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Interleaved Luo Converter Fed-Battery Charger Integrated with Solar Energy

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A B S T R A C T

This project envisages the growing global concerns over the depletion of fossil fuels and the escalating impacts of global warming have necessitated a shift toward sustainable transportation solutions. Light Electric Vehicles (LEVs) have emerged as a reliable and environmentally friendly alternative, aligning with stringent environmental safety regulations. Central to the operation of LEVs are battery packs, which provide the necessary energy to power these vehicles. However, efficient and safe management of battery charging is critical, and this is achieved through advanced power control units (PCUs) integrated into modern electric vehicle (EV) chargers. These PCUs primarily consist of AC-DC and DC-DC converters, which play a pivotal role in the charging process. The AC-DC converter transforms alternating current (AC) from the grid into direct current (DC), while the DC-DC converter adjusts the voltage levels to match the battery's requirements. These components ensure efficient energy conversion, optimal charging, and enhanced safety by preventing overcharging and overheating. Additionally, PCUs contribute to the integration of renewable energy sources, such as solar power, further promoting sustainability. Despite their advantages, challenges such as heat management, high costs, and the need for standardization remain. Future advancements in PCUs are expected to focus on improving efficiency, reducing costs, and incorporating smart charging technologies to support grid stability and battery health. Overall, power control units are indispensable in the transition to electric mobility, offering a practical solution to reduce carbon emissions and dependence on fossil fuels.

Keywords: Luo, converter, PCU, DC, AC, EV, LEV

1. INTRODUCTION

In recent years, recently, shortage of fossil fuels and increasing global warming issues are becoming worldwide concern. Therefore, to follow stringent environmental safety regulations, light electric vehicles (LEVs) offer the most reliable and realistic solution. Most of these vehicles contain a set of battery packs, which has the capability to power LEVs. To control the charging power of the battery, power control units are considered as an essential part of modern EV chargers. These power control units consist of AC–DC as well as DC–DC converters. The growing urgency to address environmental safety regulations has led to a significant focus on the development and adoption of light electric vehicles (LEVs). These vehicles, which rely on battery packs for power, offer a sustainable solution to reduce greenhouse gas emissions and dependence on fossil fuels. However, the efficient operation of LEVs depends heavily on the performance of their charging systems.

2. LITERATURE SURVEY

Min Zhang, Zhengyi Wei, Mingzhu Zhou, Feng Lian Wang, Yichang Cao, Limin Quan, 'A high step-up DC–DC converter with switched-capacitor and coupled-inductor techniques', 2022, IEEE Journal of Emerging and Selected Topics in Industrial Electronics 3 (4), 1067-1076, This article proposes a high step-up dc–dc converter with single switch, which combines a multiplier voltage cell, two winding coupled inductor, and switched capacitor. The converter attained high voltage gain by the boost cell consisting of two winding coupled inductor and switched capacitor. A passive clamp circuit consisting of diode and capacitor can reduce the voltage spike of switch S and recover leakage inductance energy. Therefore, the power switch with low on-state resistance can be used, which will reduce the conduction losses of the switch S. The main properties of the suggested converter are high voltage gain with low turn ratio n at reasonable duty cycle D, and high efficiency. The operation modes and steady-state analysis are presented. Moreover, the stress of the components, theoretical efficiency analysis, and comparison with other dc–dc converters are analyzed and presented, respectively. Finally, a 200 W prototype construct in the laboratory based on the design guidelines verifies the validity of the suggested converter.

3. BLOCK DIAGRAM

The interleaved Luo converter incorporates low input and output current ripple due to ripple cancellation. This charger operates in constant current mode up to certain battery state of charge (SOC). However, for higher SOC range, it maintains constant voltage charging using a fly back converter at the next stage. Two converters are designed in DCM to provide inbuilt zero current switching and circuit diodes show good reverse recovery. An inherent PF reregulation is obtained at input mains over a wide range of supply voltages as well as dc-link voltage. The total harmonic distortion of input current is obtained as per PQ regulations. Its prototype is built and tested to validate its improved performance over two-stage solutions. The input AC supply for the interleaved Luo converter in this battery charging system is designed to ensure efficient and high-quality power conversion while adhering to power quality (PQ) standards. The converter operates over a wide range of AC supply voltages, making it versatile for various grid conditions. By leveraging the interleaved structure, the input current is divided between the two LUO converter cells, reducing current stress on individual components and minimizing conduction losses. This design also achieves low input current ripple due to ripple cancellation, which enhances the overall power factor and reduces harmonic distortion. The system inherently provides power factor reregulation, ensuring compliance with PQ regulations such as low total harmonic distortion (THD) in the input current. As a result, the interleaved LUO converter efficiently processes the AC input supply, enabling reliable and high-performance charging for electric vehicle batteries. The rectifier converts the AC input voltage from the mains supply into a pulsating DC voltage, typically using a full-bridge diode rectifier to efficiently transform both positive and negative halves of the AC waveform into a unidirectional DC output. However, the rectified output contains significant ripple due to its pulsating nature, which is smoothed using a filter, such as a capacitor or LC filter. The capacitor absorbs high-frequency ripples, providing a relatively stable DC voltage to the LUO converter and reducing voltage fluctuations. Together, the rectifier and filter ensure efficient conversion of the AC supply into a stable DC voltage with minimal ripple, which is crucial for the proper operation of the interleaved LUO converter. This clean DC input enhances the converter's efficiency, reduces stress on switching components, and improves the overall power quality of the system. The Interleaved LUO Converter is a critical component in electric vehicle (EV) battery charging systems, designed to enhance efficiency, reduce current stress, and improve power quality. It consists of multiple LUO converter cells operating in parallel with phase-shifted control. The AC input from the mains is first rectified into pulsating DC using a full-bridge diode rectifier, followed by a filter (capacitor or LC filter) to smoothen the DC voltage and provide a stable input to the converter. Each cell includes switches (MOSFETs or IGBTs) and inductors, operating in discontinuous conduction mode (DCM) to achieve zero current switching (ZCS) and reduce switching losses. The output stage provides a regulated DC voltage for battery charging, operating in constant current (CC) mode for lower battery state of charge (SOC) and switching to constant voltage (CV) mode for higher SOC using a fly back converter. A control circuit ensures proper synchronization, output regulation, and power factor correction (PFC), maintaining compliance with power quality standards. By interleaving multiple LUO converter cells, the system achieves higher efficiency, reduced component stress, and improved power quality, making it ideal for high-performance EV battery charging. A fly back converter is a power converter that can be used for ac to dc conversion and dc to dc conversion while isolating the input and output sides. In other words, a fly back converter can produce a regulated dc output from an AC or DC input. This type of converter uses a special type of electrical transformer called fly back transformer which is basically a mutually coupled inductor. In this article let us see about a dc-to-dc fly back converter. A DC-to-DC fly back converter is a buck-boost converter where it can produce an output dc voltage that is either greater or lesser than the input dc voltage. A solar energy block generating 5 watts can be effectively integrated with a LUO converter to step up the voltage for various applications. The LUO converter, known for its high efficiency and ability to provide positive output voltage, is well-suited for low-power solar systems. In this setup, the solar panel acts as the primary energy source, converting sunlight into electrical energy. The 5-watt output from the solar block is then fed into the LUO converter, which boosts the voltage to a higher level as required by the load. This configuration is particularly useful in off-grid or portable systems, where efficient energy conversion and compact design are critical. The LUO converter's ability to minimize energy losses ensures that the limited power generated by the 5-watt solar block is utilized optimally. Driver circuit needs 12V and 5V. Microcontroller need 5V supply, so we convert 230V AC supply is first step down in to 15V by using step down transformer. Then this 15V AC is converted in to DC by using Full bridge rectifier which has high efficiency than all other methods. This 15V DC is converting into 12V DC and 5v DC by using 7812 and 7805 regulators respectively. The capacitor is used to provide smooth variation in voltage. For indication purpose we used LED with 1K resistor to limit current flow to the LED. The following figure shows the regulated power supply. A 12V 1.4Ah battery can be effectively used as a storage unit in a system incorporating a LUO converter to power a resistive load. In this setup, the battery serves as an energy reservoir, storing power generated from a source such as a solar panel or another DC input. The LUO converter, known for its ability to efficiently step up or step-down voltage, ensures that the energy from the battery is delivered to the resistive load at the required voltage level. When the system is operational, the battery supplies a stable 12V output, which is then processed by the LUO converter to match the load's specifications. The resistive load, which could be a heating element or a simple resistor, consumes the energy efficiently, with the LUO converter minimizing losses during the conversion process. This configuration is particularly useful in portable or off-grid applications, where energy storage and efficient power delivery compact are essential. The 1.4Ah capacity of the battery provides a reasonable runtime for low-power applications, making it a practical choice for small-scale systems.

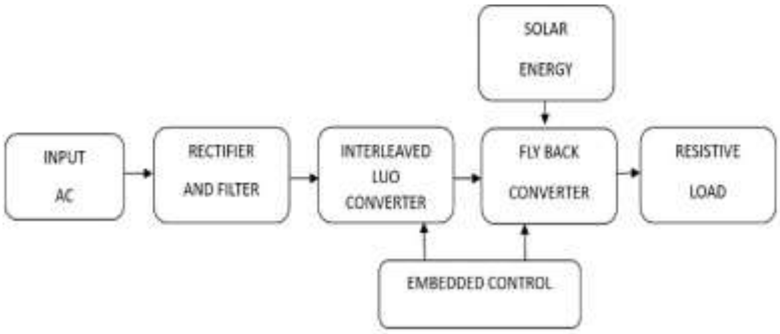

Figure 1: Block diagram of Interleaved LUO converter-fed battery charger integrated with solar energy

4. SIMULATION DIAGRAM

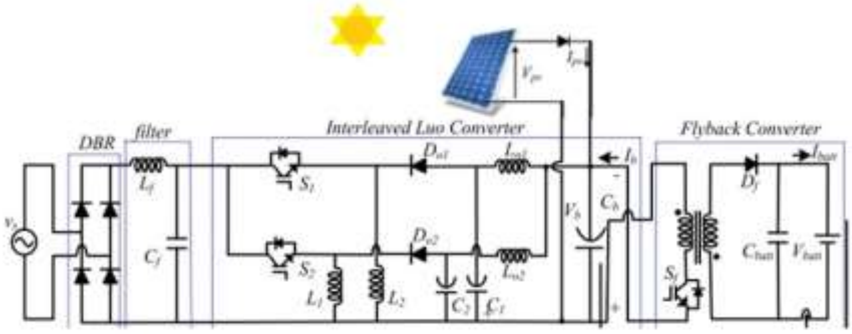

Figure 4: Block diagram of Interleaved LUO converter-fed battery charger integrated with solar energy

5. CONCLUSION

In this report work the integrated with solar energy represents a highly efficient and sustainable solution for modern energy storage systems. By combining the advantages of the Interleaved LUO Converter, such as reduced current ripple, high efficiency, and improved power density, with the renewable energy potential of solar power, this system ensures optimal charging of batteries while minimizing energy losses. The integration of solar energy not only reduces dependency on non-renewable energy sources but also enhances the system's eco-friendliness. Additionally, the interleaved topology provides better thermal management and reliability, making it suitable for high-power applications. Overall, this project offers a robust, scalable, and environmentally friendly approach to energy storage, aligning with global efforts to promote clean energy and sustainable development.

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