High Efficiency Bridgeless Single-Power-Conversion Battery Charger for Light Electric Vehicle

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***Abstract* - This paper explains the charging batteries of light electric vehicles require chargers with high efficiency and a high-power factor. To meet this need, this paper presents a bridgeless single-power-conversion battery charger composed of an isolated step-up AC-DC converter with a series resonance circuit. The bridgeless configuration reduces the conduction losses associated with the input diode rectifier, and the series-resonance circuit reduces the reverse recovery losses of the output diodes by providing zero current switching. In addition, direct and series-resonance current injection enables bidirectional core excitation by the transformer, thereby allowing high power capability. The control algorithm derived from feedback linearization is also developed, which allows the proposed charger to correct the power factor and regulate the output power in a single-stage power conversion. This simple circuit structure leads to high efficiency and a high-power factor. The theoretical concepts of the proposed charger are verified experimentally using a 1.7 kW prototype.**

***Index Terms* - Full-bridge converters, input current shaping, low-distortion input current, single-stage power factor correctors (PFCs).**

INTRODUCTION

Recent years, there has been increasing interest in various eco-friendly vehicles such as electric vehicles (EVs) and plug-in hybrid EVs, which have a significant potential to reduce environmental pollution. EVs are entirely powered by propulsion batteries charged from the grid through an on-board charger, which makes such chargers a very important part of an EV. The performance of the charger is evaluated by its power-conversion efficiency and power quality (i.e., total harmonic distortion and power factor). In addition, because the charger is installed in the EV, it must be small, lightweight, and have a long lifetime. Conventional on-board chargers for EVs are based on isolated AC-DC converters with a two-stage structure consisting of a power-factor-correction (PFC) stage and a DC-DC power-conversion stage. The PFC stage, which is usually a boost converter, converts input AC voltage to DC-link voltage with a unity power factor, whereas the DC-DC power-conversion stage, which is usually an isolated high-frequency DC-DC converter, regulates the output power and provides galvanic isolation for user safety. This structure has advantages such as accepting wide input voltage, providing a high-power factor and well-regulated output power. However, the two-stage structure also has many disadvantages, such as low efficiency and circuit complexity because of its two power-processing stages. Another major drawback is a bulky intermediate dc-link capacitor that filters power fluctuations. The high current flowing through the intermediate dc-link capacitor also causes significant power loss and considerably reduces the capacitor lifetime, leading to capacitor failure.

To eliminate the PFC stage and reduce the dc-link capacitance, single-stage approach is being investigated to replace the two-stage structures. In single-stage converters with a DC-link capacitor, the PFC stage and the DC-DC stage are merged by sharing the switches. However, because the DC-link voltage is not controlled in this scheme, it can be more than twice the grid voltage, leading to requirement of high voltage rating switches which causes high switching and conduction losses. In addition, because PFC is achieved based on the operation principle of the circuit without an additional PFC controller, the power factor is affected by changes in the grid voltage or load condition. To achieve a high-power factor without a PFC stage and a DC-link capacitor, single-stage resonance converters with inherent PFC and current-fed full-bridge converters have been introduced. These converters do not require a DC-link capacitor, thereby eliminating the associated problems. Also, almost unity power factor can be achieved using the appropriate PFC-control techniques. However, these single stage converters contain many components and an input bridge diode that not only causes high conduction losses but also requires additional heat management. To overcome these drawbacks, single-stage bridgeless topologies based on two-stage boost-fly back converter and half-bridge PFC converter have been investigated. However, such converters are suitable only for low-power applications because the applied topologies normally imply high electrical stresses. Because of these reasons, the isolated bridgeless type converters for high power capability (>1 kW) have rarely been studied. To address this situation, this paper proposes herein high efficiency bridgeless single-power-conversion battery charger shows the circuit configuration of the proposed charger, which consists of an isolated bridgeless step-up ACDC converter with a control algorithm for PFC control and to regulate the power output.

The bridgeless configuration reduces conduction losses and heat-management problems related to the bridge diode. The series-resonance circuit of the secondary side provides bidirectional core excitation, which enables high power capacity and zero-current switching (ZCS), thereby reducing the reverse-recovery problem of the output diodes. In addition, because the input energy is directly distributed to the output energy without an energy buffer, efficiency is improved. To achieve a high-power factor without additional PFC circuit, we develop a control algorithm derived from feedback linearization. This control algorithm enables the proposed charger to correct the power factor and regulate the output power through single-power-conversion. Therefore, the proposed charger is suitable as an on-board charger for EVs requiring high charging efficiency and high-quality power. The remainder of this paper is organized as follows: Section II discusses the operating principle and characteristics of the proposed charger, and Section III proposes control algorithm for single-power-conversion. Section IV presents the results of experiments conducted using a 1.7 kW prototype, which is used to verify the performance of the proposed charger. Finally, Section V concludes this paper.

For the conversion of AC- DC conversion usage of electrical vehicles we attain a higher efficiency. That AC-DC conversion consists of AC- source, rectifier circuit. The rectifier circuit consists of two diodes which is responsible for AC-DC voltage conversion. There will be an inverter circuit is present. This is responsible for DC-AC conversion. That inverter circuit will consist of two switches which means MOSFET switches. For that switching device we will give pulse for that, based on the pulse the DC voltage conversion is achieved. By using the transformers, we will increase the voltage level, which means step-up transformers is used. On the transformer side again, we connect the rectifier circuits for the AC-DC voltage conversion. There will be a filter circuit is used. That filter circuit will consist of LC- filter which is used for the pulsating output voltage into clear voltage which means DC- voltage. This is the long conversion method to get the higher DC voltage.

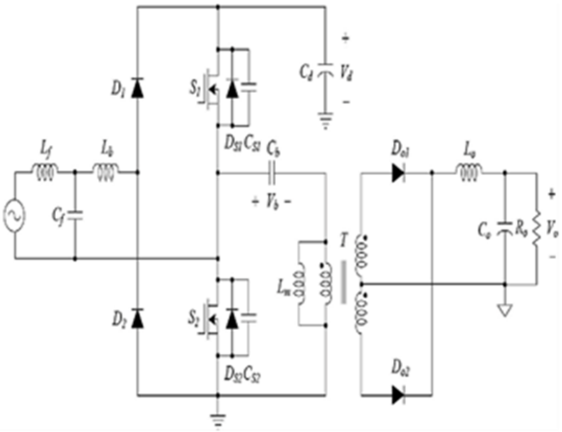


Fig 1. Power circuit diagram

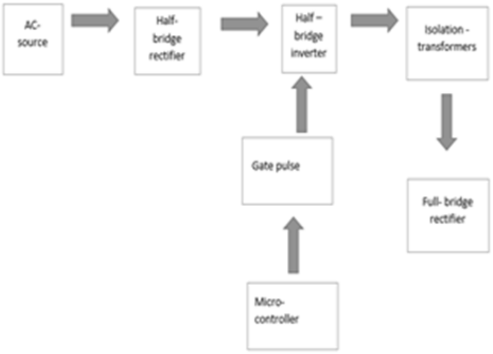


FIG. 2. BLOCK DIAGRAM

Modes of operation

In the AC-DC converter the modes of operation will be classified into two types namely. One is positive half cycle and negative half cycle. Come to the positive half cycle there will be 6 modes of operation in the AC-DC converter.

MODE-1(for positive half cycle)

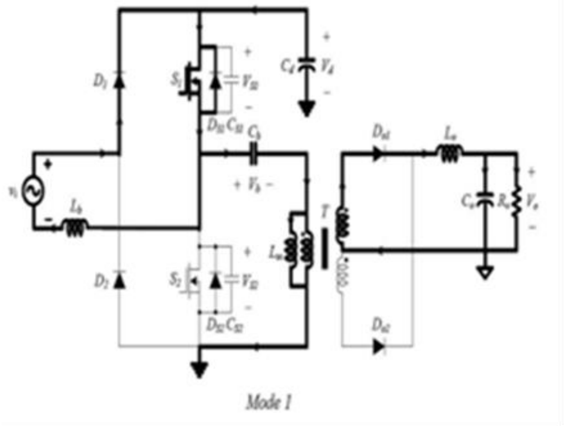


Fig .3. Circuit Diagram for Positive Half Cycle

The operation modes during Ts for a positive half line period S1 is controlled with the duty ratio D. The conduction times of S1 and S2 are DTs and (1 − D) Ts, respectively. When S1 is turned ON, the input current ii flows through Lb, D1, and S1. When S1 is turned OFF, the input current ii flows through Lb, D1, Cd, S2, and DS 2

MODE-2 (positive half cycle)

In the mode-2 positive half cycle Mode 2 [t1 , t2]: At t = t1 , S1 is turned OFF. The primary current ip charges CS 1 and discharges CS 2 . The voltage VS 2 across S2 decreases from Vd to zero, while the voltage VS 1 across S1 increases from zero to Vd . The magnetizing current iLm and boost inductor current iLb are considered constant because the time interval during this mode is negligible compared to Ts . As long as the switch S2 is turned ON before the magnetizing current iLm changes its direction, ZVS of S2 can be assured. At the secondary side, the output filter inductor current iLo freewheels through both output diodes Do 1 and Do 2 . The output diode current iDo 1 decreases while the output diode current iDo 2 increases.

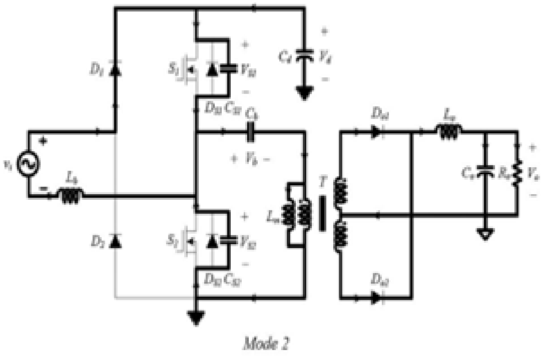
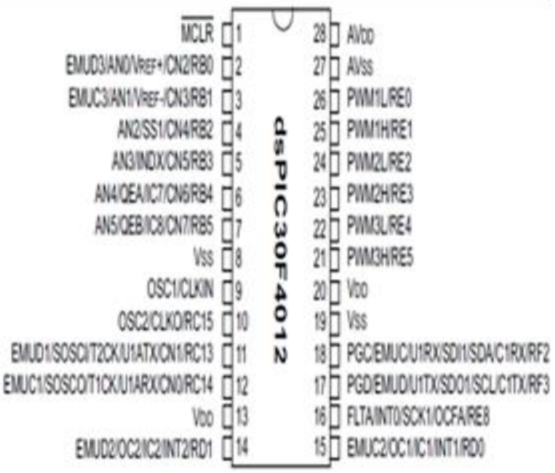


Fig .4. Circuit Diagram for Negative Half Cycle

Pin diagram



SIMULATION RESULTS

The proposed input-output converter was preliminary verified in simulation using Mat lab/Simulink. Simulation was planned such that it used the same parameters as the final implemented hardware. The simulation result of rectifier output as shown in Fig.8 and Fig.9.

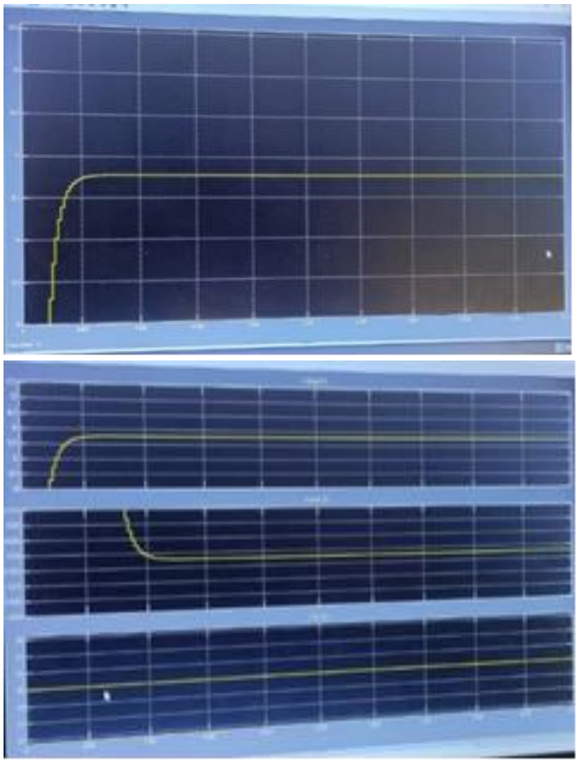


Fig 9.Output waveform

HARDWARE RESULTS

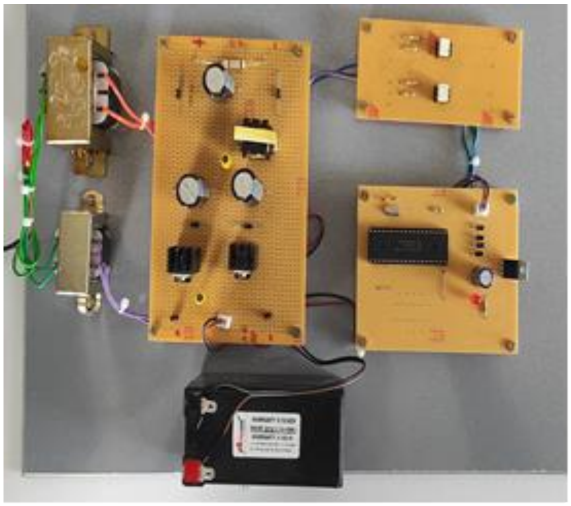


Fig.Hardware Prototype

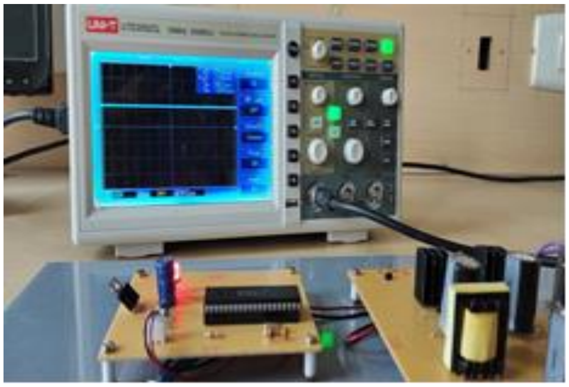


Fig.Hardware Result

CONCLUSION

This paper proposes a high-efficiency bridgeless battery charger for light EVs and analyzes its performance both theoretically and experimentally. Eliminating the input bridge diode reduces the conduction losses, and the use of a series resonance circuit provides ZCS and alleviates the reverse recovery problem for output diodes. Bidirectional core excitation of the transformer leads to a higher power capability than conventional bridgeless converters. Since the proposed charger applies the electrolytic capacitor less scheme with a sinusoidal-like dc current on the batter side, the input ac power is directly transferred to the battery side and the efficiency is improved. In addition, the proposed control algorithm enables the charger to correct the power factor and regulate the output through single-power-conversion. With these advantages, the proposed charger offers high efficiency and high-power quality. The maximum efficiency of 96.2% is achieved from the simple circuit structure and the soft-switching features for the output diodes. Also, the use of the control algorithm gives a power factor of near unity for a universal grid voltage. Therefore, the proposed charger with its control algorithm is an effective solution for EVs, which require high charging efficiency, a high-power factor, and a simple structure.

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