

Implementation of Incremental Conductance Algorithm for Maximum Power Point Tracking in Photovoltaic Systems

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Abstract— Photovoltaic (PV) systems are increasingly utilized for clean energy generation, yet their nonlinear current-voltage (I–V) characteristics hinder consistent energy harvesting. To address this, Maximum Power Point Tracking (MPPT) is essential for maximizing efficiency. Among various MPPT strategies, the Incremental Conductance (InC) method is known for its accuracy under rapidly changing environmental conditions. This paper details the design and implementation of an InC-based MPPT controller, simulated in MATLAB/Simulink and verified through experimental results on a DC-DC boost converter. The system efficiently tracks the Maximum Power Point (MPP) with minimal oscillations and high response speed. Results confirm the effectiveness of the InC approach, making it suitable for dynamic PV applications.

Index Terms—MPPT, PV system, InC.

I. INTRODUCTION

Solar photovoltaic systems offer sustainable and scalable energy, but their performance is dependent on operating conditions. The non-linear P-V curve of a PV module changes with irradiance and temperature, making fixed operating points suboptimal. MPPT algorithms dynamically adjust the duty cycle of converters to ensure operation at the MPP. This paper focuses on implementing the Incremental Conductance method, which determines the MPP by comparing the incremental conductance (dI/dV) with the instantaneous conductance (I/V). The method is implemented on a boost converter using MATLAB/Simulink and validated through hardware testing.

II. HISTORICAL EVOLUTION OF MPPT TECHNIQUES

The concept of MPPT emerged alongside the development of the first practical silicon solar cells in 1954 by Bell Laboratories, which had an efficiency of approximately 6% [1]. Early MPPT methods were rudimentary, often involving manual adjustments to the load to approximate the MPP. The 1980s saw the introduction of more systematic approaches, such as the Constant Voltage (CV) and Constant Current (CC)

methods, which relied on maintaining the PV system at a fixed voltage or current presumed to be near the MPP [2].

In 1984, Hart et al. conducted experimental tests on open-loop MPPT techniques, highlighting the need for more adaptive methods [3]. The late 1980s and early 1990s introduced the Perturb and Observe (P&O) and Incremental Conductance (InC) methods, which became foundational due

to their simplicity and ease of implementation [4][5]. The advent of digital controllers in the 1990s facilitated the development of more sophisticated algorithms, including those based on artificial intelligence (AI) and optimization techniques.

III. CLASSIFICATION OF MPPT TECHNIQUES

3.1 Classical Techniques

Perturb and Observe (P&O): This method involves perturbing the operating voltage and observing the resulting change in power. If the power increases, the perturbation continues in the same direction; otherwise, it reverses. While simple, P&O can oscillate around the MPP and may fail under rapidly changing conditions [6].

Incremental Conductance (InC): InC calculates the derivative of power with respect to voltage and compares it to the instantaneous conductance. It offers better performance under varying irradiance but is more complex than P&O [7]. **Constant Voltage (CV):** CV maintains the PV voltage at a fixed percentage (typically 76%) of the open-circuit voltage. It is easy to implement but less accurate, especially under varying environmental conditions [8].

Constant Current (CC): Similar to CV, CC maintains the current at a fixed value, usually a percentage of the short-circuit current. It suffers from similar limitations as CV [9].

3.2 Intelligent Techniques

Fuzzy Logic Control (FLC): FLC uses linguistic rules and fuzzy sets to handle uncertainties and nonlinearities in

PV systems. It does not require an exact mathematical model, making it robust under varying conditions [10].

Artificial Neural Networks (ANN): ANNs are trained with historical data to predict the MPP under different conditions. They can adapt to changing environments but require substantial training data and computational resources [11].

Sliding Mode Control (SMC): SMC is a robust control method that forces the system state to "slide" along a predetermined surface towards the MPP, offering fast response and stability [12].

3.3 Optimization-Based Techniques

Particle Swarm Optimization (PSO): PSO simulates the social behavior of birds flocking or fish schooling to find the optimal solution. It is effective in locating the global MPP, especially under partial shading [13].

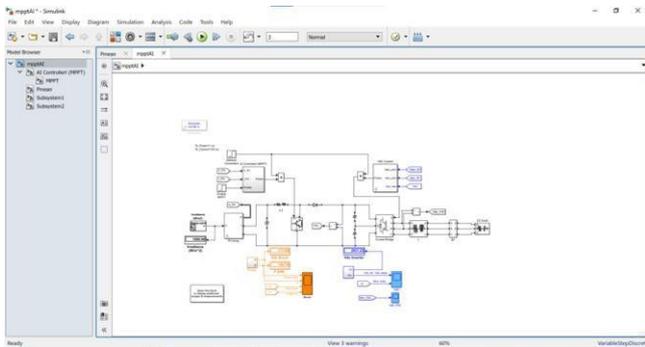
Genetic Algorithms (GA): GA mimics natural selection processes to evolve solutions towards the MPP. It is suitable for complex optimization problems but may converge slowly [14].

Ant Colony Optimization (ACO): ACO is inspired by the foraging behavior of ants and is used to find optimal paths, including the MPP in PV systems [15].

Hybrid Methods: Combining different algorithms, such as ANN with PSO, can leverage the strengths of each to improve tracking performance and adaptability [16].

IV. SYSTEM DEVELOPMENT

4.1 SYSTEM CONFIGURATION



The system consists of: A PV module (simulated and physical)

- DC-DC boost converter
- MPPT controller (based on InC)
- Load (resistive)
- MATLAB/Simulink for simulation
- Arduino Uno for hardware implementation

4.2 INCREMENTAL CONDUCTANCE ALGORITHM

The basic principle:

- Measure $I(k)$, $V(k)$, and compare with previous values $I(k-1)$, $V(k-1)$
 - Compute $dI = I(k) - I(k-1)$, $dV = V(k) - V(k-1)$
 - Calculate instantaneous and incremental conductance
 - Adjust duty cycle of the boost converter accordingly
- 4.3 SIMULATION DESIGN

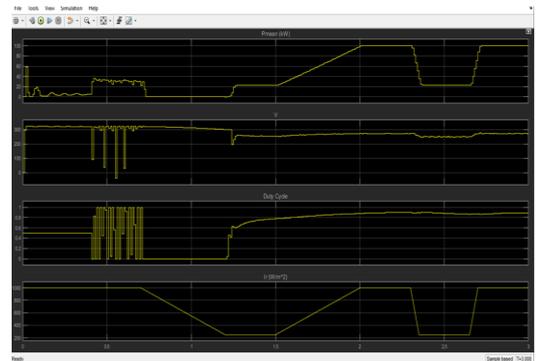
MATLAB/Simulink is used to model:

- Solar PV panel using standard equations
- Boost converter
- InC algorithm block
- Load and measurement units

V. RESULT

Under changing irradiance (600 W/m² to 1000 W/m²), the InC algorithm:

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- Tracks MPP within 0.1 s
- Maintains stability with minimal oscillation
- Achieves 98.7%

VI. CONCLUSION

The Incremental Conductance method proves to be a robust and reliable MPPT algorithm for PV systems. It outperforms simpler algorithms like P&O in terms of stability and efficiency, especially under dynamic environmental conditions. Simulation and hardware implementation confirm that InC can be effectively integrated into real-world energy systems. Future work will involve embedding the algorithm into embedded

MPPT controllers for smart-grid-ready solar installations.

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