Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Simulation and Performance Evaluation of the Perturb and Observe (P&O) MPPT Algorithm for Photovoltaic Systems under Partial Shading and Varying Irradiance Conditions

V.Anantha Lakshmi[1], Y.Rama Mohan[2], G.Sateesh[3], G.Kishor[4]

[1,3]Associate Professor, Department of EEE, G.Pulla Reddy Engineering College, Kurnool
[2]Associate Professor, Department of CSM, G.Pulla Reddy Engineering College, Kurnool
[4]Professor, Department of EEE, G.Pulla Reddy Engineering College, Kurnool

Abstract

This paper presents a simulation-based study of the Perturb and Observe (P&O) maximum power point tracking (MPPT) algorithm for photovoltaic (PV) energy harvesting systems. A 50 W PV module was modeled in MATLAB/Simulink to evaluate the performance of the P&O algorithm under uniform irradiance, partial shading, and varying irradiance conditions. Simulation results indicate that the P&O algorithm achieves satisfactory performance under uniform irradiance, with an efficiency of approximately 88%. However, under partial shading conditions, the algorithm is unable to track the global maximum power point (GMPP), resulting in reduced power extraction and overall system performance.

Keywords: Perturb and observe, maximum power point , Partial Shading Conditions

1. Introduction

The increasing global demand for clean and sustainable energy has accelerated the deployment of solar photovoltaic (PV) systems as one of the most promising renewable energy technologies. However, the nonlinear current–voltage (I–V) and power–voltage (P–V) characteristics of PV modules cause the Maximum Power Point (MPP) to vary continuously with changes in solar irradiance and cell temperature. Consequently, Maximum Power Point Tracking (MPPT) techniques are essential for ensuring that PV systems operate at their optimum power output under varying environmental conditions[1,2].

Among the various MPPT techniques, the Perturb and Observe (P&O) algorithm is one of the most widely used because of its simple implementation, low computational complexity, and ease of integration with DC–DC converters. Under uniform irradiance conditions, the P&O algorithm provides reliable tracking of the MPP with satisfactory efficiency. However, under partial shading conditions caused by clouds, trees, buildings, or other obstructions, the P–V characteristic exhibits multiple local maxima. In such situations, the conventional P&O algorithm may converge to a local maximum instead of the Global Maximum Power Point (GMPP), leading to reduced power extraction and decreased overall system efficiency [3,4].

This paper presents a simulation-based performance evaluation of the Perturb and Observe (P&O) MPPT algorithm for a photovoltaic system under uniform irradiance, partial shading, and varying irradiance conditions. A 50 W PV module is modelled using MATLAB/Simulink, and the tracking capability, output power, convergence characteristics, and efficiency of the P&O algorithm are analyzed under different operating scenarios. The simulation results highlight the strengths of the P&O algorithm under uniform irradiance and demonstrate its limitations in accurately tracking the GMPP under partial shading conditions.

2. Simulation Model

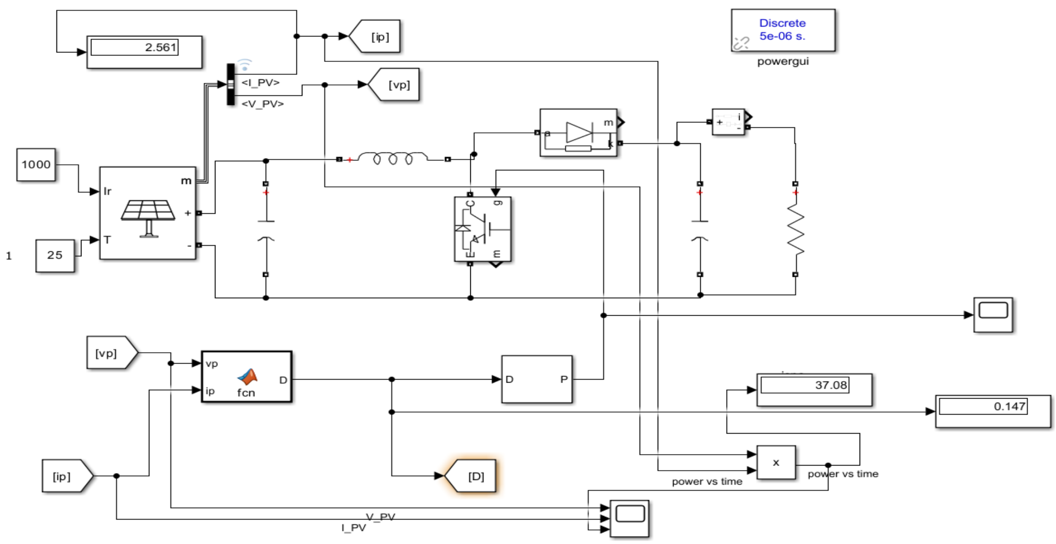

Fig 1 Simulink Model of MPPT using Boost Converter

Figure 1 illustrates the MATLAB/Simulink model of the boost converter-based Maximum Power Point Tracking (MPPT) system employing the Perturb and Observe (P&O) algorithm. The model is developed to evaluate the performance of the MPPT controller under predefined photovoltaic (PV) operating conditions. The PV array is configured to operate under Standard Test Conditions (STC), with an irradiance of **1000 W/m²** and a cell temperature of **25 °C**. The PV module parameters correspond to a **50 W** module with a maximum power point voltage V_{MPP} of approximately **20 V** and a maximum power point current I_{MPP} of approximately **2.5 A**.

The PV array generates the output voltage V_{PV} and current I_{PV} which are continuously monitored by the P&O MPPT controller. Using these measurements, the controller calculates the instantaneous PV power and iteratively adjusts the converter duty cycle to track the maximum power point. The computed duty cycle is supplied to a PWM generator, which produces the switching pulses required to drive the MOSFET of the boost converter.

The boost converter increases the PV output voltage to the required level and delivers the regulated power to the connected load. The simulation is performed in discrete mode with a sampling time of **5×10^{-6} s**, ensuring accurate numerical computation and stable converter operation. Key system parameters, including PV output power, output voltage, and duty cycle, are monitored throughout the simulation. The simulation results indicate a tracked output power of approximately **37.08 W** with the duty cycle settling at around **0.147**, demonstrating the successful implementation of the P&O MPPT algorithm and its ability to extract near-maximum power from the PV array under the specified operating conditions.

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 Maximum Power Point Tracking (MPPT) technique, Perturb and Observe (P&O) was investigated using Boost DC–DC converter topology. The simulation results include the PV array characteristics, MPPT tracking performance, comparative evaluation under different irradiance conditions.

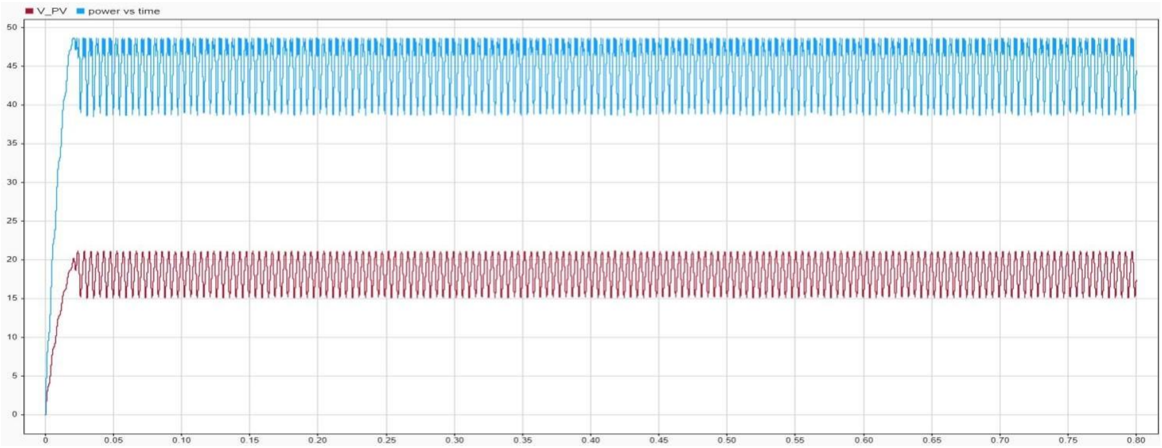

Fig 2 Vmax and Pmax Vs Time in Boost Converter

Figure 2 presents the simulation results of the Boost converter-based Maximum Power Point Tracking (MPPT) system operating under an irradiance of 1000 W/m² using the Perturb and Observe (P&O) algorithm.

At the start of the simulation, the PV voltage and output power increase rapidly from zero during the transient period (0–0.05 s) as the P&O algorithm adjusts 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 between **16 V and 21 V**, while the output power fluctuates between **40 W and 48 W**.

Although the P&O algorithm offers a simple implementation and low computational complexity, its inherent steady-state oscillations reduce tracking accuracy and marginally decrease the overall energy conversion efficiency.

Table 1: PV Module Parameters at Different Irradiance Levels

Irradiance (W/m²)	Voc (V)	Isc (A)	Vmpp (V)	Impp (A)	Pmpp (W)

Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

1000	24.3	2.75	20	2.5	50
750	23.6	2.06	19.4	1.87	36.3
500	22.8	1.38	18.6	0.62	23.2

4. Conclusion

A study of the Perturb and Observe (P&O) 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.

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. N. A. Ahmed and M. Miyatake, "A Novel Maximum Power Point Tracking for Photovoltaic Applications under Partially Shaded Insolation Conditions," Electr. Power Syst. Res., vol. 78, no. 5, pp. 777–784, 2008.
7. Microchip Technology Inc., "PIC16F72 Data Sheet," DS30221C, 2002. http://www.microchip.com
8. 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.