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Design and Implementation of P&O Method for MPPT Photovoltaic Systems

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Abstract: The global transition towards renewable energy systems requires improved control strategies to maximise the efficiency of photovoltaic (PV) installations. Due to the nonlinear I–V characteristics of PV modules and their sensitivity to irradiance and temperature variations, Maximum Power Point Tracking (MPPT) algorithms are essential for ensuring optimal energy extraction. Among existing techniques, the Perturb and Observe(P&O) method remains the most widely implemented in industry due to its simplicity, low complexity, and ease of hardware integration. However, the conventional fixed-step-size P&O algorithm exhibits steady-state oscillations around the maximum power point (MPP) and reduced tracking performance under rapidly changing environmental conditions, resulting in avoidable power losses. This paper presents an improved P&O based MPPT algorithm incorporating an adaptive step-size perturbation mechanism. Unlike the conventional approach, which employs a constant perturbation magnitude, the proposed method dynamically adjusts the step size by introducing a multiplication factor (I/V) ^2 which depends on the current to voltage ratio. A larger perturbation step is applied when the system operates far from the MPP when current dominates to accelerate convergence, while a smaller step is used near the MPP when voltage dominates to reduce oscillatory behaviour and improve steady-state stability. This adaptive strategy enhances the trade-off between dynamic response and steady-state accuracy without significantly increasing computational complexity. The proposed algorithm is evaluated through simulation under varying irradiance to replicate realistic operating scenarios. Simulation results demonstrate an 11% improvement in performance relative to the conventional method, primarily due to faster convergence and reduced steady-state oscillations. The proposed P&O method maintains simplicity while achieving better efficiency, making it suitable for industrial PV systems.

Keywords: MPPT - Maximum Power Point Tracking, P&O - Perturb & Observe, Adaptive Step-size, Renewable energy, Photovoltaic Systems

I. INTRODUCTION

Solar PV systems are some of the most in-demand and technically forward developments in the modern world. The sun delivers 1,73000 terawatts of energy, about 10,000 times more than the world's total energy consumption, which is what this industry aims to tap into. Solar PV systems have categorically spread throughout the world across various applications, such as for charging stations, satellites, etc. They have even found their way into households with the setting up of rooftop panels.

In terms of extracting the power, maximum power point tracking (MPPT)is utilized. It is a technique used to maximize energy extraction mainly in tandem with solar PV systems, but it can also be used with wind turbine etc. The primary requirement for the implementation of MPPT is the fact that it enables the output voltage to function at a point equal to or close to the maximum power operating point, allowing for the drawing of maximum available power. One of the most popular methods used in this regard is the perturb and observe (P&O) method. This method pushes (perturbs) the voltage and observes whether the direction of the operating point is in the right direction. This is one of the simplest and most cost-effective methods, but also one that is still used at an industrial level. Other common MPPT techniques include Hill climbing (HC), Incremental conductance (Inc.), and fuzzy logic control (FLC).

II. PROBLEM STATEMENT

Although the P&O method is the most commonly used, it will come with its own set of problems. Amongst these concerns, the most problematic include the ripple phenomenon, unwanted oscillations, and higher peak-to-peak variations, all of which lead to constant power fluctuations, reduced efficiency and potential stability issues.

A. Conventional P&O Algorithm

The Perturb and Observe (P&O) algorithm is one of the most commonly used techniques for Maximum Power Point Tracking (MPPT) in photovoltaic (PV) systems. The main objective of MPPT is to extract the maximum possible power from a solar panel under varying environmental conditions, such as changes in solar irradiance and temperature.

Since the output characteristics of a PV panel are nonlinear, the operating point of the system must be continuously adjusted to ensure that it operates at the Maximum Power Point (MPP), where the generated power is highest. The P&O algorithm is widely preferred because of its simple structure, ease of implementation, and low computational requirements.

The basic principle of the P&O algorithm involves periodically perturbing (slightly changing) the operating voltage or duty cycle of the DC–DC converter connected to the PV system and observing the resulting change in output power. The PV voltage and current are measured, and the output power is calculated using the relation (P = V * I). After a small perturbation is applied, the new power is calculated and compared with the previous power value. If the power increases due to the perturbation, the algorithm continues to perturb the operating point in the same direction. If the power decreases, the algorithm reverses the direction of the perturbation. In this way, the operating point moves toward the maximum power point.

The P&O algorithm operates based on the change in power (Delta P) and the change in voltage (Delta V). These values are determined by comparing the present measurements with the previous measurements. If both the change in power and the change in voltage is positive, the duty cycle is increased to move the operating point toward the MPP. If the change in power is negative while the change in voltage is positive, the duty cycle is decreased. Similar decision rules are applied for other combinations of (Delta P) and (Delta V). Through this iterative process, the operating point gradually converges toward the maximum power point.

In practical implementations, the P&O algorithm continuously measures the PV voltage and current, calculates the power, compares it with the previous power value, and adjusts the duty cycle of the converter accordingly. This adjustment controls the impedance seen by the solar panel, thereby shifting the operating point along the power-voltage curve. The process repeats continuously, allowing the PV system to respond to variations in solar irradiance and temperature.

Although the P&O algorithm is simple and widely used, it has some limitations. One major drawback is that the operating point oscillates around the maximum power point instead of remaining exactly at it. Additionally, under rapidly changing atmospheric conditions, the algorithm may temporarily move in the wrong direction because it assumes that power changes are caused only by perturbations. Despite these limitations, the P&O algorithm remains a popular choice in PV applications due to its simplicity, reliability, and ease of implementation in microcontrollers such as Arduino, DSP, and other embedded systems.

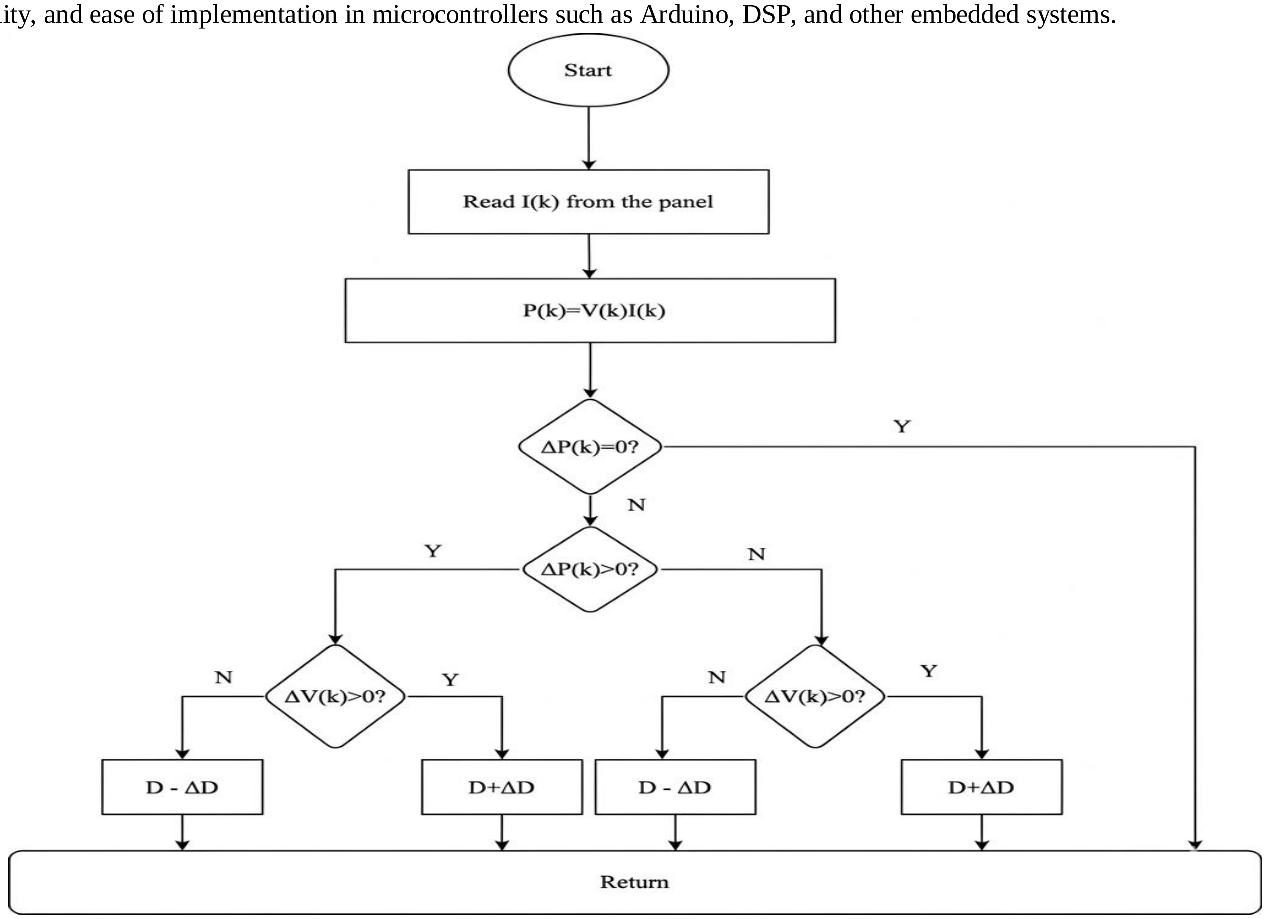


Fig. 1 Flowchart of Conventional P&O Algorithm

III. PROPOSED SOLUTION

The Perturb and Observe (P&O) algorithm is a commonly used Maximum Power Point Tracking (MPPT) method in photovoltaic (PV) systems to extract maximum power under varying irradiance and temperature conditions. Due to the nonlinear power–voltage characteristics of PV panels, the operating point must be continuously adjusted to reach the Maximum Power Point (MPP). In the conventional P&O method, the duty cycle is perturbed, and the resulting change in power is observed, where the present power is compared with the previous value to determine the perturbation direction.

In the proposed method, the algorithm is improved by introducing an additional iteration that compares the power values at k, k−1, and k−2 instants. Additionally, a multiplication factor of $(I/V)^2$ is used to adjust the duty cycle. This factor allows faster convergence when the operating point is far from the MPP and reduces the step size near the MPP, thereby minimising oscillations and improving tracking performance.

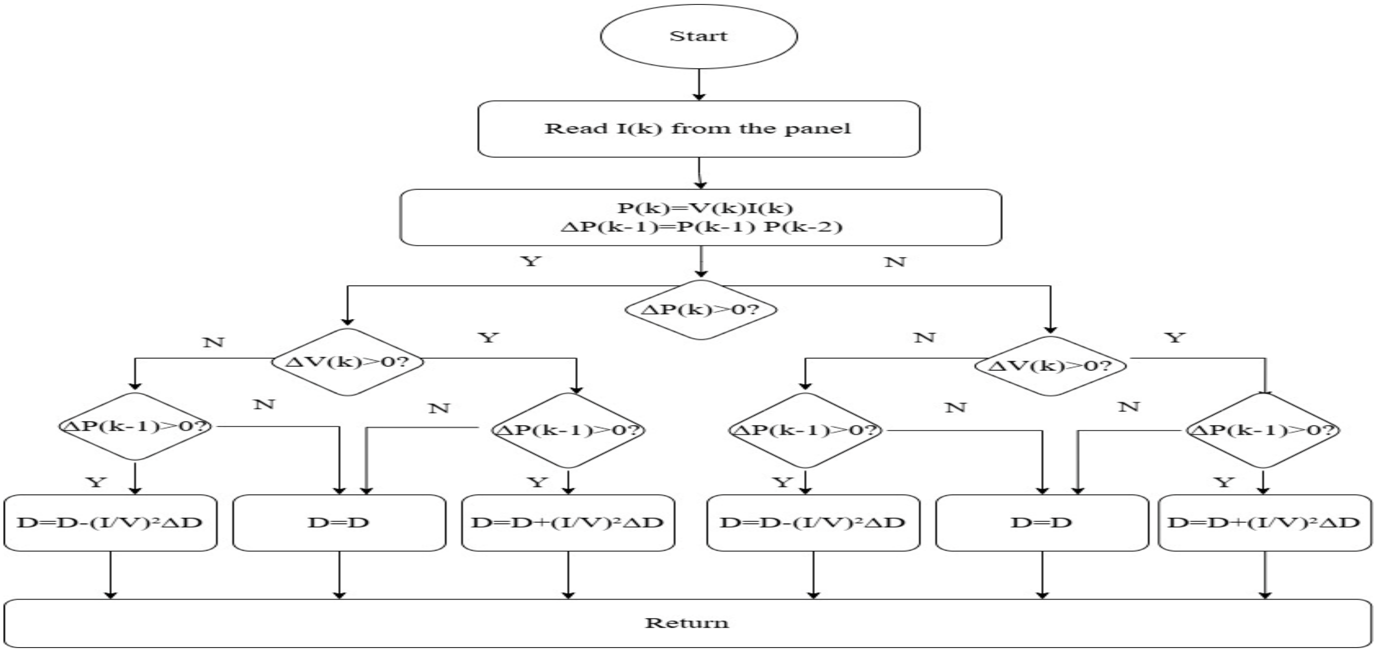


Fig. 2 Flowchart of Proposed P&O Algorithm

IV. SIMULATION AND RESULTS

A. PV Panel Modelling

As seen in the table 1, the PV System modelling is done with the number of parallel strings Np, taken as 4, and the number of series strings Ns, taken as 10. As Ns increases, voltage increases and as Np increases, current increases. The chosen model is Trina Solar TSM-250PA05.08 with a maximum power of almost 250 w and an open circuit voltage of 37.6 V. Standard test conditions of 1000 W/m^2 and 25 deg C have also been considered.

TABLE I

Electrical data under standard test conditions	Value
Parallel Strings	4
Series-connected modules per string	10
Module	Trina Solar TSM-250PA05.08
Maximum Power(W)	249.86
Cells per module (Nell)	60
Open circuit voltage Voc (V)	37.6
Short-circuit current Isc (A)	8.55
Voltage at maximum power point Vmp (V)	31
Current at maximum power Imp (A)	8.06
Temperature coefficient of Voc (%deg.C)	-0.35

PV System Parameters

- Number of cells = 60
- Number of parallel strings = 4
- Number of series strings = 10
- String Voltage
  Vstring = Number of series strings × Vm =10×31 =310V
- String Current
  Istring = Number of parallel strings × Im =4×8.06 =32.24A
- Total Power
  Ptotal = Vstring × Istring =310×32.24 =9994.4W ≈ 10kW

B. Boost Converter Design

The converter is the one of the most important components of the MPPT. One can utilise either a boost or buck converter, but in this instance a boost converter has been used. As can be seen in fig 3. The boost converter consists if an inductor, a MOSFET, a diode and a capacitor with all designed as per the need. This is connected to a MPPT Controller through a pulse width modulator.

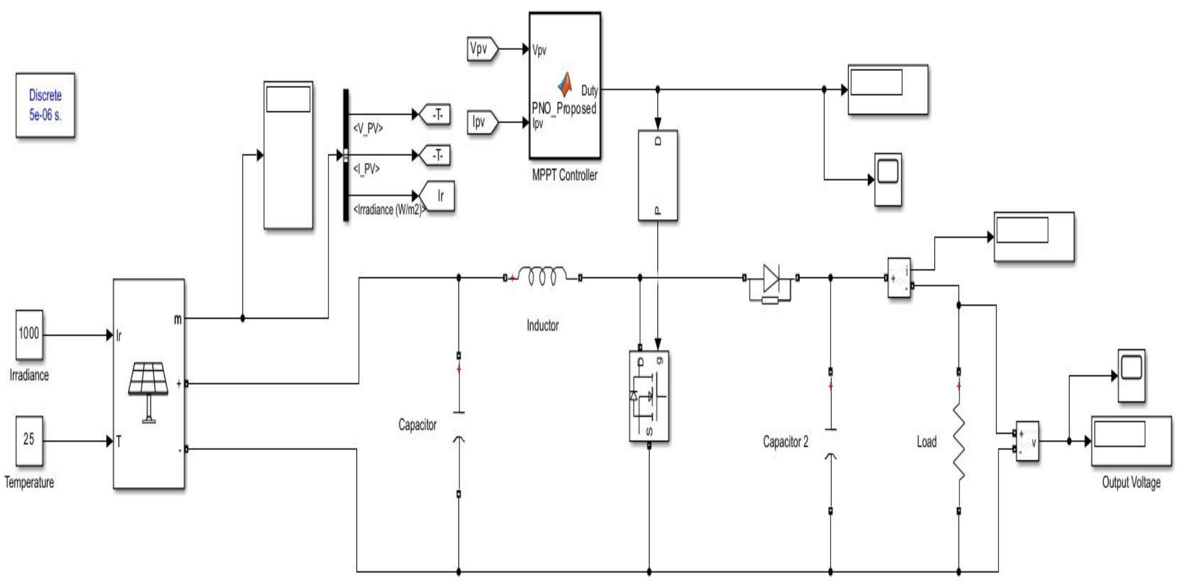


Fig. 3 Boost Converter

C. Simulation Results

The simulation of the proposed algorithm is performed in MATLAB Simulink, along with that of the conventional P & O algorithm. Both results are obtained with the identical frameworks and with the only difference being the code in the MPPT controller.

Results showed a meaningful increase in efficiency with a 11% improvement on the proposed method in comparison with the conventional one. The power Comparison shown in Figure 4 clearly indicates the same as well. Furthermore, the reduction in ripples and oscillations is visually evident in Figure 5.

Going one step further, aside from STC change, practical irradiance has also been simulated, since that is the Practical reason, which will be a more accurate representation of practical and industrial implementation, wherein a low value there is a notable improvement, as seen in Figure 6.

Overall, the simulation results of the proposed system when tested against each other show a meaningful improvement in output, which will translate to reduced power loss and better stability.

In this paper, an improved P&O method was proposed on the already existing industrial standard. A multiplication factor of $(I/V)^2$ and a previous state tracker were implemented and simulated. The effectiveness of the proposed method can only be validated in comparison with the existing method, and in doing so, the proposed method outperforms with a 11% improvement under Standard

Test Conditions. On top of that, the change in irradiance was also validated, which also showed improvement. This proves the effectiveness of the algorithm, and moving forward, it can be implemented at an industrial level to reduce power losses in a variety of industries.

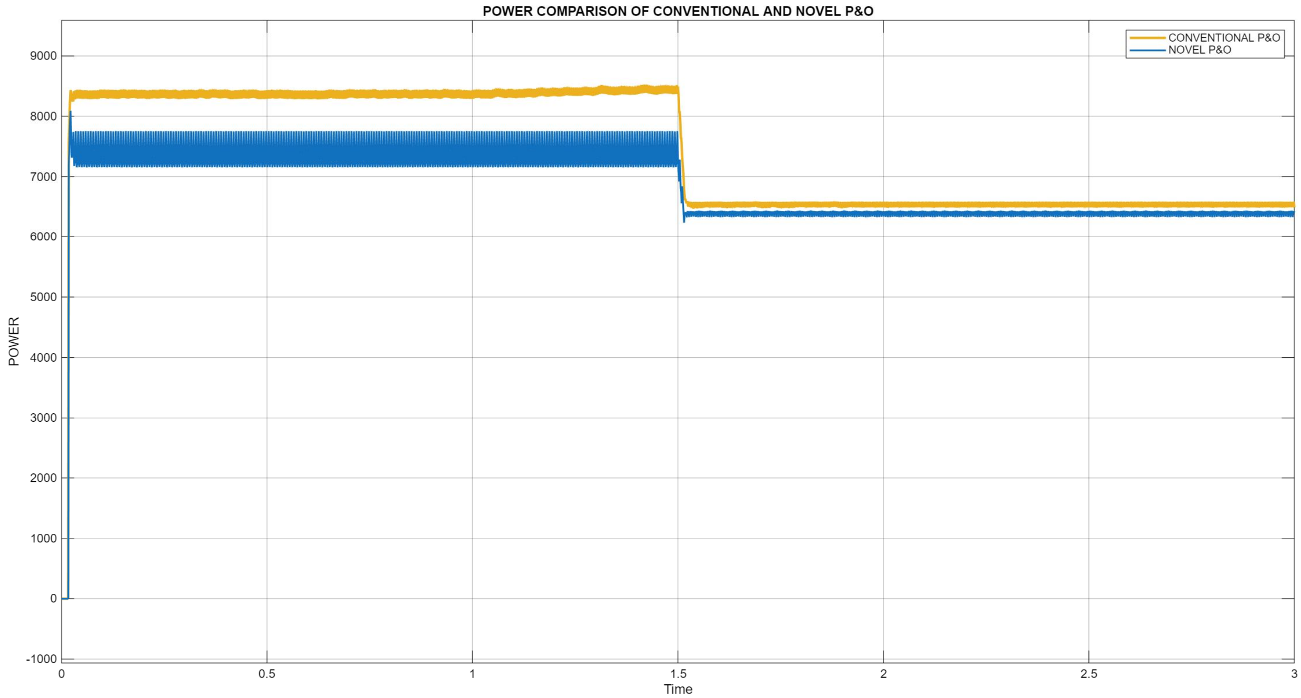


Fig. 4 Power Comparison of Basic and Proposed System

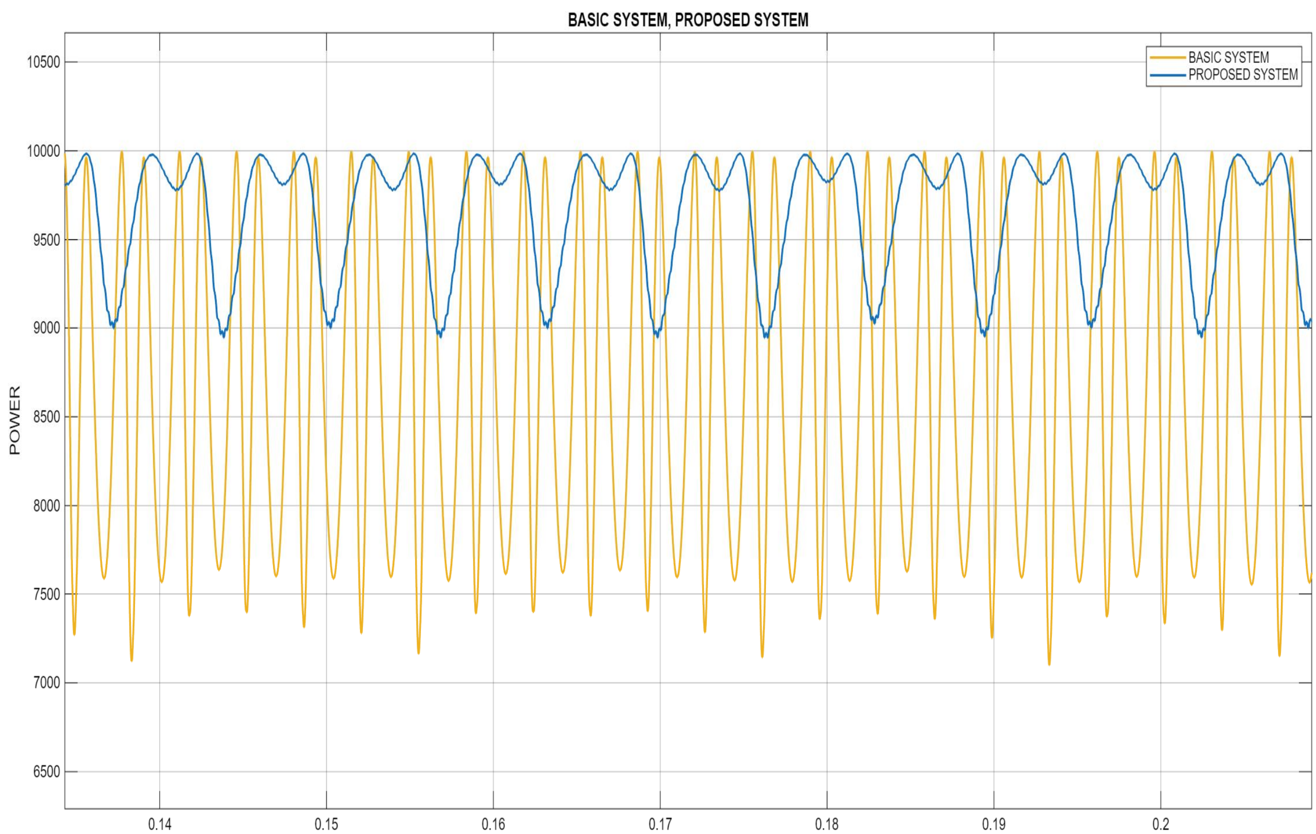


Fig. 5 Ripple Comparison

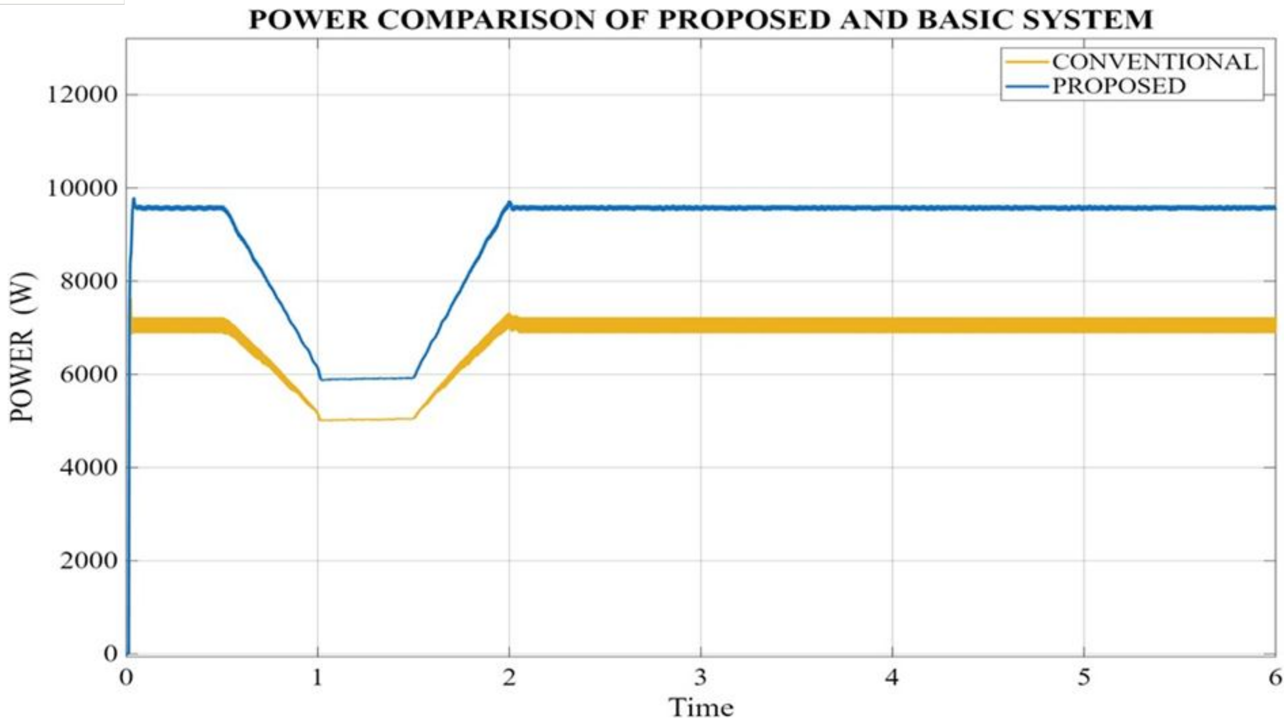


Fig. 6 Power Comparison of Irradiance Condition

V. CONCLUSIONS

The design and implementation of an improved P&O algorithm for MPPT in photovoltaic systems has shown significant enhancements in tracking efficiency, convergence speed, and stability over the conventional method. By introducing an adaptive control strategy specifically, a duty-cycle modification scaled by $(I/V)^2$ the system achieved smoother and faster tracking. Comprehensive simulations in MATLAB/Simulink validated the performance improvements, confirming higher tracking efficiency, reduced steady-state oscillations, and superior stability under both constant and rapidly changing irradiance conditions. This robust adaptive mechanism ensures precise and stable operation near the maximum power point, resulting in increased power output and better voltage regulation, which highlights the algorithm's practical effectiveness. Future work should focus on real-time hardware implementation to validate performance under practical operating conditions, enabling more efficient and robust integration of solar energy systems in large-scale applications.

REFERENCES

[1] R. Kahani, M. Jamil, and M. T. Iqbal, "An improved perturb and observed maximum power point tracking algorithm for photovoltaic power systems," *Journal of Modern Power Systems and Clean Energy*, vol. 11, no. 4, pp. 1165–1175, 2023.

[2] R. I. Jabbar, S. Mekhilef, M. Mubin, and K. K. Mohammed, "A modified perturb and observe mppt for fast and accurate tracking of mpp under varying weather conditions," *IEEE Access*, vol. 11, pp. 76166–76176, 2023.

[3] H. D. Tafti, Q. Wang, C. D. Townsend, J. Pou, and G. Konstantinou, "Global flexible power point tracking in photovoltaic systems under partial shading conditions," *IEEE Transactions on Power Electronics*, vol. 37, no. 9, pp. 11332–11341, 2022.

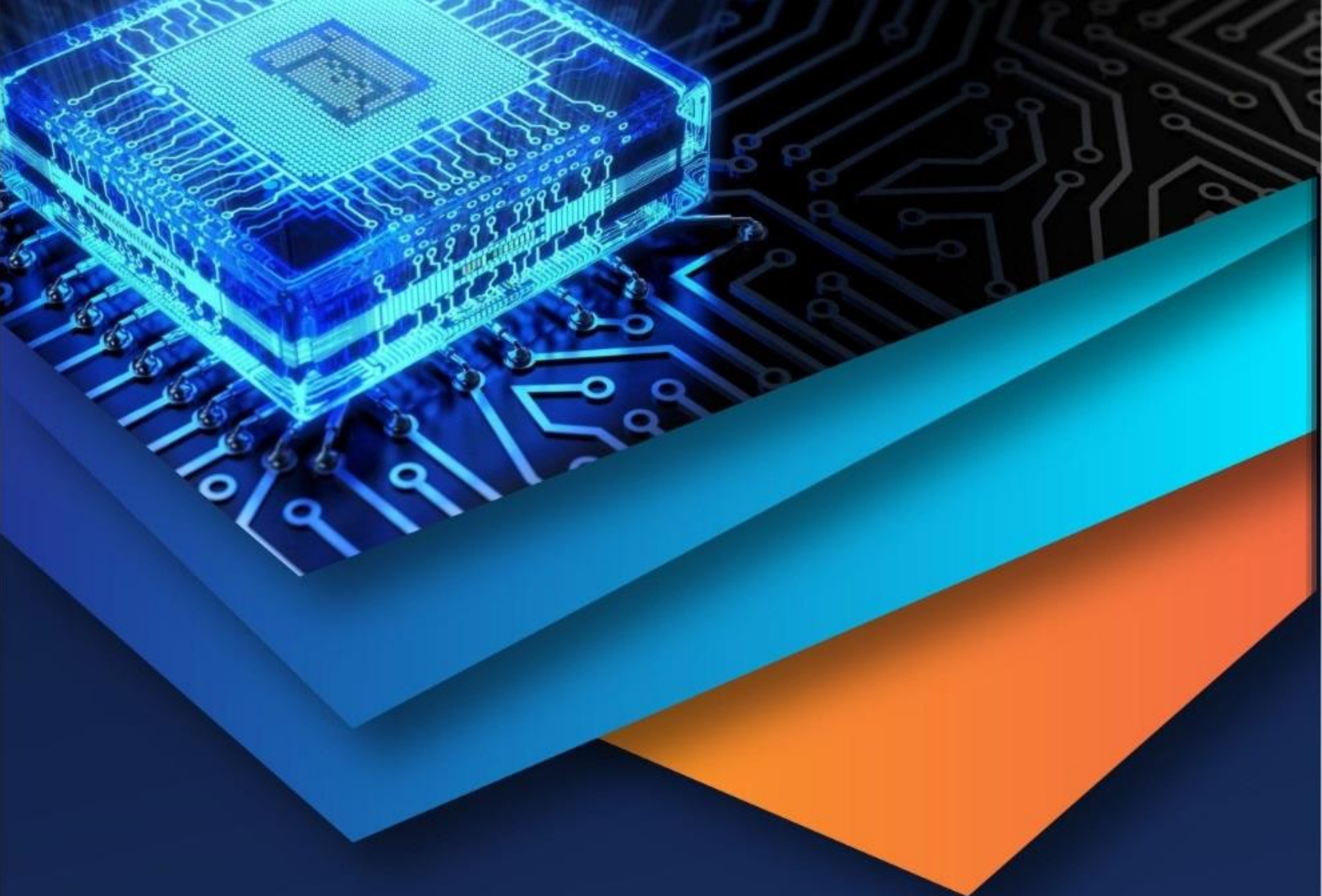
[4] P. N. Tawiah-Mensah, J. Addison, S. D. Oppong, and F. B. Effah, "An improved perturb and observe maximum power point tracking algorithm with the capability of drift avoidance in pv systems," in *Proc. 2022 IEEE PES/IAS PowerAfrica*, pp. 1–5, 2022.

[5] V. Sharma, A. K. Gupta, A. Raj, and S. K. Verma, "Ai-driven mppt: A paradigm shift in solar pv systems for achieving maximum efficiency," in *Proc. 2024 Int. Conf. Artificial Intelligence Applications in Electrical and Electronic Innovation (ICAAEEI)*, pp. 1–5, 2024.

[6] J. Ahmed and Z. Salam, "A modified p&o maximum power point tracking method with reduced steady-state oscillation and improved tracking efficiency," *IEEE Transactions on Sustainable Energy*, vol. 7, pp. 1506–1515, Oct. 2016.

[7] M. Killi and S. Samanta, "Modified perturb and observe mppt algorithm for drift avoidance in photovoltaic systems," *IEEE Transactions on Industrial Electronics*, vol. 62, pp. 5549–5559, Sept. 2015.

[8] E. P. Sarika, J. Jacob, S. S. Mohammed, *et al.*, "Standalone pv system with modified vss p&o mppt controller suitable for partial shading conditions," in *Proc. 7th Int. Conf. Electrical Energy Systems (ICEES)*, Tamil Nadu, India, pp. 51–55, Feb. 2021.



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