Performance and Analysis of Cuk Converter for Electric Vehicle Battery Charger Along with Resonant Converter

Keval Dasadiya[1(✉)], Jayraj Chanv[1], and N. Karupaiah[2]

[1] Electrical Engineering Department, School of Engineering, RK University, Rajkot, Gujarat, India
{keval.dasadiya,jayraj.chanv}@rku.ac.in

[2] Department of Electrical and Electronics Engineering, Vardhman College of Engineering, Hyderabad, Shamshabad, Telangana, India

Abstract. For electric vehicle (EV) battery chargers, this study suggests an HB-LLC resonant converter supplied by a cuk converter (EVBC). A typical home power supply, 230 V–50 Hz AC, is employed as the input in this investigation. A diode bridge rectifier, or DBR, changes the input voltage to DC. As DC-DC converters, a cuk converter and an LLC resonant converter are employed. The LLC resonant converter transforms the DC link voltage into the isolated DC voltage needed for the electric vehicle battery charger (EVBC), while the cuk converter functions in the primary inductor's continuous conductor mode (CCM). For quick charging of EV batteries, the Voltage fed LLC resonant converter provides an appropriate charge voltage. Here, MATLAB Simulink is used for simulation to analyze the parameters.

Keywords: Cuk Converter · HB – LLC Resonant Converter · Electrical Vehicle Battery Charger

1 Introduction

A DC-to-DC converter is an electrical device that converts electric power from one source of direct current (DC) to another. It uses high-frequency switching and capacitors, inductors, and transformers to smooth out switching noise. Batteries are the primary power source for portable electronics like laptops and cell phones. A resonant converter, made up of inductors and capacitors, filters harmonics to produce a sinusoidal wave. Electrical vehicles are introducing hybrid, hydrogen cell, and battery-powered options, with a wide range of technologies available. The selection process for batteries depends on the vehicle's weight, torque, speed, and motor type.

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2 Literature Review

Tests of the suggested UPF converter's performance demonstrate its appropriateness for EV battery charging in CC-CV mode with improved power quality. Furthermore, cascade dual loop PI controllers have been adjusted for mainstream use with reduced THD and smooth charging characteristics. Because of the input and output side inductors, the suggested UPF converter topology provides the inherent benefit of decreased waveforms at the input and output sides [1].

A PQ correction feature is integrated into the design of a battery charger for electric vehicles (EVs) that has a non-inverting cuk converter. The additional inverse amplifier required to convert the inverting output voltage to a conventional cuk converter has been rendered unnecessary by the EV charger equipped with the suggested converter. As low as 2.8%, the primary current THD is observed, falling within the regulations' allowable range [2].

The suggested EV charger offers the combined benefits of enhanced charging, easy control, and isolation because of the single-phase converter's DCM operation and low stress on semiconductor devices. The charger's reliability is increased because the device voltage is lower than that of a typical isolated PFC converter-based charger and is clamped to the maximum input voltage. Furthermore, the charger's size and price have been decreased [3].

Low conduction losses with current conduction through a small number of components at single switching intervals are an advantage of the isolated BL converter. One more benefit of the suggested charger is that the normal input initiator is present for both half-cycles. Because the two PFC switches share the input investor, the size and cost of the charger are decreased [5].

This paper successfully investigates three types of buck converters: switched capacitor QZSC (SC-QZSC), QZS buck converter, and classical buck converter. Three DC-DC converters have had their load voltage ripple, load current waveform, and inductor current ripple computed for analysis and comparison. The findings suggest that, in comparison to the other two topologies, the suggested SC-QZSC has less ripple content in both the output and the inductor [7].

3 Proposed Topology

Figure 1 illustrates how the Cuk converter feeds the HB-LLC resonant converter. The front-end cock converter receives the AC input from the EVBC and uses the constant inductor mode (CICM) to maintain the sinusoidal input AC current while maintaining a regulated DC link voltage of Vd.

To isolate the low voltage Vo for the EVBC, the half bridge (HB) LLC builds the resonant converter second stage and disconnects the high voltage DC link Vb. Through the use of a two-loop structure and PWM control of the Cuk converter, the harmonic free input current is obtained. The internal current control loop is created by the input inductor current feedback, whereas the external loop is created by the DC link control.

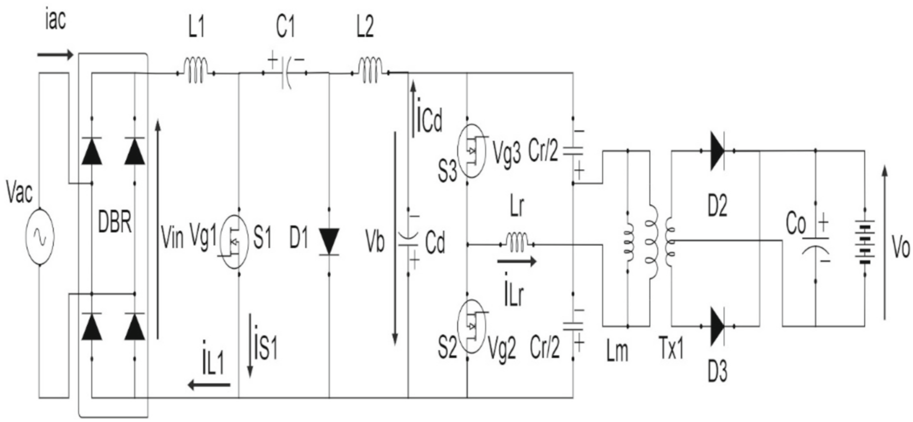


Fig. 1. Configuration of Cuk converter fed HB-LLC Resonant converter

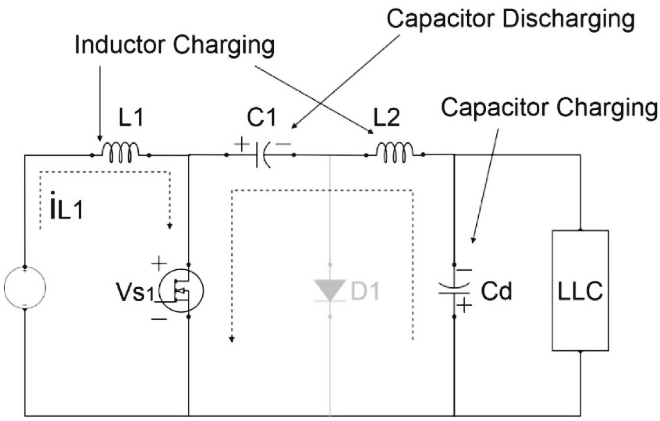
3.1 Operation

Mode 1: Fig. 2 displays the cuk converter's operating modes. The input inductor stores energy during the switch S1 on period, and capacitor C1 releases its energy through S1 to the DC link capacitor Cd. In both inductors, the current grows linearly.

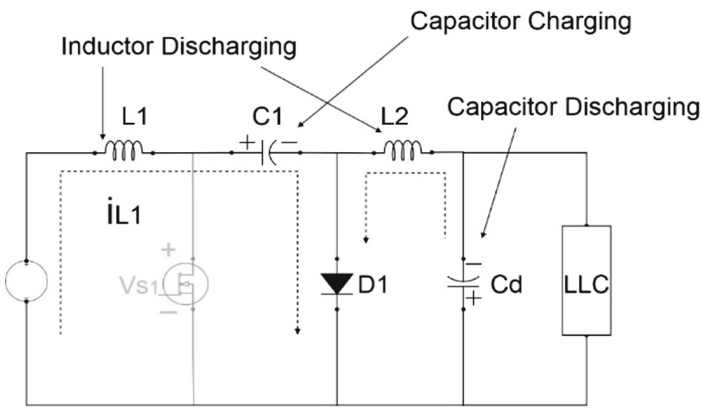
Mode 2: During the off period, both inductors discharge their energy through the Cd to the load, while C1 charges through the source voltage Vs.

Mode 3 and Mode 4: Fig. 3 illustrates the HB-LLC resonant converter's operating modes. The switching frequency of the LLC converter can be set to operate at, below, or above the resonant frequency. The maximum value of the magnetizing current is reached at the conclusion of each half-cycle of switching. When the power switch S3 flips off at the resonant frequency, the resonant circuit current decreases to this maximum magnetizing current and the power transfer to the output side is terminated. Following a dead-time delay, the converter reaches the primary ZVS condition and the power switch S2 activates with the same current.

The power transfer to the output side is halted when the converter operates below the resonant frequency, but the magnetizing current continues. This is because the resonant circuit current drops to the magnetizing current prior to the end of the power switch gate signal. ZVS is therefore still obtainable. Power switch conduction losses are decreased when the circulating current in the resonant circuit is smaller above the resonant frequency. Diodes on the secondary side commutate softly at and below the resonant frequency.



(a) Mode 1



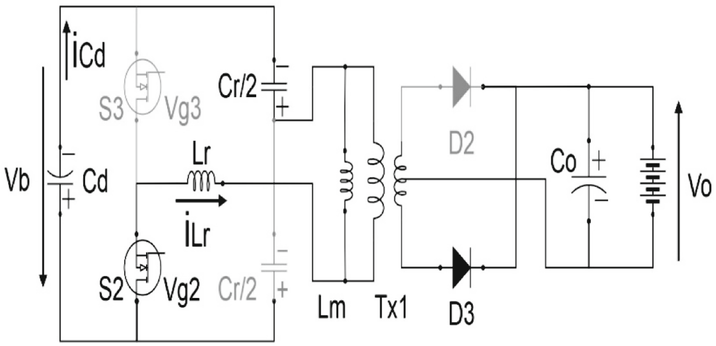
(b) Mode 2

Fig. 2. Operating modes of cuk converter

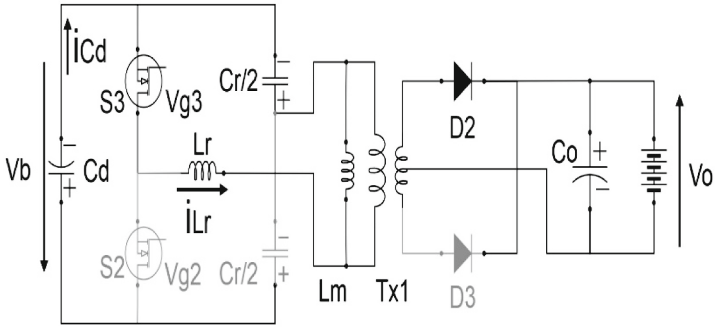
4 Simulation and Results

4.1 Simulation of Open Loop Cuk Converter

See (Fig. 4).



(c) Mode 3



(d) Mode 4

Fig. 3. Operating Modes of HB-LLC Resonant converter

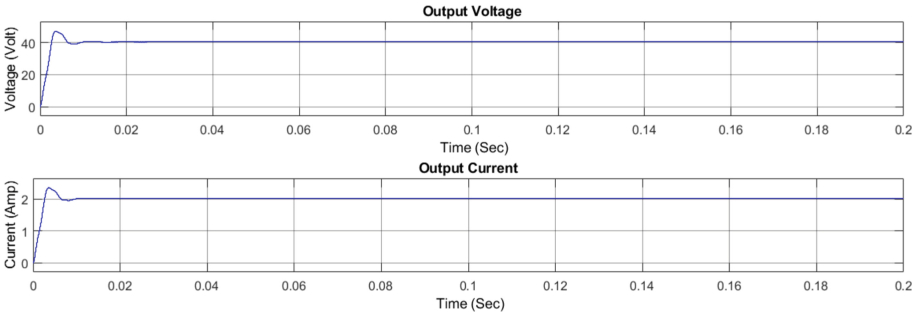


Fig. 4. Simulation results of open loop cuk converter output waveforms

4.2 Simulation of Closed Loop Cuk Converter

See Fig. 5.

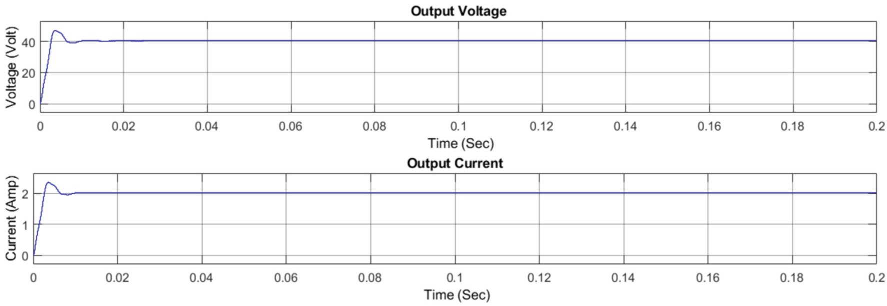


Fig. 5. Simulation results of closed loop cuk converter

4.3 Simulation of Cuk Converter Fed HB-LLC Resonant Converter with R Load in Open Loop

See Figs. 6 and 7.

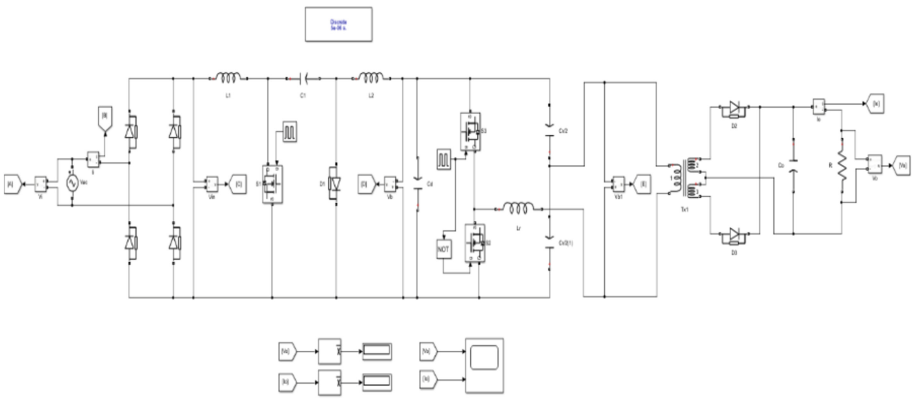


Fig. 6. Simulation of Cuk Converter Fed HB-LLC Resonant Converter with R Load in Open Loop

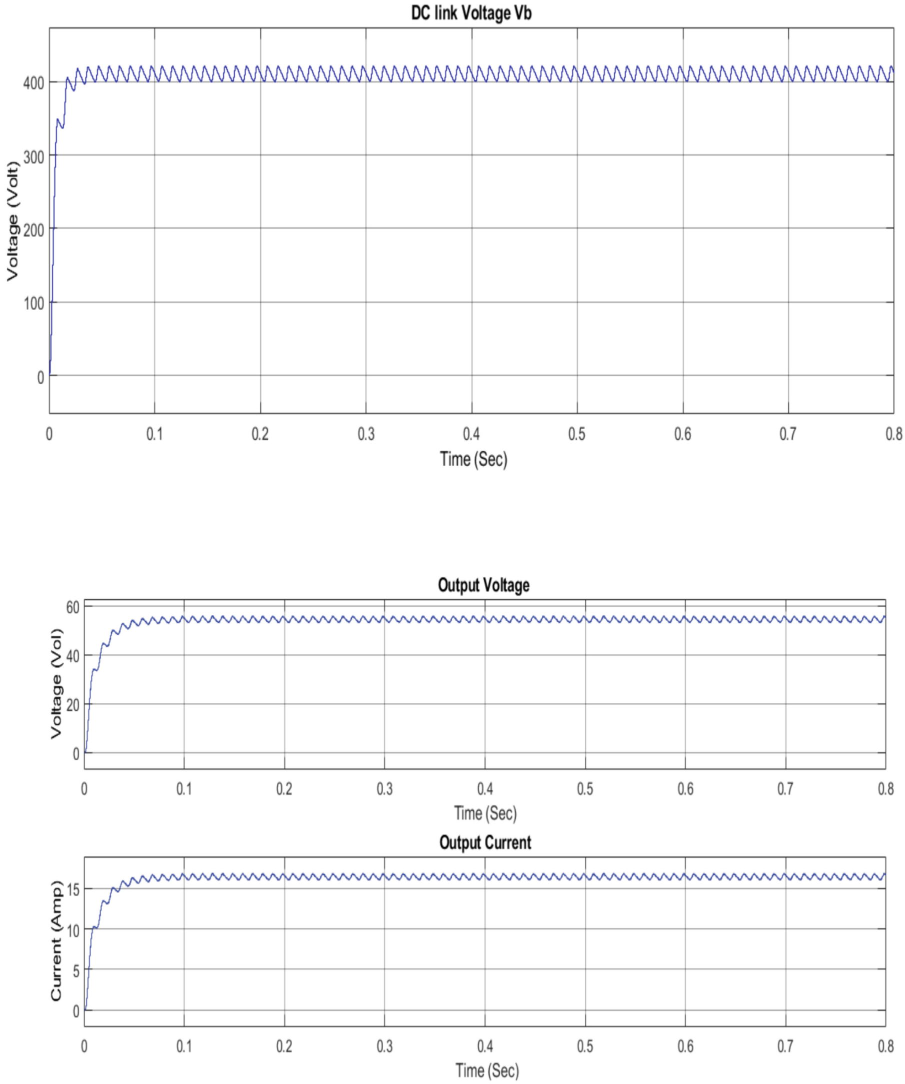


Fig. 7. Simulation result of Simulation of Cuk Converter Fed HB-LLC Resonant Converter with R Load in Open Loop

4.4 Simulation of Cuk Converter Fed HB-LLC Resonant Converter with R Load in Open Loop

See Figs. 8 and 9.

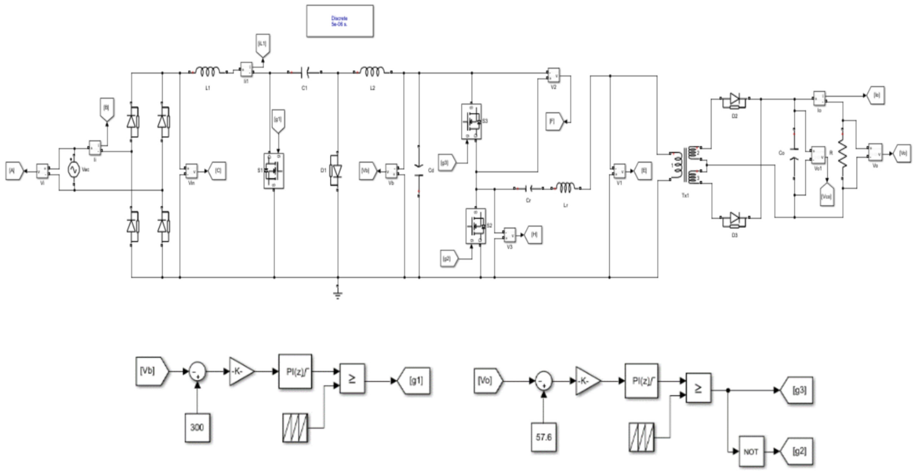


Fig. 8. Simulation of Cuk Converter Fed HB-LLC Resonant Converter with R Load in closed Loop

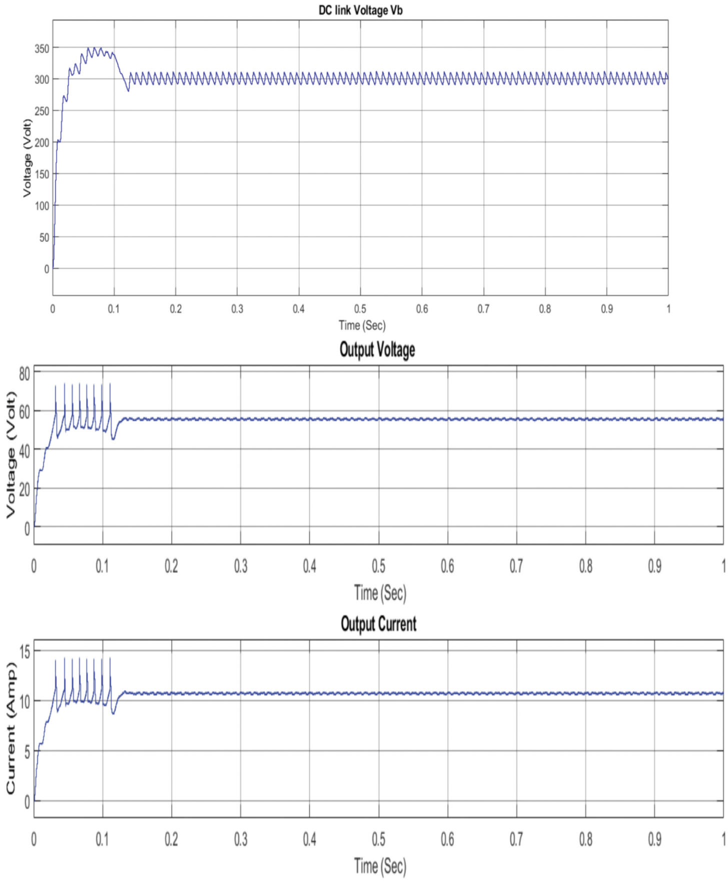


Fig. 9. Simulation results of Cuk Converter Fed HB-LLC Resonant Converter with R Load in closed Loop

5 Conclusion

For use with an electric vehicle battery charger (EVBC), a Cuk converter fed HB-LLC resonant converter has been developed. Results have been presented along with simulations of its performance and analysis. Through simulation, the suggested topology has been thoroughly examined in a steady state. There is minimal output voltage ripple as well. For battery charging applications, it is noted that the converter maintains a strictly regulated output voltage and exhibits good steady state response characteristics.

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