging systems.

Keywords: Isolated SEPIC DC-DC Converter, Electric Vehicle (EV) Charger, Efficiency, Power Quality Improvement, Proportional-Integral (PI) Control, Galvanic Isolation Technique, On-board EV Battery Chargers.

ARTICLE INFORMATION

Author(s): Shaktisinh Gohil, and Hardik A. Shah;

Received: 22/05/26; **Accepted:** 24/08/26; **Published:** 30/09/26;

E- ISSN: 2347-470X;

Paper Id: IJEER 2205B13;

Citation: 10.37391/ijeer.140304

Webpage-link:

<https://ijeer.forexjournal.co.in/archive/volume-14/ijeer-140304.html>

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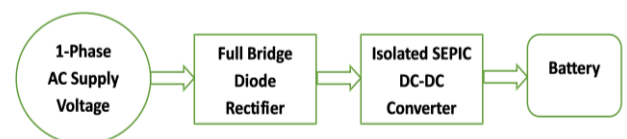


Figure 1. Block Diagram of the Proposed Charging Architecture [3][5]

1. INTRODUCTION

The rapid expansion of electric vehicles (EVs) has established the need for efficient, dependable and small power electronic converters for battery charging applications [1]. The DC-DC converter is one of the most important parts of the EV battery charging system as it provides voltage regulation, power quality improvement, and safe operation of the battery. Battery chargers must accommodate wide input voltage variations, provide high efficiency, and offer electrical isolation to enhance user safety and system reliability [2][5]. Figure 1 illustrates the block diagram of the EV battery charging system of the proposed converter, which consists of an isolated SEPIC converter and a diode bridge rectifier[3][4].

The block diagram of the proposed charging system shows the rectification process that occurs in two stages: the first stage is the full-bridge diode rectifier (AC to DC) conversion, and the second stage is an isolated SEPIC (DC to DC) conversion stage, which is used to change the voltage level to be appropriate for charging of EV batteries [5]. Conventional DC-DC converters, such as buck and boost converters, have limitations in the voltage conversion range and operational flexibility. The conventional SEPIC converter mitigates these limitations by offering a non-inverted output voltage, giving wide input voltage variation, and having the flexibility to work in both step-up and step-down configurations. Nevertheless, the conventional SEPIC converter does not provide galvanic isolation, which is a necessary requirement for EV battery charging systems. Therefore, an isolated SEPIC DC-DC converter is proposed for charging EV batteries. An isolated

SEPIC converter has emerged as a promising DC–DC converter architecture for charging EV batteries due to its additional benefits, including greater safety, decreased ground loop issues, and better compliance with international charging standards [2][6].

For EV battery charging applications, electrical isolation can be important because the battery and vehicle-side circuitry must be insulated from potentially hazardous input-side electrical conditions. The use of high frequency transformer in the energy transfer channel of an isolated SEPIC architecture provides galvanic isolation while maintaining the original step-up/step-down characteristics of the SEPIC based conversion process. Moreover, high-frequency transformer isolation may also lead to the compact physical size characteristic of low-frequency isolation, although transformer design presents other issues such as leakage inductance, winding losses, core losses, insulation, parasitic capacitance, and voltage/current stresses of semiconductors [6], [10]–[14].

The usage of isolated SEPIC converters is not a novel concept. Previous research has studied isolated SEPIC converters for power-conversion and battery-charging applications. Ewerling et al. investigated a modular SEPIC-based isolated DC–DC converter with reduced semiconductor voltage stress [10]. A PFC based EV battery charger with bridgeless isolated SEPIC converter was proposed by Singh and Kushwaha [11]. Lee and Do studied an isolated SEPIC converter with ripple-free input current and a lossless snubber [12]. Hussein et al. [14] investigated a single-phase isolated SEPIC-based charger for EV applications. These results show that the transformer-isolated SEPIC-derived structures have been already recognized as a potential research topic.

More recent studies have also extended the application of SEPIC-derived converters to EV and battery-charging systems. Ahmad et al. [15] reported a modified isolated SEPIC converter for EV charging and high-voltage applications, showing the practical importance of transformer-isolated SEPIC conversion, along with the prototype-oriented performance evaluation. Dhandapani et al. [16] investigated a bridgeless isolated SEPIC-Luo converter for EV battery charging using PI and artificial-neural-network-based control strategies. Their study considered battery charging operation and power quality performance but the converter structure is different from the isolated SEPIC architecture considered in the present work. Ugurluoglu and Karaarslan studied the bridgeless isolated SEPIC converter using PI and fuzzy control methods, focusing on the controller performance during varying operating conditions [17]. Recently, Dwivedi and Jayapragash proposed a semi-bridgeless dual-switch SEPIC-derived PFC converter for battery charging and reported low input-current THD and high efficiency through experimental investigation [18]. Although this work shows strong power quality performance, its topology is transformer less and operates under different conditions from the isolated converter studied in the present work.

These recent advances show that there are numerous performance targets that are now being researched in SEPIC based EV chargers, such as galvanic isolation, PFC, harmonic reduction, high efficiency, reduced semiconductor stress, soft switching, and enhanced control. Consequently, galvanic isolation, PI control, or EMI filtering should not be considered individually as novel contributions. Instead, the research problem becomes how to integrate these established techniques and assess them systematically for a specified EV charging requirement, while keeping a clear link between converter design, control performance, power quality, efficiency and practical implementation.

A further limitation in the existing literature is that numerical performance results are often reported under substantially different operating conditions. Converter ratings, input voltages, switching frequencies, isolation ratios, operating modes, control strategies, and experimental conditions differ among published studies. Therefore, direct claims that one converter is superior to another based only on isolated efficiency or THD values can be misleading. A scientifically significant comparison has to take into account the converter topology, power rating, voltage conversion ratio, switching frequency, control mechanism, operating mode and whether the given result is acquired from simulation or hardware. This consideration is particularly important when comparing isolated SEPIC converters with bridgeless or transformer less SEPIC-derived PFC converters.

The present study therefore focuses on the design and systematic performance assessment of an isolated SEPIC DC–DC converter intended for a medium-power EV battery-charging application. The design aims for an output power of 840W, with a nominal output voltage of 56V and output current of 15A at a switching frequency of 50kHz. The rectified input is fed to the isolated SEPIC stage, with a high-frequency transformer providing galvanic isolation. The converter is evaluated under open-loop and a proportional-integral (PI) controller based closed-loop operation. In addition, an input passive EMI filter is also added to explore its impact on the input current harmonic distortion and converter performance.

The major purpose of this work is not to claim that the individual converter characteristics are fundamentally innovative, but to offer a consolidated design and performance-assessment technique to the designated EV charging operating point. The study includes analytical component sizing, considerations of isolated transformers, open-loop and closed-loop performance evaluation, output-voltage and current-ripple analysis, efficiency assessment, input-current THD evaluation, duty-cycle characteristics, and comparison with a conventional SEPIC converter. The practical features of the implementation of the SEPIC conversion are also studied in a laboratory prototype of a conventional non-isolated SEPIC converter.

The practical analysis in this study is based on a significant distinction between the proposed topology and the implemented prototype. The laboratory hardware described in

the manuscript is a conventional non-isolated SEPIC converter rated at 56V and 3A, corresponding to approximately 168 W. It is therefore a scaled proof-of-concept implementation used to investigate the practical behavior of SEPIC energy-transfer components and the feasibility of the basic converter design. It does not experimentally validate the complete 840W isolated SEPIC topology. Accordingly, the simulation results of the proposed isolated converter and the experimental results of the conventional SEPIC prototype are treated as separate forms of evidence in this study. Full-power experimental validation of the isolated SEPIC converter, including isolated hardware testing, battery charging, thermal characterization, and insulation verification, remains an important requirement for further experimental development.

Based on the above considerations, the main contributions of this work are as follows:

Design of an isolated SEPIC converter for a specified EV charging operating point: An isolated SEPIC DC–DC converter is designed for 840W, 56V, and 15A operation at a switching frequency of 50kHz, with analytical consideration of the passive components and high-frequency transformer.

Analytical and simulation-based performance assessment: The converter operation is investigated through analytical design relationships and MATLAB/Simulink simulations, including duty-cycle characteristics, voltage regulation, ripple behavior, efficiency, and semiconductor operating conditions.

Open-loop and closed-loop comparison: To measure the impact of feedback regulation on output-voltage stability and steady-state performance, open-loop and PI-controlled closed-loop designs are compared.

Table 1. Comparison of an isolated SEPIC with conventional converters [2][5].

Parameter	Buck	Boost	Cuk	SEPIC	Isolated SEPIC
Topology	Buck	Boost	Buck-Boost	Buck-Boost	Buck-Boost
Voltage Conversion	Only Step-Down	Only Step-Up	Both Step-Up & Step-Down	Both Step-Up & Step-Down	Both Step-Up & Step-Down
Output Polarity	Non-Inverting	Non-Inverting	Inverting	Non-Inverting	Non-Inverting
Output Voltage Ripple	Moderate (~5.0%)	Moderate	Higher (~6.3%)	Low (~4.5%)	Very low (~2.1%)
Output Current Ripple	Moderate (~4.7%)	Moderate	Higher (~7%)	Low (~4.6%)	Very low (~2.6%)
Efficiency	High (~94.66%)	Low	Moderate (~93.5%)	Moderate (~93.63%)	High (~95.49%)
Isolation	No	No	No	No	Yes
EV Safety Compliance	Low	Low	Moderate	Moderate	High

Despite significant advancements in DC–DC converter configurations for EV charging, challenges such as limited voltage conversion range, lack of isolation, and increased system complexity persist. To overcome these limitations, we proposed an isolated SEPIC converter with higher efficiency, lower ripple, and better safety features.

The organization of the paper is as follows. *Section 2* describes the configuration and operating principle of the isolated SEPIC converter and develops the corresponding analytical model. *Section 3* describes the design process for the passive components, high-frequency transformer, switching devices, and input EMI filter. *Section 4* displays the simulation results of the proposed converter in open-loop and closed-loop modes using MATLAB/Simulink software, EV battery charging profile using CC-CV control, and Frequency-response analysis of the proposed LC EMI filter. *Section 5* gives comparative performance assessment of an isolated and conventional SEPIC converters which include switching loss of the MOSFET, efficiency calculation, duty-cycle characteristics, and comparison analysis. *Section 6* discusses the practical feasibility investigation using the conventional SEPIC hardware prototype and clarifies its relationship to the proposed isolated topology. Finally, *section 7* summarizes the conclusion, and future work.

2. OPERATING PRINCIPLE OF AN ISOLATED SEPIC CONVERTER

This article describes a design for the light electric vehicle's charging system. The front-end includes a full-wave diode bridge rectifier, whereas the back-end is an isolated SEPIC converter [2]. *Figure 2* depicts the circuit diagram of this charger.

It is interesting to notice that the SEPIC converter, like Buck-Boost, Cuk, and ZETA converters, uses both inductors and capacitors to generate an adjusted output. The traditional SEPIC converter uses two static switches, two inductors, and two capacitors. The present circuit layout of an isolated SEPIC converter consists of one inductor, one high-frequency transformer, two capacitors, and two static switches. The semiconductor static switches are made up of a transistor (commonly a MOSFET or IGBT) and a diode. The transistor operates as a controlled switch driven by a gate pulse, whereas the diode operates as an uncontrolled switch that switches on and off automatically depending on the voltage across it [5][12][14].

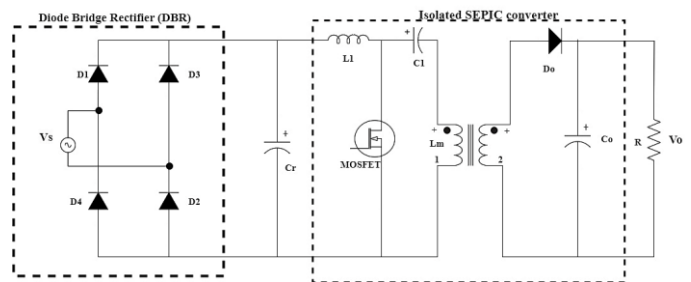


Figure 2. Circuit schematic of an isolated open-loop SEPIC converter

The proposed charger design is simple, efficient, and reliable. The system can control current during overloads or start-up and reduce the size of magnetic components, making it a good choice for electric vehicle charging applications [14].

2.1. Mode 1 Operation (Interval: $0 < t \leq DT$)

The circuit schematic of the proposed converter in Mode 1 operation is shown in figure 3 [14][15]. The reconfiguration of Mode 1 initiates with the closure of the switch (S1). During this period, the current from the DC source (DBR) is stored in the inductor L1, and the energy stored in capacitor C1 is discharged through the magnetizing inductor Lm. The current flowing through the switch (S1) is the sum of the capacitor current (IC1) and the inductor current (IL1) [17]. Equation (1) calculates the current flowing via switch (IS1) is provided by:

$$I_{S1} = I_{L1} + I_{C1} \quad (1)$$

Where IS1 is the switch current, IL1 is the inductor current, and IC1 is the capacitor current.

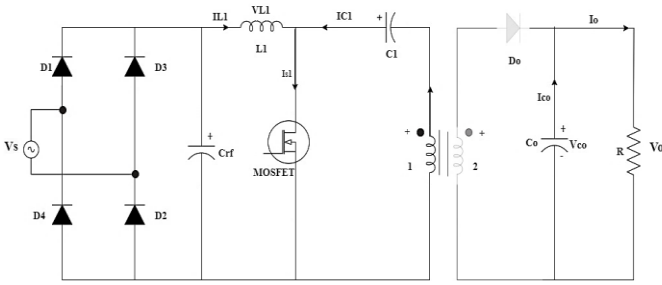


Figure 3. Circuit schematic during Mode 1 operation (MOSFET ON and DIODE OFF)

In Mode 1, the output diode (Do) is reverse-biased, causing no current flow. The energization of the load occurs through the output capacitor (Co).

2.2. Mode 2 Operation (Interval: $DT < t \leq T$)

The circuit schematic of the proposed converter for operation in Mode 2 is depicted in figure 4 [14][15]. Mode 2 operating, as illustrated in figure 4 below, is marked by the opening of the S1 switch at $t=DT$. The L1 inductor's energy is then transferred to the load via C1. The current passing through the leakage inductance (Lk) opposes the abrupt change with the aid of magnetizing inductance (Lm), thus suppressing the voltage spikes [17]. In this mode, the output diode (Do) is forward-biased, and the voltage across the primary winding is transferred to the secondary winding due to the reverse polarities of the transformer. As a result, the output capacitor (Co) is charged and supplied to the load. The transformer's leakage inductance (Lk) can be ignored at the steady state [19][20]. The voltage at switch S1 is denoted by VS1 and is determined by equation (2) as given by:

$$V_{S1} = V_{in} + V_{C1} \quad (2)$$

Where VS1 is the switch voltage, Vin is the input voltage, and VC1 is the capacitor voltage

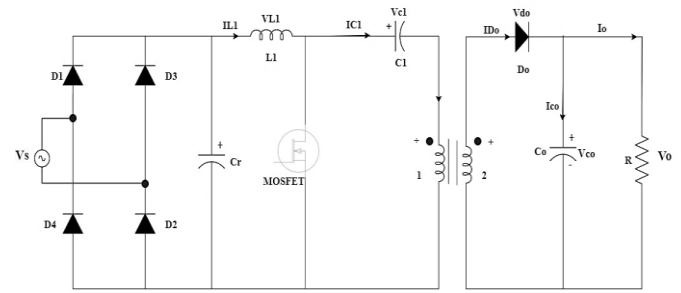


Figure 4. Circuit schematic during Mode 2 operation (MOSFET OFF and DIODE ON)

Assuming a turns ratio, $n=1$, in figure 4, the IL1 current remains uninterrupted, thus resulting in the continuity of the L1 current. The DC voltage from the DBR is fed through the inductor (L1) and the capacitor (C1) as the primary winding of the transformer. The magnetizing inductance (Lm) is the opposing pole which opposes rapid polarity change at the first moment and stores energy in the same polarity until the end of the working mode [21].

3. DESIGN OF THE PROPOSED AN ISOLATED SEPIC CONVERTER

This section describes the implementation of a proposed EV battery charger at the simulation level. The system is composed of an AC–DC rectifier stage and a high-frequency isolated SEPIC DC–DC converter. The design process adopted for each stage is discussed in the following sections, and the calculated values are given in table 2. The design details of the proposed converter are given below [22]–[27].

3.1. Design of a 1-Phase Full Wave Diode Bridge Rectifier

The AC input supply is converted into the DC output voltage with the help of a single-phase full wave diode bridge rectifier. The output capacitor of the rectifier is designed to reduce the ripple content present in the rectified DC output voltage and to provide a smooth DC supply for the converter operation. The output power (Po) of the charger is designed for 840 W. Assuming an efficiency of 90% for the isolated SEPIC DC–DC converter, the input power (Pin) to the converter is calculated as:

$$P_{in} = \frac{P_o}{\eta} = \frac{840}{0.9} = 933W \quad (3)$$

Assuming the ripple voltage percentage is 5% for the full bridge rectifier. The ripple voltage (Vr) of the rectifier is given by equation (4):

$$V_r = V_{dc} * \text{ripple percentage} = 325 * 0.05 = 16.25V \quad (4)$$

The output capacitor of the rectifier is given by equation (5):

$$C_r = \frac{P_{in}}{2f_s V_{dc} V_r} = \frac{933}{2 * 50 * 325 * 16.25} = 1766\mu F \quad (5)$$

The standard capacitor of 1800 μ F is used for simulation-based design. Where P_{in} is the output power of the rectifier which is also the input power of the isolated SEPIC converter, P_o is the output power of the isolated SEPIC converter, f_s is the supply frequency, V_{dc} is the average rectifier DC voltage, and V_r is the rectifier ripple voltage.

3.2. Design of High Frequency Transformer

The high-frequency transformer is one of the most important parts of the isolated SEPIC converter. It provides galvanic isolation, voltage transformation, and safety improvement for EV battery charging applications. The transformer design directly impacts the converter efficiency, switching performance, thermal behavior, and electromagnetic interference (EMI).

3.2.1. Transformer Turn's Ratio Calculation

The output voltage is variable by adjusting the turns ratio of the transformer. The transformer turns ratio is given by equation (6):

$$n = \frac{N_s}{N_p} = \frac{V_o}{V_p} = \frac{56}{325} = 0.17 \approx 0.2 \quad (6)$$

Where N_s is the number of turns on the secondary side of the transformer, and N_p is the number of turns on the primary side of the transformer.

3.2.2. Ferrite Core Selection

The preferable alternative is a ferrite core transformer because of negligible hysteresis and eddy current losses during high frequency operation (50kHz). The turns ratio of the transformer was chosen as 0.2 to obtain the desired output voltage under different duty cycle situations. The voltage stress was kept within safe limits. Proper winding insulation and low leakage inductance are required to decrease switching spikes and increase efficiency of energy transfer. The transformer design directly determines the converter efficiency, thermal behavior, and EMI performance. The selection of the core is based on the area product [28]. The core area product is calculated and given by equation (7):

$$A_p = \frac{P_o \cdot D_{cma}}{k_t \cdot B_{max} \cdot f_{sw}} = \frac{840 \cdot 500}{0.0005 \cdot 1600 \cdot 50000} \quad (7)$$

$$= 10.5 \text{ cm}^4$$

Where P_o is the output power, D_{cma} is the current density factor which is 500 circular-mills, k_t is the topology utilization constant, B_{max} is the maximum flux density which value is 1600G, and f_{sw} is the switching frequency.

As the proposed isolated SEPIC converter is a single-ended isolated topology, the area-product calculation of the transformer uses a topology utilization constant (k_t) of 0.0005, which is generally used for flyback/SEPIC type isolated converters due to their lower magnetic core utilization than full-bridge converters.

3.3. Design of an Isolated SEPIC DC-DC Converter

The design method of an isolated SEPIC converter is described in detail below.

3.3.1. Duty Cycle Calculation

Equation (8) gives the ideal output voltage:

$$V_o = \frac{D}{(1-D)} \cdot n \cdot V_s \quad (8)$$

However, the losses due to parasitic components such as the diode voltage drop (V_D) are not considered [5]. The output voltage with diode drop is given by equation (9):

$$V_o = \frac{D}{(1-D)} \cdot n \cdot V_s - V_D \quad (9)$$

Hence, the duty cycle is provided by equation (10):

$$D = \frac{V_o + V_D}{nV_s + V_o + V_D} = \frac{56 + 0.5}{(0.2 \cdot 325) + 56 + 0.5} \quad (10)$$

$$= 0.465 = 46.5\%$$

Where V_s stands for input voltage, D for duty cycle, n for transformer turns ratio, V_D for diode voltage drop, and V_o for output voltage.

3.3.2. Inductor Calculation

Assuming the ripple current percentage is 10% for isolated SEPIC converter. The variation in ripple current (ΔI_L or ΔI_{Lm}) is given by equation (11):

$$\Delta I_{L1} = \Delta I_{Lm} = I_o \cdot \text{ripple current percenta} \quad (11)$$

$$= 15 \cdot 0.1 = 1.5A$$

Equation (12) gives the input inductor (L_1):

$$L_1 = \frac{V_s \cdot D}{2\Delta I_{L1} \cdot f_{sw}} = \frac{325 \cdot 0.465}{2 \cdot 1.5 \cdot 50000} = 1007.5\mu H \quad (12)$$

Equation (13) provided the magnetizing inductance (L_m):

$$L_m = \frac{V_o \cdot (1-D)}{\Delta I_{Lm} \cdot f_{sw}} = \frac{56 \cdot (1-0.465)}{1.5 \cdot 50000} = 399.46\mu H \quad (13)$$

Where f_{sw} stands for switching frequency, D is duty cycle, V_s is input voltage, ΔI_{L1} is ripple current of inductor (L_1), ΔI_{Lm} is ripple current of magnetizing inductor (L_m), and V_o stands for output voltage.

3.3.3. Capacitor Calculation

Assuming the ripple voltage percentage is 10% for isolated SEPIC converter. The variation in ripple voltage of input capacitor (ΔV_{C1}) is given by equation (14):

$$\Delta V_{C1} = V_{dc} \cdot \text{ripple voltage percentage} \quad (14)$$

$$= 325 \cdot 0.1 = 32.5V$$

The variation in ripple voltage of input capacitor (ΔV_{Co}) is given by equation (15):

$$\Delta V_{Co} = V_o * \text{ripple voltage percentage} = 56 * 0.1 = 5.6V \quad (15)$$

The input capacitor (C_1) is given by equation (16):

$$C_1 = \frac{I_o \cdot D}{\Delta V_{C1} \cdot f_{sw}} = \frac{15 * 0.465}{32.5 * 50000} = 4.3\mu F \quad (16)$$

The output capacitor (C_o) is given by equation (17):

$$C_o = \frac{I_o \cdot D}{\Delta V_{Co} \cdot f_{sw}} = \frac{15 * 0.465}{5.6 * 50000} = 24.91\mu F \quad (17)$$

Where f_{sw} is switching frequency, D stands for duty cycle, I_o is output current, V_{dc} is rectified DC voltage, ΔV_{C1} is ripple voltage of input capacitor C_1 , and ΔV_{Co} is ripple voltage of output capacitor C_o .

3.4. Design of Input Passive EMI Filter

An input passive EMI filter is inserted at the input stage of the converter to reduce the input current harmonic distortion (THD) and suppress the high-frequency switching noise. The filter is made of a series inductor (L_f) and shunt capacitor (C_f). The values of the inductor and capacitor are adjusted according to the desired cutoff frequency (f_c), which is selected to be much lower than the switching frequency and much higher than the supply frequency.

3.4.1. Filter Inductor Calculation

The filter inductor (L_f) is given by equation (18):

$$L_f = \frac{1}{(2\pi f_c)^2 C_f} \quad (18)$$

3.4.2. Filter Capacitor Calculation

The filter capacitor (C_f) is given by equation (19):

$$C_f = \frac{1}{(2\pi f_c)^2 L_f} \quad (19)$$

3.4.3. Cut-off Frequency Calculation

The cut-off frequency (f_c) is the frequency at which the high-frequency switching harmonics are greatly reduced. It is chosen lower than the converter switching frequency and higher than the supply frequency so that the filter works well without influencing the fundamental input waveform. Assuming the filter inductor (L_f) is 1mH, and the filter capacitor (C_f) is 1 μ F. Equation (20) determines the cut-off frequency of the EMI filter:

$$f_c = \frac{1}{2\pi \sqrt{L_f C_f}} = \frac{1}{2 * 3.14 * \sqrt{(1 * 10^{-3}) * (1 * 10^{-6})}} = 5kHz \quad (20)$$

Where f_c stands for the cut-off frequency of the EMI filter, L_f is the filter inductor, and C_f stands for the filter capacitor.

4. SIMULATION RESULTS AND DISCUSSION

The proposed isolated SEPIC converter is simulated using MATLAB/Simulink R2021 under continuous-time operation. The ode23tb variable-step solver is used to solve the converter and control-system differential equations. The main converter parameters are maintained at the design values of 230 V AC input, 50 Hz line frequency, 56 V output voltage, 15 A output current, 840 W rated power, and 50 kHz switching frequency. table 2 shows the simulation parameters of the proposed converter [5][29]-[31].

Table 2. Simulation Parameters of the proposed converter

Parameter	Value
AC Supply Voltage (Vs)	230 V $\pm$ 10%, 50Hz
Rectified DC Voltage (Vdc)	325V
Output DC Voltage (Vo)	56V
Output Current (Io)	15A
Output Power (Po)	840W
Switching Frequency (fsw)	50kHz
Transformer turns ratio (n)	0.2
Ripple Current (Iripple)	10%
Ripple Voltage (Vripple)	10%
Input Inductor (L1)	1007.5 μ H
Magnetizing Inductor (Lm)	399.46 μ H
Input Capacitor (C1)	4.3 μ F
Output Capacitor (Co)	24.91 μ F
Rectifier Capacitor (Cr)	1800 μ F
Duty Cycle (D)	46.5%
Cut off Frequency (fc)	5kHz
Filter Inductor (Lf)	1mH
Filter Capacitor (Cf)	1 μ F
Load Resistor (R)	3.7 Ω

4.1. Open-loop Configuration of an isolated SEPIC Converter

The circuit diagram of an isolated SEPIC converter shown in figure 2 in open-loop configuration with a diode bridge rectifier. The full-wave diode bridge rectifier (DBR) is a front-end converter that converts an alternating current (AC) to a direct current (DC) [5]. The AC to DC power converter takes the utility mains and generates a separate DC. However, these converters can produce harmonic current, which can be solved by using an input passive filter that reduces the harmonics and improves the overall power quality of the system. The architecture of these converters is composed of two different stages. The first stage is rectification, which is used to obtain the DC voltage [25]. The last stage is used to convert and obtain the appropriate isolated DC voltage for charging the battery of an EV using a back-end converter (DC-DC converter, such as an isolated SEPIC). In the open-loop configuration, the switching pulses are generated using a Pulse Generator block with a switching frequency of 50 kHz and the selected duty ratio of 0.465. No feedback signal is used in the open-loop configuration.

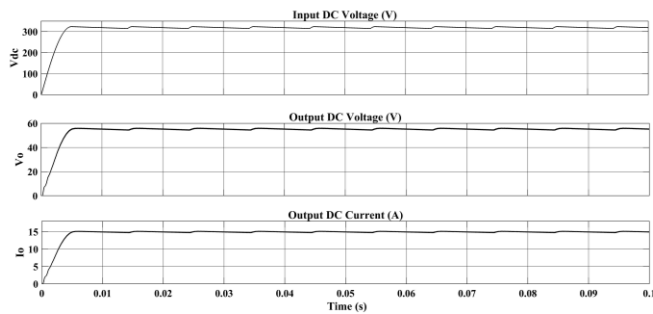


Figure 5. Waveforms of an isolated open-loop SEPIC Converter

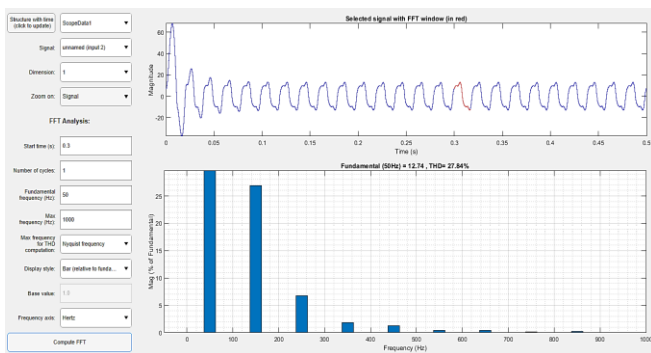


Figure 6. THD Waveform of Input AC Supply Current

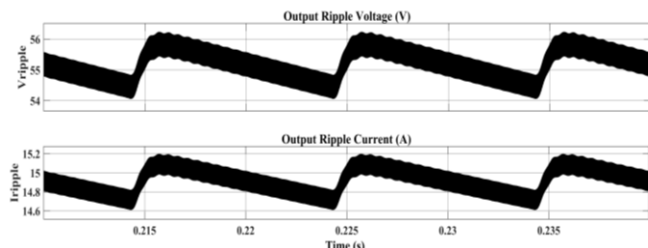


Figure 7. Output Ripple Voltage and Ripple Current Waveform

Figure 5 shows the simulation results of an isolated SEPIC converter in open-loop configuration. It shows input dc voltage (V_{dc}), output dc voltage (V_o), and output dc current (I_o). The total harmonic distortion (THD) result of the input AC supply current (I_s) with an input EMI filter is shown in figure 6, where THD for supply current (I_s) is achieved at 27.84%. Figure 7 shows the output voltage ripple (V_{ripple}) and output ripple current (I_{ripple}) waveforms of the proposed converter in open-loop mode in which output voltage ripple is 3.93% and output current ripple is 4.0% achieved.

4.2. Closed loop Configuration of an isolated SEPIC Converter

The circuit schematic of a closed-loop isolated SEPIC converter with a diode bridge rectifier is displayed in figure 8. Due to its simple and useful design, the proportional-integral (PI) controller is a widely used feedback controller for controlling the output voltage of DC-DC converters [5][32]. The PI controller is a useful tool to maintain a constant voltage since the error signal is used as feedback for the control loop. The PI control system is a grouping of proportional and integrated control systems employed in regulating plant

operations. Effectiveness is defined as the ability to keep the plant stability at the intended set points and to react fast to changes [33][34]. The integral constant (K_i) and proportional constant (K_p) are very crucial for achieving the best outcomes in this control system [35]. For efficient control, the right value of these constants needs to be adjusted for reducing overshoot errors, achieving faster response times, and improving output stability [36].

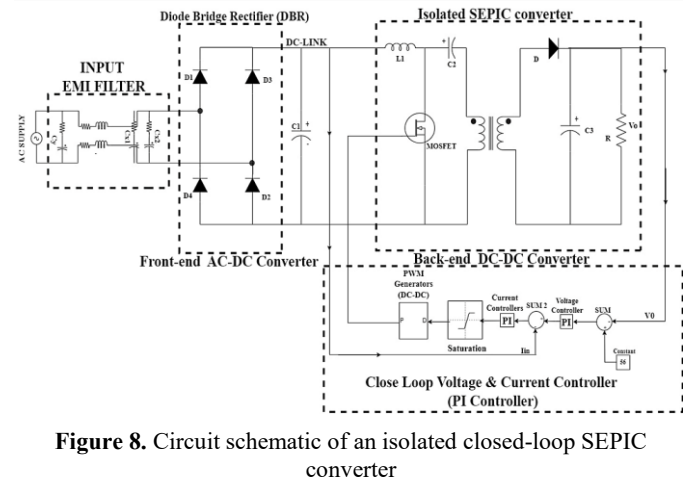


Figure 8. Circuit schematic of an isolated closed-loop SEPIC converter

In the closed-loop configuration, the output voltage and output current are measured and fed back to the control system. The measured voltage and current are compared with their respective reference values, and the error signals are processed by the PI controller. The PI-controller output is then used to generate the PWM switching signal for the converter. Thus, the closed-loop system regulates the output voltage and charging current according to the specified reference values. The PI controller was tuned using the PID Tuner App available in MATLAB Simulink R2021. A transfer-function-based tuning method was selected for the controller design. The tuning was performed in the continuous-time domain to obtain suitable controller parameters for the continuous-time converter model. In this simulation study, the static switch (MOSFET) is controlled in a closed-loop arrangement using the voltage controller and the current controller. By using trial and error method the final controller gains used in the simulation are $K_p=0.193$ and $K_i=10.670$ for the voltage controller and $K_p=0.097$ and $K_i=5.899$ for the current controller.

Simulation results of an isolated SEPIC converter in a closed-loop setup are shown in figure 9. It consists of the input dc voltage (V_{dc}), the output dc voltage (V_o), and the output dc current (I_o). Figure 10 shows the total harmonic distortion (THD) result of the input AC supply current (I_s) with the input EMI filter, where the THD for the supply current (I_s) is obtained as 6.89%. Figure 11 shows the output ripple voltage (V_{ripple}) and output ripple current (I_{ripple}) waveforms of an isolated closed-loop SEPIC converter in which output voltage ripple is 2.14% and output current ripple is 2.60% achieved. The THD result is presented as a simulation result under the specified operating condition and is not interpreted by itself as proof of compliance with a particular harmonic standard.

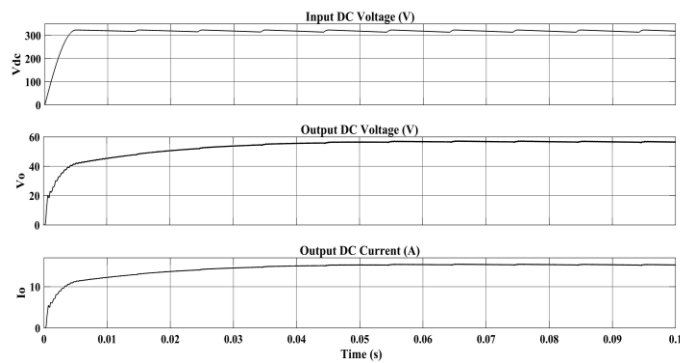


Figure 9. Waveforms of an isolated closed-loop SEPIC converter

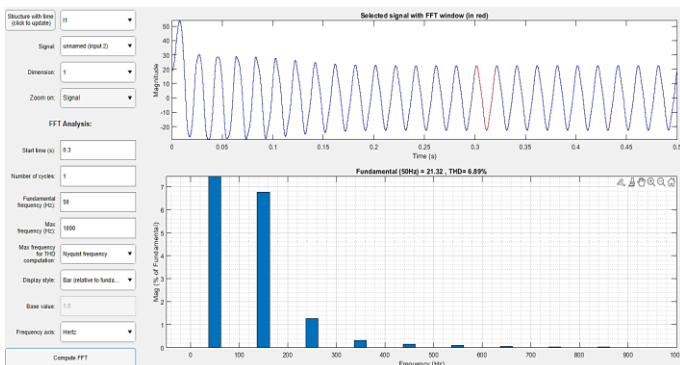


Figure 10. THD Waveform of Input AC Supply Current

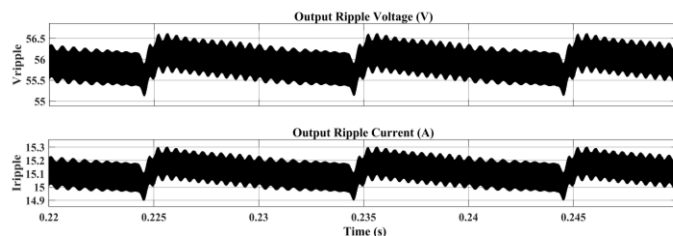


Figure 11. Output Ripple Voltage and Ripple

4.3. EV Battery Charging Profile Using CC–CV Control

Figure 12 illustrates the simulated CC–CV charging profile of a 48-V, 24-Ah lithium-ion (Li-ion) battery using the proposed isolated SEPIC converter. During the first constant-current (CC) mode, the battery charging current is kept constant at roughly 15A and the battery voltage grows slowly from its initial value to the required charging voltage of 56V. The switch from CC mode to constant-voltage (CV) mode happens at a battery voltage of roughly 56V. The battery voltage is kept at about 56V during the CV stage, and the charging current drops steadily as the battery is more and more charged. The battery SOC increases continually during the charging process, which is the anticipated charging behavior of a lithium-ion battery. Thus, the simulation demonstrates that the proposed isolated SEPIC converter with closed-loop CC–CV control can provide regulated current and voltage during the charging process and achieve the required CC-to-CV transition for EV battery-charging applications.

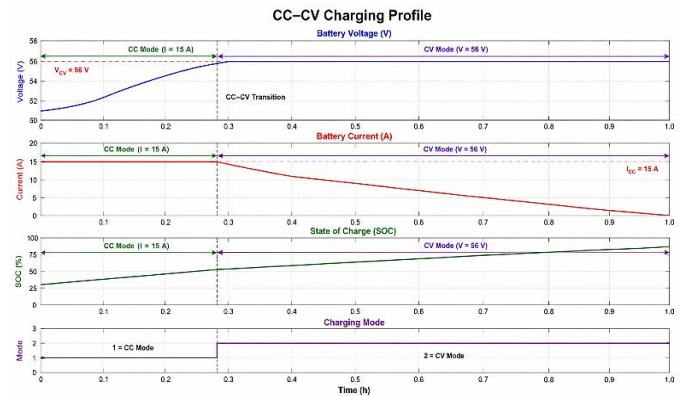


Figure 12. CC–CV Charging Profile of a 48-V, 24-Ah Lithium-Ion EV Battery

4.4. Frequency-Response Analysis of the Proposed LC EMI Filter

The frequency-response analysis of the proposed 1mH/1μF LC EMI filter was performed in MATLAB. The filter transfer function was obtained using the chosen values of the inductance and the capacitance and the frequency response was analyzed with the MATLAB Bode-plot analysis. The insertion-loss characteristic was also acquired in an effort to quantify the attenuation supplied by the filter over the frequency range of interest. The findings obtained in MATLAB shows that the cutoff frequency is about 5.03 kHz and there is a significant attenuation at the switching frequency of 50 kHz. This confirms that the LC filter is suitable to suppress the high frequency switching components. The Bode magnitude response of the 1mH/1μF LC EMI filter is shown in figure 13. The filter has a resonant response near its calculated cutoff frequency of approximately 5.03 kHz, and provides increasing attenuation at frequencies above this region. The amplitude response of the switching frequency of 50kHz shows significant attenuation of high frequency switching components. The associated insertion-loss characteristic is shown in figure 14. It exhibits an increasing attenuation with frequency and an attenuation of about 40dB near the 50kHz switching frequency. Thus, the frequency-response analysis confirms that the selected 1mH/1μF LC filter is effective for attenuating high-frequency switching noise and supports the reduction of conducted harmonic components in the proposed EV charger.

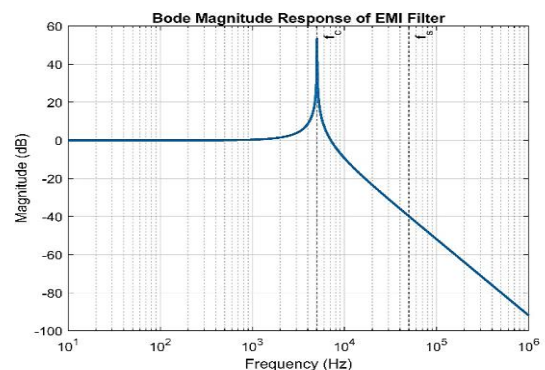


Figure 13. Bode Magnitude Response LC EMI Filter

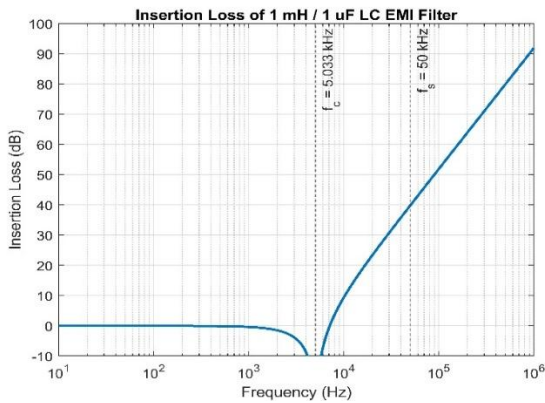


Figure 14. Insertion loss of the LC EMI Filter

5. COMPARATIVE PERFORMANCE ASSESSMENT OF ISOLATED AND CONVENTIONAL SEPIC CONVERTERS

Simulation research was performed to compare the performance of the conventional non-isolated SEPIC converter with the proposed isolated SEPIC converter for applicability for EV battery charging applications. The comparison was primarily based on switch voltage stress, diode voltage stress, efficiency variation with load current, and duty cycle versus output voltage characteristics.

5.1. Comparison of Switch Voltage and Diode Voltage Stresses

Figure 15 shows the simulated switch voltage stress (V_{ds}) across the MOSFET switch and the diode voltage stress (V_d) of the conventional SEPIC converter during steady-state operation. The top waveform is the voltage across the drain-source of the MOSFET switch, and the bottom waveform is the voltage stress across the output diode.

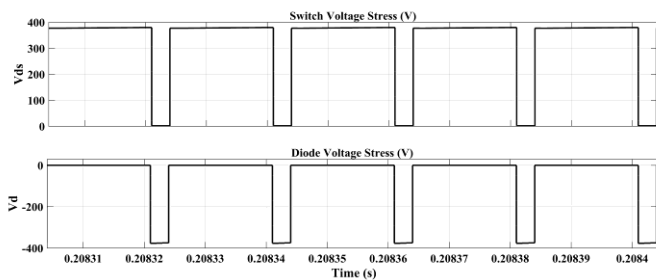


Figure 15. Simulated switch and diode voltage stresses of a conventional SEPIC converter

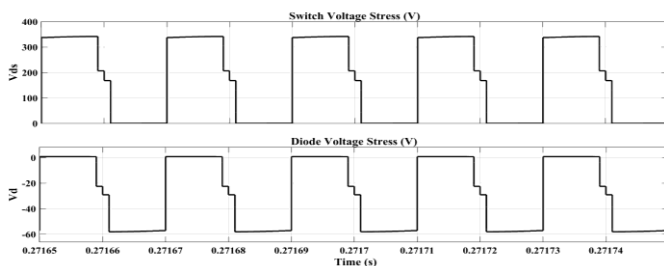


Figure 16. Simulated switch and diode voltage stresses of an isolated SEPIC converter

The MOSFET is subjected to a maximum voltage stress of about 380V during the high-frequency switching operation. The diode is subjected to a reverse voltage stress of about -380V in the off-state condition of the converter. The generated waveforms demonstrate the normal switching operation and energy transfer properties of the conventional SEPIC converter. However, the lack of galvanic isolation and the switching transients result in a substantial voltage stress across both semiconductor devices. The stress analysis shows that reliable operation of the converter under realistic EV charging conditions needs higher rated semiconductor devices and adequate protection circuits.

Figure 16 displays the simulated switch voltage stress (V_{ds}) across the MOSFET switch and diode voltage stress (V_d) of the isolated SEPIC converter under steady-state operating conditions. The upper waveform is the voltage across the drain-source of the MOSFET switch, and the lower waveform is the voltage stress across the output diode. In the switching operation, the MOSFET is subjected to a peak voltage stress of around 340–345V due to the high-frequency switching action and transformer-coupled energy transfer. The waveform also indicates intermediate voltage transitions due to parasitic inductance and switching transients in the converter circuit. The diode is subjected to reverse voltage stress of almost -60V in the off-state functioning in the same way. The achieved results confirm consistent switching performance and good operation of the semiconductor devices in the isolated SEPIC converter.

5.2. MOSFET Switching Loss Analysis

To calculate the MOSFET switching loss of an isolated SEPIC converter from figure 13, the standard switching-loss equation is used:

$$P_{sw} = \frac{1}{2} V_{ds} I_d (t_r + t_f) f_{sw} \quad (21)$$

$$= \frac{1}{2} * 345 * 15 * (60 + 50)$$

$$= 14.23W$$

Where P_{sw} is the MOSFET switching loss, V_{ds} is the drain to source voltage, I_d is the drain current, t_r is the rise time, t_f is the fall time, and f_{sw} is the switching frequency.

From figure 16, the values are obtained as $V_{ds} = 345V$, $I_d = 15A$, $t_r = 60ns$, $t_f = 50ns$, and $f_{sw} = 50kHz$. Substituting these values into equation (21), the MOSFET switching loss is calculated as $P_{sw} = 14.23W$. Hence, the predicted MOSFET switching loss is about 14.23W, which is within the permissible operating range for medium-power EV battery charging applications.

5.3. Efficiency Versus Load Current Analysis

To calculate the efficiency of an isolated SEPIC converter, the input power to the isolated SEPIC converter is calculated as equation (22):

$$P_{in} = V_{in} * I_{in} = 325 * 2.7067 = 879.67W \quad (22)$$

Efficiency of the isolated SEPIC converter is given by equation (23):

$$\eta = \frac{P_o}{P_{in}} * 100\% = \frac{840}{879.67} * 100\% = 95.49\% \quad (23)$$

Where P_{in} is the input power to the isolated SEPIC converter, V_{in} is the measured input dc voltage, I_{in} is the measured input dc current, η is the efficiency of the isolated SEPIC converter, and P_o is the output dc power.

Figure 17 shows a comparison of simulated efficiencies between the proposed isolated SEPIC converter and the conventional SEPIC converter under different load-current conditions. Both converters exhibit an increase in efficiency as the load current rises. However, the proposed isolated SEPIC converter consistently exhibits higher efficiency than the conventional SEPIC converter across the entire operating range.

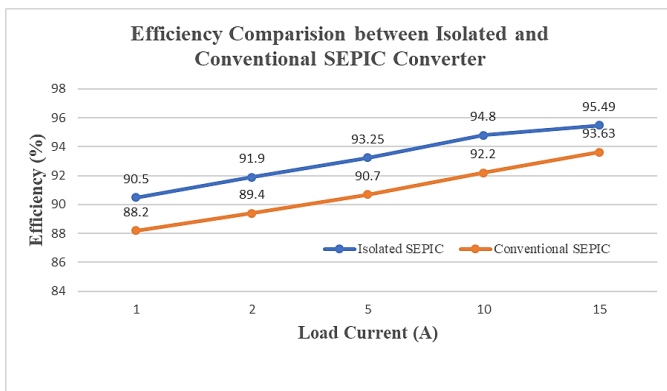


Figure 17. Efficiency comparison of an isolated and conventional SEPIC converters at different load currents

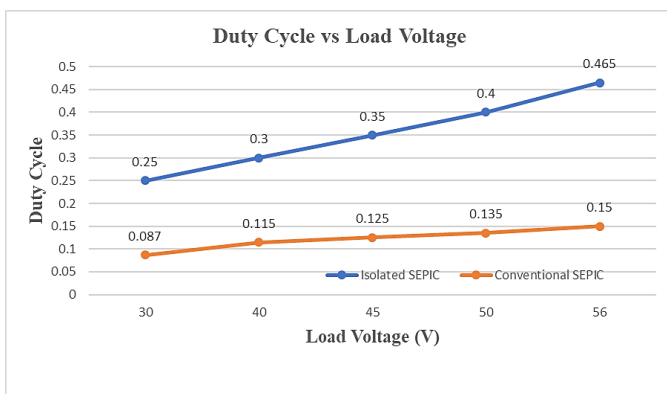


Figure 18. Duty cycle variation of an isolated and conventional SEPIC converters at different load voltages

The isolated SEPIC converter achieved an efficiency of 90.5% at the load current of 1A, while the conventional SEPIC converter achieved an efficiency of 88.2%. Similarly, the efficiency of an isolated SEPIC converter is 95.49% at 15A load current, and the efficiency of a conventional SEPIC converter is 93.63%. The results clearly demonstrate that the proposed isolated SEPIC converter provides improved

performance and energy conversion efficiency for EV battery charging applications as compared to the conventional SEPIC converter.

5.4. Duty Cycle Versus Output Voltage Characteristics

The duty cycle vs. output voltage characteristic was investigated to assess the voltage conversion capability of both converters. Figure 18 shows the relationship between the duty cycle and the load voltage for the proposed isolated SEPIC converter and the conventional SEPIC converter. From the graphs, the duty cycle increases with an increase in load voltage for both the converter topologies. However, the isolated SEPIC converter needs a larger duty cycle than the conventional SEPIC converter to obtain the appropriate output voltage because of the transformer isolation and the accompanying voltage conversion characteristics.

For the isolated SEPIC converter, when the load voltage increases from 30 V to 56 V, the duty cycle increases from 0.25 to 0.465. However, the conventional SEPIC converter is operated at a lower duty cycle range of 0.087 to 0.15 for the same output voltage range. The results indicate that the isolated SEPIC converter has superior voltage gain capabilities and better voltage control features, which are suited for EV battery charging applications. Furthermore, the steady and stable increase of the duty cycle proves the correct operation of the converter and the appropriate regulation of the output voltage for the different load situations.

Table 3. Performance Analysis of an isolated Open-loop SEPIC converter

	Without EMI filter	With EMI filter	Observation
Output DC Voltage (V_o)	55.24V	53.46V	Voltage regulation is reduced with an EMI filter
Output DC Current (I_o)	14.93A	14.45A	Current is slightly decreased with the EMI filter
Output Power (P_o)	824.73W	772.4W	Power reduced with EMI filter
Efficiency (η)	94.25%	94.05%	Efficiency slightly decreased
Supply Current THD	272.99%	27.84%	Reduce (89.80%) with EMI filter
Output Voltage Ripple	5.5%	3.92%	Decrease (28.73%) with EMI filter
Output Current Ripple	5.0%	4.0%	Decrease (20.00%) with EMI filter

Table 4. Performance Analysis of an isolated Closed-loop SEPIC converter

	Without EMI filter	With EMI filter	Observation
Output DC Voltage (V_o)	56V	56V	Well regulated
Output DC Current (I_o)	15.14A	15.14A	Stable under control
Output Power (P_o)	847.84W	847.84W	Maintained at rated value
Efficiency (η)	94.59%	95.49%	Slightly increase with EMI filter
Supply Current THD	269.97%	6.89%	Good reduction (97.44%) with EMI filter
Output Voltage Ripple	5.1%	2.14%	Decrease (58.04%) with EMI filter
Output Current Ripple	4.9%	2.60%	Decrease (46.94%) with EMI filter

Table 5. Comparative Performance of an isolated open-loop and closed-loop SEPIC converter during supply voltage variation with an EMI filter

Supply Voltage Variation (V)	Open-loop Configuration				Closed-loop Configuration			
	Output Voltage (V)	Output Current (A)	Efficiency η (%)	THD (%)	Output Voltage (V)	Output Current (A)	Efficiency η (%)	THD (%)
325	53.46	14.45	94.05	27.84	56	15.14	95.49	6.89
230	37.62	10.17	93.49	29.30	56	15.14	94.80	9.68
180	30.27	8.18	92.60	32.20	56	15.14	94.10	10.68

Table 6. Comparative Analysis of the proposed converter with existing DC-DC converters topologies

Converter Topology	Control Technique	Output Voltage (V)	Efficiency (%)	THD (%)	Voltage Ripple (%)	Isolation	Reference
Bridgeless SEPIC	PI/ PFC	48–54	93–94	18–22	~5	No	[7]
SEPIC-Luo	PI/ ANN	48–56	94–95	16–20	~4	No	[9]
Conventional SEPIC	Open Loop	50–55	90–93	20–25	~5	No	[5]
Buck	PWM	48	88–92	22–28	~5	No	[5]
Boost	PWM	48–60	90–93	20–26	~5	No	[3]
Cuk	PWM	48–55	91–94	18–24	~6	No	[5]
Proposed Isolated SEPIC	PI	56	95.49	6.89	2.14	Yes	Present Work

The different simulated parameters for an isolated open-loop and closed-loop SEPIC converter is shown in *tables 3 and 4*, respectively. After comparing simulation results for both open-loop & closed-loop configurations, we find that the closed-loop configuration of an isolated SEPIC converter provides improved performance characteristics. An isolated SEPIC converter in a closed-loop arrangement with an EMI filter that maintained an output voltage of around 56V and an output current of 15A across the load. The simulation results show a high efficiency of 95.49%, a low supply current THD of 6.89%, and much reduced output voltage and output current ripple, which is 2.14% and 2.60%, respectively.

Table 5 shows the change in input supply voltage for both open-loop and closed-loop modes in an isolated SEPIC converter. These comprise the output voltage (V_o), output current (I_o), efficiency (η), and THD. From the above comparison, it is verified that closed-loop configuration in the proposed converter gives better results while considering all given factors. As can be seen from Table 6, the proposed converter demonstrates 6.89% input-current THD, lower voltage and current ripple, and better efficiency under the specified simulation conditions. Because the literature converters operate at different power levels, input voltages, topologies, and switching frequencies, the reported values are not used for direct numerical ranking. A high-frequency transformer is incorporated to offer galvanic isolation, which is not present in typical converters such as buck, boost and Cuk. Furthermore, the usage of a closed-loop PI controller improves voltage regulation and dynamic response. These features make the proposed converter very suitable for electric vehicle battery charging applications under changing input conditions.

The enhanced performance of the closed-loop design compared to the open-loop system is due to the control and filtering effects on the functioning of the converter. The major reduction in total harmonic distortion (THD) is mainly due to the use of the input EMI filter, which reduces the high-frequency switching harmonics generated by the rectifier and converter stages. The filter operates as a low-pass network which reduces the higher-order harmonic components in the input current and so improves the quality of the waveform and reduces the THD from a highly distorted condition to an acceptable level. Furthermore, the closed-loop control also helps to reduce the THD by keeping a steadier duty cycle, which reduces the variation in switching behavior and the harmonics injection to the supply. The combined effect of the output filter components and the closed-loop PI controller is primarily responsible for the reduction in the output voltage and current ripple.

The comparison in detail with traditional converters like buck, boost, Cuk, and SEPIC indicates that the proposed isolated SEPIC converter achieves higher efficiency, reduces output voltage ripple, and provides galvanic isolation, thus considerably improving safety and flexibility for medium-power EV battery charging applications under wide input voltage variations.

6. PRACTICAL FEASIBILITY VALIDATION THROUGH CONVENTIONAL SEPIC HARDWARE PROTOTYPE

The hardware prototype serves as proof-of-concept validation for the core mathematical sizing formulas of the SEPIC energy-transfer elements. The obtained experimental findings give practical insight into a SEPIC converter implementation and establish the feasibility of the proposed isolated SEPIC architecture. Experimental realization of the complete isolated topology will be considered in future work. A case study of a

conventional non-isolated SEPIC converter working in open-loop mode has been experimentally explored to establish the practical feasibility of the proposed EV battery charger and to offer a comparative performance evaluation. The hardware prototype of a conventional SEPIC converter was designed using power MOSFET (IRF840), an inductor ($L_1=3.30\text{mH}$, $L_2=4.50\text{mH}$), a coupling capacitor ($C_1=20\mu\text{F}$, 450V), a high-speed diode (MUR3020PT), a PWM pulse generator circuit and an output filter capacitor ($C_o=330\mu\text{F}$, 200V). The converter was operated with a fixed switching frequency (50kHz) and constant duty cycle (15%) without feedback regulation. The experimental investigation confirmed that the conventional SEPIC converter can perform both step-up and step-down voltage conversion depending upon the applied duty ratio. However, the converter was operating in open-loop mode, and as a result, the control of output voltage was very sensitive to fluctuations in the input voltage and load disturbances.

The hardware prototype was designed with an output rating of 56V and 3A . The experimental setup was implemented in the laboratory using the dSPACE DS1104 real-time controller platform for PWM pulse generation at a 50kHz switching frequency [28]. The MOSFET switch was operated with a duty cycle of 0.15 at a switching frequency of 50kHz . A TLP250 high-speed, high isolation photo coupler was employed for MOSFET gate driving. The converter output is monitored using digital meters for measuring output voltage and current and is connected to a 48V , 24Ah Li-ion battery as the charging load. The experimental setup of the conventional SEPIC converter is shown in figure 19. The complete setup consisted of two stages: (1) AC-DC rectifier stage, and (2) SEPIC DC-DC converter stage.

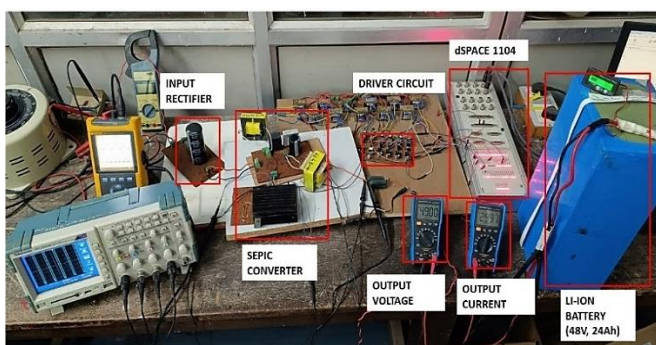


Figure 19. Experimental setup of conventional SEPIC converter

Figure 20 shows the experimentally generated gate pulse waveform for the SEPIC converter at a switching frequency of 50kHz and duty cycle of 15% . The PWM signal generated through the dSPACE DS1104 controller provided a stable switching operation for the MOSFET switch. The experimental waveform demonstrates the correct creation of the switching pulse and the satisfactory operation of the open-loop converter. Figure 21 shows the experimentally observed output voltage and output current waveforms of the conventional SEPIC converter.

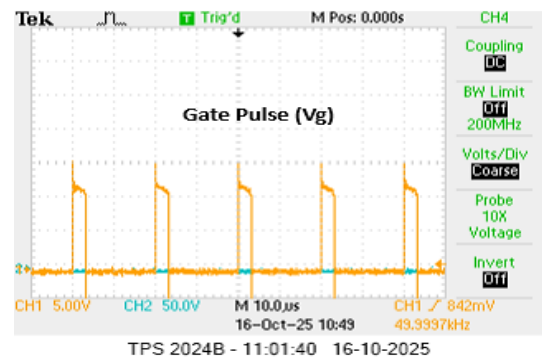


Figure 20. Gate pulse of SEPIC converter

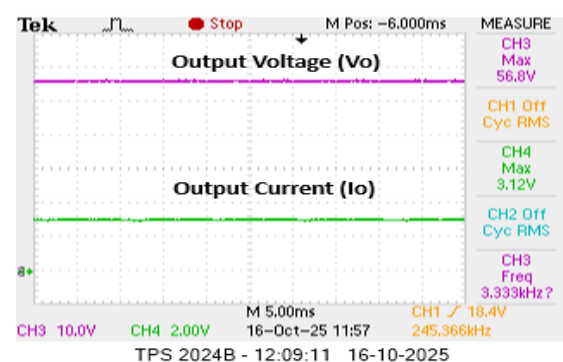


Figure 21. Output voltage and output current waveform

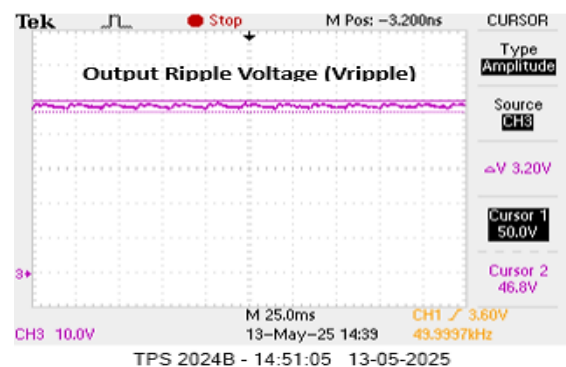


Figure 22. Output ripple voltage of SEPIC converter

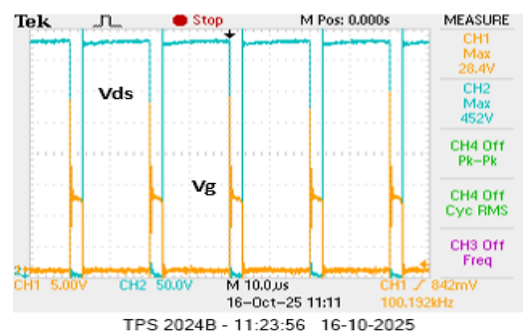


Figure 23. Gate pulse and voltage across the MOSFET

The output voltage was around 56V, and the output current was around 3A under operational conditions. The converter was able to achieve the appropriate level of output voltage although some mild fluctuations in voltage and current were observed. The experimentally determined output ripple voltage waveform of the conventional SEPIC converter is presented in *figure 22* where the ripple voltage was observed to be comparatively low with a value of approximately 3.20V. *Figure 23* shows the gate pulse waveform (V_g) and the drain to source voltage waveform (V_{ds}) across the MOSFET switch during the operation of the converter. The waveform was recorded with a digital storage oscilloscope at a switching frequency around 50kHz. The orange trace is the gate pulse signal delivered to the MOSFET, and the blue trace is the matching drain-to-source voltage. The experimental results indicate the high-frequency switching action, parasitic inductance, and transient effects of the practical hardware circuit produced the maximum switching voltage stress of about 452V in the MOSFET during the converter operation. The switching waveform analysis demonstrates the practical switching characteristics of the conventional SEPIC converter under open-loop operation.

The experimental results verify that the conventional open-loop SEPIC converter can provide regulated DC output voltage with both step-up and step-down conversion capabilities. However, numerous practical limitations are sensitivity to load variation, dependence on fluctuation of the input voltage, absence of automatic voltage regulation, switching stress across the MOSFET, and lack of galvanic isolation.

7. CONCLUSION AND FUTURE WORK

The isolated SEPIC converter was comprehensively evaluated through simulation for the 840W, 56V, 15A EV battery charging application. The converter was evaluated under both open-loop and closed-loop PI-controlled operation using MATLAB Simulink. Closed-loop simulation demonstrated improved input current quality, regulated output voltage, reduced ripple, high conversion efficiency, and reduced sensitivity to supply-voltage variations compared with open-loop operation.

The system's performance was thoroughly examined for both open-loop and closed-loop control topologies. The quantitative simulation results confirmed that the proposed closed-loop system provides a tightly regulated output voltage of about 56V and a stable charging current of 15A for varying input voltages. The converter has attained a maximum simulated efficiency of 95.49% with very low ripples of 2.14% and 2.60% in the output voltage and current, respectively. Moreover, an input passive filter was included to reduce the grid current total harmonic distortion (THD) to 6.89% under the investigated closed-loop condition. The CC-CV charging profile further demonstrates the suitability of the simulated converter configuration for EV battery-charging operation.

The proposed converter is designed for 840W (56V, 15A), whereas the available laboratory prototype is rated at 168W (56V, 3A), corresponding to 20% of the target power rating. The prototype is therefore considered a scaled proof-of-concept implementation rather than full-power validation. The experimental prototype was used to verify the practical feasibility of the basic SEPIC power-stage operation, energy-transfer principle, and component sizing approach. However, these experimental results do not constitute direct experimental validation of the proposed isolated SEPIC converter or its 840W simulation results.

The present study is therefore primarily a simulation-based investigation of the isolated SEPIC converter. The comparative studies have validated that closed-loop PI schemes offer much better dynamic voltage regulation, steady tracking performance, and improved power quality than the open-loop system. Future work will include experimental evaluation of the isolated architecture under full hardware loading conditions. Overall, the simulation results and scaled conventional SEPIC hardware prototype provide a systematic assessment of the proposed isolated SEPIC configuration and establish a foundation for its future hardware development and experimental validation in EV battery-charging applications.

REFERENCES

- [1] Abdelfatah, A.; Hossam, H. H. M.; Mostafa, F. S.; Maher, A. A.; Ahmed, S. A. A. A Comprehensive Review on Charging Topologies and Power Electronic Converter Solutions for Electric Vehicles. *Journal of Modern Power Systems and Clean Energy*, vol. 12, no. 3, May 2024, pp. 675-694.
- [2] Mohammad, F.A.; Siti, R. S. R.; Nasrudin, A.R.; Mohammad, N.A.; Elmi, A.B. Recent Developments in DC-DC Converter Topologies for Light Electric Vehicle Charging: A Critical Review. *Applied Sciences*, vol.13, no.3, January 2023, pp. 1-35.
- [3] Ali, Emadi. *Advanced Electric Drive Vehicles*. CRC Press, Boca Raton, FL., 2014.
- [4] S. S. Sayed; A. M. Massoud. Review on state-of-the-art unidirectional non-isolated power factor correction converters for short-/long-distance electric vehicle. *IEEE Access*, 2022, vol.10, pp. 11308-11340.
- [5] S. N. Gohil; H. A. Shah; A. R. Gauswami. Design and simulation of SEPIC converter for EV battery charger. *International Journal of Electrical and Electronics Engineering*, Nov. 2024, vol. 11, no. 11, pp. 93-99. doi: 10.14445/23488379/ijece-v11i11p110.
- [6] S. Ahmad; N. Tan; M. Baharuddin; G. Buticchi. A High-Performance Isolated SEPIC Converter for Non-Electrolytic LED Lighting. *IEEE Access*, vol. 9, 2021. doi:- 10.1109/ACCESS.2021.3125522.
- [7] Manish, D.; R. Jayapragash. New SEPIC Derived Semi-Bridgeless PFC Converter for Battery Charging Application. *IEEE Access*, 2025, vol. 13. doi:- 10.1109/ACCESS.2025.3529351.
- [8] Ihsan, A.M.; Turki, K.H. Design and Simulation of High Gain SEPIC DC-DC Converter. *Journal of Engineering and Sustainable Development (JEASD)*, January 2023, vol. 27, no. 01, pp. 138-148.
- [9] Meena, D.; Padmathilagam, R.; Arulvizhi, S.; Nammalvar, P. Performance evaluation of bridgeless isolated SEPIC-Luo converter for EV battery charging using PI and ANN controller. *International Journal of Power Electronics and Drive Systems (IJPEDS)*, June 2024, vol. 15, no. 02, pp- 935-946.
- [10] M. V. M. Ewerling; T. B.Lazzarin; C. H. I. Font. Modular SEPIC-Based Isolated DC-DC Converter with Reduced Voltage Stresses across the Semiconductors. *Energies*, Oct. 2022, vol. 15, no. 21, pp. 1-18.

- [11] Bhim, Singh; Radha, Kushwaha. A PFC-Based EV Battery Charger Using a Bridgeless Isolated SEPIC Converter. *IEEE Transactions on Industry Applications*, 2019, vol. 56, no. 1, pp. 477–487.
- [12] Sin. Lee; H. Do. Isolated SEPIC DC–DC Converter with Ripple-Free Input Current and Lossless Snubber. *IEEE Transactions on Industry Applications*, February 2018, vol. 65, no. 2, pp. 1254–1262.
- [13] Jitendra, Gupta; Bhim, Singh. Single-Stage Isolated Bridgeless Charger for Light Electric Vehicle with Improved Power Quality. *IEEE Transactions on Industry Applications*, October 2022, vol. 58, no. 5, pp. 6357–6367.
- [14] Bayan, Hussein; Nima, Abdi; Ahmed, Massoud. Design of a Single-Phase Isolated SEPIC-Based Charger for Electric Vehicles. *IEEE Symposium on Industrial Electronics & Applications (ISIEA)*, September 2020, pp. 1–6. doi: 10.1109/ISIEA49364.2020.9188177.
- [15] J. Ahmad; C. H. Lin; M. S. Khan; H. D. Liu; M. Fahad. Modified Isolated SEPIC Converter for EV Charging and High Voltage Applications. *2023 International Conference on Power, Instrumentation, Energy and Control (PIECON)*, 2023, doi: 10.1109/PIECON56912.2023.10085847.
- [16] M. Dhandapani; P. Ravichandran; S. Arulvizhi; N. Pachaivanan. Performance evaluation of bridgeless isolated SEPIC-Luo converter for EV battery charging using PI and ANN controller. *International Journal of Power Electronics and Drive Systems*, 2024, vol. 15, no. 2, pp. 935–946, doi: 10.11591/ijpeds.v15.i2.pp935-946.
- [17] A. Ugurluoglu; A. Karaarslan. Simulation of fuzzy logic and PI control methods on a bridgeless isolated SEPIC converter for electric vehicle chargers. *International Advanced Researches and Engineering Journal*, 2024, vol. 8, no. 3, pp. 141–153, doi: 10.35860/iarej.1501059.
- [18] M. K. Dwivedi; R. Jayapragash. New SEPIC Derived Semi-Bridgeless PFC Converter for Battery Charging Application, *IEEE Access*, 2025, vol. 13, pp. 12068–12080, doi: 10.1109/ACCESS.2025.3529351.
- [19] O. Balapanuru; M. Lokhande; M. V. Aware; S. Gupta. Unsymmetrical Dual-Input Isolated High Gain Bidirectional DC–DC Converter with Inherent Current Sharing for Light EV Applications. *IEEE Transactions on Transportation Electrification*, March 2024, vol. 10, no. 1, pp. 2070–2081.
- [20] Gabriel, Tibola; Erik, Lemmen; Jorge L. Duarte; Ivo Barbi. Passive Regenerative and Dissipative Snubber Cells for Isolated SEPIC Converters: Analysis, Design, and Comparison. *IEEE Transactions on Power Electronics*, 2017, vol. 32, no. 12, pp. 1–13.
- [21] Kenan, G.; Mehmet, N.A. High-Efficiency Single-Stage Isolated Sepic-Flyback AC–DC Led Driver. *Electronics*, December 2023, vol. 12, no. 24, pp. 1–20. <https://doi.org/10.3390/electronics12244946>
- [22] M. Karupiah; P. Dineshkumar; K. Karthikumar. Design an Electric Vehicle Charger Based SEPIC Topology with PI Controller. *International Conference on Advances and Developments in Electrical and Electronics Engineering (ICADEE)*, 2020.
- [23] Virbora, N.Y. SEPIC Converter Design Guide. National Polytechnic Institute of Cambodia, August 2020.
- [24] John, Betten. Technical Article: Isolating a SEPIC. Texas Instruments, 2024.
- [25] Anthony, Fagnani. Using the TPS55340 as a SEPIC Converter. Texas Instruments, 2012.
- [26] Dongbing, Zhang. AN-1484 Designing A SEPIC Converter. Texas Instruments, 2013.
- [27] Ankita, Samani; Sweta, Parnar. Design of SEPIC Converter using MATLAB. *International Journal of Innovative Trends in Engineering (IJITE)*, 2016, vol. 13, no. 2, pp. 88–93.
- [28] Alpeshbharathi, Gauswami; Hardik, Shah. A Comparative Simulation–Hardware Co-Validation Framework for SEPIC and Full-Bridge DC–DC Converters in Electric Vehicle Battery Charging via dSPACE DS1104. *Turkish Journal of Engineering*, May 2026, vol. 10, no. 2, pp. 534–547. doi:10.31127/tuje.1828170
- [29] Trivedi, Bhavin; Bhavesh, Patel; Jay, Desai; Kamlesh, Sonwane. Analysis of SEPIC Converter. *International Journal of Engineering Development and Research (IJEDR)*, 2018, vol. 6, no. 2, pp. 489–494.
- [30] J. Leema Rose; B. Sankaragomathi. Design, Modeling, Analysis and Simulation of a SEPIC Converter. *Middle-East Journal of Scientific Research*, 2016, vol. 24, no. 7, pp. 2302–2308.
- [31] Rahul, Pandey; Bhim, Singh. PFC-SEPIC converter-fed half-bridge LLC resonant converter for e-bike charging applications. *IET Electrical Systems in Transportation*, 2020, vol. 10, no. 3, pp. 225–233.
- [32] Radha, Kushwaha; Bhim, Singh. An Improved SEPIC PFC Converter for Electric Vehicle Battery Charger. *IEEE*, 2019, pp. 1–8.
- [33] Syed, Faiz; A.A. Apte. EV Battery Charger using SEPIC Converter with PFC based technique. *International Research Journal of Modernization in Engineering Technology and Science*, 2021, vol. 3, no. 2, pp. 1326–1332.
- [34] Abhishek, Kumar; Ranjitha, V.; Sandhya, B.; Megha, M. An EV Battery Charger Using a PFC based Bridgeless SEPIC Converter. *International Journal of Engineering Research & Technology (IJERT)*, 2018, vol. 6, no. 13, ISSN 278-0181, pp. 1–5.
- [35] Onur, Kircioglu; Murat, Unlu; Sabri, Camur. Modeling and Analysis of DC-DC SEPIC Converter with Coupled Inductors. *IEEE*, 2016.
- [36] J. Gnanavadeivel; K. S. Revathy; S.T. Jaya Christa; N. Senthil Kumar. Analysis and Design of Single-phase AC-DC Modified SEPIC Converter. *Applied Mechanics and Materials*, Trans. Tech. Publications, Switzerland, 2014, vol. 573, pp. 108–114.



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