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# Simulation-Based Performance Comparison of Perturb and Observe and Particle Swarm Optimization MPPT Algorithms for Photovoltaic Systems

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**Abstract:** ***In this paper, a comparative study is conducted between two MPPT methods: Perturb and Observe (P&O) and Particle Swarm Optimization (PSO) algorithms for photovoltaic (PV) solar energy harvesting. MATLAB/Simulink was used to develop PV models of 50W cells to simulate the P&O algorithm at uniform irradiance and PSO under partial shading and varying irradiance levels. Results demonstrate that although P&O performs well at uniform irradiance (~88% efficiency), it fails to track the global maximum power point (MPP) under partial shading. PSO, on the other hand, successfully determines the global MPP under partial shading conditions, achieving ~95% tracking efficiency.***

**Keywords:** Perturb and Observe, Particle Swarm Optimization, Partial Shading Conditions

## 1. Introduction

The growing demand for clean and sustainable energy has led to the widespread adoption of solar photovoltaic (PV) systems as an effective renewable energy source. Owing to the nonlinear power–voltage (P–V) characteristics of PV modules, the operating point corresponding to the Maximum Power Point (MPP) varies continuously with changes in solar irradiance and temperature. To ensure maximum energy extraction under varying environmental conditions, Maximum Power Point Tracking (MPPT) algorithms are employed.

Conventional MPPT techniques, such as Perturb and Observe (P&O) and Incremental Conductance (INC), provide satisfactory performance under uniform irradiance conditions. However, under partial shading caused by clouds, trees, or nearby structures, multiple local maxima appear on the P–V curve, making it difficult for these methods to identify the Global Maximum Power Point (GMPP) and resulting in significant power losses ranging from 20% to 70% [1], [2].

To overcome these limitations, metaheuristic optimization techniques such as Particle Swarm Optimization (PSO) have been widely adopted because of their ability to perform global searches and avoid convergence to local maxima [3], [4]. This paper presents the performance of P&O and PSO algorithms under both uniform irradiance and partial shading conditions.

## 2. Block Diagram

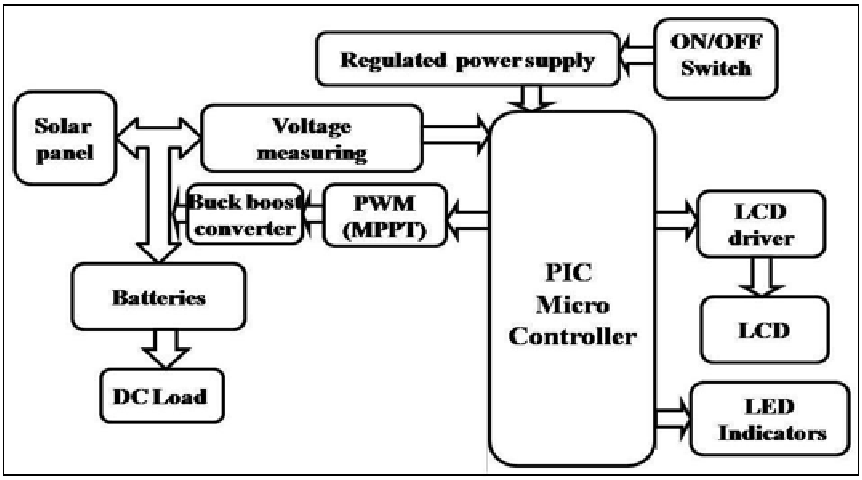


**Figure 3:** Block Diagram of Solar MPPT

Fig. 1 illustrates the block diagram of the solar PV based MPPT system, with the PIC Microcontroller serving as the central processing unit that coordinates all system operations. The solar panel feeds the generated voltage to the voltage measuring block, which continuously senses and forwards the

PV voltage and current signals to the PIC microcontroller for real-time processing.

Based on the sensed values, the microcontroller executes the P&O MPPT algorithm and generates the appropriate PWM signals, which are applied to the Buck-Boost converter to regulate the duty cycle and ensure maximum power extraction from the solar panel.

The converter output is then used to charge the batteries and supply the connected DC load, ensuring efficient and continuous power delivery. The regulated power supply, controlled by an ON/OFF switch, powers the entire control circuitry, while the output side includes an LCD driver, LCD display, and LED indicators driven by the PIC microcontroller to provide real-time visual feedback of system parameters such as voltage, current, and operating status.

## 3. Simulation Results

All simulations were performed in the MATLAB/Simulink environment using the single-diode photovoltaic (PV) model under Standard Test Conditions (STC), with an irradiance of 1000 W/m² and a cell temperature of 25°C. The performance of two Maximum Power Point Tracking (MPPT) techniques, namely Perturb and Observe (P&O) and Particle Swarm Optimization (PSO), was investigated using both Boost and SEPIC DC–DC converter topologies. The simulation results include the PV array characteristics, MPPT tracking performance, comparative evaluation of the algorithms, under different irradiance conditions.

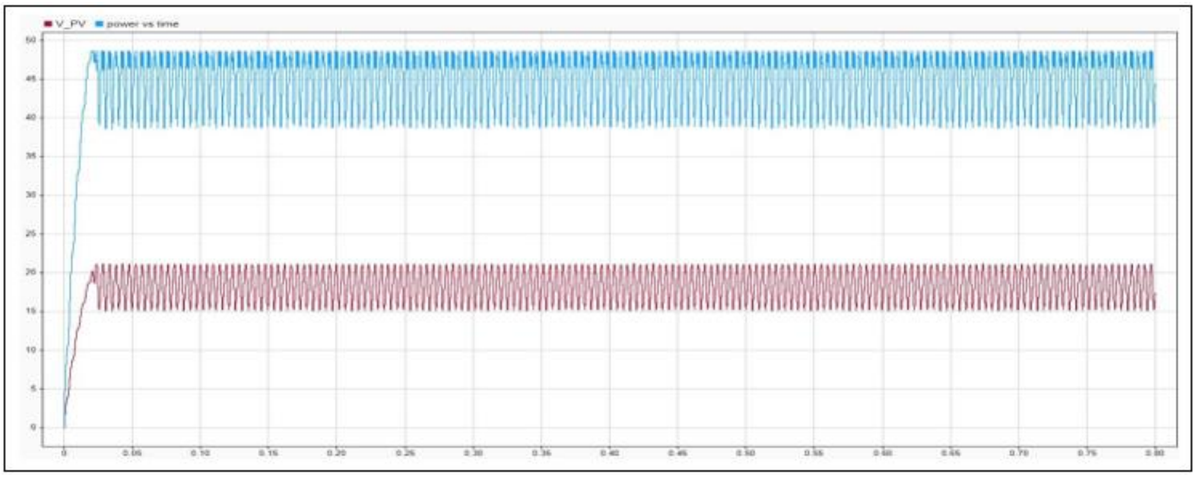


**Figure 2:** Vmax and Pmax Vs Time in Boost Converter under an irradiance of 1000 W/m² using the Perturb and Observe (P&O) algorithm

At the beginning of the simulation, both the PV voltage and output power increase rapidly from zero during the initial transient period (0–0.05 s), as the P&O algorithm perturbs the converter duty cycle to locate the maximum power point (MPP). After approximately 0.05 s, the system reaches steady-state operation. The PV voltage stabilizes within a range of approximately 16 V to 21 V, while the output power varies between 40 W and 48 W.

A key observation from the figure is that the P&O algorithm exhibits continuous oscillations around the maximum power point (MPP) throughout the simulation due to its inherent perturbation mechanism. As a result, the operating point never settles exactly at the MPP, causing periodic fluctuations in voltage and power and leading to a small but unavoidable power loss. The average tracked power is approximately 44 W, compared to the theoretical maximum of 50 W at 1000 W/m², corresponding to a tracking efficiency of about 88%. Although the P&O algorithm is simple and computationally efficient, its persistent steady-state oscillations reduce tracking accuracy and overall energy conversion efficiency, highlighting the need for advanced MPPT techniques or improved converter topologies to achieve better performance.

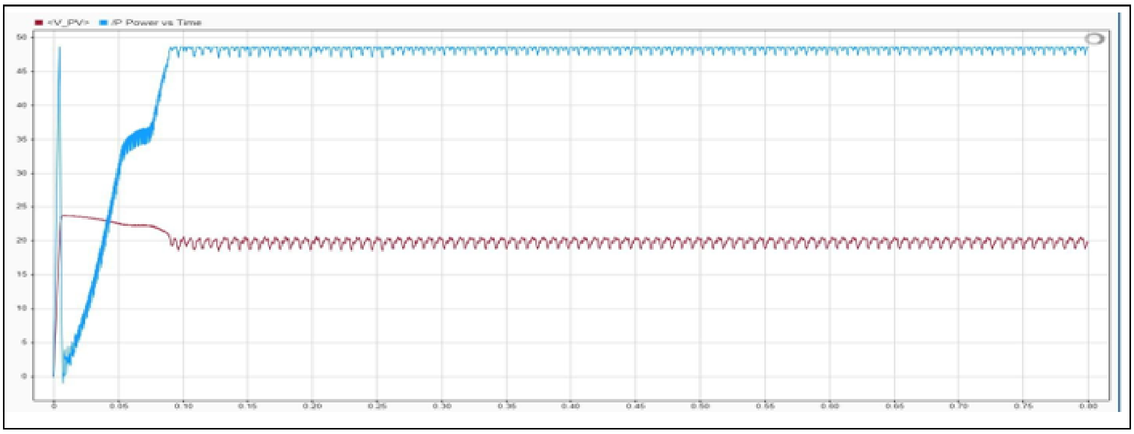

**Figure 3:** Vmax and Pmax Vs Time in Sepic Converter



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**Figure 3** illustrates the simulation results of the **SEPIC converter-based MPPT system** at **1000 W/m²** irradiance using the **Perturb and Observe (P&O)** algorithm. Following a brief transient period (0–0.10 s), the PV voltage stabilizes at approximately **19–20 V**, while the output power settles between **50–52 W**, closely matching the theoretical maximum power of the PV array. Compared to the Boost converter, the SEPIC converter exhibits reduced steady-state oscillations, improved tracking accuracy, and enhanced stability, achieving an average tracking efficiency of approximately **95%**. These results demonstrate the superior MPPT performance and higher power conversion efficiency of the SEPIC converter under standard operating conditions.

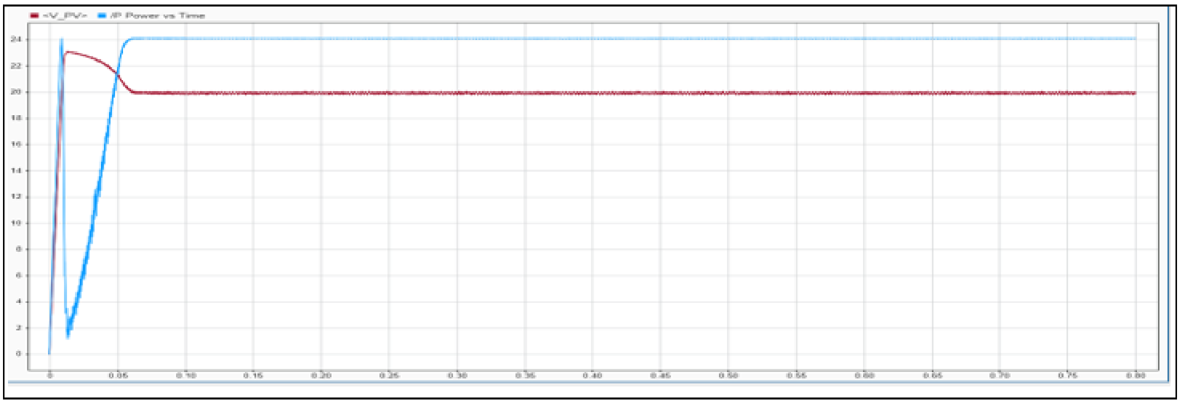

**Figure 4:** Vmax and Pmax Vs Time in Sepic Converter With 500 W/M²

**Figure 4** shows the simulation results of the SEPIC converter-based MPPT system operating at **500 W/m²** irradiance using the **P&O** algorithm. Following a brief transient period (0–0.05 s), the algorithm successfully tracks the maximum power point, with the PV voltage stabilizing at approximately **20 V** and the output power at around **24 W**. The steady and ripple-free response throughout the simulation confirms the effective tracking capability, stability, and adaptability of the P&O-based SEPIC converter under reduced irradiance conditions.

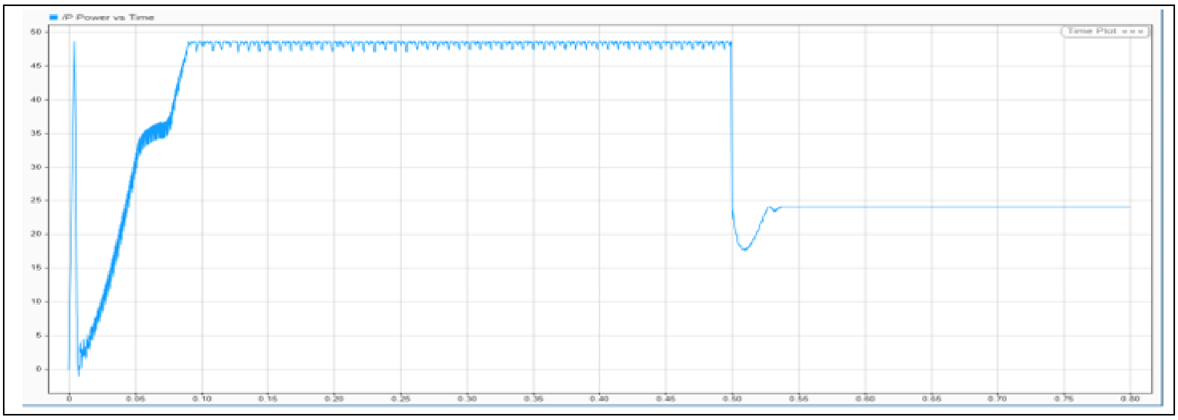

**Figure 5:** Pmax Vs Time in Sepic Converter with Sudden change in irradiance

**Figure 5** illustrates the **Pmax** versus time response of the SEPIC converter under a sudden change in irradiance using the **Perturb and Observe (P&O)** MPPT algorithm. Initially, the output power rises from zero and stabilizes at approximately **50 W** after **0.10 s** under **1000 W/m²** irradiance. At **0.50 s**, the irradiance is abruptly reduced to **500 W/m²**, causing the output power to drop to about **18 W**. The P&O algorithm quickly re-tracks the new maximum power point and restores the output power to approximately **24–25 W** within **0.05 s**, where it remains stable. These results demonstrate the fast dynamic response, robustness, and effective tracking capability of the P&O-based SEPIC converter under sudden irradiance variations.

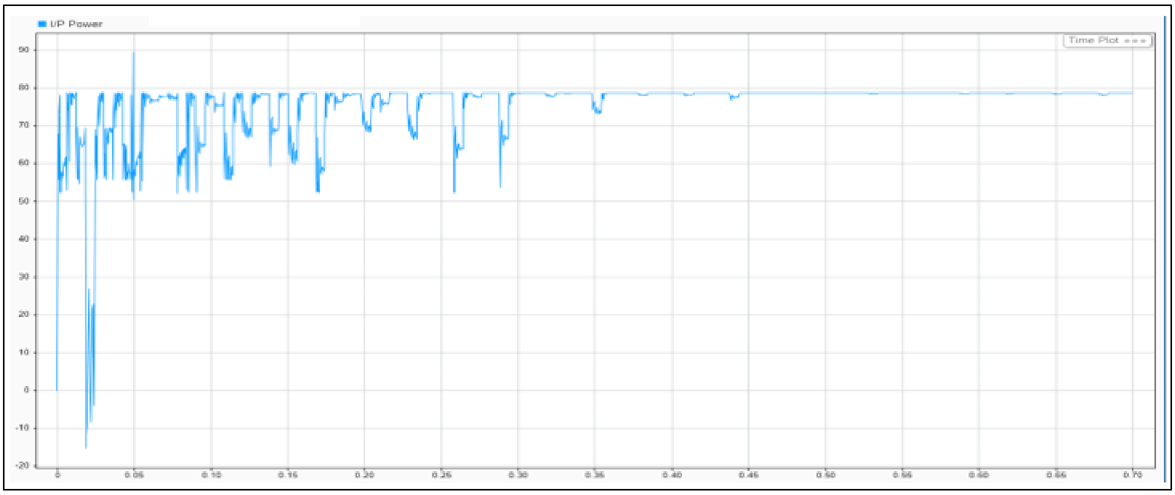


**Figure 6:** Pmax Vs Time Using PSO algorithm

**Figure 6** shows the output power response of the PV system using the **PSO-based MPPT** algorithm. During the initial **0–0.30 s**, the algorithm searches for the global Maximum Power Point (MPP), causing the output power to fluctuate between **55 W and 80 W** as the particles update their positions based on **pbest** and **gbest** values. After approximately **0.30 s**, the algorithm converges to the global MPP, and the output power stabilizes at around **78–80 W** with negligible oscillations. This smooth steady-state response demonstrates the superior tracking accuracy and stability of the PSO algorithm compared to the conventional P&O method, resulting in improved energy extraction and overall system efficiency.

The P-V characteristic curve of the four series-connected PV panels under partial shading conditions with irradiance levels of 1000, 750, 500, and 350 W/m² exhibits a global Maximum Power Point of 80W. The PSO algorithm successfully converges to this global MPP as confirmed by the output power waveform which stabilizes at approximately 78–80W after t = 0.30 sec.

A comparative analysis of the two MPPT algorithms tested in this project- Perturb and Observe (P&O) and Particle Swarm Optimization (PSO)- reveals significant differences in tracking accuracy, convergence speed, and performance under partial shading conditions.

## 4. Conclusion

A comparative evaluation of the Perturb and Observe (P&O) and Particle Swarm Optimization (PSO) MPPT algorithms was carried out using a 50 W photovoltaic system modeled in MATLAB/Simulink. The simulation results show that the P&O algorithm provides satisfactory performance under uniform irradiance but suffers from steady-state oscillations and reduced tracking accuracy under changing irradiance and partial shading conditions.

In contrast, the PSO algorithm effectively tracks the Global Maximum Power Point (GMPP), exhibits faster convergence with minimal oscillations, and maintains higher tracking efficiency under non-uniform irradiance. The results indicate that the PSO-based MPPT achieves an efficiency of approximately **95%**, outperforming the P&O algorithm, which achieves about **88%** under uniform conditions. Therefore, PSO is a more reliable and efficient MPPT technique for photovoltaic energy harvesting, particularly in practical applications where irradiance conditions vary dynamically.

## References

[1] T. Esram and P. L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," IEEE Trans. Energy Convers., vol. 22, no. 2, pp. 439–449, June 2007.

[2] D. P. Hohm and M. E. Ropp, "Comparative Study of Maximum Power Point Tracking Algorithms," Prog. Photovolt.: Res. Appl., vol. 11, no. 1, pp. 47–62, Jan. 2003.

[3] K. Ishaque and Z. Salam, "A Review of Maximum Power Point Tracking Techniques of PV System for Uniform Insolation and Partial Shading Condition," Renew. Sustain. Energy Rev., vol. 19, pp. 475–488, Mar. 2013.

[4] M. Miyatake, M. Veerachary, F. Toriumi, N. Fujii, and H. Ko, "Maximum Power Point Tracking of Multiple Photovoltaic Arrays: A PSO Approach," IEEE Trans. Aerosp. Electron. Syst., vol. 47, no. 1, pp. 367–380, 2011.

[5] K. L. Lian, J. H. Jhang, and I. S. Tian, "A Maximum Power Point Tracking Method Based on Perturb and-Observe Combined with Particle Swarm Optimization," IEEE J. Photovolt., vol. 4, no. 2, pp. 626–633, 2014.

[6] M. A. G. de Brito, L. Galotto, L. P. Sampaio, G. de Azevedo e Melo, and C. A. Canesin, "Evaluation of the Main MPPT Techniques for Photovoltaic Applications," IEEE Trans. Ind. Electron., vol. 60, no. 3, pp. 1156–1167, Mar. 2013.