Implementation of Hybrid Boost-Sepic Converter for Ev Charging Application

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Abstract - Implementation of a Hybrid Boost SEPIC (HBSC) converter for an electric vehicle (EV) battery charging application. The HBSC converter is designed to efficiently boost a low DC input voltage to a regulated output suitable for battery charging. The system is powered by a 4V DC input, simulating the output of a solar panel, and boosts this voltage to 12V using the HBSC topology. The SEPIC stage ensures a non-inverting output, making it suitable for direct connection to the battery. Simulation of the HBSC converter was carried out using MATLAB Simulink (2021), and an efficiency of 83% was achieved under standard operating conditions. For hardware implementation, a Regulated Power Supply (RPS) provides the 4V input, while a gate driver circuit, powered by a 12V adapter, is used to drive the IRF460 MOSFET switches. The Arduino Uno microcontroller generates PWM signals, which are level-shifted by the gate driver from 5V to 12V to ensure proper switching of the MOSFETs. Energy storage and transfer within the converter are managed by the inductors and capacitors in both the boost and SEPIC stages, which facilitate voltage regulation and boost functionality. A relay circuit, triggered when the RPS is active, integrates protection by disconnecting the input when the battery voltage reaches 12V, as detected by a voltage sensor. This feature safeguards the battery from overcharging and enhances system reliability.

Key Words: solar panel , hybrid boost-SEPIC converter, EV charging .

1.INTRODUCTION

The purpose of the Hybrid Boost-SEPIC Converter (HBSC) is to integrate the advantages of both the boost and SEPIC power conversion methods. While the SEPIC converter offers more versatility by having the ability to either increase or decrease the voltage, the Boost converter raises the input voltage to a higher output value. These two approaches are used in the hybrid design to create a converter that can effectively manage a broad range of input voltages while preserving a steady output voltage. Applications where the input voltage may fluctuate, such electric cars or renewable energy systems, benefit greatly from this capability. The HBSC increases overall efficiency and dependability by combining these converters. Even when the input voltage fluctuates, it guarantees that linked devices receive a steady power supply and reduces energy loss. It is therefore a useful technology for contemporary power management requirements. The HBSC is especially helpful in real-world systems that need to be highly reliable and efficient while dealing with variable input sources. For instance, the input voltage in renewable energy systems like solar power can change dramatically based on the surrounding environment.

The input voltage may also drop as the battery drains in battery-powered applications. Additionally, by lessening the strain on individual components during the switch between boost and SEPIC modes, this converter design decreases component stress. In systems where long-term operation and efficiency are crucial, this results in increased reliability, longer component life, and decreased heat generation. It is a good option for applications in battery- powered devices, renewable energy systems, electric vehicles, and other power-sensitive technologies because it combines the best features of the boost and SEPIC converters to provide a stable and effective method of voltage regulation across a wide input voltage range.

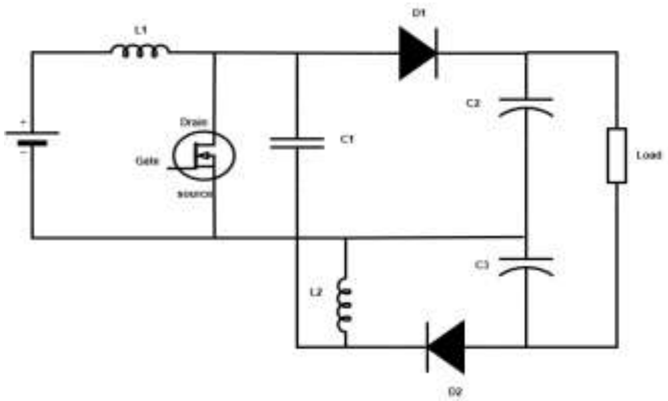
2. OBJECTIVE

To design a hybrid Boost-SEPIC DC-DC converter for electric vehicle (EV) charging applications, specifically aimed at delivering a regulated 12V constant output to efficiently charge a 12V battery. The converter should maintain stable output with minimal voltage and current ripple

3. HYBRID BOOST SEPIC CONVERTER

The HBSC combines the characteristics of both the Boost and SEPIC topologies to achieve enhanced performance in DC-DC voltage conversion. The converter works by integrating the step-up functionality of the Boost converter with the continuous current feature of the SEPIC converter, providing a high voltage gain with continuous input current and improved efficiency. The key advantage of this hybrid topology is that it provides a high voltage gain while maintaining continuous input current, meaning the system avoids high current ripple and electromagnetic interference (EMI). The boost portion of the converter ensures a voltage step-up, while the SEPIC portion ensures stable output even when the input voltage fluctuates, making the hybrid design highly effective for a wide range of input voltage conditions

TOPOLOGY



MODE I

When the MOSFET switch is turned ON, Inductor L1 begins to store energy directly from the input supply (Vin) as current flows through the path: Vin → L1 → MOSFET → Ground. At the same time, Capacitor C1 discharges through Inductor L2, causing L2 to store energy as well. The current path is: C1 → L2 → MOSFET → Ground. During this mode, both Diode D1 and Diode D2 are reverse-biased, so no current flows to the output. All input energy is stored in L1 and L2, and the load is momentarily isolated from the source.

MODE II

When the MOSFET switch is turned OFF, the magnetic fields in L1 and L2 collapse, and their polarities reverse due to Lenz's Law. As a result, L1 discharges its energy through Diode D1, supplying current to the output via Co1 and the load. The path is: L1 → D1 → Co1 → Load → Co2. Simultaneously, L2 also discharges; its reversed polarity causes Diode D2 to become forward-biased, and current flows through L2 → D2 → Co2. This current continues through the load and Co1, supporting output power delivery. Thus, during Mode 2, both inductors transfer their stored energy to the output capacitors and the load, ensuring continuous power supply and voltage regulation.

DESIGN OF HYBRID BOOST SEPIC CONVERTER

DESIGN EQUATIONS OF BOOST CONVERTER

DUTY CYCLE

$$D = \frac{V_O - V_I}{V_O} \quad (1)$$

INDUCTOR

$$L_1 = \frac{V_I\, D}{\Delta_{iL} F_S} \text{ (H)} \quad (2)$$

$$L_2 = \frac{V_I}{\Delta_{iL} F_S} \times D \quad (3)$$

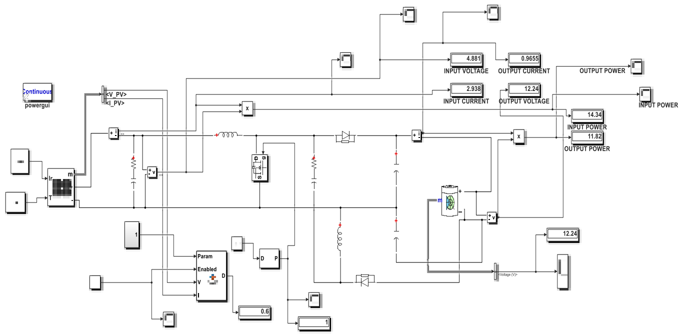
CAPACITOR

$$C_1 = \frac{I_O\, D}{\Delta_{VO} F_S} \text{ (F)} \quad (4)$$

$$C_2 = \frac{I_i \times D}{V_{ripple} \times 0.5 \times F_S} \quad (5)$$

$$C_3 = \frac{I_O D}{V_{ripple} \times 0.5 \times F_S} \quad (6)$$

SIMULATION OF HYBRID BOOST SEPIC CONVERTER



Solar panel gives variable power to HBSC which is controlled by using POA. Therefore, 4 V is given as constant input voltage to HBSC by using P&O algorithm. HBSC is operating at a duty cycle of 0.5. HBSC is designed using 0.6mH and 0.576mH inductors, 250μF and 1300μF capacitors. 12V is obtained as output voltage from HBSC. This voltage is applied to battery of electric vehicle. The proposed design is simulated using MATLAB/Simulink model 2021

SIMULATION RESULTS

Figure 4.2 shows the output voltage of the solar panel. The panel used from the Simulink model is user defined. By increasing the series and parallel strings the required rating has been obtained. 4.828V is obtained as output voltage from solar panel.

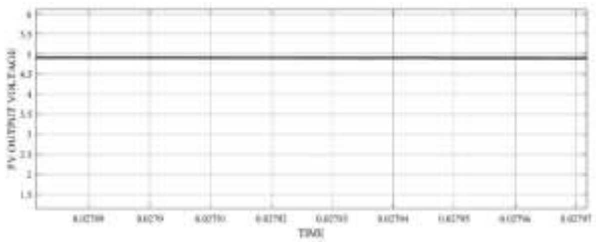


Figure 4.2 Waveform of solar panel output voltage

Figure 4.3 shows the output current of the solar panel. 2.939 A is obtained as output current from solar panel.

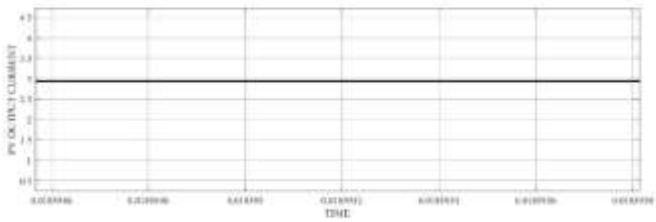


Figure 4.3 Waveform of solar panel output current

Figure 4.4 shows the output power of the solar panel. 14.34 W is obtained as output power from solar panel.

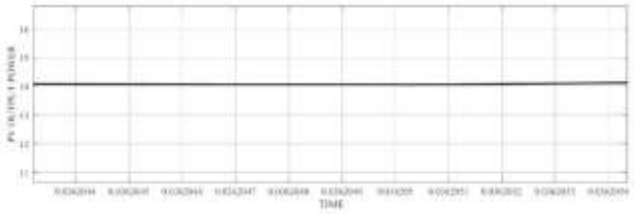


Figure 4.4 Waveform of solar power

Figure 4.5 shows the output voltage obtained from the HBSC for the designed duty cycle. 12 V is obtained as output voltage from the HBSC.

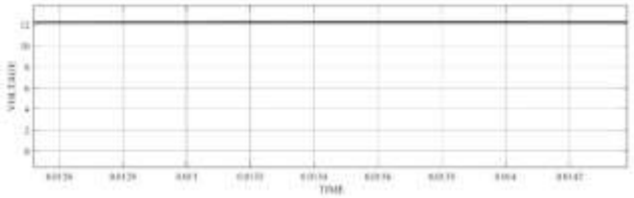


Figure 4.5 Waveform of HBSC output voltage

Figure 4.6 shows the output current of the HBSC for the designed duty cycle. 1 A is obtained as output current from the HBSC.

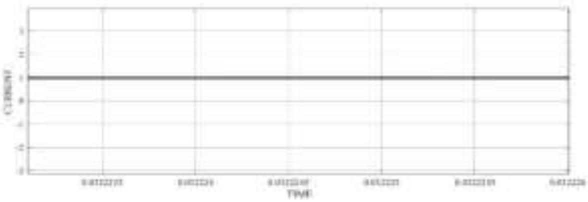


Figure 4.6 Waveform of HBSC output current

Figure 4.7 shows the output power of the HBSC for the designed duty cycle. 11.82 W is obtained as output power from the HBSC.

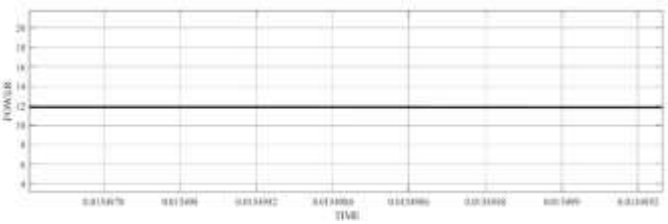
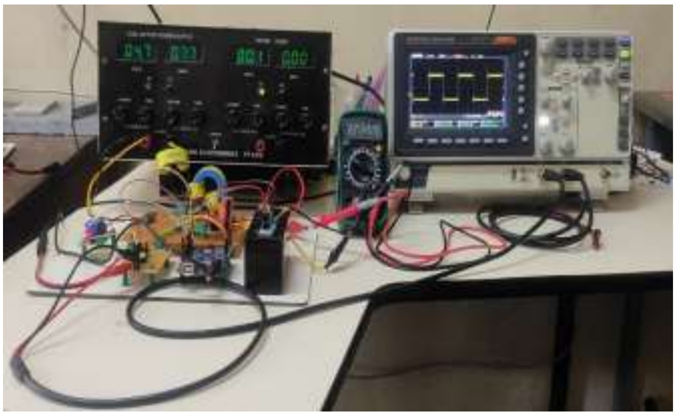


Figure 4.7 Waveform of HBSC output power

HBSC PROPOSED SYSTEM



The proposed Hybrid Boost-SEPIC Converter (HBSC) is designed to efficiently charge a 12.5V, 1.3Ah battery for electric vehicle (EV) applications by combining the advantages of both Boost and SEPIC topologies. The converter uses two inductors (L1 = 0.6 mH, L2 = 0.576 mH) and three capacitors (C1 = 250 μF, C2 and C3 = 1300 μF) to achieve a regulated and ripple-free 12V output. L1 is part of the Boost stage, stepping up the input voltage, while L2 and C1 form the SEPIC stage, ensuring continuous input current and non-inverting voltage regulation. The IRFP460 MOSFET, controlled by a TLP250 optocoupler-based gate drive circuit, manages switching, with PWM signals generated from an Arduino via digital pin 9. Gate protection and performance are enhanced using two 10Ω resistors and a polyester film capacitor between Vcc and the MOSFET gate. The Arduino also reads battery voltage via analog pin A0 using a voltage divider sensor. When the battery voltage reaches 12.5V, a signal is sent to a single-channel relay connected to digital pin 8, which disconnects the Regulated Power Supply (RPS), preventing overcharging. The use of U1660G diodes, 1N4007 protection diodes, and custom-wound inductors further ensures safe and efficient operation. This HBSC design offers improved voltage regulation, reduced input current harmonics, and a wider input range, making it well-suited for EV battery charging under varying supply conditions.

CONCLUSION

In my project, I have implemented a Hybrid Boost SEPIC (HBSC) converter for an EV charging application. In the simulation, the input to the HBSC converter is a 4V DC source, representing the output of a solar panel. This 4V is boosted to 12V using the HBSC converter. The SEPIC stage provides a non-inverting output, which is connected to a battery for charging. The simulation was done using MATLAB Simulink (2021 version), and an efficiency of 83% was achieved. In the hardware implementation, a Regulated Power Supply (RPS) is used to provide a 4V input to the HBSC converter. A gate driver circuit, powered by a 12V adapter, is used to drive the converter. An Arduino Uno is used to generate PWM pulses, which are fed into the gate driver. The gate driver amplifies the 5V PWM signal from the Arduino to 12V to turn on the IRF460 MOSFET switches in the converter. During operation, the boost and SEPIC inductors, along with the capacitors, store energy and help boost the voltage to 12V, which is then used to charge the battery. A relay circuit is also used in the system, which is activated when the RPS is turned on. A voltage sensor monitors the battery voltage. When the battery voltage reaches 12V, the sensor sends a signal to the relay circuit, which then disconnects the input voltage to prevent overcharging the battery.

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