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Design and Implementation of A 100 W Interleaved Synchronous Boost Converter for Rural Solar Applications

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ABSTRACT: The current breakthroughs in energy storage technologies, power electronic converters, motor drives, and appropriate control theories have the globe paying special attention to electric vehicles, or EVs. One of the home transportation technologies that will soon be greatly favoured over traditional automobiles is EVs. Since the power produced by DC sources fluctuates simultaneously and is not stable, converters are necessary to alter the power as needed. Therefore this project proposes a Design and Implementation of a 100 W Interleaved Synchronous Boost Converter for Rural Solar Applications. This system incorporates multiple stages designed to efficiently convert and manage power from a solar panel, store energy in a bidirectional battery converter, and deliver electricity to the grid or an EV. The solar panel is first interfaced with an interleaved SEPIC boost converter, which boosts the input DC voltage from the photovoltaic system to a higher voltage required for the charging process. The converter's operation is controlled by a PI controller, ensuring that the DC voltage stays within desired limits. The system also includes a bidirectional battery converter that allows for energy storage, which can be used for supplying power when solar energy is insufficient. The system features a single-phase Voltage Source Inverter (VSI), controlled by pulse-width modulation (PWM) pulses, to deliver the DC power to the AC grid. The system's performance is monitored and regulated by various controllers that ensure efficient energy conversion, optimal power delivery, and safe charging of the EV. This design aims to provide an efficient, reliable, and sustainable charging solution that integrates renewable energy sources into the grid. This project is implemented by using MATLAB SIMULINK 2024a and DSPIC30F4011 Controller.

1. Introduction

Photovoltaic (PV) is a technology that directly converts solar energy into direct current (DC) electricity using semiconductor materials. The fundamental component of a PV system is the solar cell, typically made from highly purified silicon. When sunlight, composed of packets of energy called photons, strikes the cell, the photons excite the electrons in the semiconductor material. This process generates an electric current the photovoltaic effect. Individual solar cells are connected together to form PV modules, commonly known as solar panels. These modules are then interconnected into larger units called arrays to achieve the desired power output. A complete PV system also includes components like an inverter to convert the DC electricity into alternating current (AC) for use in homes and businesses or for feeding into the electrical grid. Other necessary components often include mounting structures, wiring, and balance-of-system (BOS) electronics. PV systems are highly versatile, ranging from small-scale rooftop installations on residential buildings to massive utility scale solar farms.

PV technology has experienced dramatic growth and cost reductions in recent decades, positioning it as a cornerstone of the global transition to sustainable energy. It offers a clean, renewable energy source that produces electricity without emitting greenhouse gases during operation. While challenges remain, such as intermittency (electricity generation depends on sunlight availability) and the need for efficient energy storage solutions, continued innovation in materials science, manufacturing, and system integration is driving photovoltaic toward becoming one of the most cost-effective and widespread forms of electricity generation worldwide. Photovoltaic (PV) is directly converts solar energy into direct current (DC) electricity using semiconductor materials, primarily silicon. This conversion relies on the photovoltaic effect: when sunlight (photons) strikes a solar cell, it excites electrons in the semiconductor, generating an electric current. Individual cells are connected to form PV modules (solar panels), and multiple modules are grouped into arrays to achieve the desired power output.

A complete PV system includes these arrays along with an inverter, which is crucial for converting the DC electricity into alternating current (AC), making it usable for household appliances or for feeding into the public electrical grid. PV systems are highly versatile, ranging from small-scale rooftop installations on homes to vast, utility scale solar farms.

2. Recent Works

High-gain DC–DC converters have been extensively researched for renewable applications. Various techniques such as switched-capacitor cells, coupled inductors, and voltage multipliers have been proposed to increase voltage gain. However, these topologies increase circuit complexity and cost.

Recent literature emphasizes:

- Ripple reduction using interleaving
- Efficiency improvement via synchronous MOSFET rectification
- Advanced MPPT and PI-based control methods
- Integration with battery energy storage

Despite improvements, many systems remain complex or expensive for rural deployment. Therefore, a simple, efficient, and cost-effective 100 W converter is proposed.

3. Proposed Work Explanation

3.1 System Overview

In this proposed system the working process of the proposed 100 W interleaved synchronous boost converter for rural solar applications begins with the solar photovoltaic (PV) panel generating a low-voltage DC output that varies with irradiance and temperature. This variable PV voltage and current are fed into the interleaved synchronous boost converter, which consists of two parallel boost converter phases operated with phase-shifted PWM signals. The interleaving action reduces input current ripple and distributes current stress evenly across the switches. Synchronous MOSFETs are used instead of diodes to minimize conduction losses and improve conversion efficiency.

3.2 Pv System

A photovoltaic (PV) system is a renewable energy technology that directly converts sunlight into electrical power using the photovoltaic effect in semiconductor based solar cells. The basic unit of a PV system is the solar panel, and several panels are interconnected to form a PV array that generates the required output voltage and current. The power generated is in the form of direct current (DC), which fluctuates with solar irradiance, temperature, and shading, making power conditioning and control essential. To maximize energy harvesting, PV systems employ Maximum Power Point Tracking (MPPT) techniques that continuously adjust the operating point to ensure optimal power output.

Non Linear Characteristics of I-V Curve is given by,

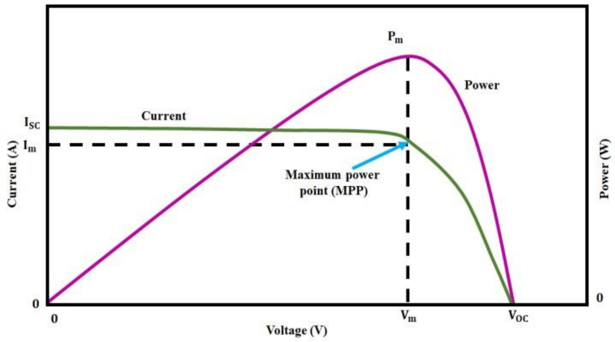


Figure 1: *Non Linear Characteristics of I-V Curve*

3.3 Interleaved Sepic Boost Converter

The interleaved boost sepic converter can be obtained by paralleling conventional boost and sepic converter with a phase shift of 180°. The PV panel output current is shared among the input inductors.

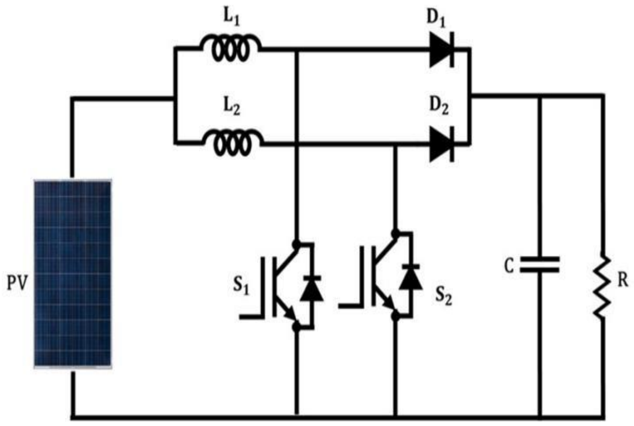
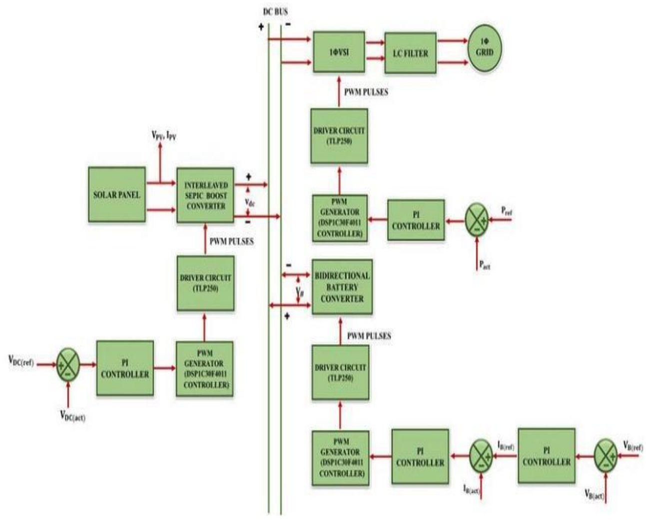


Figure 2: *Interleaved Sepic Boost Converter*

3.4 Bidirectional Battery Converter

The excess energy from the PV is stored in the battery using bi-directional battery converter. The energy management of the proposed work is performed by battery units and a bidirectional converter. The converter maintains the potential at PCC at an optimum level of 600 V which is more than the maximum storage capacity of batteries (540 V). The properly connected low-voltage battery series eliminates the voltage equalization problem found in single-cell battery. Thus, the optimum DC link voltage is maintained at the PCC with increased battery life cycle. At first the ON time of the pulse period is maintained at 50% and the converter will neither work in step up nor step down mode and there will not be power stream between battery and grid.

3.5 Block Diagram



4. Results and Discussion

MATLAB Simulink 2024a simulation and hardware testing were performed. Observations:

- Ripple reduction observed due to interleaving
- Stable DC output under varying loads the battery converter operates in:
- Buck mode (Charging)
- Boost mode (Discharging) It maintains DC bus stability during low solar availability. 3.5 Voltage Source Inverter 4 the VSI converts regulated DC to AC power. PWM control ensures
- Unity power factor
- Low Total Harmonic Distortion (THD)
- Grid synchronization An LC filter reduces switching harmonics
- Efficiency range: 92–95%
- future scope of the 100 W interleaved synchronous boost converter includes further

optimization for higher power ratings and improved efficiency through

- The use of wide band-gap semiconductor devices such as SiC or GaN.
- Integration with advanced maximum power point tracking (MPPT) algorithms can enhance energy extraction from solar panels under varying environmental conditions.

5. Conclusion

This work presented an IoT-based real-time water purity monitoring and alert system designed to support sustainable shrimp farming by enabling continuous observation of critical water quality parameters. The proposed system successfully integrates sensors for monitoring pH, temperature, salinity, and turbidity with a microcontroller and cloud-based platform to provide real-time data visualization and instant alert notifications. The major outcome of this research is the significant reduction in monitoring delay and human dependency when compared to conventional manual methods, allowing farmers to respond quickly to unfavourable water conditions and thereby reduce shrimp stress and mortality. The system improves overall farm management by converting raw sensor data into actionable information that supports timely and informed decision-making.

The importance of this work lies in its practical applicability and cost-effective design, making it suitable for adoption in both small-scale and large-scale shrimp farms. By enabling remote access to water quality information, the system reduces the need for constant on-site supervision and contributes to efficient resource utilization. The proposed solution is highly relevant to modern aquaculture practices, where maintaining stable water quality is a persistent challenge due to environmental variability. The system can be applied not only in shrimp farming but also in fish farms, aquaculture research facilities, and other smart farming environments that require continuous water quality monitoring.

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