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Simulation and Hardware Implementation of MPPT for Solar PV System

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Abstract
This project presents the hardware implementation of a Maximum Power Point Tracking (MPPT) system for a solar photovoltaic (PV) panel. A hardware prototype was developed using a PIC16F72 microcontroller and a boost converter to charge a 12 V battery from a 12 V, 3 W PV module. The system measures the PV module voltage and battery voltage through resistive voltage dividers and computes the appropriate PWM duty cycle to extract maximum power from the PV module.
The experimental results demonstrate the practicality of implementing a low-cost P&O-based MPPT controller using an 8-bit PIC microcontroller for standalone solar battery charging applications while highlighting the limitations of the conventional P&O algorithm under non-uniform irradiance conditions.

Keywords: MPPT, Solar PV, Perturb and Observe, Partial Shading.
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1. Introduction
Renewable energy technologies, particularly solar photovoltaic (PV) systems, have emerged as an effective solution to address the growing demand for electricity while reducing environmental impacts. The power–voltage (P–V) characteristic of a PV module is inherently nonlinear, and its maximum power output is obtained at a unique operating point known as the Maximum Power Point (MPP). Since the location of the MPP changes continuously with variations in solar irradiance and temperature, Maximum Power Point Tracking (MPPT) algorithms are essential for maintaining optimal power extraction.
Conventional MPPT techniques, including Perturb and Observe (P&O) and Incremental Conductance (INC), provide satisfactory performance under steady and uniform irradiance conditions. However, under partial shading caused by clouds, surrounding buildings, or trees, the P–V characteristic exhibits multiple local power peaks. As a result, these conventional methods may converge to a local maximum instead of the Global Maximum Power Point (GMPP), leading to significant power losses ranging from 20% to 70% [1], [2].
To overcome this limitation, metaheuristic optimization techniques such as Particle Swarm Optimization (PSO) have been proposed. Owing to their global search capability, PSO-based methods can avoid local optima and effectively identify the GMPP under partial shading conditions [3], [7].
This paper presents the design and implementation of a solar battery charger incorporating an MPPT controller based on the PIC16F72 microcontroller. The hardware implementation utilizes a 12 V, 3 W monocrystalline PV module, a boost converter, voltage sensing circuits, and the conventional P&O MPPT algorithm. In addition, MATLAB/Simulink models are developed to evaluate the performance of P&O under uniform irradiance, varying irradiance, and partial shading conditions using a 50 W PV

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module. The simulation results are used to assess the tracking capability of the algorithm under different operating environments.

2. Solar MPPT System

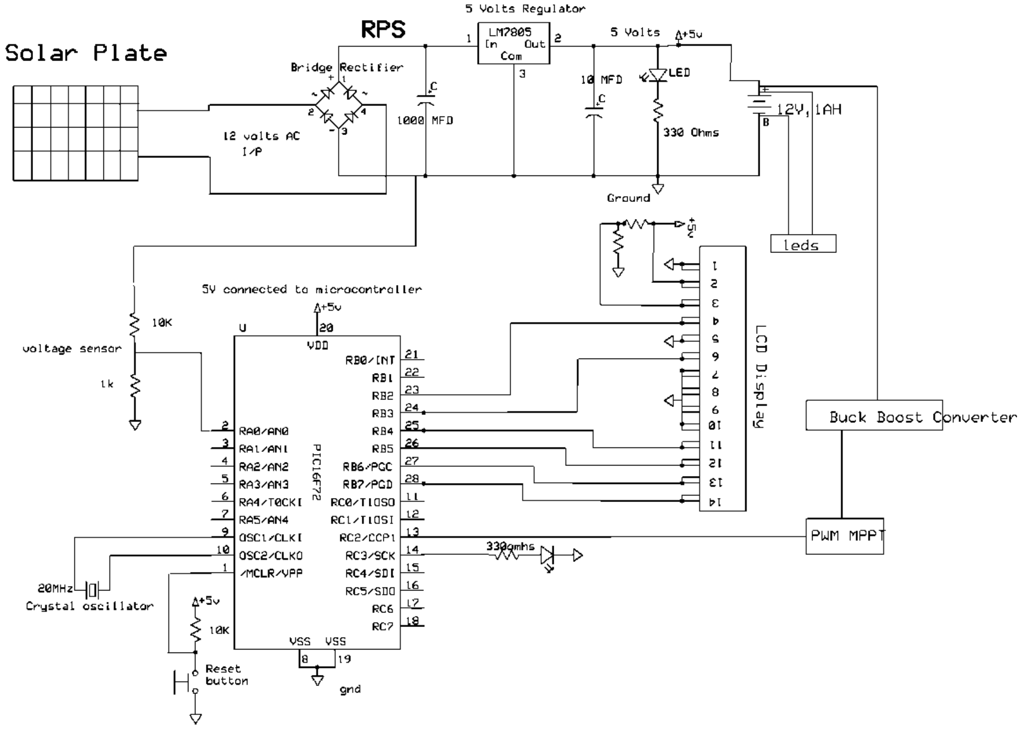

Fig 1 Schematic diagram of solar MPPT System

Figure 1 presents the schematic diagram of the solar photovoltaic (PV)-based Maximum Power Point Tracking (MPPT) system, illustrating the complete interconnection of all hardware components. The solar PV panel serves as the input power source, and its output voltage is measured using a voltage sensing circuit consisting of a resistor divider network with 10 kΩ and 900 Ω resistors. This network scales the PV voltage to a level compatible with the 5 V analog-to-digital converter (ADC) input of the microcontroller.

A regulated power supply (RPS) provides a stable DC supply to the control circuitry. It consists of a 12 V AC single-phase input, a bridge rectifier, a 1000 µF filter capacitor, and an LM7805 voltage regulator, which generates a regulated 5 V DC output to power the PIC16F72 microcontroller, LCD module, and other control components.

The PIC16F72 microcontroller acts as the central controller of the MPPT system. Its input/output ports interface with the voltage sensing circuit, LCD display, LED indicators, and the PWM control input of the SEPIC converter. Based on the measured PV voltage, the microcontroller executes the MPPT algorithm and generates the required PWM signal to regulate the converter duty cycle, thereby ensuring continuous operation at the maximum power point. A 20 MHz crystal oscillator provides a stable clock source for accurate program execution, while a reset push button allows manual system initialization whenever required.

The 16 × 2 LCD module is connected to the designated data and control pins of the microcontroller through a 330 Ω current-limiting resistor. It continuously displays real-time system parameters such as PV voltage, current, and operating status. The PWM output generated by the microcontroller is applied to the gate driver of the SEPIC converter, enabling effective duty-cycle control and maximum power extraction from the solar PV panel.

3. Hardware Implementation

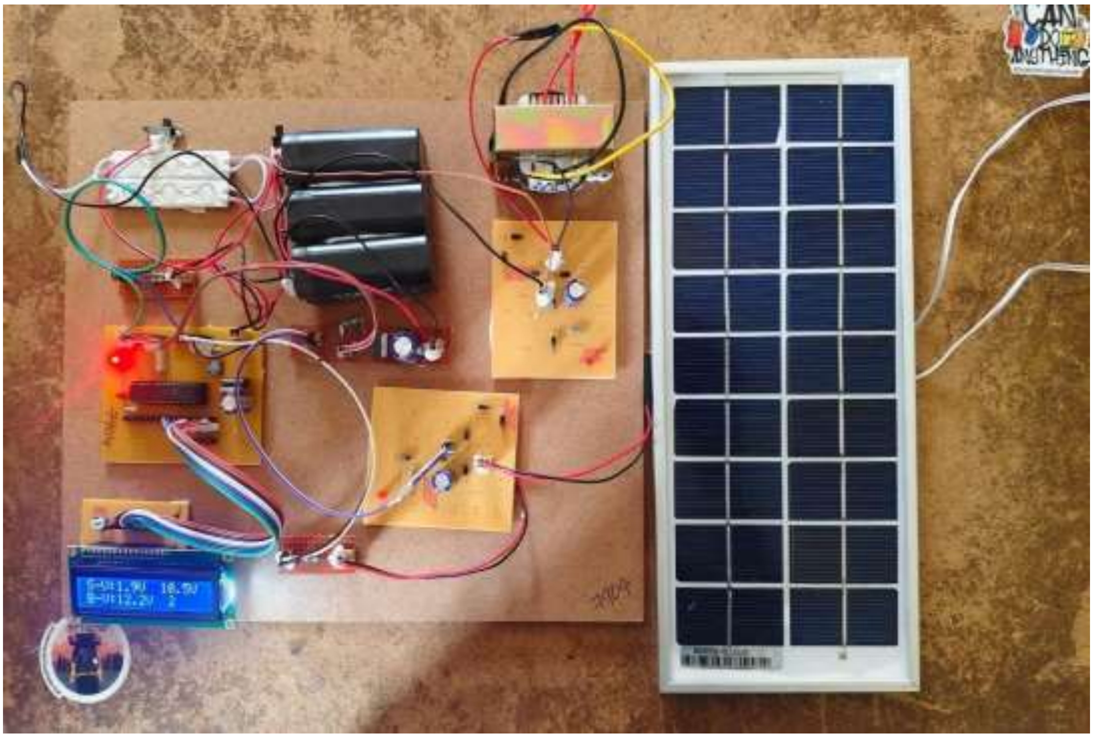

Fig 2 Hardware model Prototype Model of the Solar PV based MPPT System

The hardware prototype was tested under varying outdoor illumination conditions to evaluate the performance of the P&O MPPT algorithm with the Buck-Boost converter across different irradiance levels. Under Full Sun conditions at 1000 W/m², the solar panel produced a voltage of 12.4V, and the converter successfully regulated the output to 12.9V, confirming effective MPPT operation at peak irradiance. As irradiance decreased to 600 W/m² under partial shade and further to 300 W/m² under low irradiance, the panel voltage dropped to 10.1V and 7.8V respectively, while the converter maintained regulated output voltages of 12.6V and 12.2V, demonstrating the ability of the MPPT algorithm to continuously track and extract maximum available power.

Under the most challenging overcast condition at 150 W/m², the panel voltage fell to 5.5V, yet the converter still delivered a stable output of 11.8V, validating the effectiveness of the Buck-Boost topology in stepping up low input voltages. The LCD display provided accurate voltage readings with a measurement error of ±0.1V throughout all test conditions, confirming the reliability of the sensing and display circuitry. Overall, the results demonstrate that the proposed MPPT system maintains stable and consistent output voltage regulation across a wide range of irradiance conditions, successfully validating the hardware implementation.

TABLE 1: Performance of the P&O MPPT algorithm with the Buck-Boost converter Under Varying Irradiance

Test Condition	Irradiance (W/m²)	Panel Voltage (V)	Output Voltage (V)
Full Sun	1000	12.4	12.9

Partial Shade	600	10.1	12.6
Low Irradiance	300	7.8	12.2
Overcast	150	5.5	11.8

4. Conclusion

In this paper hardware implementation of a Maximum Power Point Tracking (MPPT) system for a solar photovoltaic (PV) panel is done and was tested under varying outdoor illumination conditions to evaluate the performance of the P&O MPPT algorithm with the Buck-Boost converter across different irradiance levels.

Hardware implementation using a PIC microcontroller enabled real-time PWM control, sensor monitoring and LCD display, with measurement results confirming reliable performance across varying irradiance levels. Overall, the system provides a practical and cost-effective solution for solar energy utilization, promoting clean energy adoption and laying a strong foundation for future enhancements using advanced control strategies.

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