International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Simulation and Performance Analysis of the Perturb and Observe MPPT Algorithm for Photovoltaic Systems Using a SEPIC Converter

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 using SEPIC Converter**.** To evaluate the performance of the P&O algorithm under uniform irradiance, partial shading, and varying irradiance conditions a 50 W PV module was modeled in MATLAB/Simulink. Simulation results indicate that the P&O algorithm achieves satisfactory performance under uniform irradiance, with an efficiency of approximately 88%.

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

1. Introduction

The continuous growth in global energy demand, together with the rapid depletion of conventional fossil fuel resources, has made the development of sustainable alternative energy sources a critical priority in the twenty-first century. Fossil fuels—including coal, oil, and natural gas—have been the primary sources of energy for industrial and economic development for more than a century. However, their extensive combustion releases significant amounts of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere, contributing to climate change, air pollution, and long-term environmental degradation. Consequently, there is an increasing global emphasis on the adoption of clean, renewable, and environmentally sustainable energy technologies to reduce dependence on fossil fuels and mitigate their adverse environmental impacts.

Renewable energy refers to energy derived from naturally replenishing resources such as solar radiation, wind, rainfall, tidal movements, and geothermal heat. Unlike conventional fossil fuels, these resources are continuously renewed through natural processes and are therefore considered virtually inexhaustible for practical energy applications. Growing concerns over global energy security, the depletion of fossil fuel reserves, and the need to reduce greenhouse gas emissions have accelerated the development and adoption of renewable energy technologies worldwide.

International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

The use of renewable energy sources like solar photovoltaic (PV) has become one of the major solutions for meeting increasing energy demands while protecting the environment. The power-voltage (P-V) characteristic of solar panels is nonlinear, with an operating point that corresponds to maximum power delivery, called the Maximum Power Point (MPP). This MPP varies depending on irradiance and temperature changes, requiring tracking algorithms known as MPPT controllers[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. [3,4].

This paper presents a simulation-based performance evaluation of the Perturb and Observe (P&O) MPPT algorithm for a photovoltaic system using SEPIC Converter. 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.

2. Simulation Model

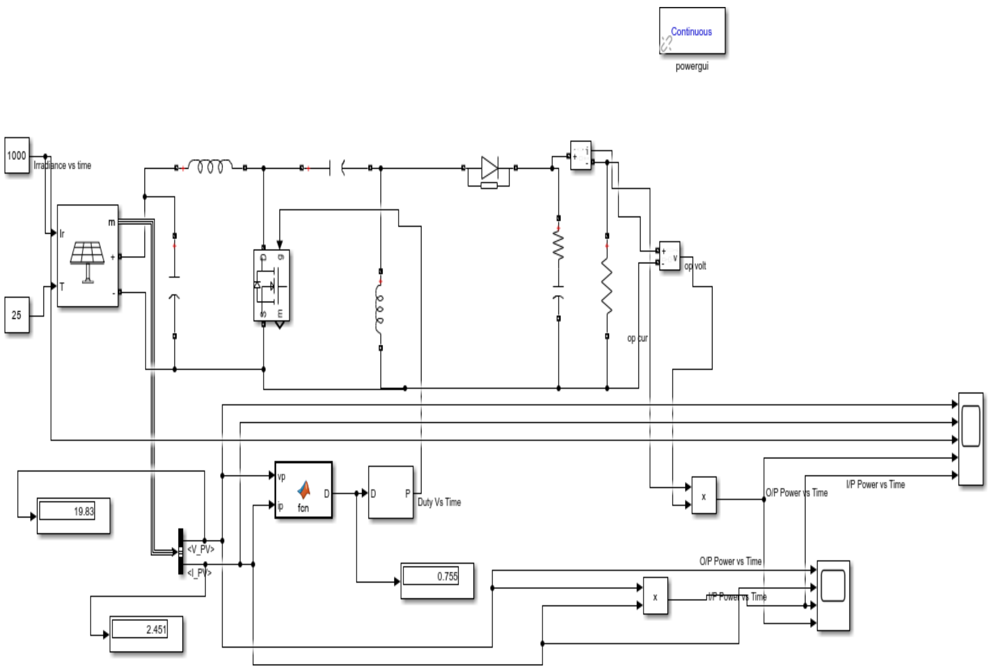

Fig 1 Simulink Model of MPPT using SEPIC Converter

Figure 6.3 illustrates the MATLAB/Simulink model of the MPPT system employing a **SEPIC Converter** to evaluate the performance of the **Perturb and Observe (P&O)** algorithm under Standard Test Conditions (STC). The PV array is configured with an irradiance of **1000 W/m²** and a temperature of **25 °C**, producing a maximum power of **50 W** with a maximum power point voltage **Vmp** of **20 V** and a maximum power point current **Imp** of **2.5 A**. The PV terminal voltage **V_{PV}** and current **I_{PV}** are continuously measured and supplied to the P&O MPPT controller, where the instantaneous PV power is calculated and used to determine the optimal duty cycle required for maximum power extraction.

The computed duty cycle is applied to a PWM generator, which generates the switching pulses for the SEPIC converter. Unlike a conventional boost converter, the SEPIC converter consists of two inductors, a series coupling capacitor, a power switch, a diode, and an output filter capacitor, enabling both step-up and step-down voltage conversion while maintaining a non-inverted output voltage. This bidirectional voltage conversion capability provides enhanced operational flexibility under varying PV operating conditions.

The simulation is performed in continuous conduction mode (CCM), with measurement blocks incorporated to monitor the output voltage, output power, and duty cycle throughout the simulation period. The obtained simulation results, including a duty cycle of **14.93** and a corresponding power-related value of **3.748**, demonstrate that the P&O algorithm effectively tracks the maximum power point under the specified operating conditions. Consequently, the developed SEPIC converter-based MPPT model serves as a reference platform for evaluating and comparing the MPPT performance of the SEPIC and Boost converter topologies under identical PV source and load 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, P & O was investigated using SEPIC 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 Sepic Converter

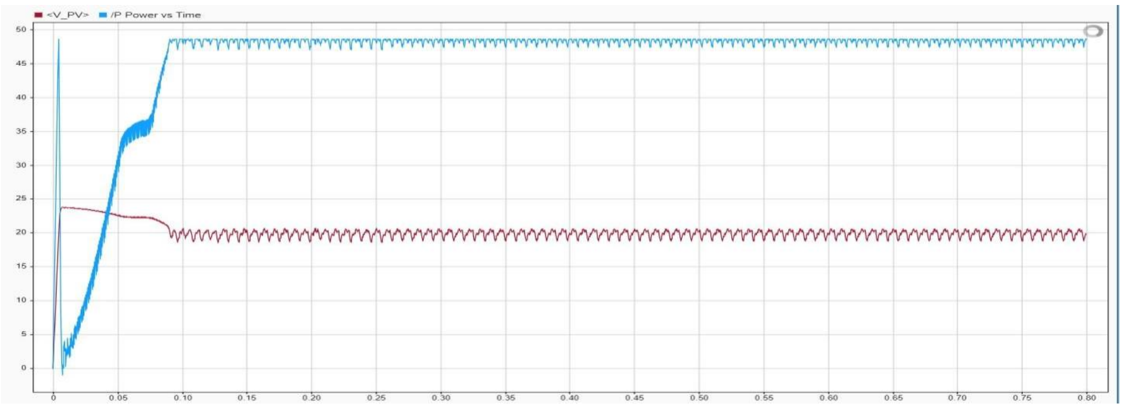

Figure 2 presents the simulation results of the SEPIC converter-based Maximum Power Point Tracking (MPPT) system employing the Perturb and Observe (P&O) algorithm under a uniform irradiance of 1000 W/m². The figure illustrates the variation of the PV voltage and output power with respect to time.

At the beginning of the simulation, the output power increases rapidly from zero and experiences a transient response during the interval 0–0.10 s, as the P&O algorithm iteratively adjusts the converter duty cycle to locate the Maximum Power Point (MPP). This search process results in temporary fluctuations and a slight overshoot in both the voltage and power waveforms. After approximately 0.10 s, the system reaches steady-state operation. The PV voltage stabilizes in the range of 19–20 V, while the output power settles between 50 W and 52 W, which closely matches the theoretical maximum power of the 50 W PV module under an irradiance of 1000 W/m².

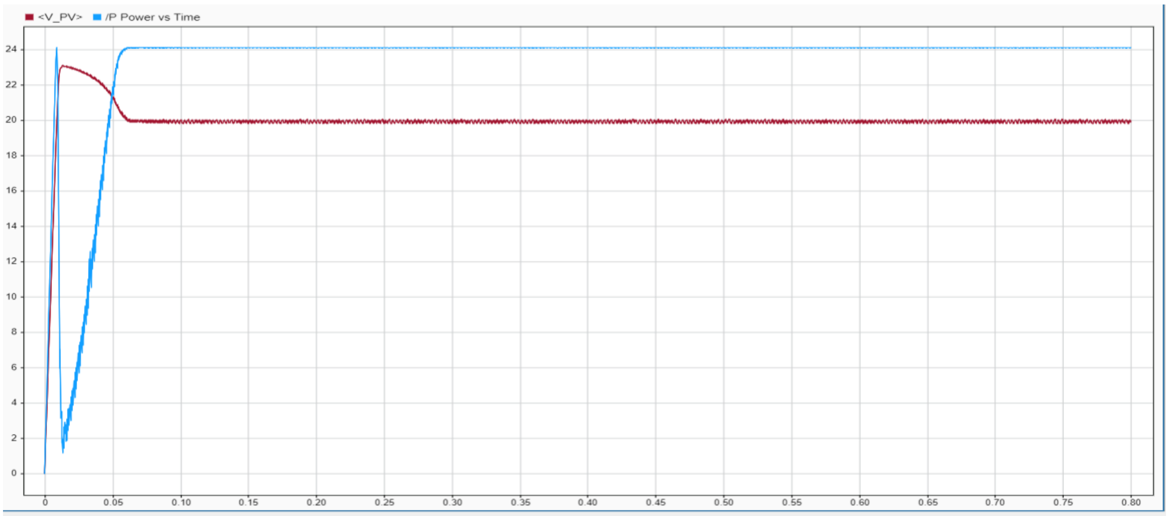

Fig 3 Vmax and Pmax Vs Time in Sepic Converter With 500 W/M²

Figure 3 presents the simulation results of the SEPIC converter-based MPPT system operating under a reduced solar irradiance of **500 W/m²**, illustrating the variations of the maximum PV voltage **Vmax** and maximum output power **Pmax**, with respect to time. At the beginning of the simulation, both waveforms exhibit a short transient response as the Perturb and Observe (P&O) algorithm continuously perturbs the converter duty cycle to locate the maximum power point (MPP). This transient behavior, observed during the interval from **0 to 0.05 s**, is characterized by a rapid increase in output power accompanied by a slight overshoot before convergence, while the PV voltage also experiences minor fluctuations before reaching its steady-state value.

After approximately **0.05 s**, both the voltage and power responses stabilize, indicating successful convergence of the MPPT algorithm. The PV voltage remains nearly constant at approximately **20 V**, whereas the output power settles at around **24 W**, which closely matches the expected maximum power available from the PV array under **500 W/m²** irradiance. This value is approximately half of the rated power obtained under Standard Test Conditions (**1000 W/m²**, **50 W**), thereby demonstrating the proportional relationship between solar irradiance and PV output power.

Throughout the remainder of the simulation period (**0.05–0.80 s**), both waveforms remain stable with negligible oscillations, confirming the effectiveness of the P&O algorithm in maintaining operation at the maximum power point. The results demonstrate that the SEPIC converter, when integrated with the P&O MPPT controller, provides reliable and stable maximum power tracking under reduced irradiance conditions, thereby validating the robustness and adaptability of the proposed MPPT system across varying solar operating environments.

SEPIC converter exhibits significantly lower steady-state oscillations in both voltage and power, indicating improved MPPT tracking accuracy and enhanced operating stability. The average extracted power is approximately 50 W, corresponding to an MPPT tracking efficiency of about 95%, which is considerably higher than the 88% achieved by the boost converter under identical operating conditions. These results demonstrate that the SEPIC converter provides superior MPPT performance by reducing steady-state ripple, improving tracking precision, and enhancing overall power conversion efficiency, making it a more suitable converter topology for photovoltaic energy harvesting applications.

4. Conclusion

Performance of the Perturb and Observe (P&O) MPPT algorithm 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.