IMPROVED POWER QUALITY TRANSFORMER LESS SINGLE-STAGE BRIDGELESS CONVERTER BASED CHARGER FOR LIGHT ELECTRIC VEHICLES

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ABSTRACT

Light electric vehicles (LEVs) can benefit from this article's presentation of a small, cheap charger with improved supply-side performance. The charger's foundation is a BSIC converter, which stands for bridgeless switched inductor Cuk. Chargers for LEVs typically have an extra converter that allows low-voltage (24-72 V) charging of e-rickshaw, e-bike, and e-cycle batteries. Because of the switching inductor design of the charger, the single-stage step-down dc voltage gain is larger, and the charger is more reliable at these low voltages. Charger operation in discontinuous current mode situation reduces sensor size and cost, which is interesting. The efficiency, compactness, and cost of the charger are all greatly enhanced by its high-gain transformer less design. A prototype model with 220 V nominal supply voltage requirements, 50 Hz, and an 850 W rated current is used to evaluate the charger's performance. We test the charger's dynamic and steady-state characteristics in a variety of environments. You could also check the charger's startup behaviour to make sure it begins charging softly. The proposed charger layout is superior than the existing one, and a brief comparison with existing LEV chargers is provided to illustrate this point.

INDEX TERMS—SIC converters, better power quality, LEV battery chargers, and DCM conduction are all terms related to switched indicator Cuk technology.

1.INTRODUCTION

Since there has been a dramatic increase in the number of automobiles using charging stations, there is great anticipation among power distributors and consumers for charging stations that offer enhanced power quality solutions. Figure 1 shows the typical components of an LEV current charger, which typically include a dc link capacitor (CDC), one particular or non-isolated dc-dc converter, and a rectifier diode bridge (DBR). Input power factor (PF), distortion factor (DF), displacement factor (DIF), and overall system efficiency are all impacted by the depletion of the supply of harmonics-rich distorted current caused by a heavy dc-link capacitor and DBR.

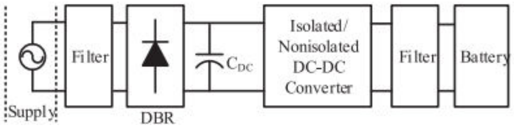


Fig. 1.1 Structure of conventional charger configurations for LEVs.

energy supply [2]. Traditional low power rating chargers suffer from the issues listed above; Active power factor adjustment for single-phase systems techniques aim to fix this. Between DBR and CDC, an APFC approach uses an improved DC-DC converter the power quality of the charger's supply-side performance. An APFC converter's capabilities are defined by the charger's design. A charger can have either one or two stages. An additional dc-dc converter is needed in two-stage configurations, as opposed to the one used in single-stage chargers, which uses a single APFC dc-dc converter for both the supply-side and load-side needs. Research on two-stage charger designs for EV and LEV charging has focused on various APFC methods [3]-[5].

Efficiency[8], control complexity[5], number of devices[6], conduction and switching losses [7], and overall performance are all areas where each technique has its advantages and disadvantages. Several studies have demonstrated that charger efficiency may be improved with the use of bridgeless APFC converters by reducing conduction losses in the APFC stage. Some or all of the DBR is eliminated by these converters [9, 10]. In [11], a thorough analysis of bridgeless APFC converters is provided. Aiming to reduce losses and the number of charger components without sacrificing the advantages of dual-stage chargers, recent concepts for bridgeless integrated charging systems have been put forward [12], [13].

By integrating two dc-dc converters, which share semiconductor components, the number of devices and associated losses may be reduced. Nevertheless, they are not ideal for use in LEVs because to the increased control complexity and device strains. Most notably, single-phase two-stage chargers do not produce ripple in the charging current. On the other hand, other writers claim that correctly controlled low-frequency ripples in the charging current have no effect on the battery's performance [14], [15].

Several researchers have suggested several designs for single-stage chargers for electric cars and long-range electric vehicles (LEVs), which improve power quality on the supply side and eliminate the limitations of dual-stage power supplies [16], [17]. The charges in a single stage are characterized by a compact design, a reduced number of components, and a high power density [18, 19]. Furthermore, a two-stage charger arrangement isn't always the best option; sometimes, a well-designed single-stage charger might achieve better results. Because of their low output voltage capabilities [21] and the significant supply current distortion that happens at crossing zero, the typical buck converter and normal boost converter are not appropriate to be used to serve as an APFC for one-stage LEV chargers. This is why buck-boost derived converters like Luo dc, Zeta, CSC, Cuk, and SEPIC—dc converters may solve most applications' issues that arise from using buck and boost derived converters.

Out of all the buck-boost the Cuk dc-dc converter, and other dc-dc appliances has the best ripple characteristics of input and output currents [22]. Unfortunately, because to their low gain capabilities, standard Direct current to direct current converters that use a buck-boost design aren't the best choice for offering a transformer-free single-stage charging alternative for LEVs. The efficiency and the charger's dynamic performance degrade over time due to the low voltage of LEV batteries and the transformer less charger architecture working at a low duty ratio [23]. Because of this, a transformer is required to provide the required dc voltage rise in the bulk of one-stage LEV chargers that employ traditional dc-dc converters. Meanwhile, the charger becomes more cumbersome and costly due to the addition of the transformer. The devices are also subjected to increased voltage stress due to the transformer's leakage inductance [24]. This led researchers to focus on developing a transformer less charger for electric vehicles that only requires one step [25]. However, academics seldom discuss the best practices for installing transformer less chargers for LEVs so that the power quality is maximized. In recent times, there have been endeavours to enhance the voltage gain capabilities of traditional dc-dc converters. This class includes uses for linked inductors, multiplier circuits, quadratic converters, cascade converters, interleaved front end structures, switched inductors, and hybrid switched inductor-capacitor architectures [26].

Connected inductors allow the coupling coefficient to significantly impact the converter's operational characteristics, as opposed to the cascade and multiplier technique, which results in additional components, more costs, decreased efficiency, and more intricate circuitry. Compared to the cascaded converter, the quadratic converter is more efficient, but it increases strains caused by voltage and current [27]. In response to these concerns, a switching dual network was suggested in [28] that makes use of split inductors or capacitors together with two or three diodes. Traditional converters' dc gain may be adjusted with networks with switched capacitors and switched inductors by charging and discharging inductors and capacitors in series and parallel, respectively. A converts SI to Cuk PFC, suggested for usage as a charger for LEVs in reference [29]. However, because to its intricate control system and bigger magnetic components, this charger is rather expensive according to CCM; thing to do. The DBR on the front side of the charger also increases the number of components and the conduction losses. A charger with improved power quality built on a single-stage BSIC PFC converter is introduced in this work. Here are the main points that this article brings up.

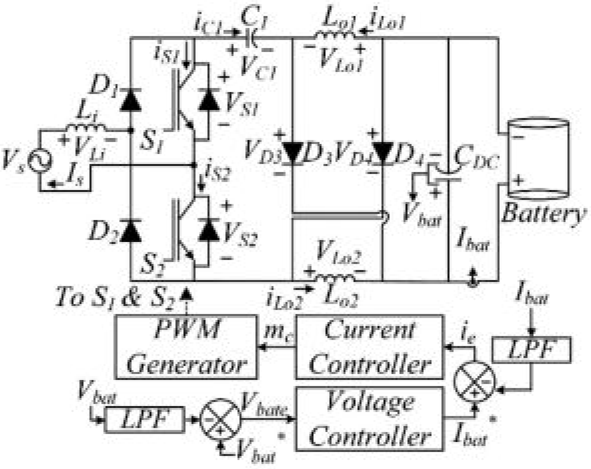


Fig. 1.2. BSIC PFC converter-based transformer less charger configuration.

1) This charger provides a one-stage charging solution for LEVs, doing away with the requirement for as a switch or connected minimization of component

counts in inductors.2) By minimizing the amount of magnetic components and associated losses and the necessity for sensors, the BSIC converter is developed and controlled under the DCM condition. Also, the DCM operation gets rid of the PLL system, which makes the control implementation step much easier.
3. The charger's conduction losses and total device count are reduced by virtue of the front side's bridgeless architecture.

4. We also use both constant-current and constant-voltage charging modes to test and validate power source's enhanced power quality performance across a wide range of source voltages.
5) A comparison is made between the supplied charger configuration and a typical Cuk PFC converter [4] and a SI Cuk PFC converter [29] based on many factors, such as the amount of components, control complexity, cost, size, and supply-side performances.

2.CIRCUIT SPECIFICATIONS

2.1 AC-DC CONVERTER:

A rectifier is an electrical device that converts alternating current (AC), which runs in both directions at random intervals, to direct current (DC), which travels in just one direction, a process known as rectification. Rectifiers have several applications and are employed in sources of energy and for the reception of radio transmissions, among others. Rectifiers contain a variety of parts, such as diodes for vacuum tubes, valves for mercury arcs, and diodes for solid state devices. In contrast, an inverter may accomplish the exact opposite by changing the voltage from DC to AC.

The only real difference between a diode and a rectifier is their practical use; in this context, a single rectifier The diode works by reversing alternating current (AC) by blocking its positive or negative waveform component, resulting in direct current (DC). To improve upon the efficiency of converting AC to DC, most rectifiers employ a series of interconnected diodes rather than a single diode. Before silicon semiconductor rectifiers were invented, vacuum tube diodes and rectifier stacks made of copper(II) oxide and selenium were used.

2.1.1 HALF-WAVE RECTIFIER:

Half wave rectification involves passing one half of an alternating current wave while blocking the other half. Power transfer efficiency is severely lacking since the output is just 50% of the original signal. The process of half-wave rectification can be achieved using either one or 3 diodes connected in a 3 phase circuit, depending on the input voltage.

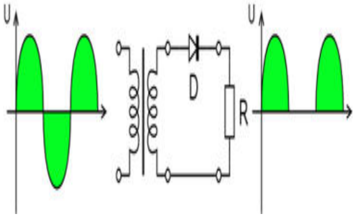


Fig. 1.3A half wave rectifier's

A half wave rectifier's DC output voltage may be calculated using the two following exact equations:

$$V_{rms} = \frac{V_{peak}}{2} V_{dc} = \frac{V_{peak}}{\pi}$$

2.1.2FULL-WAVE RECTIFIER:

A full-wave rectifier completely transforms the input waveform into an output waveform with a fixed positive or negative polarity. Because it converts the bipolar input waveform to direct current (DC), full-wave rectification is superior. For half-wave rectification, a circuit with a transformer with a central tap that is not requires four diodes instead of simply one. A bridge rectifier, or diode bridge, is a configuration of four diodes:

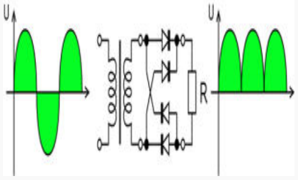


Fig. 1.4 full-wave rectifierfixed positive.

Two diodes, either cathode-to-cathode or anodes-to-anodes, can make a full-wave rectifier in the event that the transformer's center tap for single-phase AC. In order to get producing the identical voltage as the bridge rectifier mentioned before, the secondary windings of the transformer must be doubled.

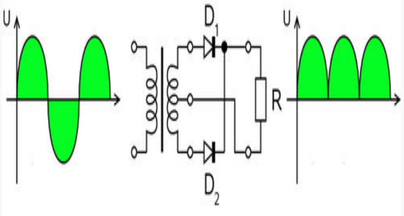


Fig. 1.5full-wave rectifier cathode-to-cathode.

Anodes and cathodes were once housed in a single vacuum tube, with a single tube serving as a diode in a common configuration for vacuum tube rectifiers. As an example of a popular combo, consider the 5U4 and 5Y3.

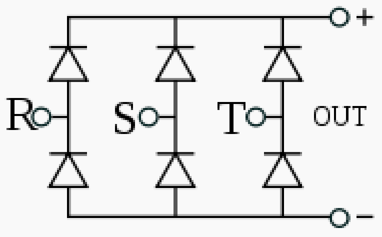


Fig.1.6 A three-phase bridge rectifier.

BUCK CONVERTER STEP-DOWN CONVERTER

A DC-to-DC converter is a piece of equipment that accepts a DC input voltage and produces an output voltage of the same kind. It is common for the input and output voltages to be different. Among the many uses for DC-to-DC converters are noise isolation and management of power buses. The following are descriptions of several typical topologies for DC-to-DC converters.

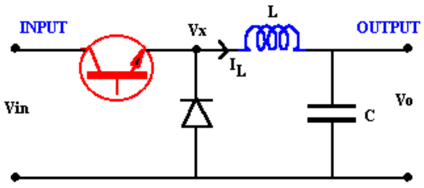
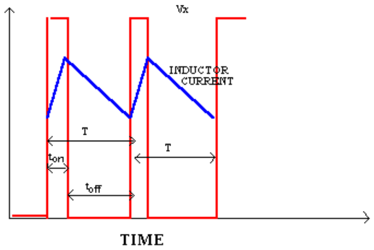


Fig. 1.7 Buck Converter



Voltage and current changes

In order to analyze the voltages in this circuit, let's look at how the inductor current changes during a single cycle. Drawing on the partnership

$$V_x - V_o = L\frac{di}{dt} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

3. RESULTS AND DISCUSSION

Experiments on a Simulation in a controlled environment have validated all aspects of the design, analysis, command, and functionality of the single-stage transformer less improved power quality charger based on BSIC converters. Furthermore, the total control performance is evaluated for both steady state and shifting dynamics when operating under different charging conditions.

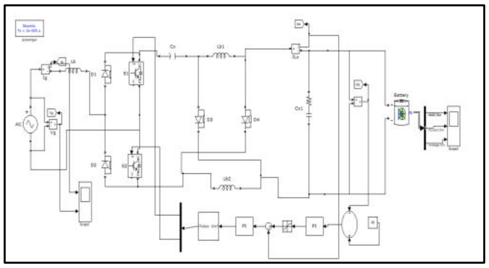


Fig.6.1 Circuit diagram of Transformer Less Single-Stage Bridgeless Converter.

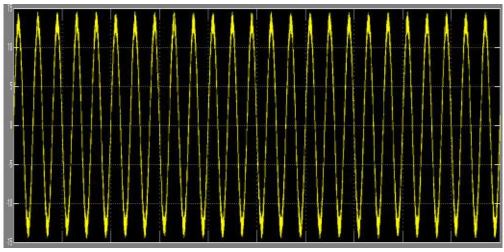


Fig 6.2 Input Voltage waveform.

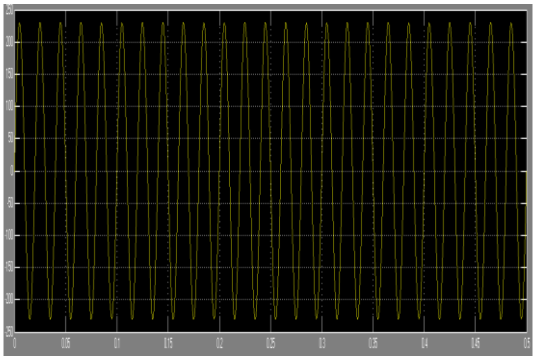


Fig 6.3InputCurrent waveform.

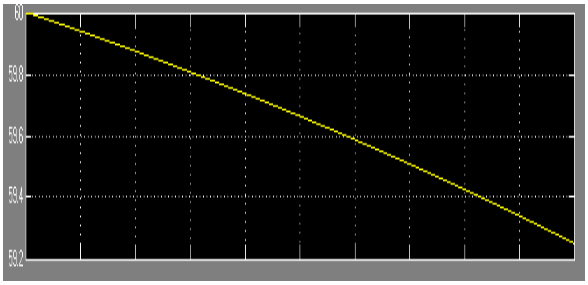


Fig 6.4Battery Output SOC waveform.

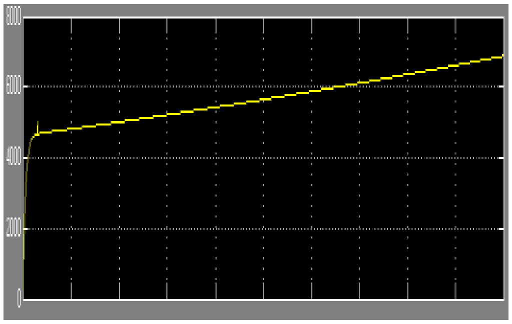


Fig 6.5BatteryOutput Currentwaveform.

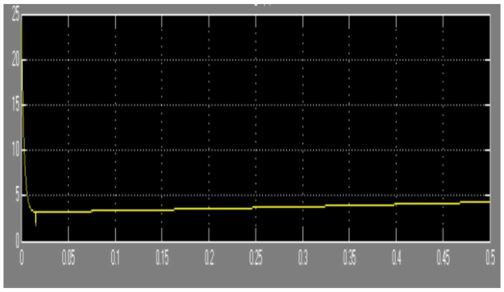
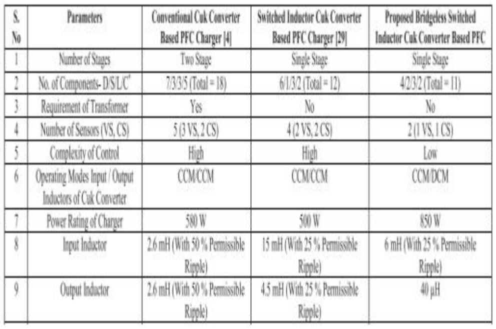


Fig 6.6Battery Output Voltagewaveform.

Table I Comparative Analysis Of Proposed Bsic Pfc Converter With Existing Chargers Configurations



S. No	Parameters	Conventional Cuk Converter Based PFC Charger [4]	Switched Inductor Cuk Converter Based PFC Charger [29]	Proposed Bridgeless Switched Inductor Cuk Converter Based PFC
1	Number of Stages	Two Stage	Single Stage	Single Stage
2	No. of Components- D/S/L/C'	7/3/3/5 (Total = 18)	6/1/3/2 (Total = 12)	4/2/3/2 (Total = 11)
3	Requirement of Transformer	Yes	No	No
4	Number of Sensors (VS, CS)	5 (3 VS, 2 CS)	4 (2 VS, 2 CS)	2 (1 VS, 1 CS)
5	Complexity of Control	High	High	Low
6	Operating Modes Input / Output Inductors of Cuk Converter	CCM/CCM	CCM/CCM	CCM/DCM
7	Power Rating of Charger	580 W	500 W	850 W
8	Input Inductor	2.6 mH (With 50 % Permissible Ripple)	15 mH (With 25 % Permissible Ripple)	6 mH (With 25 % Permissible Ripple)
9	Output Inductor	2.6 mH (With 50 % Permissible Ripple)	4.5 mH (With 25 % Permissible Ripple)	40 μH

4. CONCLUSION

As a single-phase, single-stage transformer less solution for LEVs, this article presents a charger that is based on a bridgeless switched inductor Cuk (BSIC) PFC converter. In comparison to conventional dc-dc converters, this charger offers a higher step-down dc voltage gain, which is good. Consequently, LEV batteries are effectively bypassing the transformer altogether by making use of the bigger step-down voltage gain. By combining the CC and CV modes into one step, we may improve many power quality on the supply side measures, including power factor, distortion factor, and supply current total harmonic distortion (THD). Furthermore, fewer sensing devices with optimal control complexity were considered throughout the charger's control development. All of the charger's components have been carefully considered and designed to work reliably and safely within the charger's and battery's respective voltage specifications. Results from tests conducted at constant and under various dynamics are shown to support the predictions of the theoretical study. Performance testing and verification of the charger has been conducted during line and load regulation. A comparison of the several charger topologies and the BSIC converter-based charger has been made, with a brief explanation and tabular presentation of the results. Finally, it has been proven that the given charger design offers several advantages, such as lower prices, smaller size, better supply-side performance, fewer components, and easier control mechanisms.

5.REFERENCES

[1] NITI Aayog and WEC, "Zero-emission vehicles: Towards a policy framework," NITI Aayog, New Delhi, India, Rep., 2008. [Onlne]. Available: https://niti.gov.in/writereaddata/files/document_publication/ EV_report.pdf

[2] Z. Yang and P. C. Sen, “Recent developments in high power factor switch-mode converters,” in Proc. IEEE Can. Conf. Electron. Comp. Eng., Waterloo, ON, Canada, 1998, vol. 2, pp. 477–480.

[3] H. Wang, S. Dusmez, and A. Khaligh, “A novel approach to design EV battery chargers using SEPIC PFC stage and optimal operating point tracking technique for LLC converter,” in Proc. IEEE App. Power Electron. Conf. Expo., Fort Worth, TX, USA, 2014, pp. 1683–1689.

[4] R. Pandey and B. Singh, “A power-factor-corrected LLC resonant converter for electric vehicle charger using Cuk converter,” IEEE Trans. Indus. Appl., vol. 55, no. 6, pp. 6278–6286, Nov–Dec. 2019.

[5] D. Kim and B. Lee, “Asymmetric control algorithm for increasing efficiency of nonisolated on-board battery chargers with a single controller,” IEEE Trans. Veh. Technol., vol. 66, no. 8, pp. 6693–6706, Aug. 2017.

[6] A. V. J. S. Praneeth and S. S. Williamson, “A wide input and output voltage range battery charger using buck-boost power factor correction converter,” in

Proc. IEEE Appl. Power Electron. Conf. Expo., Anaheim, CA, USA, 2019, pp. 2974–2979.

[7] S. Ryu, D. Kim, M. Kim, J. Kim, and B. Lee, “Adjustable frequency–dutycycle hybrid control strategy for full-bridge series resonant converters in electric vehicle chargers,” IEEE Trans. Indus. Electron., vol. 61, no. 10, pp. 5354–5362, Oct. 2014.

[8] A. M. Elrajoubi, S. S. Ang, and K. George, “Design and analysis of a new GAN-Based ac/dc converter for battery charging application,” IEEE Trans. Ind. Appl., vol. 55, no. 4, pp. 4044–4052, Jul./Aug. 2019.

[9] H. Yang, H. Chiang, and C. Chen, “Implementation of bridgeless Cuk power factor corrector with positive output voltage,” IEEE Trans. Ind. Appl., vol. 51, no. 4, pp. 3325–3333, Jul./Aug. 2015.

[10] A. Dixit, K. Pande, S. Gangavarapu, and A. K. Rathore, “DCM-based bridgeless PFC converter for EV charging application,” IEEE J. Emerg. Sel. Topics Ind. Electron., vol. 1, no. 1, pp. 57–66, Jul. 2020.

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