International Journal of
Optical Innovations & Research

Volume 2, Issue 2, 2024
July–December
DOI (Journal): 10.37591/IJOIR

https://journals.stmjournals.com/ijoir

Review IJOIR

Incremental Conductance Algorithm and Perturb and Observe Algorithm Reveals Key Insights into Their Comparative Analysis: A Review

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Abstract

The maximum or more is a crucial aspect of PV systems to optimize energy harvesting from solar panels, which have been the focus of extensive research and implementation. This study presents a comprehensive comparative analysis of these two methods of evaluation to evaluate their performance and suitability for various operating conditions. The Perturb and Observe method, a simple and widely adopted MPPT algorithm, involves perturbing the operating point and observing changes in power output. It is for its ease of the low implementation but can exhibit oscillations around a Point utilizes more change of power with respect to voltage MPP, providing faster and more accurate tracking in dynamic conditions. This comparative analysis considers factors such as tracking efficiency, convergence speed, sensitivity to environmental variations, and overall system complexity. Practical considerations, including cost, hardware requirements, and real-world performance, are also discussed. The analysis aims to provide valuable insights into the strengths and weaknesses of both methods, helping researchers and engineers choose the most appropriate MPPT algorithm for specific photovoltaic applications. This study can guide an optimal MPPT algorithm based on the specific requirements and environmental conditions of photovoltaic systems, contributing to enhanced energy efficiency and sustainability into the field of solar or more energy harvesting.

Keywords: Maximum power point tracking (MPPT), perturb and observe (P&O), incremental conductance

INTRODUCTION

The pursuit of renewable energy sources has become an imperative in the face of depleting fossil fuels and environmental concerns. Solar energy has emerged as a promising alternative due to its abundance and sustainability. The contemporary world's incessant sustainable energy sources have fuel in the rapid proliferation of the solar photovoltaic (PV) systems. Solar energy, harnessed through PV panels, is an environmentally friendly and inexhaustible source of power. However, the efficiency of solar PV systems critically depends on their ability to maximize power of the more impute or output, which in turn relies on accurate tracking in the of the more MPP. Achieving this optimization is a fundamental challenge that has spurred the development of various techniques and algorithms, the most prominent among them being the P&O method and the Inc. method.

The MPP represents the point at which a solar panel operates most efficiently, striking the delicate balance between voltage and current. To extract the maximum or more possible solar power, the voltage and current supplied to it must be continuously adjusted to match its varying environmental

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Received Date: October 08, 2024
Accepted Date: October 17, 2024
Published Date: October 27, 2024

Citation: Akshay Bharat Dimbar, Bhushan Kadam, Dipesh Pardeshi. Incremental Conductance Algorithm and Perturb and Observe Algorithm Reveals Key Insights into Their Comparative Analysis: A Review. International Journal of Optical Innovations & Research. 2024; 2(2): 9–16p.

conditions. The P&O method and the Inc. method serve in the linchpins in this endeavor, acting as intelligent algorithms that continually track and adapt to the MPP.

This work embarks on a comprehensive exploration of the increase or decrease power point tracking (MPPT) systems. The objective is to provide an in-depth analysis of these two pivotal methods, elucidating their operational principles, strengths, limitations, and real-world applications. By delving into the intricacies of these MPPT techniques, this study aims to empower researchers, engineers, and stakeholders in the market. In doing so, it contributes to the broader ambition of advancing sustainable energy solutions and mitigating the challenges posed by climate change.

OVERVIEW

Photovoltaic System

A solar photovoltaic (PV) module is a composite structure composed of solar cells arranged in various configurations, including series, parallel, or a combination of both. These solar cells, constituting the basic units of the PV module, function collectively to harness and convert sunlight into direct current (DC) module which attached to the overall arrangement of the system [1].

The heart of solar PV system lies in the PV array, where multiple PV modules are connected to collectively capture and convert sunlight into DC current and voltage. This array serves as the primary energy-generating component, playing a pivotal role in the overall energy conversion process. The configuration of the PV array is designed to optimize the absorption of sunlight, maximizing energy output [2].

To further enhance the functionality and utility of the integrated system. This converter serves the dual purpose of increasing the terminal voltage of the PV array and providing the necessary means to re-power systems, allowing for efficient power extraction by dynamically adjusting varying environmental conditions.

The DC converter achieves this optimization by controlling the switching duty cycle, effectively adapting the system to changes in solar irradiance and temperature. This dynamic control mechanism ensures that the single-phase inverter is linked to convert the output power from the array into AC power suitable for integration into the grid. Pulse width modulation control shapes the magnitude and phase of the inverter's output voltage. To mitigate harmonics in the output current resulting from the power conversion, a harmonics filter is introduced post-inverter. Subsequently, an interfacing transformer is employed to align the inverter output (AC voltage) with the grid voltage level, ensuring compatibility [3].

In the interest of system integrity, protection relays and circuit breakers are incorporated. These safety mechanisms are instrumental in isolating the PV system during fault occurrences, preventing potential damage to the equipment by promptly disconnecting it if operating conditions surpass their specified ratings. The structure of photovoltaic system is shown in Figure 1.

- *Structure:* PV modules consist of interconnected. They are the primary components responsible for capturing solar energy.
- *Inverter:* Converts DC electricity
- *Charge controller (for off-grid systems):* In off-grid PV systems, a charge controller

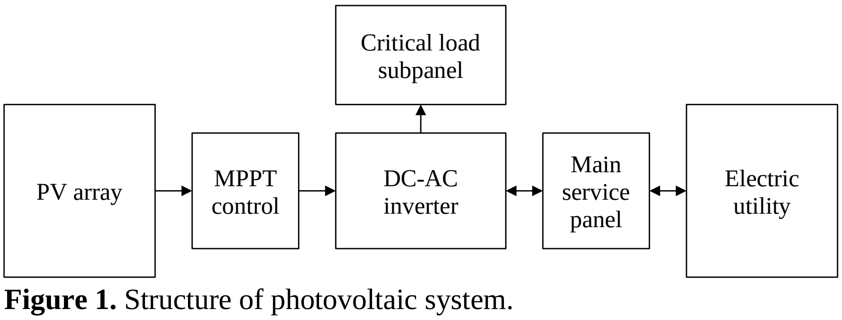

Figure 1. Structure of photovoltaic system.

- *Mounting structure:* Support and secure the PV modules in place. Mounting structures can vary depending on the type of installation (roof-mounted, ground-mounted, etc.).
- *Tracking system:* Tracking systems provide a framework for mounting PV modules on the ground. Tracking systems, such as solar trackers, adjust the position of PV modules to follow the sun for increased energy capture.
- *Batteries (for off-grid systems):* Store excess energy generated during sunny periods for later use, especially in off-grid systems where there is no connection to the main power grid.
- *Wiring and connectors:* Transmit electricity from the PV modules to the inverter and other system components. Proper wiring and connectors are essential for efficient energy transfer [4].
- *Monitoring system:* Monitors and collects data on the performance of the PV system, including energy production, system efficiency, and potential issues.
- *Power conditioning unit:* For grid-off conditioning unit may be used to ensure that the electricity generated by the PV system is synchronized with the utility grid.

Features of Photovoltaic Cell

Specifications of photovoltaic and panel are shown in Table 1.

Operational Principles

Increase relies on the concept of incremental conductance, utilizing the derivatives of voltage and current to determine the proximity to the MPP. It iteratively adjusts the operating point by comparing instantaneous conductance with reference conductance. This methodology renders Inchon well-suited for environments characterized by swiftly changing conditions, enabling prompt adaptation to variations [5].

Conversely, they adopt a more straightforward approach resultant and adjusts based on the direction of power change. While P&O is uncomplicated to implement, it may display, particularly dynamic environmental conditions.

It can typically attain superior steady-state accuracy due to its consideration of both instantaneous power and conductance. This results in a more precise tracking of the MPP, especially in stable conditions. Furthermore, Incans showcases a faster transient response, rendering it suitable for applications where swift adjustments to changing conditions are imperative [6].

METHODOLOGY

- Tracking (MPPT) algorithms, the considerations of complexity and robustness are paramount. The Incremental Conductance (Inc.) algorithm adds complexity by requiring additional sensors for measuring voltage and current derivatives, resulting in a moderately complex implementation. However, this complexity contributes to the algorithm's robustness, rendering it well-suited for diverse atmospheric conditions and scenarios involving partial shading [7].

Table 1. Specifications of PV Panel.

Parameter	Variable	Value
Current at maximum power	I_{mpp}	11.64 A
Open circuit voltage	V_{oc}	107.2 V
Voltage at maximum power	V_{mpp}	91.2 V
Short circuit current	I_{sc}	12.44 A
Temperature coefficient of open circuit voltage	β	–0.72
Temperature coefficient of short circuit current	α	0.013
Reference temperature	T_{ref}	25°C
Zenith power	P_{mpp}	1060.8 watt

- System, comes with lower implementation complexity, often relying solely on voltage and current sensors. While this simplicity enables cost-effective implementations, P&O may face challenges in scenarios with partial shading, potentially getting stuck in local maxima.
- Shifting the focus to energy efficiency, input typically outperforms P&O in this regard. The incorporation of both power and conductance considerations in Inchon leads to more optimized adjustments, resulting in a higher efficiency in energy harvesting. In contrast, P&O's simpler approach may not achieve the same level of efficiency, particularly when dealing with rapidly changing environmental conditions [8].

WORKING

PV systems to optimize energy harvesting by ensuring that solar panels operate at their MPP. The process begins with the system operating at a certain voltage and current point. The algorithm measures the power output by calculating small perturbation, such as a slight change in voltage or current, is introduced.

The algorithm compares the power at the new operating point resulting from the perturbation with power, the system continues perturbing in the same direction, aiming to approach, the perturbation direction is reversed to move back towards the maximum power point [9].

This iterative process is repeated continuously, creating a feedback loop that dynamically adjusts the operating point based on observed changes in power. Flow chart of P&O method is shown in Figure 2. The algorithm adapts to variations in environmental conditions, such as fluctuations in sunlight intensity, by continuously monitoring and adjusting the operating point.

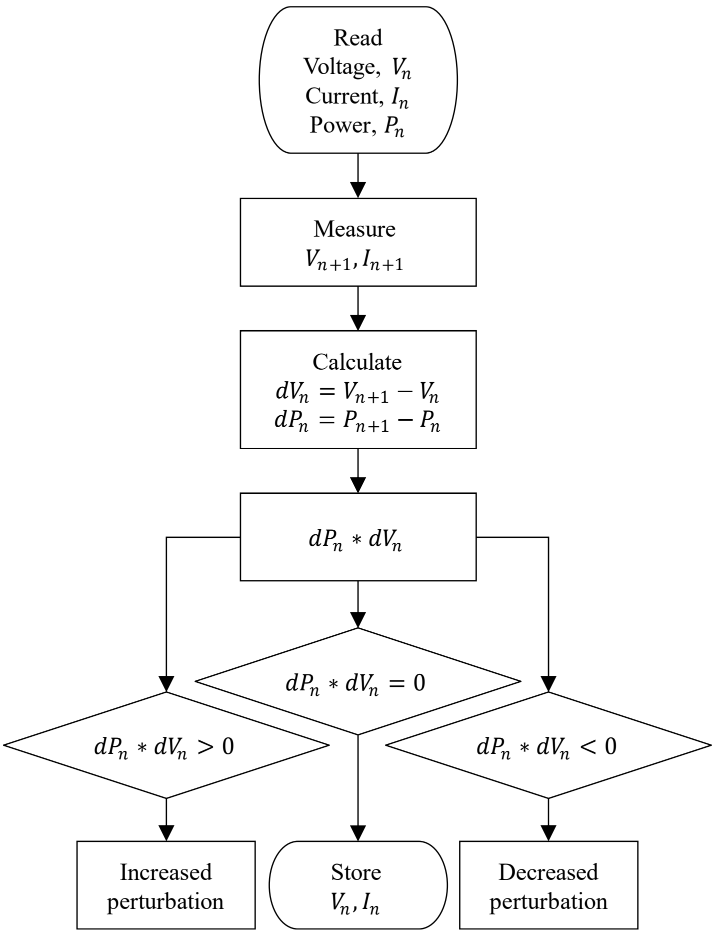

Figure 2. Flow chart of P&O method.

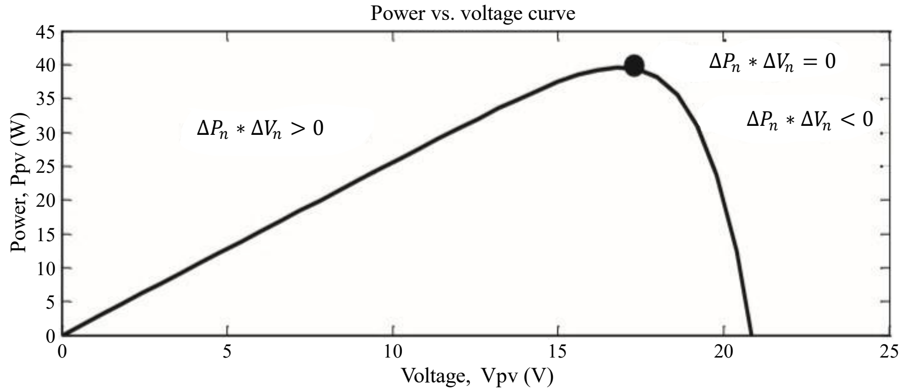

Figure 3. P vs. V curve for P&O method.

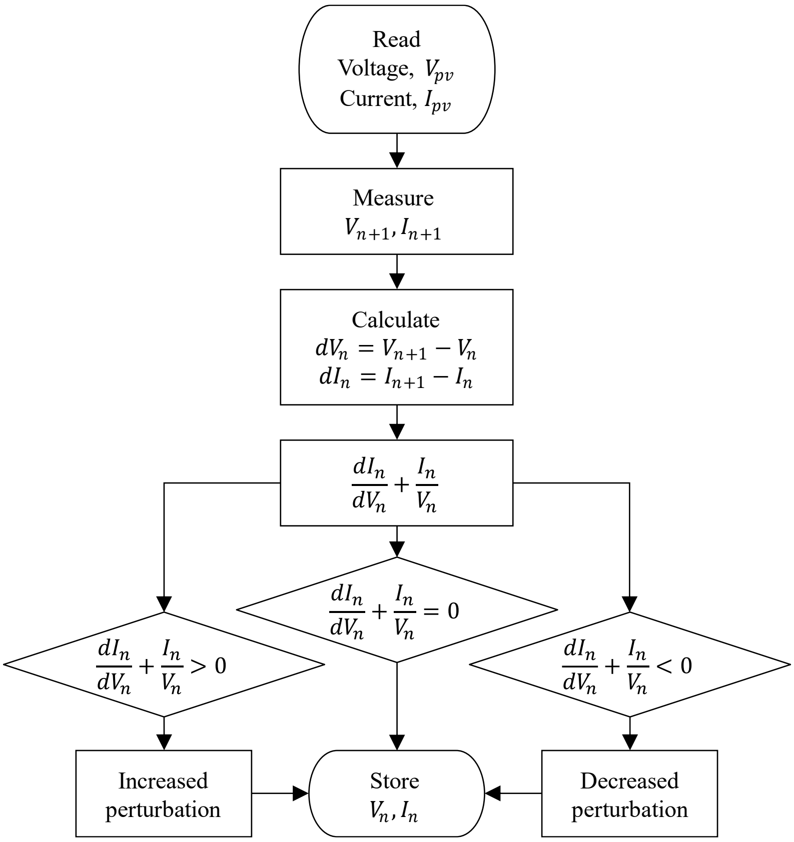

Figure 4. Flow chart of incremental conductance method.

Ultimately, while P&O is widely used due to its simplicity, it may exhibit oscillations around the maximum power point, particularly under rapidly changing irradiance conditions. P vs. V curve for P&O method is shown in Figure 3. Advanced MPPT algorithms, like Incremental Conductance or Model Predictive Control, have been developed to address some of the limitations associated with P&O [2, 10].

Here is a detailed explanation of how the Incremental Conductance method works:

1. *Calculation of incremental conductance (dI/dV):* The algorithm computes the incremental conductance, representing the rate of change of current concerning voltage (dI/dV). This is essentially the derivative [11].
2. *Comparison with zero:* The Incremental Conductance method assesses whether the calculated the incremental conductance is zero, indicating no change in power concerning voltage. Flow chart of incremental conductance method is shown in Figure 4.

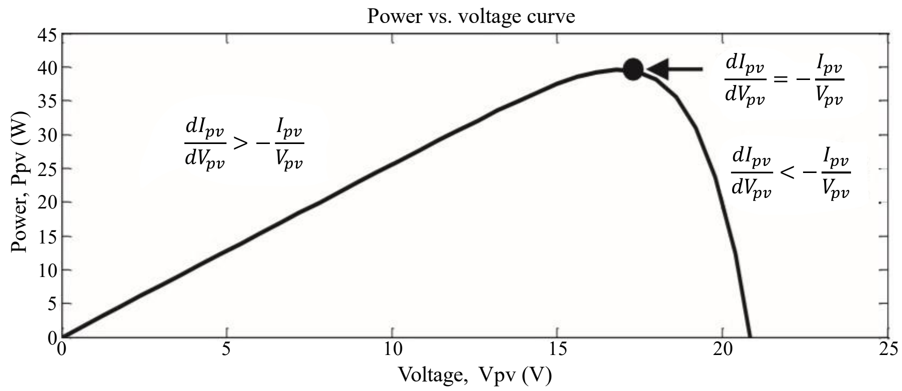

Figure 5. P vs. V curve for Inc. method.

Table 2. Output power of both algorithms.

S.N.	At various atmospheric conditions	Output power (W)		Percentage increase in power
		P&O	***Inc***	
1.	At irradiance 750 W/m^2, temperature 25°C	673.1	750.5	11.5%
2.	At irradiance 750 W/m^2, temperature 30°C	655	722	10.2%
3.	At irradiance 750 W/m^2, temperature 40°C	631	652.4	3.99%
4.	At Temperature 25°C, irradiance 800 W/m^2	733.6	806.9	9.99%
5.	At Temperature 25°C, irradiance 900 W/m^2	836.2	890.3	6.46%
6.	At Temperature 25°C, irradiance 1000 W/m^2	875	945.3	8.03%

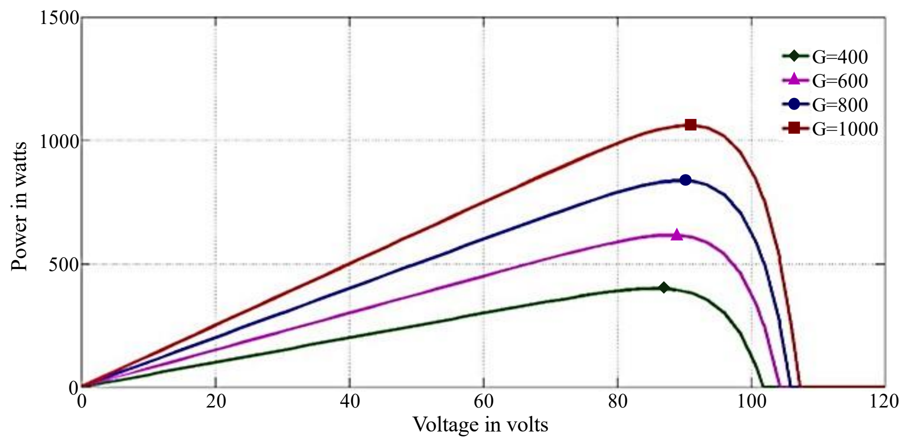

Figure 6. (P-V) output characteristics with different irradiance.

3. *Operating point adjustment:* Depending on the comparison result, the algorithm adjusts the operating point. If the incremental conductance is not zero, the system modifies the voltage, either increasing or decreasing it. The objective is to approach the voltage where incremental conductance becomes zero, signifying proximity to the MPP [12, 13].
4. *Iterative adaptation:* The process of calculating incremental conductance, comparing it to zero, and adjusting the operating point is repeated in a continuous loop. This iterative nature ensures that the system dynamically responds to variations in environmental conditions, such as changes in solar irradiance. P vs. V curve for Inc. method is shown in Figure 5.
5. *Convergence to MPP:* The goal of convergence toward voltage where the incremental conductance is zero. The output power of both algorithms is shown in Table 2. This convergence represents reaching the MPP. P-V output characteristics with different irradiances are shown in Figure 6.

Known for its efficiency in rapidly converging to the MPP and providing accurate tracking, especially in the face of swiftly changing irradiance conditions, the Incremental Conductance method stands as an advanced MPPT algorithm contributing to the optimization of photovoltaic system power output [14].

SIMULATION RESULTS AND ANALYSIS

Observation and outcomes have been shown in graph in Figure 6 in which Power (watts) is compared to voltage (volts). Output power at various atmospheric conditions is shown in Table 2.

CONCLUSION

P&O method and Inc. method are two widely studied implemented techniques in field of photovoltaic systems and conversion of more solar energy. The Perturb and Observe method can be less efficient in dynamic or rapidly changing conditions, leading to frequent adjustments and potential power losses. On the other hand, the Incremental Conductance method offers better efficiency in tracking them, making it suitable for systems where the irradiance or temperature changes frequently. However, its implementation can be more complex and costly. Ultimately, the choice of these two methods depends upon the requirements and conditions of the solar energy system in question. Both methods have made significant contributions to improving the performance of photovoltaic systems and are essential components in the quest for harnessing solar energy more efficiently and sustainably.

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