IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁝ Impact Factor 8.021 ⁝ Peer-reviewed / Refereed journal ⁝ Vol. 11, Issue 7, July 2023

DOI: 10.17148/IJIREEICE.2023.11719

Implementation of novel P&O method for MPPT using Arduino

Sunil Kumar S[1], Arrshith R G[2]

Engineer, Transportation BU, Tata Elxsi, Bangalore, Karnataka, India[1]

Senior Engineer, ET Systems India, Bangalore, Karnataka, India[2]

Abstract: This research paper focuses on the implementation of the Perturb and Observe algorithm on a Maximum Power Point Tracking (MPPT) controller for solar energy generation. The energy output of solar cells is highly variable and heavily influenced by weather conditions. The proposed MPPT system utilises a micro-controller to regulate a DC-DC power stage and facilitate battery charging. By employing a voltage or current perturbation technique and comparing the power generated by the solar panel output, the system dynamically adjusts to achieve optimal power extraction. The Perturb and Observe algorithm is chosen due to its effectiveness and relatively low complexity. The objective of this study is to design and construct a 100W MPPT system using an open-source Arduino micro-controller board. Through the utilisation of MPPT techniques, it is anticipated that the system will achieve enhanced power conversion efficiency. This research aims to contribute to the advancement of MPPT technology and its application in solar energy systems.

Keywords: MPPT, Perturb and Observe, Arduino, Stable P&O Algorithm, Novel P&O Algorithm

I. INTRODUCTION

Renewable energy-based power generation, particularly solar energy, has emerged as a crucial component of the power sector due to its abundant availability and environmental benefits. Solar panels play a pivotal role in converting light energy into electrical energy, which can be stored in batteries or connected to the AC grid. To optimise solar power generation, it is essential to design efficient charge controllers and enhance the performance of solar panels. One of the key challenges in solar power generation is the design of an effective Maximum Power Point Tracking (MPPT) algorithm that enables solar panels to operate at their maximum power point (MPP) under varying environmental conditions. The MPPT algorithm dynamically adjusts the terminal operating voltage or current of the solar panel to extract the maximum available power. By achieving optimal power extraction, MPPT algorithms significantly improve the power conversion efficiency of solar panels.

This research project focuses on the implementation of a novel Perturb and Observe (P&O) MPPT algorithm using Arduino, aiming to provide a steady and stable output for solar power systems. The main objective is to develop and prototype an innovative P&O method that enhances the performance of MPPT controllers. The use of Arduino microcontrollers facilitates the implementation of the P&O algorithm and enables its integration into the MPPT system. By employing the proposed P&O method, the project aims to overcome the limitations of traditional MPPT algorithms and provide a more reliable and efficient solution. The stability and steady output of the P&O algorithm are crucial in ensuring consistent power generation and maximising the energy yield of solar panels.

The project involves integrating the algorithm into the MPPT system, utilising the voltage and current data from the solar panel to control the duty cycle of a pulse width modulation (PWM) signal. The implementation also includes the design of a DC/DC converter as an interface between the solar panel and the load. Experimental results will be presented to demonstrate the performance and effectiveness of the novel P&O algorithm compared to traditional MPPT methods. The focus will be on achieving a stable and steady output, thereby optimising the energy conversion process and improving overall system efficiency.

By providing a novel P&O algorithm for MPPT using Arduino, this research project aims to contribute to the advancement of solar power generation technologies. The proposed algorithm offers the potential to enhance the stability and reliability of MPPT systems, enabling more efficient utilisation of solar energy. Ultimately, this research project strives to promote the adoption of sustainable energy systems and accelerate the transition to a greener and cleaner future.

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⋇ Impact Factor 8.021 ⋇ Peer-reviewed / Refereed journal ⋇ Vol. 11, Issue 7, July 2023
DOI: 10.17148/IJIREEICE.2023.11719

II. METHODOLOGY

The methodology employed in this research project focuses on the implementation of a novel Perturb and Observe (P&O) method for Maximum Power Point Tracking (MPPT) using Arduino microcontrollers. The P&O algorithm, known for its robustness and cost-effectiveness, is widely utilised in MPPT applications. This algorithm operates by iteratively adjusting the voltage supplied to the solar module, aiming to approximate the Maximum Power Point (MPP). The following function block and procedure outline the working principle of the system, including impedance matching and the utilisation of the optimised or novel P&O algorithm.

1. Functional Block and Working procedure:

The functional block diagram of the MPPT system using Arduino is show

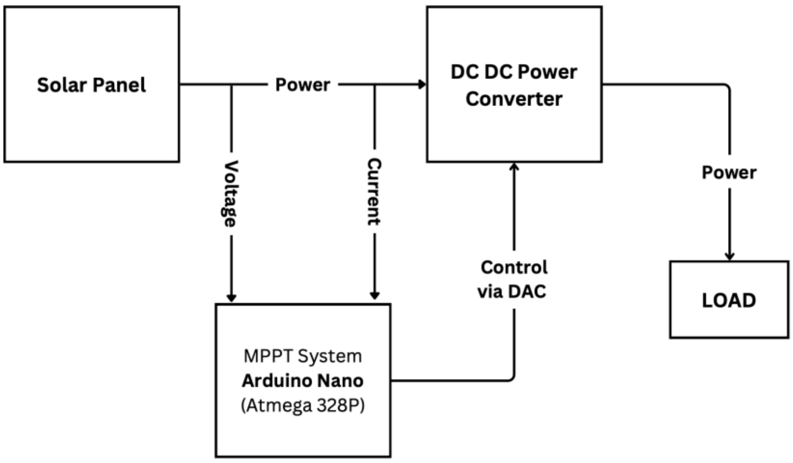

Figure 1. Functional Block Diagram of the System

1. **Measurement of Solar Module Power Output:** The first step in the working procedure is to measure the power output of the solar module or array. This is done by monitoring the voltage and current generated by the solar panel.

2. **Initial Voltage Adjustment:** The voltage supplied to the solar panel is adjusted to an initial value. This adjustment can be done using a DC-DC converter controlled by an Arduino microcontroller.

3. **Power Output Comparison:** After adjusting the voltage, the power output of the solar module is measured and compared with the previous measurement. The objective is to determine whether the power output has increased or decreased.

4. **Increment/Decrement Voltage Adjustment:** Based on the comparison of power outputs, the voltage supplied to the solar panel is further adjusted. If the power output has increased, the voltage is incrementally increased in the same direction. Conversely, if the power output has decreased, the voltage is decremented in the subsequent iteration.

5. **Iterative Process:** Steps 3 and 4 are repeated in an iterative manner until the Maximum Power Point (MPP) is approximated. The voltage adjustment continues until further changes in voltage result in a decrease in power output.

6. **Impedance Matching:** To optimise power extraction from the solar panel, the impedance seen by the panel needs to match the load impedance. This is achieved by adjusting the duty cycle of the DC-DC converter, which varies the impedance seen by the panel.

7. **Sampling and Adjustment:** Throughout the operation, the system continuously samples the voltage and current of the solar panel and adjusts the duty cycle of the DC-DC converter accordingly. This allows the system to dynamically adapt to changes in solar irradiance and temperature conditions.

DOI: 10.17148/IJIREEICE.2023.11719

8. Utilisation of Arduino Microcontroller: The Arduino microcontroller plays a crucial role in implementing the MPPT algorithm. It receives input from the solar panel's voltage and current sensors, calculates the power output, and controls the voltage adjustment process through the DC-DC converter.

9. Integration of Advanced Analytics: In some cases, larger computers may be utilised for advanced analytics and load forecasting to further enhance the performance of the MPPT system. These analytics can provide valuable insights into energy production, load requirements, and system optimisation.

10. Evaluation and Performance Analysis: The performance of the implemented MPPT system is evaluated based on its ability to track the MPP accurately and efficiently. The power output, voltage, and current data are analysed to assess the stability and effectiveness of the novel P&O method.

2. Hardware:

This general-purpose PCB board hosts a complete MPPT system, optimising solar energy utilisation. It incorporates an Arduino Nano with 14 digital I/O pins and 6 analog input pins, programmed using Arduino Software IDE. The ACS712 current sensor module accurately measures current, while the XL6009 DC to DC buck-boost converter regulates voltage. An IRF540N N-Channel MOSFET acts as a robust logic switch, and a DPDT relay routes circuits effectively. A 100W load resistor consumes electrical power, and the Sendust core inductor filters and stores current efficiently. This setup, integrating solar panel, PV modules, and advanced MPPT components, ensures reliable and optimised solar electricity supply to electrical equipment, making it suitable for various applications in residential and industrial settings.

The circuit operates in two modes: MPPT mode and bypass mode. In bypass mode, the output directly comes from the solar panel, with the MPPT circuit deactivated, and the relay directs the output. In MPPT mode, power flows through the Arduino Nano, and the MPPT algorithm continuously evaluates the PV module output, comparing it with the load to determine and maintain the best power, maximising the system's efficiency at the maximum power point.

This integrated system effectively performs maximum power point tracking, ensuring optimal solar power utilisation for various applications in residential and industrial settings. This integrated hardware, combined with the MPPT algorithm, creates an efficient solar battery charger system suitable for residential and industrial applications.

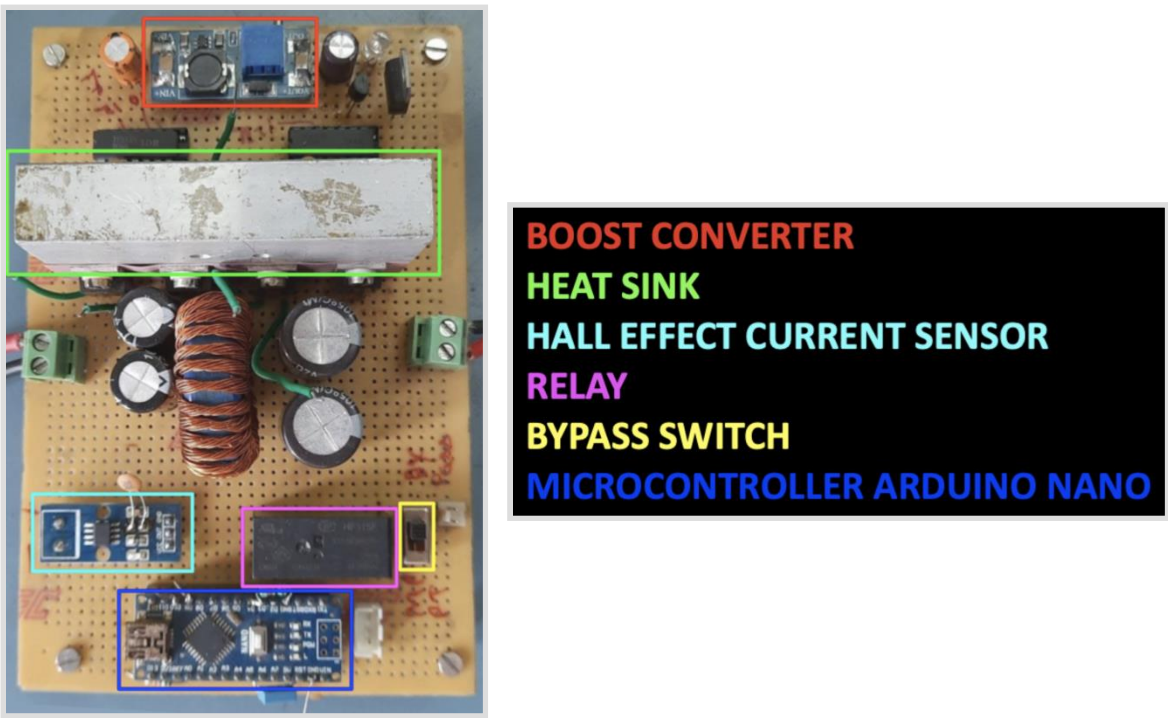

Figure 2. MPPT System Circuit Diagram

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 8.021 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 11, Issue 7, July 2023
DOI: 10.17148/IJIREEICE.2023.11719

3. Algorithm:

As shown in the figure [flow chart] below, the algorithm starts with the measurement of the solar panel's voltage (V) and current (I) as its first step. Using these measurements, the algorithm calculates the instantaneous power (P) output of the solar panel in the second step (P = V * I). The measured power (P) is then compared with the previously measured power (p(k-1)). If the current power (P) is found to be greater than the previous power (p(k-1)), it indicates that the perturbation vector (the direction of adjustment) is correct, and the system is approaching the maximum power point (MPP) on the power-voltage curve. In this case, the algorithm takes a proactive step by incrementally increasing the duty cycle of the power stage. The duty cycle adjustment allows the system to fine-tune its operation and ensure it remains on the trajectory towards the MPP, even as environmental conditions change. Conversely, if the current power (P) is less than the previous power (p(k-1)), it implies that the perturbation vector is incorrect, and the system has moved away from the MPP. In this scenario, the algorithm takes corrective action by reducing the duty cycle of the power stage. By reducing the duty cycle, the system reorients itself towards the MPP and continues the process of tracking the peak point for maximum power output.

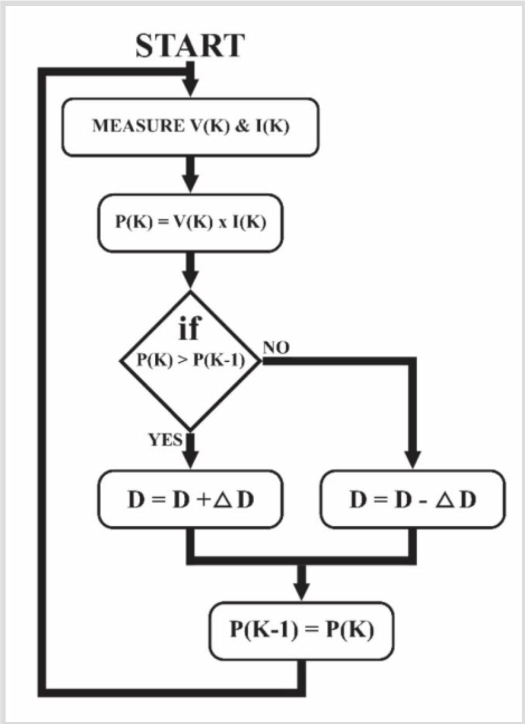

Figure 3. Flow Chart

The algorithm operates in a continuous cycle of measurement, calculation, comparison, and adjustment, ensuring it dynamically adapts to varying environmental conditions. As a result, the system effectively tracks the maximum power point, extracting the most energy from the solar panel at any given time. This MPPT algorithm's simplicity and efficiency make it suitable for a range of solar energy applications in both residential and industrial settings. However, it is essential to conduct rigorous testing and analysis to validate its performance and demonstrate its advantages in practical scenarios. Such experimental validation and performance assessment would be valuable aspects to include in any paper discussing this MPPT technique, substantiating its effectiveness and relevance in real-world applications.

III. RESULTS

Table 1 presents the real-world experimental results obtained by applying the MPPT algorithm to different load impedances, simulating load regulation conditions. The main objective of these experiments was to evaluate how effectively the MPPT algorithm can track the peak power point under a wide range of load variations, effectively matching the impedance between the load and the solar panel as the load conditions change. The effective tracking of peak power observed in the experiments signifies that the MPPT algorithm successfully maintains a close match between the load impedance and the source impedance of the solar panel.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⪤ Impact Factor 8.021 ⪤ Peer-reviewed / Refereed journal ⪤ Vol. 11, Issue 7, July 2023

DOI: 10.17148/IJIREEICE.2023.11719

By dynamically adapting the power stage's duty cycle, the algorithm optimises power transfer and ensures that the solar panel continuously generates the maximum possible power output, regardless of the load variations.

TABLE I POWER OUTPUT FOR DIFFERENT MODES

Load	Bypass Mode [in Watts]	MPPT Mode [in Watts]
5 Ohm Resistor [100W]	57 W	~ 120 W
10 Ohm Resistor [100W]	33 W	~ 120 W
Series Resistance 5 Ohm and 10 Ohm Resistors [100W]	22 W	~ 115 W
Parallel Resistance 5 Ohm and 10 Ohm Resistors [100W]	77 W	~ 115 W

Also the proposed algorithm has been compared with standard P&O algorithm. The tracking efficiency and steady state oscillation was compared between the both. We can see Power (Y-Axis) verses Time (X-Axis) plot for standard and P&O algorithm in Figure 3 and Figure 4 respectively which is shown below.

Figure 4. Standard Algorithm

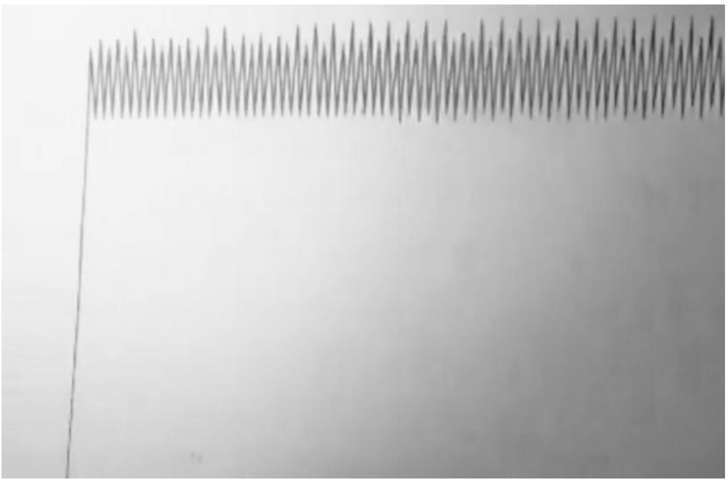

Figure 5. Developed Algorithm

IV. CONCLUSION

In conclusion, this paper successfully implemented and tested an MPPT algorithm based on the hill-climbing method using an 8-bit microcontroller and a 100-Watt solar panel. The MPPT device demonstrated effective tracking of the maximum power point under varying load and input power conditions, outperforming conventional P&O methods with minimized steady-state oscillations. The results highlight the algorithm's efficiency in dynamically adjusting the power stage's duty cycle to optimize power extraction from the solar panel, ensuring peak performance in different environmental conditions.

The growing importance of solar PV systems in residential and industrial applications underscores the significance of efficient MPPT techniques for maximizing energy yields. The scalability of the algorithm to handle higher power capacities, such as 1 KW, adds to its practicality and potential for broader commercial adoption.

Overall, the implemented MPPT algorithm has proven to be a valuable tool for extracting the maximum available power from PV modules and efficiently tracking the optimal power point in various weather conditions. The findings of this research contribute valuable insights to the field of solar energy utilization and offer practical guidance for designing high-performance MPPT systems, paving the way for more efficient and sustainable solar energy applications in the future.

DOI: 10.17148/IJIREEICE.2023.11719

REFERENCES

[1] Li, H., Yang, D., Su, W., Lu, J., & Yu, X. (2018). An Overall Distribution Particle Swarm Optimization MPPT Algorithm for Photovoltaic System under Partial Shading. IEEE Transactions on Industrial Electronics.
[2] Rezk, H., AL-Oran, M., Gomaa, M. R., Tolba, M. A., Fathy, A., Abdelkareem, M. A., ... El-Sayed, A. H. M. (2019). A novel statistical performance evaluation of most modern optimization-based global MPPT techniques for partially shaded PV system. Renewable and Sustainable Energy Reviews.
[3] Yilmaz, U., Kircay, A., &Borekci, S. (2018). PV system fuzzy logic MPPT method and PI control as a charge controller. Renewable and Sustainable Energy Reviews.
[4] Ahmed, J., & Salam, Z. (2018). An Enhanced Adaptive P&O MPPT for Fast and Efficient Tracking Under Varying Environmental Conditions. IEEE Transactions on Sustainable Energy, 9(3), 1487–1496.
[5] Nabipour, M., Razaz, M., Seifossadat, S. G., &Mortazavi, S. S. (2017). A new MPPT scheme based on a novel fuzzy approach. Renewable and Sustainable Energy Reviews, 74, 1147–1169.
[6] Rezk, H., Aly, M., Al-Dhaifallah, M., &Shoyama, M. (2019). Design and Hardware Implementation of New Adaptive Fuzzy Logic-Based MPPT Control Method for Photovoltaic Applications. IEEE Access, 7, 106427–106438.
[7] Ramanarayanan V, Switched Mode Power Conversion, Course Notes, IISc, 2004.
[8] Mohan, Undeland and Robbins, Power Electronics: Converters, Applications and Design, Wiley,Third Edition 2007.
[9] Fundamentals of Power Electronics, RW Erickson and D Maksimovic, Springer, Second Edition 2005
[10] www.ti.com: Test Report: PMP21529 4-Switch Buck-Boost Bi-directional DC-DC Converter Reference Design
[11] www.ti.com: Application Report SLVA535B–January 2018–Revised July 2018
[12] Inductor design : https://www.ee.iitb.ac.in/course/~emlab/assets/tfdesign.pdf
[13] High Efficiency 4-Switch Buck-Boost Controller Provides Accurate Output Current Limit – Design Note 499 Tage Bjorklund.
[14] R. P. Severns and G. Bloom, Modern DC-to-DC Switchmode Power Converter Circuits, New York: Van Nostrand Reinhold Company, 1985.
[15] D. W. Hart, Introduction to Power Electronics, Englewood Cliffs, NJ: Prentice Hall, 1997.
[16] 16. P. T. Krein, Elements of Power Electronics, New York: Oxford University Press, 1998.
[17] Pressman, Switching Power Supply Design, 2nd Ed., New York: McGraw-Hill, 1998.
[18] A.M. Trzynadlowski, Introduction to Modern Power Electronics, New York: Wiley Interscience, 1998.
[19] R. Erickson and D. Maksimovic, Fundamentals of Power Electronics, 2nd Ed., Norwell, MA: Kluwer Academic, 2001
[20] M. H. Rashid, Power Electronics Circuits, Devices, and Applications 3rd Ed., Upper Saddle River, NJ: Pearson Prentice Hall, 2003.
[21] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications and Design, 3rd Ed., New York: John Wiley & Sons, 2003

