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PV-Battery Based AC/DC Hybrid Multiport LLC converter for Power Routing System

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Abstract: This paper presents a PV-Battery Based AC-DC Hybrid Multiport LLC Converter for efficient power routing in smart grids. It integrates a photovoltaic (PV) module, battery energy storage system (BESS), and a multiport LLC resonant converter for seamless power transfer between DC and AC loads. The system employs a Maximum Power Point Tracking (MPPT) algorithm to optimize PV output, while a bidirectional DC-DC converter manages battery charging and discharging. The LLC converter uses zero-voltage switching (ZVS) for reduced losses, and grid-synchronized bidirectional inverters handle power exchange between the grid and local sources, improving overall efficiency and reliability
Keywords: Dc-DC Converter, LLC converter, multiport converter, MPPT, PV battery hybrid circuit, ZVS.

I. INTRODUCTION

The growing demand for renewable energy integration and efficient power management has led to the development of advanced hybrid power conversion systems. Among various renewable sources, solar photovoltaic (PV) energy has gained significant attention due to its abundant availability and sustainability. However, the intermittent nature of solar energy necessitates an energy storage system (ESS) to ensure a stable and reliable power supply. A battery energy storage system (BESS) is commonly used alongside PV to store excess energy and supply power during low solar availability.
To efficiently manage power flow between PV, battery, AC loads, and the grid, a multiport power converter is essential. This paper proposes a PV-Battery Based AC-DC Hybrid Multiport LLC Converter, which integrates a high-frequency LLC resonant converter for improved efficiency and reduced switching losses. The LLC converter operates under zero voltage switching (ZVS), enhancing the overall efficiency and reliability of the power system.

A. Background

The integration of renewable energy sources, particularly photovoltaic (PV) systems, with energy storage solutions has become essential for ensuring reliable and efficient power delivery. However, conventional power conversion methods face challenges in handling multiple energy sources and different load types while maintaining high efficiency. To address this issue, a PV-Battery Based AC-DC Hybrid Multiport LLC Converter is introduced as an advanced power routing system. This system enables seamless energy transfer between PV panels, battery storage, and AC/DC loads, optimizing power distribution based on demand and availability.
The multiport LLC resonant converter is a highly efficient power conversion topology that utilizes soft-switching techniques to minimize switching losses, making it ideal for high-frequency power conversion. The system consists of multiple power ports, where the PV source acts as the primary energy generator, while the battery serves as an energy buffer, storing excess energy and supplying power during low solar irradiance conditions. The LLC resonant converter ensures efficient DC-DC conversion, while a hybrid AC-DC power routing mechanism enables flexible distribution of energy to both AC and DC loads. A power management system controls the energy flow between different ports, ensuring optimized performance and high reliability.
This hybrid system offers several advantages over traditional converters, including higher efficiency, reduced component size, enhanced system reliability, flexible power routing, and improved energy utilization. By dynamically managing power flow, it ensures stable operation for applications such as smart grids, electric vehicle charging stations, hybrid renewable energy systems, and microgrid solutions. The incorporation of MPPT (Maximum Power Point Tracking) for PV optimization and bidirectional DC-DC converters for efficient battery management further enhances system performance.
Overall, the PV-Battery Based AC-DC Hybrid Multiport LLC Converter represents a significant advancement in power electronics, enabling intelligent energy distribution and maximizing the utilization of renewable energy sources.

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B. Overview

The PV-Battery Based AC-DC Hybrid Multiport LLC Converter is a power management system designed to efficiently integrate multiple energy sources and dynamically distribute power between AC and DC loads. This system is particularly useful for renewable energy applications, where fluctuations in power generation and load demand require a flexible and intelligent power routing mechanism. By incorporating an LLC resonant converter, the system ensures high efficiency and reduced switching losses through soft-switching operation, making it suitable for high-frequency power conversion. The converter features multiple input and output ports, allowing seamless integration of a photovoltaic (PV) source, battery storage, and hybrid AC/DC loads. The PV source generates DC power, which is either supplied directly to the load or stored in the battery through a bidirectional DC-DC converter. The LLC resonant converter facilitates efficient DC-DC power conversion, while a dedicated inverter is used for AC load supply. A power management system continuously monitors energy availability and demand, ensuring optimal power routing to maximize efficiency and reliability. This hybrid system operates in different modes based on power availability and load requirements. Under high solar irradiance, excess PV power is stored in the battery for later use. During periods of low solar generation, the battery discharges to maintain continuous power supply. The MPPT (Maximum Power Point Tracking) algorithm ensures that the PV system operates at its maximum efficiency, while the hybrid converter maintains stable voltage and current regulation across the system. Designed for smart grids, microgrids, electric vehicle charging stations, and off-grid renewable energy solutions, the hybrid multiport LLC converter enhances energy utilization by dynamically adjusting power flow. Its compact size, high efficiency, and flexible power routing capabilities make it an ideal solution for modern energy management systems.

C. Objective

1) Development of a Multiport Power Routing System

Design an LLC resonant converter to achieve high efficiency with zero voltage switching (ZVS) and reduced switching losses.
Implement a bidirectional DC-DC converter to manage battery charging/discharging.
Integrate a bidirectional AC-DC inverter for seamless power exchange between DC and AC loads.

2) Optimization of Power Flow and Energy Management

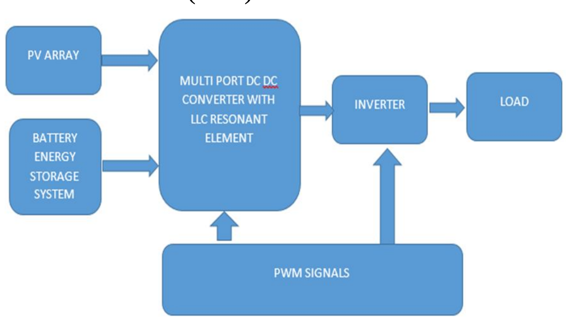
Implement Maximum Power Point Tracking (MPPT) to maximize PV energy extraction.
Design a hybrid energy management algorithm for dynamic power distribution between PV, battery, and AC/DC loads.
Ensure seamless power routing between multiple energy sources and loads.

3) Enhancing System Efficiency and Stability

Utilize soft-switching techniques to minimize power losses and improve overall efficiency.
Maintain stable voltage regulation under varying solar irradiation and load conditions.
Implement harmonic reduction strategies for improved power quality.

II. STRUCTURE OF THE PROPOSED CONVERTER

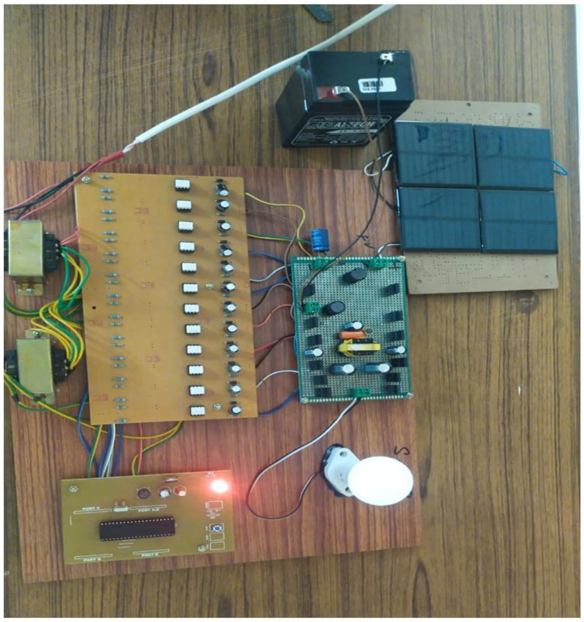
The increasing demand for efficient and flexible power management systems has led to the development of hybrid AC/DC power routing architectures. This paper presents the hardware implementation of a PV-battery-based AC/DC hybrid multiport LLC resonant converter for efficient power routing. The proposed system integrates photovoltaic (PV) and battery energy storage to ensure seamless power distribution between AC and DC loads. The LLC resonant converter is employed to achieve high efficiency, soft switching, and reduced electromagnetic interference (EMI).



A. Block diagram of multiport LLC converter

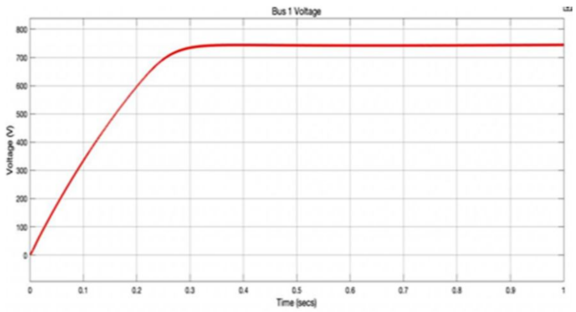
A multiport configuration is utilized to enhance power flexibility and optimize energy flow, enabling effective load sharing and improved system reliability. The control strategy is designed to dynamically manage power distribution among the ports, ensuring stability under varying load and source conditions. The hardware prototype is developed using a PIC16F877A microcontroller for real-time control, and experimental results validate the system's performance in terms of efficiency, voltage regulation, and load adaptability. The proposed PV-battery-based hybrid multiport LLC converter demonstrates its potential for renewable energy integration and efficient power routing in modern AC/DC microgrid applications.

1) Multiport Converter

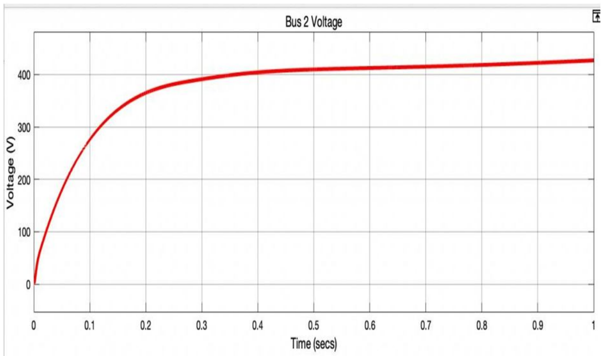


Multiport LLC converter

2) Output Voltage Dc Load

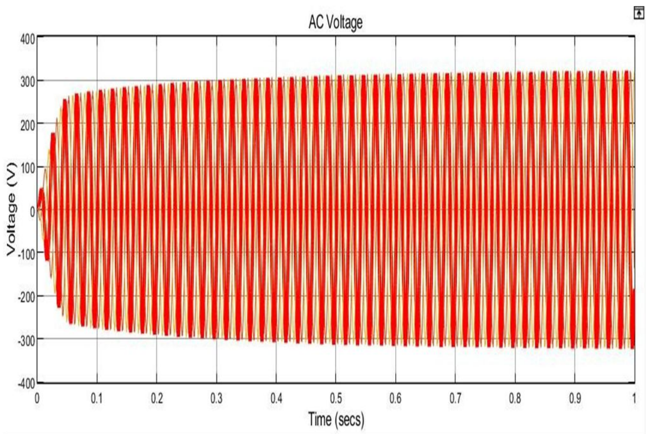


Output voltage of DC bus 1 (High Voltage)



Output voltage of DC bus 2 (Low Voltage bus)

3) Output Voltage Of Ac Load



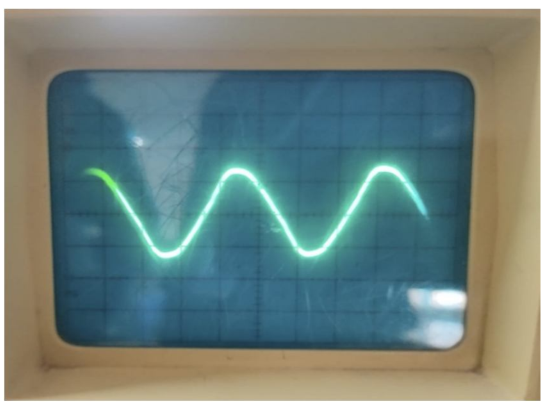
Output voltage of AC load

III. RESULT

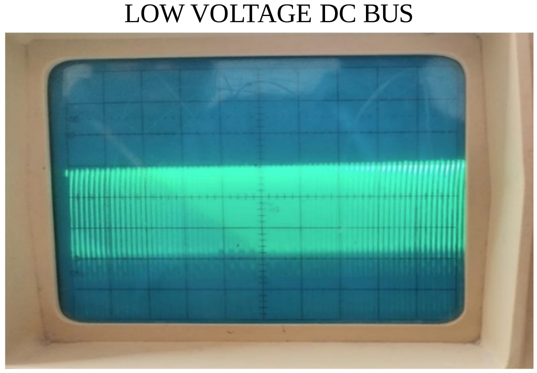
A 230v, 50Hz Single phase AC power supply is given to a step down transformer to get 12v supply. This voltage is converted to DC voltage using a Bridge Rectifier. The converted pulsating DC voltage is filtered by a 2200uf capacitor and then given to 7805 voltage regulator to obtain constant 5v supply. This 5v supply is given to all the components in the circuit. A RC time constant circuit is added to discharge all the capacitors quickly. The battery is connected with solar panels for energy storage purpose. And this energy is connected to multiport converter. DC low and high voltages are obtained in this circuit in various buses. To ensure the ac power supply a LED is connected for indication purpose.

A. Output Waveforms

AC OUTPUT VOLTAGE BUS



LOW VOLTAGE DC BUS



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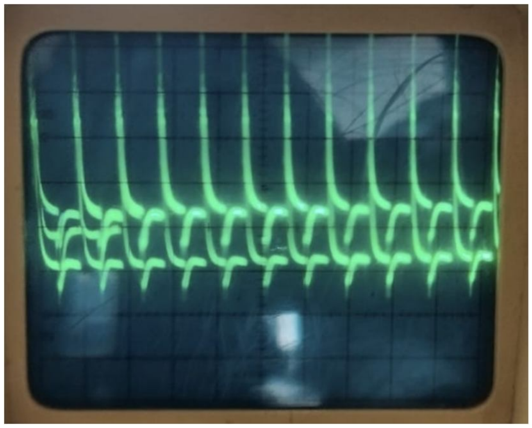
HIGH VOLTAGE DC BUS



IV. CONCLUSION

The implementation of the PV-battery-based AC/DC hybrid multiport LLC resonant converter demonstrates a highly efficient and flexible power management solution for modern energy systems. By integrating photovoltaic (PV) energy and battery storage, the system ensures seamless power distribution to both AC and DC loads, optimizing energy utilization and improving reliability. The LLC resonant converter plays a crucial role in achieving soft-switching, reducing switching losses, and minimizing electromagnetic interference (EMI), leading to high efficiency in power conversion.

The proposed multiport configuration enables efficient power routing and dynamic load sharing, ensuring stability under varying source and load conditions. The PIC16F877A microcontroller-based control strategy effectively manages real-time power flow, incorporating Maximum Power Point Tracking (MPPT) for optimal PV performance and bidirectional DC-DC conversion for efficient battery management. Experimental results validate the system's capability in voltage regulation, load adaptability, and overall efficiency, confirming its suitability for practical applications.

Overall, the PV-battery-based AC/DC hybrid multiport LLC converter provides a compact, reliable, and highly efficient solution for renewable energy integration in applications such as smart grids, microgrids, electric vehicle charging, and off-grid power systems. Its ability to intelligently manage energy flow and optimize power distribution makes it a promising advancement in hybrid power conversion technology.

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