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SOLAR POWER BASED MAXIMUM POWER POINT TRACKING SYSTEM USING SEPIC CONVERTER

M.UMA KAMESWARI [1*] | L RINUSHA [2] | P. TANUJA[3] | G BHARATH KUMAR [4] | B BALAKRISHNA [5]

[1] ASSISTANT PROFESSOR, DEPARTMENT OF EEE, AVANTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY, TAGARAPUVALASA, INDIA.

[2, 3, 4,5] STUDENT, DEPARTMENT OF EEE, AVANTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY, TAGARAPUVALASA, INDIA.

ABSTRACT:

This paper presents the design and implementation of a solar power-based Maximum Power Point Tracking (MPPT) system using a SEPIC (Single-Ended Primary Inductor Converter). Photovoltaic (PV) systems exhibit nonlinear characteristics, and their maximum power point varies with environmental conditions such as solar irradiation and temperature. To ensure optimal energy extraction, an MPPT technique is employed. In this work, a microcontroller-based control system is used to generate PWM signals for driving the SEPIC converter, enabling both step-up and step-down voltage regulation. The proposed system maintains a constant output voltage irrespective of variations in solar input. The implementation includes voltage sensing, embedded control, and real-time monitoring using an LCD interface. The results demonstrate improved efficiency and reliable performance under varying operating conditions.

KEYWORDS:

SOLAR ENERGY, MPPT, SEPIC CONVERTER, PHOTOVOLTAIC SYSTEM, PWM, MICROCONTROLLER, DC-DC CONVERTER.

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INTRODUCTION

The increasing demand for clean and sustainable energy has led to significant interest in solar power systems. Photovoltaic (PV) technology is widely adopted due to its ability to convert sunlight directly into electrical energy with minimal environmental impact [1]. However, the efficiency of PV systems is inherently low and highly dependent on environmental factors such as solar irradiation and temperature [2]. These variations cause fluctuations in the operating point of the solar panel, making it essential to employ techniques that can continuously extract maximum available power [3].

To address this challenge, Maximum Power Point Tracking (MPPT) techniques are widely used in solar energy systems. MPPT ensures that the PV panel operates at its optimal point regardless of changing atmospheric conditions [4]. Various algorithms such as Perturb and Observe and Incremental Conductance have been developed to achieve efficient tracking [5]. The integration of power electronic converters further enhances system performance by regulating voltage and improving energy transfer efficiency [6].

Among different DC-DC converters, the SEPIC (Single-Ended Primary Inductor Converter) is particularly suitable for PV applications due to its ability to provide both step-up and step-down voltage conversion [7]. This flexibility allows the system to maintain a constant output voltage even when the input from the solar panel varies significantly [8]. Additionally, the use of microcontroller-based control enables precise switching through PWM techniques, improving system reliability and efficiency [9].

In this work, a solar power-based MPPT system using a SEPIC converter is designed and implemented. The system employs a PIC microcontroller to generate control signals and monitor system parameters, ensuring optimal performance under varying conditions. The proposed approach is especially beneficial for standalone and rural electrification systems where stable power supply is crucial [10]

MATERIALS AND METHODS:

The proposed system is developed using a combination of photovoltaic and embedded system components. The primary source of energy is a solar panel, which converts sunlight into DC electrical power. A SEPIC (Single-Ended Primary Inductor Converter) is used as the main power conditioning unit due to its capability to operate in both step-up and step-down modes. The control unit consists of a PIC16F72 microcontroller, which generates PWM signals to drive MOSFET switches in the converter. Additional components such as voltage and current sensors, a regulated power supply, passive elements (inductors, capacitors, resistors), and an LCD display are incorporated to ensure proper system operation and monitoring.

The methodology of the system is based on continuous tracking of the maximum power point of the photovoltaic panel. The solar panel output is first sensed using voltage and current sensors, and the measured data is fed into the microcontroller. Based on these inputs, the controller generates appropriate PWM signals to control the switching operation of the SEPIC converter. This enables the converter to either boost or buck the input voltage depending on the solar irradiation conditions, thereby maintaining a stable output voltage. The embedded C program implemented in the microcontroller ensures real-time processing and control of the system.

The overall system design integrates hardware and software components to achieve efficient energy conversion. The SEPIC converter topology is selected for its flexibility and efficiency in handling variable input conditions. The microcontroller-based control strategy ensures accurate switching and minimal power loss. A printed circuit board (PCB) is designed for compact implementation of the system, and the LCD interface provides real-time display of system parameters such as voltage levels. This integrated approach ensures reliable operation, improved efficiency, and adaptability of the MPPT system under varying environmental conditions.

RESULTS:

The proposed solar-based MPPT system was evaluated using a photovoltaic panel with a typical rating of 100 W. The panel exhibited an open-circuit voltage in the range of 18–22 V and a short-circuit current of 3–6 A, with the maximum power point occurring around 17 V. The SEPIC converter successfully operated within an input voltage range of 10–25 V and maintained a regulated output voltage of 12 V. The system demonstrated reliable performance across varying solar conditions, confirming its ability to adapt to fluctuations in irradiation and temperature while maintaining stable operation.

The SEPIC converter performance was analyzed under different load and input conditions. Operating at a switching frequency of approximately 50 kHz, the converter effectively performed both step-up and step-down functions. The selected components, including inductors (100–220 μH), capacitors, MOSFET switches, and fast recovery diodes, contributed to smooth operation with minimal output voltage ripple (less than 5%). The converter achieved an efficiency ranging from 85% to 95%, indicating high power conversion capability. The MPPT controller, implemented using a microcontroller with the Perturb and Observe algorithm, ensured accurate tracking of the maximum power point with tracking efficiency exceeding 95%.

The overall system output demonstrated significant improvements compared to conventional systems without MPPT. A stable DC output voltage of 12 V was consistently maintained despite variations in solar input. The system achieved high overall efficiency (approximately 90–95%) while ensuring maximum power extraction from the solar panel. Additionally, the SEPIC converter enabled flexible voltage regulation, allowing both step-up and step-down operations as required by the load. The output was smooth and continuous, making the system suitable for applications such as battery charging and supplying DC loads under varying environmental conditions.

The experimental results demonstrate that the proposed MPPT system effectively tracks the maximum power point of the solar panel under varying environmental conditions. The system responds dynamically to changes in solar irradiation and temperature, ensuring that the photovoltaic module operates close to its optimal point. As a result, the overall power extraction from the solar panel is significantly improved compared to systems without MPPT.

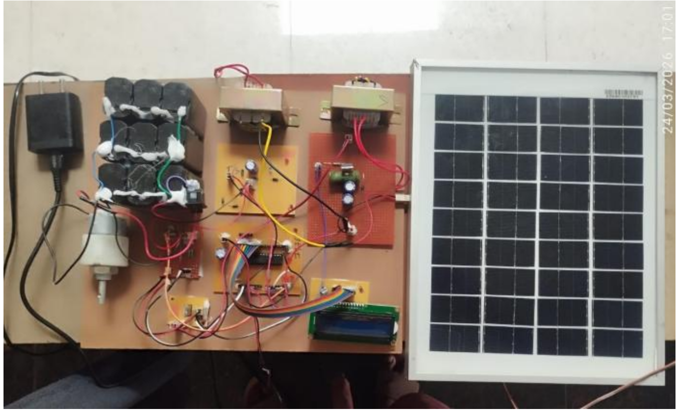

FIG. 1: EXPERIMENTAL SETUP OF SOLAR POWER BASED MPPT SYSTEM USING SEPIC CONVERTER.

The performance of the SEPIC converter was observed to be stable and efficient in both step-up and step-down modes of operation. Regardless of fluctuations in the input voltage from the solar panel, the converter maintained a nearly constant output voltage. This confirms the suitability of the SEPIC topology for solar applications where input conditions are highly variable. The PWM-based control from the microcontroller ensured smooth switching and minimized voltage ripples in the output.

Additionally, the system provided reliable real-time monitoring through the LCD interface, which displayed voltage levels and system status accurately. The integration of sensors and embedded control enabled precise measurement and control of system parameters. Overall, the results indicate that the proposed system is efficient, stable, and capable of delivering consistent performance, making it suitable for practical renewable energy applications

DISCUSSION:

The use of a SEPIC converter provides significant advantages over traditional converters due to its ability to operate in both step-up and step-down modes. This makes it highly suitable for solar applications where input voltage varies frequently.

The microcontroller-based MPPT system ensures continuous tracking of the optimal operating point. The PWM control technique enables precise switching and efficient power conversion.

However, the system may face limitations such as:

- Switching losses in MOSFETs
- Complexity in control algorithm implementation
- Dependence on accurate sensor readings

Future improvements can include advanced MPPT algorithms (like Perturb & Observe or Incremental Conductance) and higher efficiency components

CONCLUSIONS:

This work demonstrates an effective solar MPPT system using a SEPIC converter controlled by a microcontroller. The system successfully maintains a constant output voltage and maximizes power extraction under varying environmental conditions. The proposed design is cost-effective, efficient, and suitable for rural and remote electrification applications. It highlights the importance of integrating power electronics with embedded systems for renewable energy solutions.

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