Designing of MPPT Solar Charge Controller using Arduino

19EEE381-OPEN LAB

Report

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Amrita School of Engineering

Department of Electrical and Electronics Engineering

Program Educational Objectives (PEOs)

PEO1: Graduate can demonstrate electrical and electronics engineering problem solving skill along with proficiency in communication and professional excellence in project management and execution.

PEO2: Graduate can be employable in engineering services including ICT enabled sectors and also motivated for entrepreneurship.

PEO3: Graduate will be competent for higher studies in world class universities and research in industrial organizations.

PEO4: Graduate will manifest social commitment, environmental awareness and moral and ethical values in professional and other discourses.

Program Specific Outcomes (PSOs)

PSO1: Build and manage electro dynamic systems using Knowledge on electrical technology and semiconductor devices for allied services.

PSO2: Use computational tools and network dynamics for design, analysis and control of power systems integrated with renewable energy and Electric Vehicle.

PSO3: Leverage digital technologies employing state-of- the art control techniques and embedded controllers for industrial applications.

BONAFIDE CERTIFICATE

This is to certify that the open lab project report entitled **"**Designing of MPPT Solar Charge Controller using Arduino**",**
submitted by

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is in partial fulfillment of the requirements for the award of the **Degree of Bachelo**r **of Technology** in **"Electrical and Electronics Engineering"** is a bonafide record of the work carried out at Amrita School of Engineering, Coimbatore.

Internal Examiner External Examiner

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ABSTRACT

Maximum Power Point Tracking (MPPT) solar charge controllers play a vital role in optimizing solar energy utilization by ensuring efficient power transfer from photovoltaic panels to battery storage systems. This project involves the design and implementation of an MPPT solar charge controller using an Arduino Nano and a buck converter to regulate the charging process. By dynamically adjusting the operating point of the solar panel, the controller maximizes power extraction, enhancing overall system efficiency.

The Perturb and Observe (P&O) algorithm is employed to continuously track the maximum power point, adjusting the duty cycle of the converter accordingly. The system incorporates voltage and current sensing circuits, allowing real-time monitoring of power flow. MOSFET-based switching is used for efficient power conversion, ensuring minimal losses. The integration of a battery protection mechanism safeguards against overcharging and deep discharge, improving battery lifespan and reliability.

This implementation enables improved energy harvesting, making it well-suited for solar power applications requiring stable and efficient charging. By effectively managing power conversion, the MPPT controller enhances energy utilization while maintaining system stability.

INTRODUCTION

Solar energy is a widely utilized renewable energy source, with photovoltaic (PV) systems playing a crucial role in power generation. However, the efficiency of solar power extraction is significantly affected by environmental factors such as temperature and irradiance. To maximize energy utilization, Maximum Power Point Tracking (MPPT) algorithms are employed to dynamically adjust the operating point of the PV panel, ensuring optimal power transfer to the load or storage system.

MPPT charge controllers are essential in battery-based solar systems, where maintaining efficient charging is critical for long-term performance and reliability. The power conversion stage typically involves a buck converter, which steps down the panel voltage to match the battery charging requirements while minimizing losses. The Arduino Nano serves as the central processing unit, implementing the Perturb and Observe (P&O) MPPT algorithm, which continuously adjusts the duty cycle of the buck converter to track the maximum power point.

Efficient power conversion in MPPT controllers relies on high-frequency switching using MOSFETs, combined with current and voltage sensing circuits for real-time feedback. Proper regulation of power flow prevents overcharging and deep discharge, thereby extending battery life and enhancing system stability.

By implementing an MPPT solar charge controller, the efficiency of solar energy harvesting is significantly improved, making it well-suited for applications in standalone solar systems, off-grid power solutions, and renewable energy-based battery storage systems.

PROBLEM STATEMENT

Photovoltaic (PV) systems are inherently affected by variations in sunlight intensity and temperature, leading to fluctuations in the power output of solar panels. Without an efficient power management system, a significant portion of the available energy remains underutilized, reducing the overall efficiency of solar energy harvesting. Conventional charge controllers operate at a fixed voltage, failing to adapt to changing environmental conditions, which results in suboptimal charging of batteries and increased power losses.

To address this issue, a Maximum Power Point Tracking (MPPT) solar charge controller is required to dynamically adjust the operating point of the PV panel for maximum power extraction. The system must efficiently regulate the power flow using a buck converter, controlled by an Arduino Nano, and implement a real-time MPPT algorithm to optimize energy conversion. Additionally, ensuring safe battery charging with overcharge and deep discharge protection is essential for enhancing system reliability and longevity.

This project aims to design and implement an MPPT-based solar charge controller that improves energy conversion efficiency, optimizes battery charging, and ensures stable operation under varying environmental conditions.

METHODOLOGY

Solar Power Input Block

The solar panel serves as the primary power source, converting sunlight into DC electricity. However, due to varying solar irradiance and temperature, the panel's output voltage and current fluctuate, affecting power generation efficiency.

Voltage and Current Sensing:

- A voltage divider circuit steps down the solar panel voltage for measurement by the Arduino Nano's ADC.
- A current sensor (ACS712 or shunt resistor with an op-amp) measures the real-time current drawn from the panel.

Power Computation:

The Arduino Nano calculates power ($P = V \times I$) and continuously monitors the panel's operating point.

The sensed parameters are used in the MPPT algorithm to determine the optimal duty cycle for the buck converter.

MPPT Control Block

MPPT Algorithm (Perturb and Observe - P&O Method)
The Perturb and Observe (P&O) algorithm is implemented to track the Maximum Power Point (MPP) dynamically.

- Measure: The solar panel voltage (Vpv) and current (Ipv) are read using sensors.

- Calculate Power: Compute $P_{pv} = V_{pv} \times I_{pv}$.

- Compare Power Change:

If power increases, perturbation (duty cycle change) continues in the same direction.

If power decreases, the direction of perturbation is reversed.

Adjust Duty Cycle: The Arduino Nano updates the PWM signal controlling the MOSFET in the buck converter.

This ensures real-time tracking of MPP, maximizing energy extraction from the solar panel.

Buck Converter Block
The buck converter steps down the solar panel voltage to an appropriate level for battery charging and load supply.

Buck Converter Operation:

- MOSFET Turn-On (Charging Phase):

The MOSFET is turned ON by the PWM signal.
Current flows through the inductor, storing energy.

- MOSFET Turn-Off (Discharging Phase):

The MOSFET is turned OFF, and the inductor releases its stored energy.
Current flows through the diode to the battery and load.

The output voltage is regulated based on the duty cycle (D):
Vo=D×VinV_{o} = D \times V_{in}Vo=D×Vin
where D is dynamically adjusted by the MPPT algorithm.

Battery Management Block
The battery serves as an energy storage unit, supplying power when the solar panel output is insufficient.

Battery Voltage Sensing: A voltage divider circuit measures battery voltage to prevent overcharging and deep discharge.

Protection Mechanisms:

- If battery voltage exceeds a set threshold, charging is stopped to prevent overcharging.
- If battery voltage drops too low, the load is disconnected to prevent deep discharge.

Load Management Block

The load (DC motor) is powered by either:

- Solar panel (when sufficient power is available)
- Battery (when solar power is insufficient or unavailable)

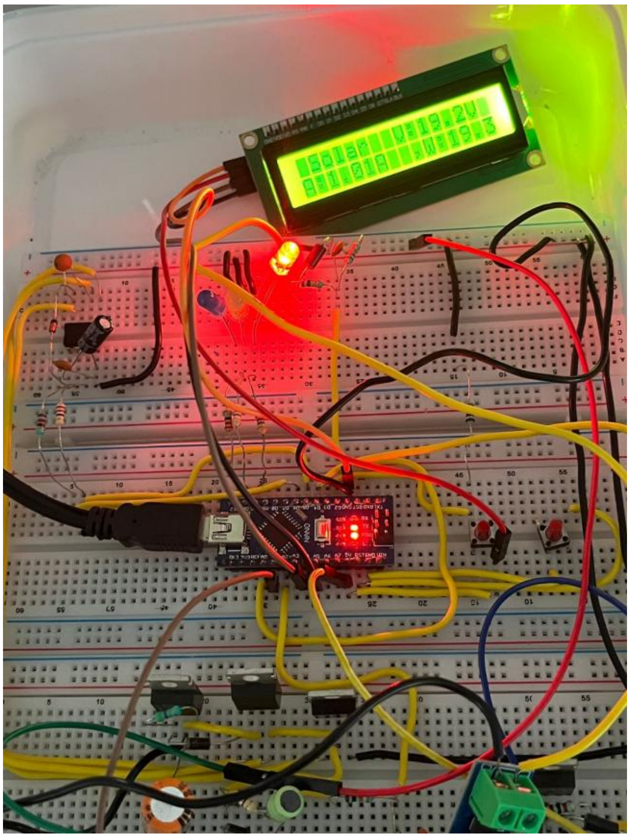
A MOSFET and transistor-based switching circuit ensures a seamless transition between solar and battery power sources.

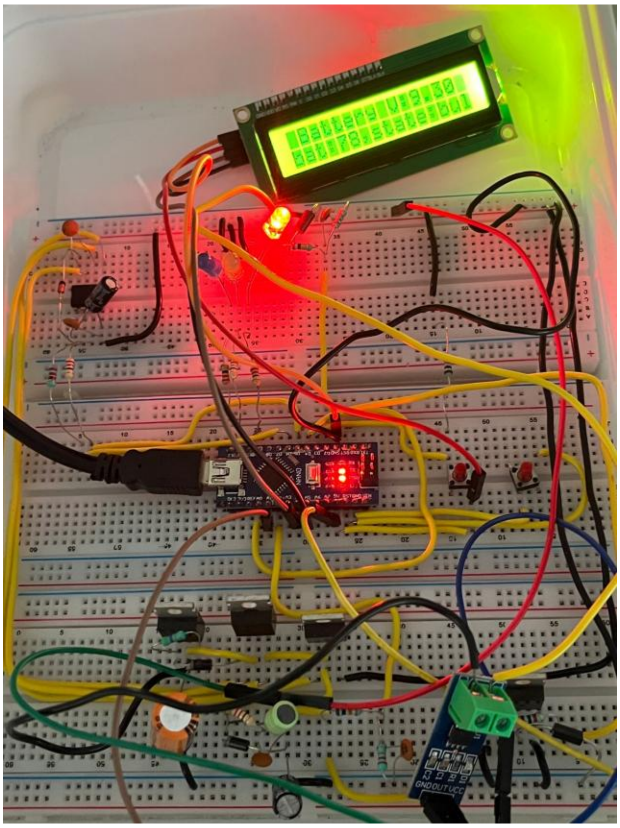
Controller Block (Arduino Nano for MPPT Implementation)

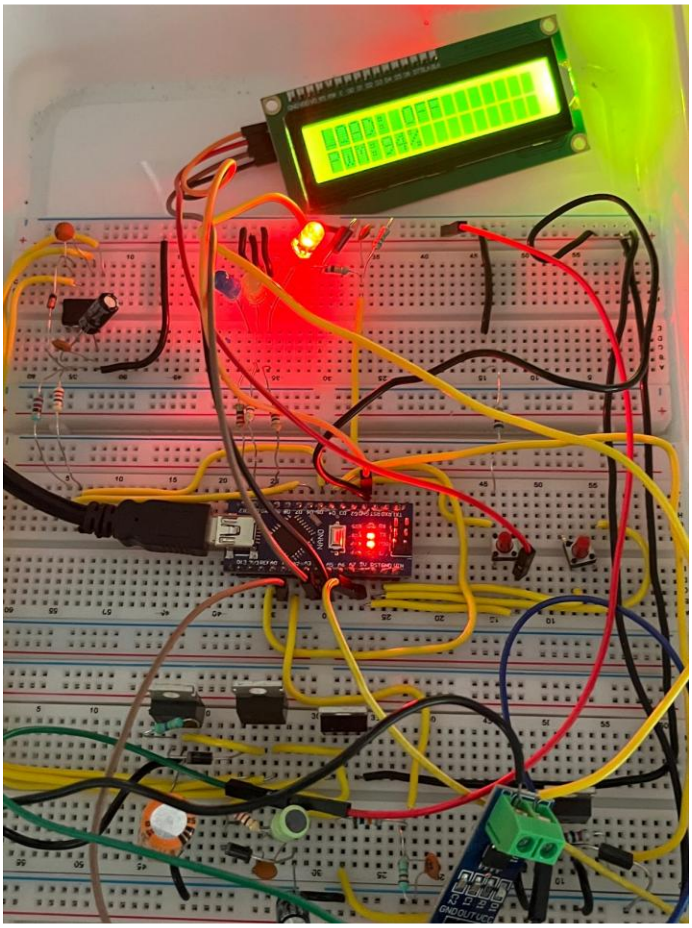
The Arduino Nano is responsible for:

- Reading voltage and current values from sensors
- Executing the MPPT algorithm to track the maximum power point
- Generating PWM signals for the buck converter
- Managing battery charging and protection
- Ensuring smooth load switching between solar and battery power

RESULTS



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CONCLUSIONS & FUTURE WORK

The implementation of an MPPT Solar Charge Controller using an Arduino Nano and a buck converter has successfully optimized the utilization of solar energy for battery charging and load supply. The Perturb and Observe (P&O) MPPT algorithm ensures maximum power extraction from the solar panel under varying environmental conditions. The buck converter efficiently steps down the voltage to charge the battery while ensuring stable output for the load. The system effectively manages power flow between solar, battery, and load, ensuring uninterrupted operation with minimal energy wastage.

Additionally, the system includes overcharge and deep discharge protection, enhancing battery lifespan and reliability. The load switching mechanism ensures seamless power delivery, prioritizing solar energy when available and switching to battery power when necessary.

Future Works

- **Advanced MPPT Algorithms:** Exploring machine learning-based or incremental conductance MPPT techniques for faster and more accurate tracking.

- **Bidirectional Power Flow:** Modifying the system to enable bidirectional energy transfer, allowing the battery to supply power back to the grid or other loads when needed.

- **Digital Signal Processing (DSP) Integration:** Utilizing high-performance microcontrollers or DSP-based control systems for precise real-time power regulation and load balancing.

- **Wireless Monitoring and Control:** Implementing IoT-based remote monitoring to track system performance and battery health via a mobile app or cloud platform.

- **Hybrid Energy Integration:** Extending the system to incorporate wind or other renewable energy sources for enhanced energy reliability.

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