RESEARCH ARTICLE

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Design and Simulation of PFC based CUK Converter for Electric Vehicles Battery Charger

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ABSTRACT

This paper describes a battery charger for plugin electric vehicles based on power factor conversion and CUK converter in the design of electric vehicles.. The integrated battery charger is supplied from the conventional three-phase inverter for electric vehicle, which is a power factor-correcting buck boost converter. The PFC controller changes battery voltage and monitors the converter's power supply to achieve a fast and high output unit power factor. The proposed power factor controlling which is alternative to the relationship between the input voltage rectified and the battery voltage. Simulation has been used to assess the practicality and efficiency of the battery charger of the proposed converter topology.

Keywords: CUK Converter, Electric Vehicle Batter Charger, PFC, PI Control.

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INTRODUCTION

A very alarming rate of depletion of fossil fuels occurs as a result of their constant use in energy production, vehicles, factories, etc. About time for these outlets to disappear. So, the origins of electric cars have gained a new level of attention. A new generation of batteries for electric cars is on its way to meeting future energy demands without the need for gasoline or diesel. Lithium-ion, lead acid, nickel zinc and other types of battery chargers are available for electric vehicles. In addition to being plentiful, these electric car outlets have a significant impact on our climate. This is another important reason why so many countries are switching from fossil fuels to electric car technology.

The new technologies used today to move the transport worldwide to a greener and more affordable way is a battery-powered electric car. For these cars, large battery packs are used with final energy power, usually recharged by a battery charger based on the AC-DC converter. These chargers are essentially built from a DBR-Diode Bridge Rectifier (CC-DC) converter to communicate the charge signals in constant tension, constant current or constant continuous voltage (CC/CV) mode to the battery packs to send the power DC on the load side.

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The current input quality profile and the harmonic range are required to ensure optimum energy consumption and long life of the battery when transmitting these recharging signals. Since DBR has a negative effect on the input power profile due to its non-linear nature, it also uses a PFC based independent DC-DC transformer. A PFC converter high-frequency separation is useful in order to optimise charging properties by blocking harmonics or unwanted signals from penetrating the battery. Conventional EV-battery chargers are based on conventional AC-DC converters and have inherent harmonical injection inconveniences, voltage distortion and very low PF current (0.8-0.85). A number of AC-DC converters, with or without high frequency isolation, are also defined in the literature to increase the real power utilisation of charging circuits.

Like conventional CUK Convertor diode bridge rectifier, Bridgeless SEPIC, Bridgeless Zeta Converter, etc., many forms of converters in charge. In the charging system, the Bridgeless Cuk Converter is used to overcome the disadvantages of these converter. This paper designs and advances the proposed improved bridge-free, high power and enhanced performance Cuk Converter-based EV battery charger. It offers a low cost and high capacity EV-based recharge solution. This loader incorporates less components, avoids the input and output of rip-offs, switch voltage and current voltage, body diodes and noise conductivity. This increases performance. The additional benefit of the topology proposed is that unwanted capacitive connection is eliminated and unwanted conduction through the inactive switch diode is stopped.

Literature Review

A level 2 charger incorporating PFC converter with a bridge-free boost and an isolated full-pitch transient step transducer, and isolated DC-DC transducer with total bridge change is provided in [1]. Power switches are used to achieve high density and high performance silicon carbide. At a frequency of 200 kHz, maximum efficiencies of 95%, and minimum THD 4.2% are reached.[2] Smart homes and smart grids are the most common modes of power distribution between electric vehicles and the grid. In the literature, there are two more modes, grid to vehicle and home to vehicle, which are described in detail. You should run your car at home. With a charger that runs from a home to an automobile, the charging current is adjusted based on household power usage and in-house appliances, allowing for more efficient charging. Vehicle to grid is intended to compensate in-house reactivity through the use of the vehicle charger.

In [3], the electric scooter is designed with an on-board battery charger. A plumbing battery of 180 V, 12 Ah and 110 V, 60 Hz, single phase outlet, can be charged. The adapter also has the ability to charge batteries. The DC-DC low voltage converter idea is suggested. A DC-DC adapter is suggested for charging a 12-V auxiliary battery from the 180-V battery.

For the entire ZVS range, as well as a synchronous resonant DC-DC transformer operating in DCM, the appropriate dead time and reverse current specifications can be determined in [4]. Without emulation or experimental verification, parameters can be collected from component datasheets without emulation or experimental verification. DC motors can be powered by a variety of PFC topologies, including Diode Bridge, Buck, Buck-Boost and SEPIC at the initial stage..

Simulating and analysing various topologies is required in [5]. PFC topologies based on diode bridge rectifiers are the better option for low power applications, according to a this study. When the DC voltage output is greater than the desired input, boosting the PFC topology can help. Buck-based PFC topologies are acceptable if the DC output voltage is less than RMS. It is important to know the AC voltage of the source.

The experimental validation of the proposal concept is performed with 100 W of power with a 90 V supply. The design of a Buck converter with continuous on-time control is recommended in[6]. With maximum voltage and universal service, the effectiveness is measured as 0,96. The key drawback of the Buck style PFC converter, which requires a large philtre at the input, is the discontinous input present.

In[7], The engineered converter has an advantage of less power strain on switches and decreased conduction loss in switches and inducers with smaller dimensions. In addition, the switch provides an extra two-switch boosted buck boost topology. The universal line voltage input with low THD achieves an efficiency of 93 percent.

Proposed Work

From the last section we have seen the change in output voltage due to changes in input voltage, low power factor and larger input Total Harmonic Distortion as both the normal diode bridge rectifier and the open band corrector. The method used here is controlled by the average current. The output voltage is regulated by changing the actual amplitude signal and its mean value in average current control mode. The voltage at the terminal is regulated by the operation of the output voltage controller, and the input side current is controlled by the input side error compensator. The input voltage variation is controlled by the voltage transmission compensator so that the output of the voltage transmitter is increased and vice versa if the input voltage is lowered [8].

PWM signals are produced by comparing the output of the proportional integral device to the output of the SAW.

Most electronic equipment connected to the grid draws the non-sinusoidal line current discontinuous rather than the smooth wave current. This current includes a range of harmonics that flow through both the power grid and the machinery. A single-phase AC-DC bridge corrective system followed by a broad-condensing system draws a non-sinusoidal peak current discontinuously and therefore the presence of harmonic currents in both the AC-DC rectifier circuit and in the power grid connected to that converter.

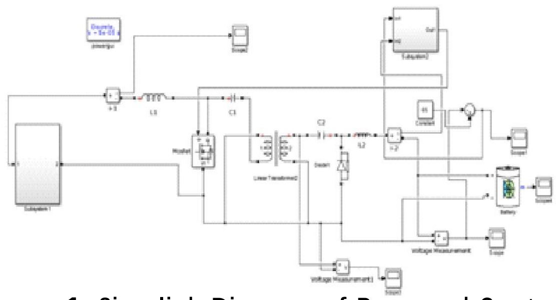

Figure 1: Simulink Diagram of Proposed Control

The traditional approach for PFC controllers with a single phase is an internal loop that controls the current input while an external loop controls the DC-link voltage[9].

In addition to the sensed output current and output of the outer loop, the internal loop reference is multiplied. This problem can be restricted and better executed using the closed loop Cuk controller-based AC-DC converter in Figure 1 [10].

Batteries are usually charged with constant voltage and current. A constant current is applied to the battery until a predetermined voltage level is reached.It then switches to a constant voltage mode in which the battery current is gradually reduced along with its state of charge. An isolated CUK converter is shown in figure 2, and the voltage waveforms on both sides of a high frequency transformer are shown in figure 3.

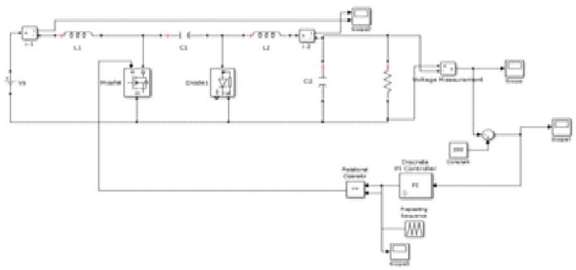

Figure 2: Isolated Cuk Converter

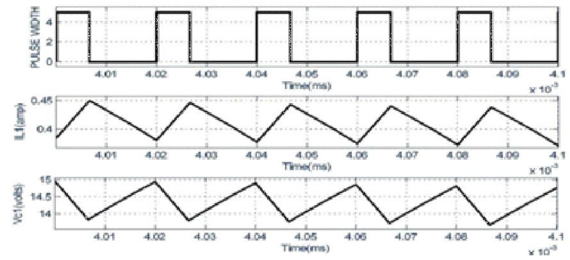

Figure 3: Waveforms of open loop CUK converter

Simulation Results

The proposed Single phase CUK converter shown in Figure 2. The control technique used here changes the charging of the battery in constant voltage mode in which state of charging is maximized. As the battery is fully charged at the end of this mode, the source current also decreases. Because very little current is coming from the source, only the voltage loop is active in this mode. In this mode of charging, a power factor converter is not possible. Voltage and current of the battery are sensed independently to enforce the control system. They are compared with the reference values and given to the two PI controllers as described in the control sections [11-15].

PWM switching system, the output of the present PI corresponds to a saw tooth carrier wave in the switching block of the PWM switch. The high frequency switch is driven by the pulses acquired at the output of the pulse width block. With this technique, the output voltage has fewer harmonics and a more uniform switching method.

Therefore, the duty ratio for this converter is controlled by two PI controllers, which produce a sinusoidal input current with a low total harmonic distortion value, and provide enhanced battery features in two different types of batteries. Controlling DC-DC converters with PI is one of the standard methods. Previously for pulse control and system performance improvement, a proportional (P) controller is used. It is impossible to stabilise a process of higher order. A proportional integral controller is obtained by combining proportional and integral control strategies. The PI controller's output is equal to the sum of the proportional and integral error signals. This controller can eliminate forced oscillations and stable state errors by using a proportional integral.

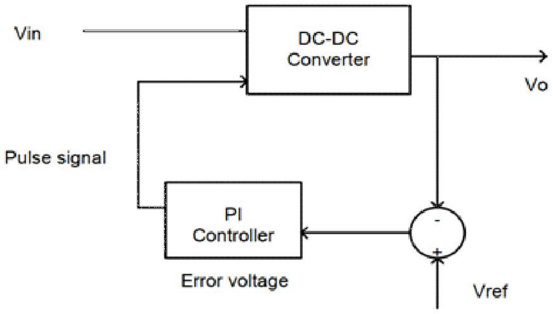

Figure 4: PI Controller General Representation

The simulation parameters are shown in given table I.

Table I: Simulation Parameters

PARAMETRS	RATING
Transformer voltage V1	220V
Transformer voltage V2	220V
Inductor L1 and L2	6 mH 4 Mh
Switching Frequency	25 kHz
Transformer Turns Ratio	1:1
Capacitor C1 and C2	0.88uF, 15uF
Battery Rating	100 Ah, 60V
DC Link Capacitor	4.7mH
Filter inductor	3 mH

Case 1: Working of CUK Converter in Open Loop

Supply Voltage Vi = 270V, Capacitance C1 = 0.66 uF , C2 = 2200uF , L1 = 2.5 mH , L2 = 4.3 mH , R = 114.2ohm, Constant Voltage = 200V and KP =0.01, KI =1. The input voltage of 270V has been taken, the output voltage is (compared with the reference voltage of 200V and the error is given to the PI controller, the output of the PI controller is used to provide switching to the CUK converter. The simulation result shows that the output voltage is tracked in a correct way.

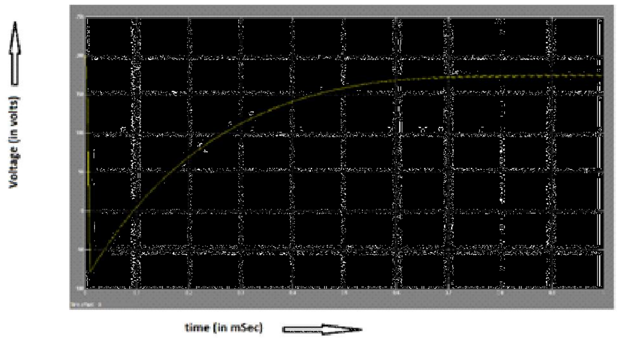

Figure 5: Cuk converter output voltage

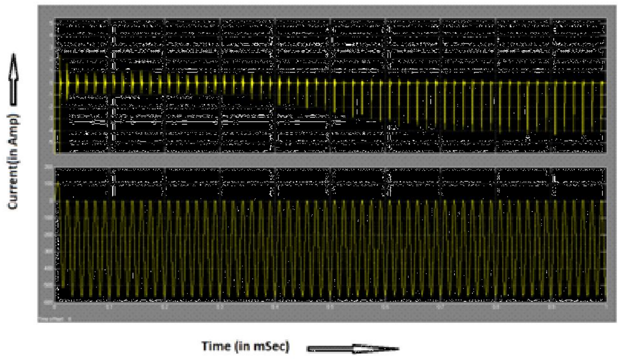

Figure 6: Output of input Inductor and Output inductor current

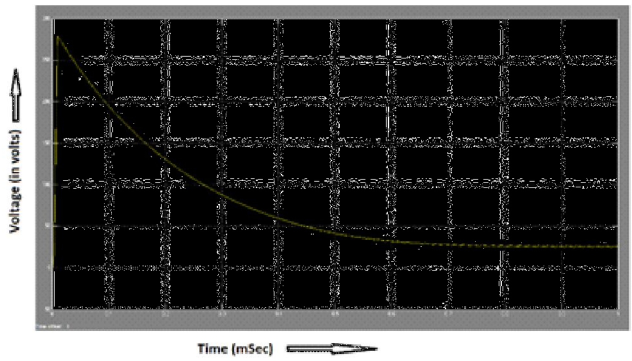

Figure 7: show the control voltage of the Cuk converter is compared with the reference voltage of 200V and error is given PI controller.

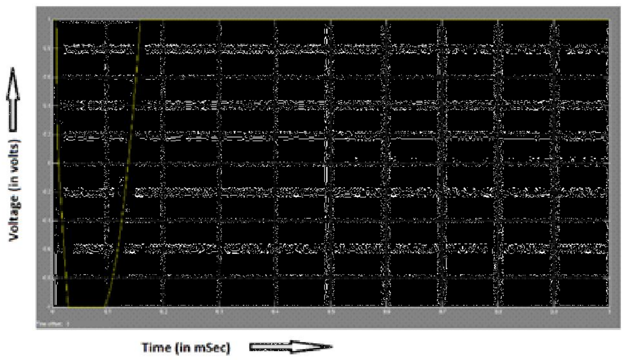

Figure 8: Output Voltage of PI Controller using CUK Converter

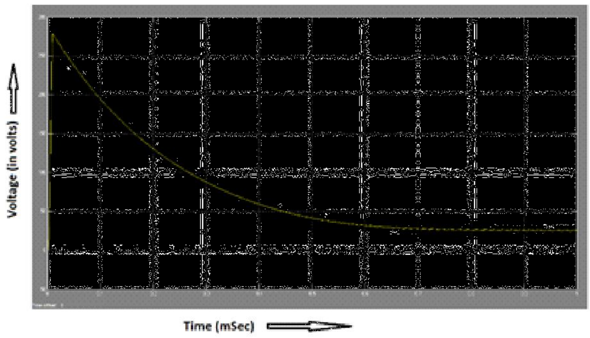

Figure 9: CUK Converter Control Voltage

Using a PI controller, the output voltage of the CUK converter is shown and compared to the output current of the sawtooth wave in Figure 8. The converter output voltage is determined by its performance.

Case 2: Working of CUK Converter in Closed Loop

Figure to Figure 12 shows the simulation results for this project. As a result, we have plotted the input rectified voltage, output voltage and an Fast Fourier Transform analysis of the input current.

This is done by comparing the CUK converter's output voltages with the reference voltage, giving an error to the PI converter's output, comparing the CUK converter's output current to the PI controller's output, comparing the PI controller's output to the PI form, and using that form's output to switch to the CUK converter.

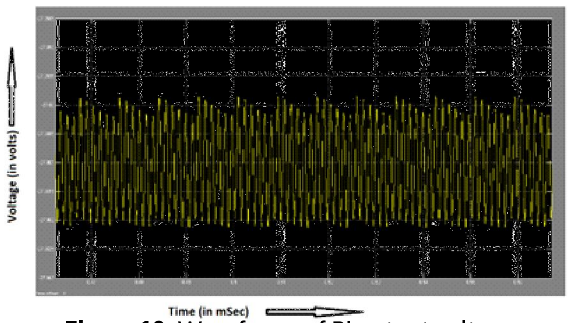

Figure 10: Waveforms of PI output voltage

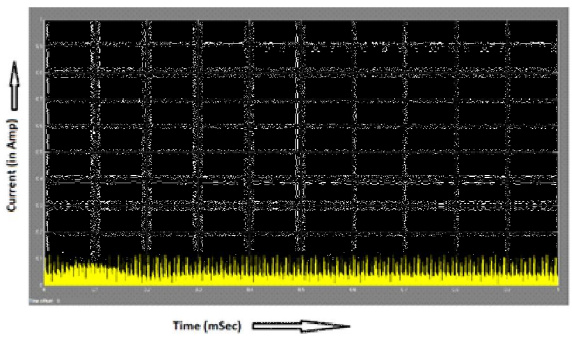

Figure 11: Output of input inductor current

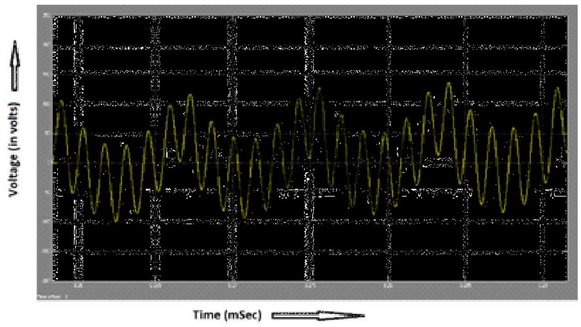

Figure 12: Waveforms of constant voltage at the output terminal

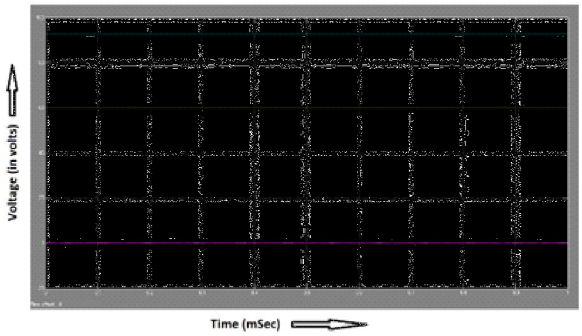

Figure 13: Battery Voltage Characterstics

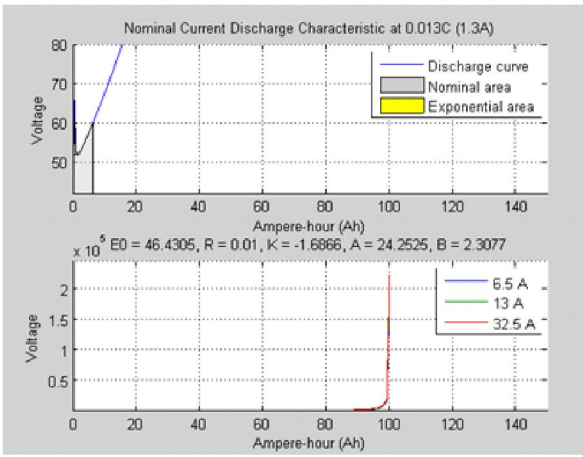

Figure 14: Battery Discharge Characteristics

A power factor of 1 is achieved when the source voltage and the source current are both in phase.

Conclusion

This paper proposes the unitary power factor CUK converter with the support of a CC-CV mode battery charger for isolation of high frequency transformers. The modelling, analysis and simulation of the battery charger for the electric vehicle based on an isolated CUK converter was done. The major advantage of the PI double-loop controller is a smooth and better power supply. For the loading conditions of the standalone system the proposed converter operates at an efficiency of approx. 93%. There is also low ripple current input and output side of the inducers.

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