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A Single-Stage Bridgeless PFC Charger with Enhanced Power Quality for LEV-Mounted Solar PV Panels

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Abstract - Researchers are looking at ways to merge solar photovoltaic (PV) with electric vehicles (EVs) due to the rising popularity of both sectors for long-term growth sustainability. One growing industry is the installation of photovoltaic panels on light-electric vehicles (LEVs). There is a lot of space for creativity in the little literature on onboard charging methods that include integrated grid and solar PV inputs for an LEV-mounted PV panel. This article presents a power factor corrected (PFC) charger that centres on the same and has a three-port topology that connects to the grid, PV panels, and batteries. The battery can be charged either in tandem with the grid or separately by the PV panels. Its stated goal is to simplify the design while simultaneously enhancing the source current's total harmonic distortion (THD) to meet the requirements of the IEC 61000-3-2 standard. When designing the controller for each input, PSIM software makes use of small-signal modelling in conjunction with ac-sweep analysis. In a steady-state PV system, the output is free of disturbances thanks to a maximum power point tracking (MPPT) method with variable step sizes. It is designed to function at its best even when faced with dynamically demanding conditions, such as unexpected power input disruptions, wide swings in output power demand, and abrupt changes in grid voltage. In order to prove that the charger works, we built a prototype in the lab that can provide 500 W of output power and 1.2% total harmonic distortion (THD) in grid current.

Key Words: Light electric vehicle (LEV), maximum power point tracking (MPPT), power factor-corrected (PFC) charger, solar photovoltaic (PV), total harmonic distortion (THD).

1.INTRODUCTION

New research opportunities have been made possible by the increasing acceptance and attractiveness of light electric vehicles (LEVs) with a photovoltaic (PV) panel mounted on top of the vehicle, especially in developing countries like India. Electric vehicle (EV) charging systems are one of the most active research topics. For totally grid-dependent EVs, several power factor-corrected (PFC) chargers have been proposed during the past few decades [1], [2], [3], [4], [5], [6], and [7]. Interestingly, these configurations are categorised according to their architecture as either single-stage [1], [2], [3], [4] or two-stage [5], [6], [7] chargers. The fundamental idea behind a PFC charger is to retain a high power factor at the input while delivering a ripple-free current to the battery. For two-stage topologies to do both tasks, two converters (ac–dc and dc–dc) are required. In single-stage charging, however, a single ac–dc interfacing converter performs both tasks. It now has the inherent advantages of a more straightforward structure and increased effectiveness [1]. In a two-stage onboard charger, galvanic isolation is typically used by adding an isolated dc–dc converter to the second stage. However, the use of transformers is not required by the SAE J1772 standard as a safety requirement for EVs. Furthermore, isolation with grid input is not required because battery ground is always in a floating state with a vehicle's chassis [8], [9], and [10]. For safety precautions, the large transformer can be swapped out for small, affordable relay circuits [10].

Additionally, because of leakage inductance, adding transformers to isolated topologies results in increased size, losses, complexity, and switch stress. As a result, non-isolated single-stage topologies are gaining traction as affordable LEV charging options. In general, boost converter-based PFC architecture is widely used for grid input sinusoid current shaping [11]. However, because of output voltages greater than the grid voltage peak, its use for single-stage low-voltage charging applications is restricted. Other topologies with buck-boost capabilities, such Cuk, SEPIC, and Zeta, are excellent choices for such applications in order to overcome these problems [12]. Among all the choices listed above, Cuk converter-derived topologies provide a number of advantages, such as constant current at input and output and native protection against inrush current.

A diode-bridged rectifier (DBR) is cascaded with a Cuk converter to create a traditional bridged Cuk rectifier [13]. Conduction losses in DBR, however, have a negative impact on charger efficiency. To increase efficiency, a number of bridgeless Cuk topologies have been suggested as substitutes for bridged Cuk topologies [14], [15], [16], [17], and [18]. The PFC rectifier described in [14] does not require a bridge since it uses two Cuk circuits, each of which operates in an alternative voltage polarity. It decreases each component's utilisation while increasing the number of components. By using a common Cuk circuit for both positive and negative voltage polarity, work in [15] and [16] has decreased the number of components. In [15], a novel control technique is used to reduce the size of the output capacitor. Furthermore, increased efficiency in [16] comes at the expense of an additional regulated switch.

2. System Description

In [17], a bridgeless Cuk PFC topology with soft switching for full voltage and load capacity is described. Although it increases efficiency and lowers switching and conduction losses, the application of soft switching necessitates extra semiconductor devices and passive components. Nevertheless, grid input is the only way for these single-stage bridgeless PFC topologies to charge. For the maximum power point tracking (MPPT) of a PV panel with integrated LEV, an additional dc–dc converter would be needed [19]. An illustration of traditional charging topologies in blocks [20],

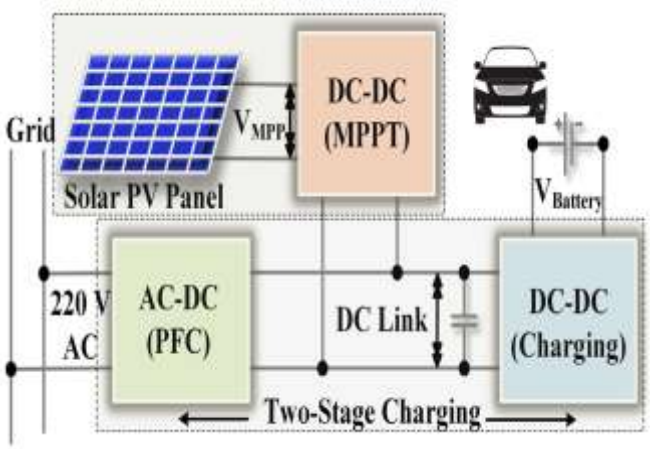


Fig. 1. Conventional solar PV incorporated PFC charging system.

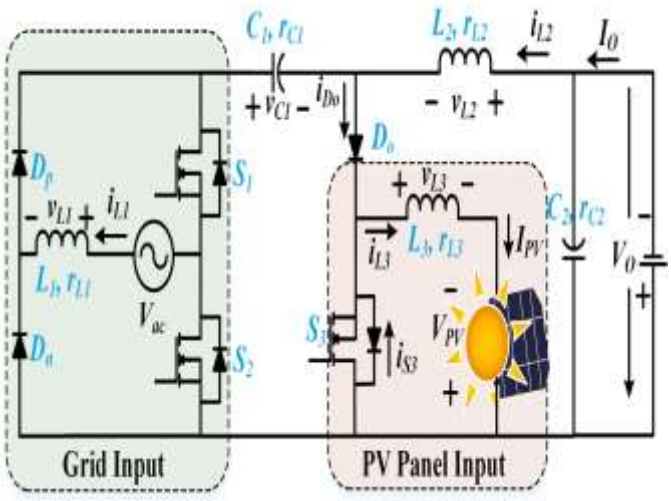


Fig. 2. Schematic of bridgeless LEV charger.

Figure 1 illustrates [21], [22], [23] for dual input sources that include both grid and PV panel input. It is clear that in order to obtain the necessary charging configuration, three converters are used. Here, an ac-dc converter handles power factor correction, a dc-dc converter at the PV panel end handles MPPT, and another dc-dc converter is used for battery charging. This kind of setup is pretty typical for high power output. However, it requires a large number of magnetic and switching components. In [24], a different configuration that does not require a dc–dc converter to accomplish the MPPT is proposed as a solution to this issue. In this case, a PV panel is added straight across the DC link without the need for an interface converter. However, the PV panel needs to be built to run at a higher voltage at the maximum power point (MPP) because the PFC converter is running in boost mode in this setup. Using a multiport charger is another way to integrate several sources while lowering the number of components [25]. Both the AC mains and PV panels can be used to charge EVs. By using a single power converter for all activities, it lowers costs and increases efficiency.

It can only use one power source at a time, though. A Z-source inverter serves as the basis for the multiport PFC charger described in [26], which carries out a single-stage power conversion. Nevertheless, a greater number of switching components are needed. It is rare to find a multi-input PFC charger that causes all sources simultaneously and separately with lower component counts. A Cuk-derived bridgeless dual-input LEV charger is shown in Fig. 2 to solve the above mentioned problems. In this case, the PV panel is the secondary input and the grid is the primary input. An additional switch and inductor are added to a standard bridgeless Cuk charger to accommodate an extra source.

The unique qualities of this charger and the contributions of this effort are described below. 1) Compared to traditional DBR-based ac–dc chargers, the presented charger's bridgeless architecture at grid input reduces losses. 2) It also benefits from non-pulsating currents at each port because it is built on a Cuk converter. 3) Additionally, single-stage power conversion and component sharing between two sources guarantee a decrease in the overall number of components. 4) In addition, a PV panel attached to the secondary input improves the grid current's power quality (PQ), a feature that is generally absent from conventional PV and grid-assisted battery charging systems. Measurements of the grid current's total harmonic distortion (THD), especially at lower power levels, verify this.

5) This charger enables both sources to operate simultaneously and independently, unlike a few reported integrated multiport PFC chargers. 6) Adding a high frequency transformer is a simple way to introduce isolation. Sections II and III contain comprehensive design equations for this charger as well as a detailed operating analysis that describes various charging modes. Section IV also provides an overview of complete controller design. Sections V–VII include in-depth explanations of the experimental findings, comparative analysis, and conclusions, respectively.

3. Principles of Configuration and Operation

The primary goal of the control architecture shown in Figure 4 is to carry out the maximum power tracking of PV panel input and sinusoidal grid current shaping while managing

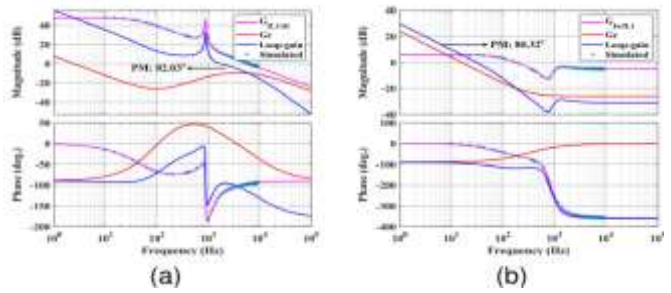


Figure 3 shows the frequency response of (a) GIL1/d1, controller (type-3), and loop-gain, and (b) GIo/IL1, controller (PI), and loop-gain output current. Here, voltage mode MPPT control generates DS2 for switch S3, whereas current mode PFC control generates DS1 for switches S1 and S2.

To create appropriate current compensators, the charger is subjected to small-signal analysis. The ESR of capacitors (rC1 and rC2), parasitic resistances of inductors (rL1, rL2, and rL3), and resistance of the wire (Ro) that connects the battery to the charger are all taken into account. State space variables include the voltage (vC1 and vC2) across capacitors and the currents (iL1, iL2, and iL3) passing through inductors. To create the necessary plant transfer function, state equations of the topology described for each operational mode are required. The generalized state equation is written as.

$$\dot{x} = [A_j][x] + [B_j][u] \text{ and } y = [C_j][x] + [D_j][u]. \quad (10)$$

In this context, $[x] = [i_{L1}, i_{L2}, i_{L3}, v_{C1}, v_{C2}]^T$, $[y] = [i_{L1}, i_{L3}, i_o]^T$, $[u] = [V_{ac}, V_{bat}, V_{PV}]^T$. Appendix contains matrices for each mode of operation in the equation above. It is followed by averaging and the average state space equation is shown as

The outer current compensator of PFC control generates a current reference that is further multiplied by a rectified unit sine template to generate i∗L1. An absolute value of the sensed inductor current (iL1) is compared with generated reference i∗L 1 and passed to the inner current controller. A type-3 compensator is employed for inner loop control to provide an adequate phase margin. The bandwidth of inner loop is comparatively high for faster dynamics and effective PFC control. As evident from frequency response of loop-gain in Fig. 5, phase margin of the inner and outer loop are 82.03◦ and 80.32◦, respectively. The result and discussion section further validates the controller's stable dynamic performance under diverse operating conditions.

The modeling and control of electric vehicle (EV) chargers focuses on managing power flow and battery states. Systems are typically modeled using two power conversion stages: an AC/DC stage for Power Factor Correction (PFC) and an isolated DC/DC stage to regulate the CC-CV (Constant Current - Constant Voltage) In order to provide adequate charging rates for the growing number of electric cars (EVs) and plug-in hybrid electric vehicles, charging stations must be well-designed. The pressure on the traditional grid would increase the cost of charging. Therefore, using local renewable energy sources in addition to the traditional grid, such as solar (PV) electricity, may improve the performance of charging stations. In this study, the grid and PV sources work together to sustain the EV load.

The PV is renowned for being irregular and very reliant on local and climatic factors. For continuous operation of a hybrid PV-based charging station in a system that is linked to the grid and to make up for the intermittent nature of PV, a battery storage system (BSS) is coupled with the PV. In order to fulfil the various demands of EVs load in a range of conditions, hybrid sources-based charging stations should normally be available, effective, and reliable. In order to maximize on-site PV energy, meet the variable demand of EVs while taking into account the quick reaction of BSS, and reduce grid stress, this study proposes and executes an effective hierarchical energy management method. This approach enhances dependability, affordability, and overall performance. To ensure the safe functioning of BSS and reduce losses during the conversion stage, an effective bidirectional power conversion stage for BSS is presented in the form of an interleaved buck-boost converter. charging. [1, 2, 3, 4, 5]

4.Simulation Results And Discussion

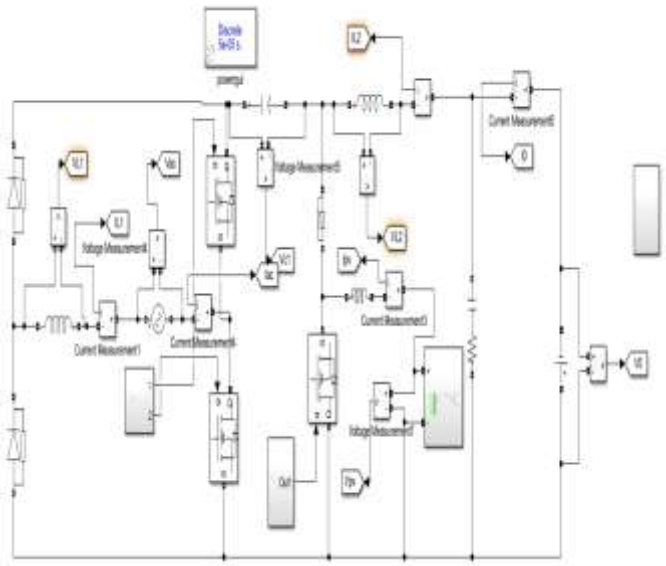


Fig. 4. System Simulation diagram

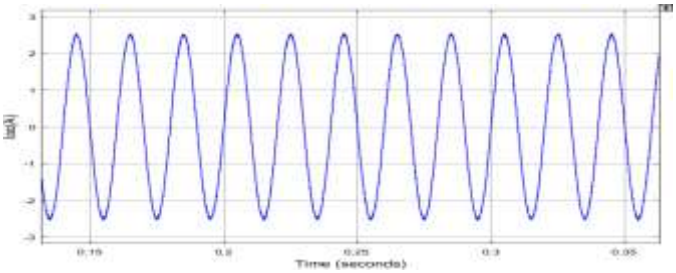


Fig.5.The graph represents the AC current \(I_{ac}\) versus time, likely measured at the output of a power-electronic

converter in your grid-connected PV and EV charging station simulation.

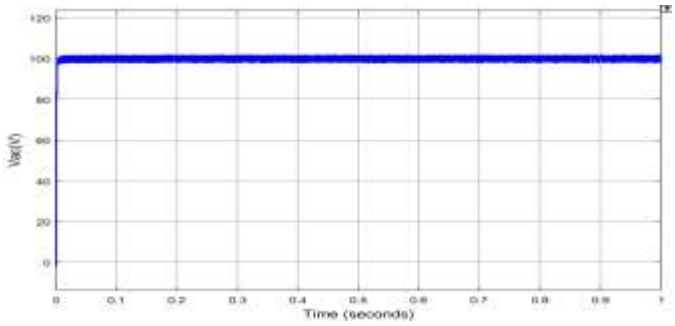


Fig.6.The graph shows the output voltage \(V_{ac}(V)\) versus time (0–1 second).

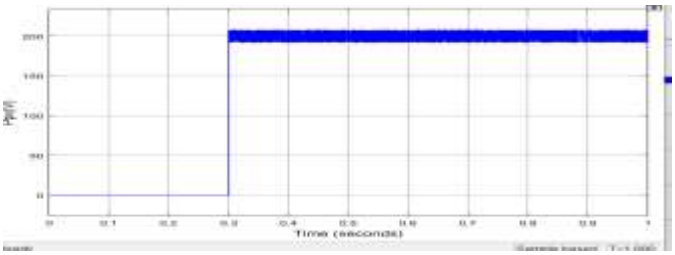


Fig.7.The graph represents the PV power output \(P_{PV}\) versus time in a MATLAB/Simulink simulation. The output power rises at approximately \(0.3\) seconds and then remains near \(200\text{W}\).

For the steady-state examination of the charger described in Section II, a 500 W proof-of-concept is created. Additionally, the created prototype is used to verify the charger's performance under different dynamic settings. Therefore, under various operating situations, the charger's essential wave shapes and input current THD are measured and reported in this part. A programmable ac source (Chroma 61602) generates grid input, and a PV simulator is employed as a secondary input to provide 121.48 W at its MPP under irradiance conditions of 1000 W/m2. A bank of 48 Ah, 72 V lead acid batteries is used to test the charger. Hall-Effect-based voltage sensors (LV 25-P) and current sensors (LA 55-P) make up the sensing circuit. Real-time control is implemented using a C2000 microcontroller (MCU) TMS320F28379D. The switching frequency and the sampling frequency are equal.

displays an image of the designed prototype with annotations. The charger's capacity to function with both sources concurrently or separately is one of its key features. Here, the charger's ability to function well with each source separately is confirmed. Different waveforms related to chargers operating in grid charging mode and PV stand-alone charging mode Grid input satisfies output power requirements with good PQ indices because there is no PV panel input confirmed by a PQ analyser. The THD of grid current is 1.2%, Additionally, it attests to the prototype's ability to supply rated output power only from the grid. For the same, a variable step size MPPT approach described in [27] is used.

This technique's ability to produce output at MPP without disruption is a major advantage over traditional P&O and incremental conductance methods. The PV stand-alone procedure can be used to confirm this. The PV panel at MPP supplies the charger with 121.05 W at 40 V. The tracking efficacy of the method used is 99.67%, display the charger's steady-state waveform under both sources and rated load conditions, display its PQ indices. In order to achieve high power factor operating, the waveform demonstrates that grid current is sine-shaped and follows grid voltage. THD is determined to be 1.2%, and its harmonic components are displayed Solar irradiance is maintained at 1000 W/m2 in dual input mode. The remaining power is supplied by grid input since the PV panel input is confirmed to be running at its MPP. The duty cycle fluctuation for both grid input and PV panel input in steady-state operation is depicted. The theoretical discussion is exactly in line with the duty waveforms' wave pattern.

5. CONCLUSION

The suggested single-stage bridgeless PFC charger successfully improves the charging performance of Light Electric Vehicles (LEVs) by combining high-efficiency power conversion and better power quality. The elimination of the typical diode bridge minimises conduction losses, therefore improving the total efficiency. The inbuilt Power Factor Correction enables the charger to achieve a power factor near to unity and current THD within international norms. The addition of the solar PV panel allows the battery to draw renewable energy, thus decreasing the dependency on the utility grid and cutting running expenses. To conclude, the suggested system offers a small, efficient, environment friendly and dependable charging option for future generation electric mobility.

In this a grid and PV panel interfaced charger for LEV is developed which has the merit of enhanced PQ of grid current. Both sources provide dc output power. Both can be used at the same time or independently. Small signal analysis is done for analysing the frequency response of the planned charger which is further validated by ac-sweep in PSIM. It enhances ac current PQ and PV panel input MPPT in the steady state as well as dynamic operational settings. Each source shares few components so that the total number of components is reduced. There is no need for a big filter as each input has an inductor. Another advantage of the charger layout compared to standard topologies is the improvement in THD of the grid current in dual input operation. In this case, the addition of PV panel improves the voltage profile of common intermediate capacitor between two sources, and minimises the THD. The operation of the provided topology is verified on a 500-W laboratory prototype under steady state and several dynamic circumstances.

REFERENCES

[1] T.-T. Le, R. M. Hakim, and S. Choi, "A high-efficiency bidirectional single-stage AC–DC converter under wide voltage range for fast chargers," IEEE Trans. Power Electron., vol. 38, no. 4, pp. 4945–4956, Apr. 2023.

[2] H. Nazi, E. Babaei, S. Tohidi, and M. Liserre, "An isolated SRC-based single phase single stage battery charger for electric vehicles," IEEE Trans. Transport. Electrific., vol. 9, no. 1, pp. 1252–1262, Mar. 2023. Authorized licensed use limited to: Indian Institute of Technology Hyderabad. Downloaded on March 05,2025 at 06:11:40 UTC from IEEE Xplore. Restrictions apply. KUMAR AND SINGH: SINGLE-STAGE BRIDGELESS PFC CHARGER WITH ENHANCED POWER QUALITY 619

[3] H. Kim, J. Park, S. Kim, R. M. Hakim, H. Belkamel, and S. Choi, "A single-stage electrolytic capacitor-less EV charger with single- and three-phase compatibility," IEEE Trans. Power Electron., vol. 37, no. 6, pp. 6780–6791, Jun. 2022.

[4] B. Vardani and N. R. Tummuru, "A single-stage bidirectional inductive power transfer system with closed-loop current control strategy," IEEE Trans. Transport. Electrific., vol. 6, no. 3, pp. 948–957, Sep. 2020.

[5] S. R. Meher and R. K. Singh, "A standard two stage on-board charger with single controlled PWM and minimum switch count," IEEE Trans.Ind. Appl., vol. 59, no. 4, pp. 4628–4639, Jul./Aug. 2023.

[6] A. Singh, J. Gupta, and B. Singh, "Design and control of two stage battery charger for low voltage electric vehicles using high gain buck-boost PFC AC–DC converter," IEEE Trans. Ind. Appl., vol. 59, no. 5, pp. 6125–6135, Sep./Oct. 2023.

[7] M. Tong, M. Cheng, S. Wang, and W. Hua, "An on-board two-stage integrated fast battery charger for EVs based on a five-phase hybrid excitation flux-switching machine," IEEE Trans. Ind. Electron., vol. 68, no. 2, pp. 1780–1790, Feb. 2021.

[8] C.-Y. Oh, D.-H. Kim, D.-G. Woo,W.-Y. Sung, Y.-S. Kim, and B.-K. Lee, "A high-efficient non isolated single-stage on-board battery charger for electric vehicles," IEEE Trans. Power Electron., vol. 28, no. 12,
pp. 5746–5757, Dec. 2013.



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