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Enhancing Power Tracking Efficiency in Stand-Alone PV Systems via Adaptive Perturb and Observe (P&O) Optimization

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Abstract

Enhancing efficiency in photovoltaic (PV) power production is a significant engineering challenge, particularly under varying weather and climatic conditions. PV systems offer a green and inexhaustible source of energy; actually, their performance is highly affected by climate variables like as solar sunlight, cell temperature, and partially cloudy conditions. The Maximum Power Point Tracking (MPPT) algorithm commonly utilizes Perturb and Observe (P&O) technique. However, when a large perturbation step is utilized, the algorithm method may oscillate around the peak maximum power point. Conversely, using a small step size enhances tracking accuracy but significantly slows the response time, limiting the system's ability to promptly reach the true MPP under rapidly changing environmental conditions. For solving these issues, a better approach is proposed that uses adaptive step sizes within. This improved algorithm dynamically adjusts the duty cycle of the boost converter's, allowing for more efficient and precise tracking of the MPP with changing climate conditions. A microcontroller is required for the hardware implementation of MPPT. This microcontroller is a component of a robust circuit, namely a solar charge controller. The off-grid PV electricity system is simulation based on MATLAB/Simulink R2024a. The adapted P&O algorithm produces a smoother output and achieves higher efficiency than the traditional fixed-step P&O.

Keywords: Photovoltaic, P&O algorithm system, Adaptive step size

1. Introduction

In recent years, the usage of Renewable Energy Sources (RES) in power generation systems has rapidly increased, spurred by shortages and environmental problems connected with conventional fuels [1], [2]. Thus, various RES, such as wind energy, solar energy (both thermal and photovoltaic), biomass, and hydroelectric power, etc., are being utilized to mitigate the effects of global warming caused by gas emissions. Solar PV is a promising renewable energy source for several reasons, silent operation, abundant, long-life time, clean energy, and requiring minimal maintenance [3]. Currently, photovoltaic arrays (PVAs) are among the most commonly used and viable green sources of electricity worldwide [4].

However, a output power provided by PV panel is fundamentally variable due to its non-linear properties, which are influenced by factors like as sunlight, ambient temperature, and the type of the connected load. To extract the greatest available power under variable conditions, the PV system must be optimized for efficient operation at its greatest MPP, which can be achieved by implementing MPPT techniques [5]. These strategies are classed according to their utilization of real-time voltage and current measurements, as well as direct and indirect tracking the MPP method.

The traditional indirect method determines a solar array's MPP using either fractional open-circuit voltage method or a predetermined proportion of the short-circuit current [6], [7], [8]. A look-up table method is produced in advance that correlates with environmental factors such as light intensity and temperature to the optimal voltage or duty cycle to control the maximum power output [9]. Fuzzy logic consists of inputs, fuzzification, and outputs. These are used in controllers designed to adjust the duty cycle of the boost converter, ensuring that the PV system operates closer to the MPP [10]. AI-based techniques make use of algorithms that are able to learn from data and instantly adjust to changes. These techniques provide more advanced ways to monitor the MPP in PV systems, such as Artificial Neural Networks (ANN), Genetic Algorithms (GA), and Particle Swarm Optimization (PSO) [11]-[14].

Direct approaches, for example, the Perturb & Observe, and Incremental Conductance (INC) technique, operate by regularly altering the operating voltage of the solar system to iteratively approach the optimal power point within a steadily closer search range. Additionally, P&O method has been frequently employed due to its easy implementation on inexpensive digital controllers, generally good performance, and straightforward structure. The drawback of the traditional fixed-step P&O algorithm is the oscillation around the MPP under changing sunlight conditions. Numerous methods have been developed to adapt the P&O method via dynamic steps in order to handle the issue oscillation around the MPP.

Several recent studies have developed strategies in which data is sent via IoT devices to cloud platforms or local controllers, using various strategies for optimizing, like Cuckoo Search (CS), Artificial Bee Colony (ABC), and Grey Wolf (GW) Optimizatio [15].

In this paper, an adaptive dynamic step-size P&O MPPT algorithm is proposed, which calculates the slope of the power–voltage curve to adjust the step size accordingly, enabling more accurate tracking of the PV system's maximum power point. The proposed approach can effectively improve efficiency and MPPT response simultaneously, in contrast to the conventional fixed step size strategy.

2. Model for PV Cell

The electrical behavior of photovoltaic cells is commonly represented by a mathematical model known as the single-diode, illustrated in Fig. 1.

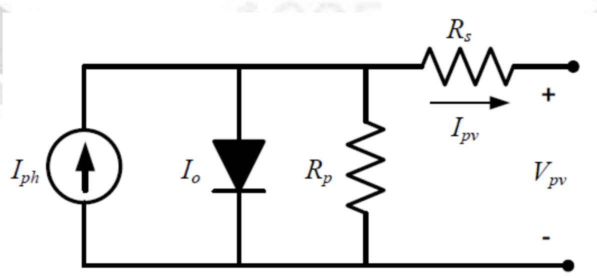

Figure 1: Single-diode PV cell model

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Vol. 32, No. 3. \ 2025 ISSN: 2616 - 9916

$$I_{pv} = \mathrm{I}_{Ph} - \mathrm{I}_{o} - \frac{\mathrm{V_D}}{\mathrm{R_P}} \quad (1)$$

$$\mathrm{V_D} = V_{pv} + I_{pv}\mathrm{R_S} \quad (2)$$

$$I_{pv} = I_{Ph} - I_{sat.}(e^{\frac{V_D}{nV_T}} - 1) - \frac{V_{pv} + I_{pv}R_s}{R_p} \quad (3)$$

The mathematical of the open-circuit voltage is as follows: -

$$V_{oc} = \frac{nKT}{q}\ln(\frac{I_{ph.}}{I_o} + 1) \quad (4)$$

The mathematical of the short-circuit current I_{sc} is as follows: -

$$I_{sc} \approx I_{Pv.} \quad (5)$$

Where V_T $equal\ to = \frac{KT}{q}$ the thermal voltage (=25 mv at 25°C), T represented absolute Temperature of p-n junction, in Kelvin (K), Electron charge $q = 1.6 \times 10^{-19}$, in Coulombs (C), and K Boltz man constant, $= 1.380649 \times 10^{-23} J/K$.

Figure 2 shows the properties of a PV array as expressed by (I-V) and (P-V) graphs with different radiation intensity, which were evaluated at setting temperature of 25^oC and intensity level of $\left(1000\frac{W}{m^2}, 850\ \frac{W}{m^2}, 700\frac{W}{m^2}, 550\frac{W}{m^2},\ and\ 400\ \frac{W}{m^2}\right)$. However, Fig. 3 presents the results of simulations conducted to examine the non-linear characteristics of the solar cell's output in terms of I–V and P–V curves with respect to cell temperature that have been investigated in steps $(25^o\ C, 30^oC, 35^oC, 40^oC, and\ 45^oC)$. The MPP point varies when one of these two parameters' changes. As a result, voltage and current should be adjusted to attain the optimal operating point.

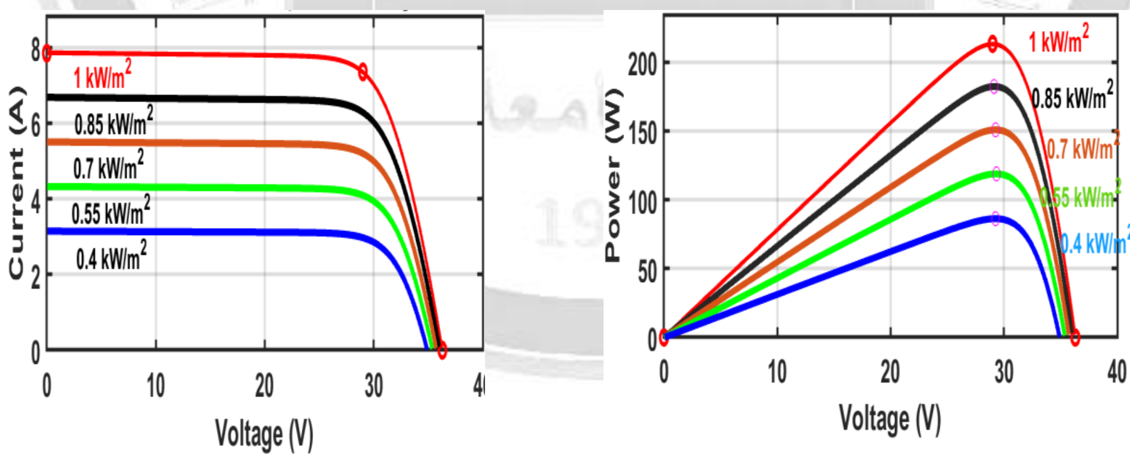


Figure 2: The effects of radiation on the solar panels' characteristics.

Vol. 32, No. 3. \ 2025 ISSN: 2616 - 9916

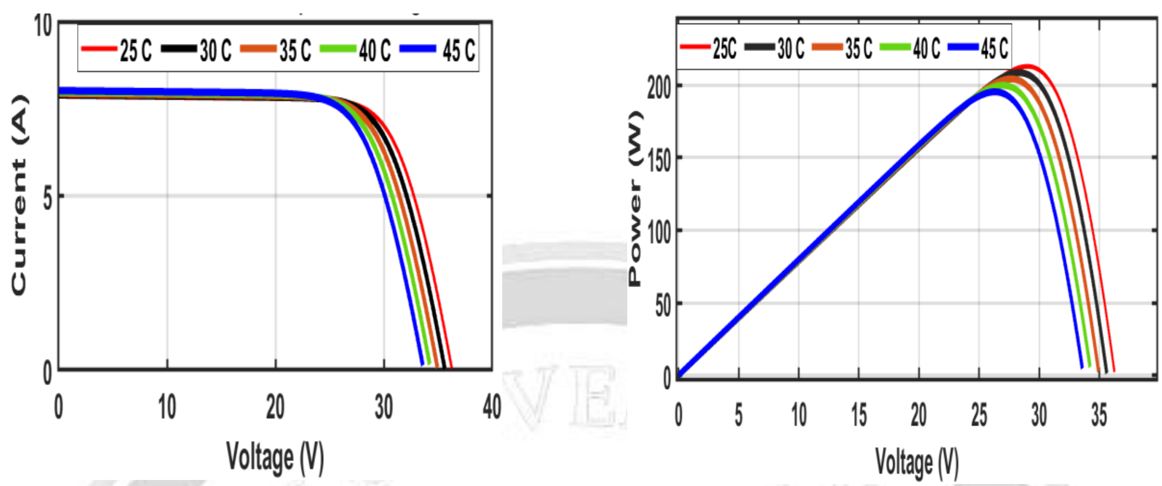


Figure 3: The impact of temperature on the characteristics of solar panels

3. PV Boost Converter

A DC voltage booster circuit is link among PV array and the direct current load in stand-alone solar power plants. The adjustment of PV-array uncontrolled DC voltage to appropriate DC value. In order to maximize power extraction, the load needs to be tuned to match the solar panel's voltage and current.

Figure 4 demonstrates an ideal block structure for the simulated PV-system used for obtaining MPPT strategies. It consists of the following main components: a PV module, a DC-DC converter, a P&O MPPT algorithm, a (PWM) signal, and output load resistance. In an MPPT system, a boost DC-DC converter is positioned between the DC-load and the specific photovoltaic module, adjusting the unregulated DC voltage from the PV cell to a DC-wanted level. The reference voltage signal is provided by P&O method, and duty cycle (D) of the gate pulse is adjusted in response to the error signal to control the DC-DC switching transistor. The duty cycle is provided by [16], [17]:

$$D_{(k)} = 1 - \frac{V_i}{V_o} \tag{6}$$

The $V_{o.}$ depends on the $V_{i.}$ and duty cycle.

$$V_{o.} = \frac{V_{i.}}{1 - D_{(k)}} \tag{7}$$

These equations for inductors and capacitors can be derived from the lossless.

$$L(min) = \frac{V_{i.} \cdot D_{(k)}}{\Delta I_{o.} \cdot f_{sw.}} \tag{8}$$

$$C(min) = \frac{I_{o.} \cdot D_{(k)}}{\Delta V_{o.} \cdot f_{sw.}} \tag{9}$$

Where $\Delta V_{o.}$ and $\Delta I_{o.}$ are the output voltage and current ripples, respectively, and $f_{sw.}$ is the switching frequency. Table 1 lists the key electrical parameters of the system's boost converter. These component values have been carefully selected to ensure that the boost converter operates smoothly and efficiently within the proposed system.

Table 1: Schedule for setting the parameter components of the boost converter

Parameter of boost	Values
Capacitance (C1)	$1e^{-6}F$
Capacitance (C2)	$0.467\ e^{-3}F$
Inductance (L)	$1.147\ e^{-3}H$
D.C Load (RL)	50Ω

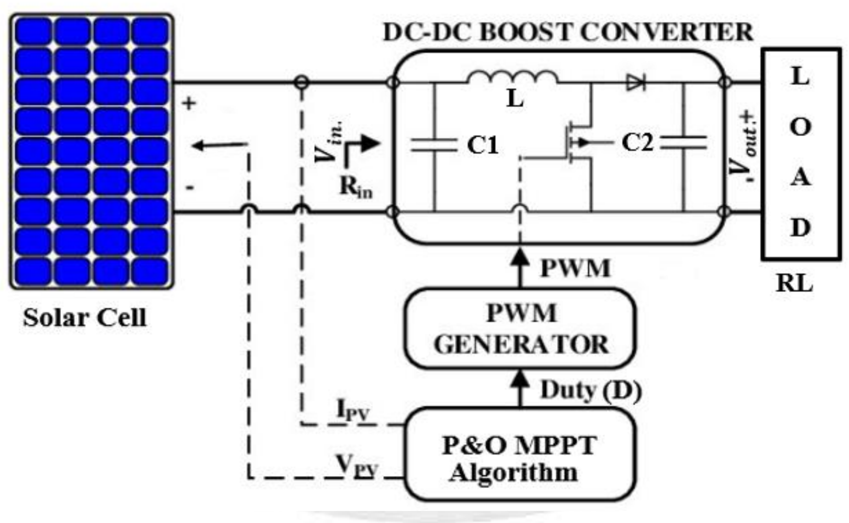


Figure 4: A block schematic for off-grid PV systems

Vol. 32, No. 3. \ 2025 ISSN: 2616 - 9916

4. MPPT Algorithm Implementation

4.1 Traditional P&O Technique

In photovoltaic systems, one of the most popular optimum MPPT strategies is the classical P&O method. It functions by varying the solar panel’s operating voltage through adjustments, or by making small changes, and monitoring that result variation in optimal power $P_{out.}$. The method reverses the direction of the perturbation if the power decreases after the perturbation, and continues changing the voltage in the same direction if the power increases. The P&O method approaches the tracking MPP, where the solar panel generates its maximum power output, by iteratively repeating this process. Despite being straightforward to use, the classic P&O technique may be slower or less accurate when temperature and irradiance fluctuate rapidly, and it may experience oscillations around the MPP under steady-state conditions. Figure 5 depicts the flow diagram of the classical P&O technique, which details the step-by-step logic required to track the MPP in a photovoltaic system. To determine the PV module’s power change (ΔP), the method begins by measuring the potential difference $V(k)$ and current $I(k)$, then compares them with the potential difference $V(k-1)$ and current $I(K-1)$ from previous iteration. The method keeps changing the voltage $\Delta V(K)$ in the same way, either by raising or decreasing it, if the power has improved. The direction of the voltage perturbation $\Delta V(K)$ is reversed if the power falls. The four operational scenarios with different step sizes to extract the MPP, are represented in Table 2.

Table 2: Provides a summary of procedure based on the voltage change

ΔP	ΔV	$V_{ref.}(k+1)$
increase	increase	$V(k)+\Delta V(k)$
decrease	decrease	$V(k)+\Delta V(k)$
increase	decrease	$V(k)-\Delta V(k)$
decrease	increase	$V(k)-\Delta V(k)$

Vol. 32, No. 3. \ 2025 ISSN: 2616 - 9916

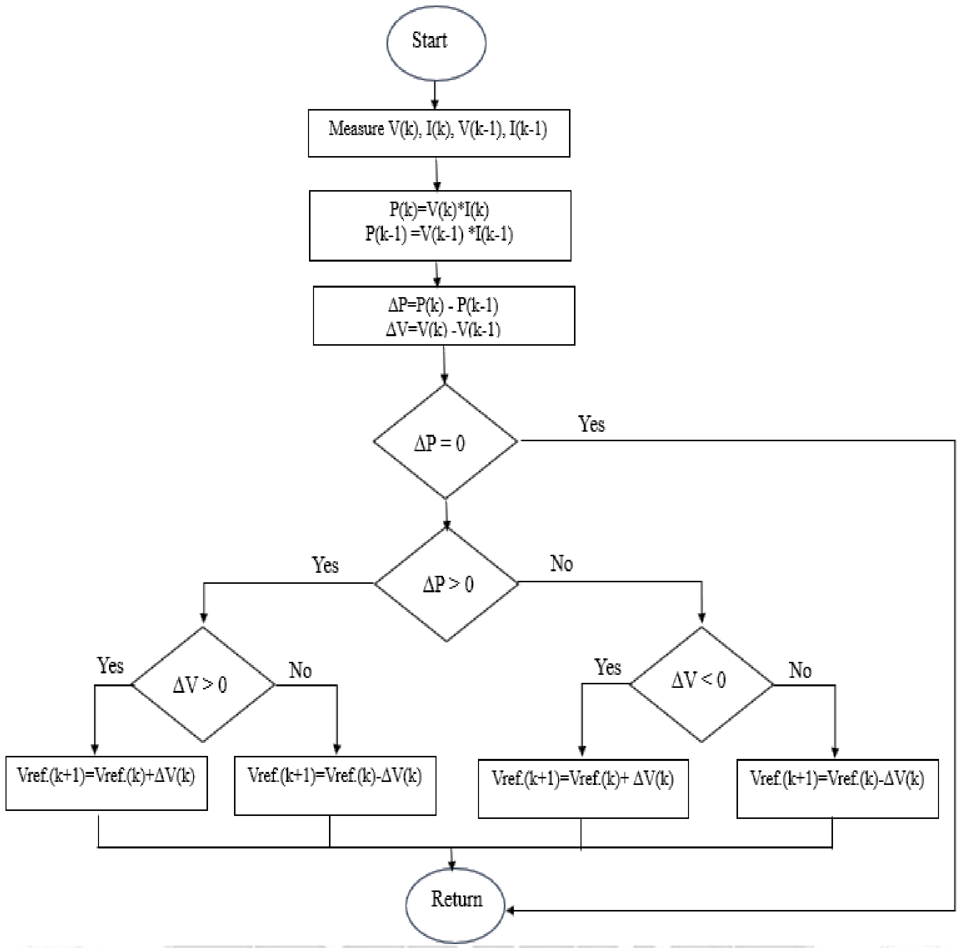


Figure 5: Flow diagram of the classical P&O technique.

4.2 Proposed Enhancement of P&O

Improving the accuracy and dynamic performance of MPPT in photovoltaic systems during quickly changing climates is the goal of the suggested adaptive dynamic steps to the perturb and observe algorithm. During rapid variations in temperature or sunlight, traditional P&O techniques may not be successful to track actual MPP due to steady-state oscillations around the MPP. The improved method reduces oscillations and accelerates convergence by using an adaptive perturbation step that changes according to the rate of power change. The proposed technique employs a dynamic selection mechanism based on real-time analysis of slope variations in the (P-V) characteristic curve. Furthermore, it is easier to differentiate between actual MPP swings and environmental fluctuations when a decision process based on both voltage and power trends is included. These modifications result in increased energy harvesting efficiency, improved system stability, and overall enhancement of PV system performance, such as the slope of the (P–V) curve. To enhance the efficiency of MPPT in PV systems, a dynamic size approach based on a slope variation can be employed. The algorithm sets a larger size to guarantee quick tracking when the PV system (slope is large) $\left|\frac{dp}{dV}\right|$ operating far from the MPP. Conversely, a smaller size is chosen to reduce oscillations and enhance steady-state performance

 ISSN: 2616 - 9916

when the process is close to MPP and slope $\left|\frac{dp}{dV}\right|$ is to be low. On the other hand, when slope of the (P-V) curve is very small (≈ 0), PV system is considered to have reached its MPP. At this stage, there is minimal variation in output power with respect to voltage, indicating that the system is operating at or near its highest efficiency. Consequently, no further adjustment to the operating voltage is required. The step size is adjusted based on this slope. Indeed, a dynamic step-size function can be defined:

$$\Delta V = f\left(\left|\frac{dP}{dV}\right|\right) \tag{10}$$

Where:

$$\Delta V = \begin{cases} \Delta V(Large) & \left|\frac{dP}{dV}\right| > \text{th1} \\ \Delta V(Medium) & \text{th2} < \left|\frac{dP}{dV}\right| \leq \text{th1} \\ \Delta V(Small) & \left|\frac{dP}{dV}\right| \leq \text{th2} \end{cases} \tag{11}$$

Where the slope thresholds th1 and th2 are determined via simulations. In P&O with variable step, the voltage update rule is:

$$V(k+1) = V(k) + sign\left|\frac{dP}{dV}\right| . \Delta V \tag{12}$$

In the context of MPPT algorithms, particularly those based on the P&O method, the function $sign\left|\frac{dP}{dV}\right|$ plays a critical role in determining whether the operating voltage should shift either to the left (reduction) or to the right (raise). Figure 6 illustrates (P–V) curve of a PV system, highlighting slope at different operating points.

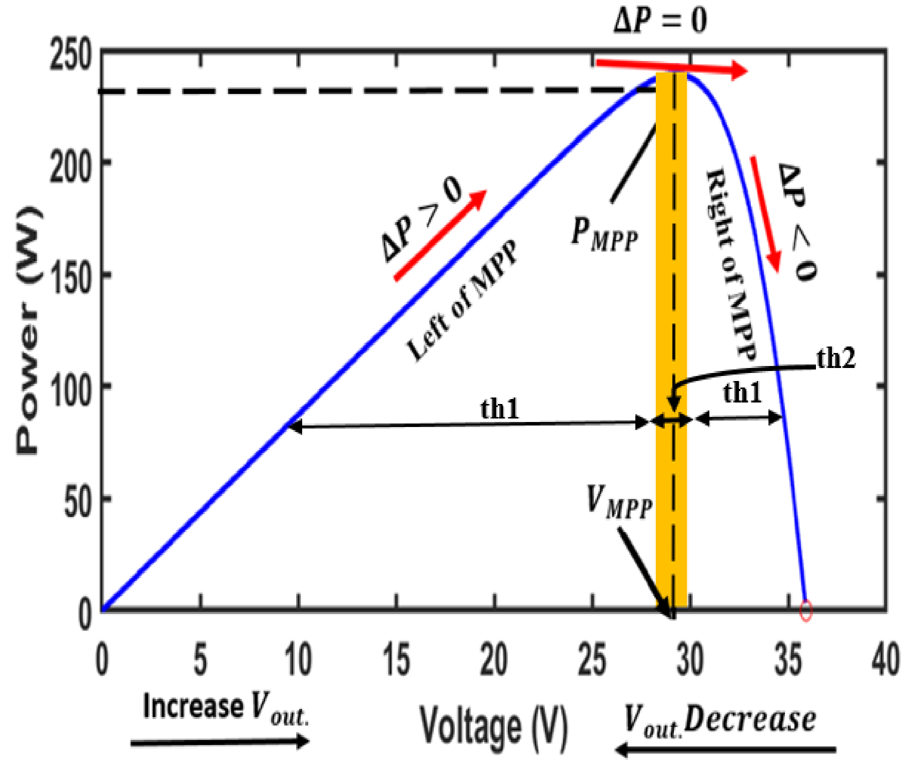


Figure 6: P–V curve illustrating the operational slope thresholds direction.

5. **Results of simulations**

Figure 7 illustrates the MATLAB simulation R2024a model of the PV system, which has been created and compared to the classic P&O algorithm in order to verify the performance of the AP&O algorithm presented in this work.

The study uses a pattern that simulates a 5-second period with two scenarios: sudden and gradual shading conditions, which are commonly used in PV system testing to evaluate the dynamic response of MPPT an algorithm.

The first scenario, which involves a gradual change in sunlight is illustrated in Fig. (8-a), and depicts the variation in solar sunlight over time. Initially, from (0 to 1.5) seconds, the illumination stays constant at 1000 W/m². On the other hand, from (1.5 to 2)seconds, a smooth transition in irradiance is observed, reaching a minimum value and staying at 600 W/m². After 3 seconds, the sunlight gradually increases back to 1000 W/m² and remains steady. Fig. (8-b) shows the current I_{MPP} and voltage V_{MPP} overtime at the MPP tracking, and Fig. (8-c) shows the $P_{max.}$ of solar PV under test.

In the second scenario, with a sharply change in sunlight, illustrated in Fig. (9-a), the irradiance initially remains constant at 1000 W/m² from (0 to 1.5) seconds. Then, it drops sharply to 600 W/m² and remains steady from (1.5 to 2) seconds. After this, there is another fall that lasts for time (2 to 3) seconds and reaches a minimum of about 200 W/m². The irradiance then rises in two periods, reaching 500 W/m² in around 3 seconds and 600 W/m² in 3.5 seconds, and remains there until the end of the period at 5 seconds. Figure (9-b) shows the current I_{MPP} and voltage V_{MPP} overtime at the MPP tracking, and Fig. (9-c) shows the $P_{max.}$ of solar PV under test. Table 3 presents the performance characteristics of a user-defined photovoltaic (PV) solar module operating under different levels of solar sunlight at a constant T=25°C.

Finally, based on the first and second scenarios, the P_{Load} is compared over a 5-second period utilizing both classic and adaptive P&O MPPT algorithms, as illustrated in Figs. (8-d) and (9-d). The adaptive P&O, on the other hand, responds more efficiently and quickly, with fewer oscillations than the conventional P&O, which exhibits greater fluctuations. Table 4 illustrates a comparison between the proposed MPPT approach and other applications in earlier studies.

Table 3: Characteristics of a "user-defined" PV solar module under varied sun illumination at an average temperature of 25°C.

Illumination levels (W/m^2)	$V_{oc}(V)$	$I_{sc}(A)$	$V_{MPP}(V)$	$I_{MPP}(A)$	$P_{MPP}(W)$
E1=1000	74.4	8.52	62.4	8.03	501.072
E2=600	72.779	5.152	61.954	4.803	297.595
E3=500	72.274	4.294	61.798	3.988	246.45
E4=200	69.528	1.718	59.984	1.595	95.674

Table 4: Evaluates the proposed MPPT technique with different uses in previous research studies.

ref.	Model of PV panal	MPPT Technique	Efficiency %
[18], (2021)	Kyocera KC200GT-200 W	Hybrid FLC and P&O Algorithm	98.5%
[19], (2022)	Mono-CL-100W	Deep ANN	99.77%
[20], (2021)	Bifacial LG340N1T-V5- 340 W	Inverter simulation	98.58%
Proposed Method	User-defined-500W	Conventional P&O	97.8%
	User-defined-500W	Adaptive P&O	99.2%

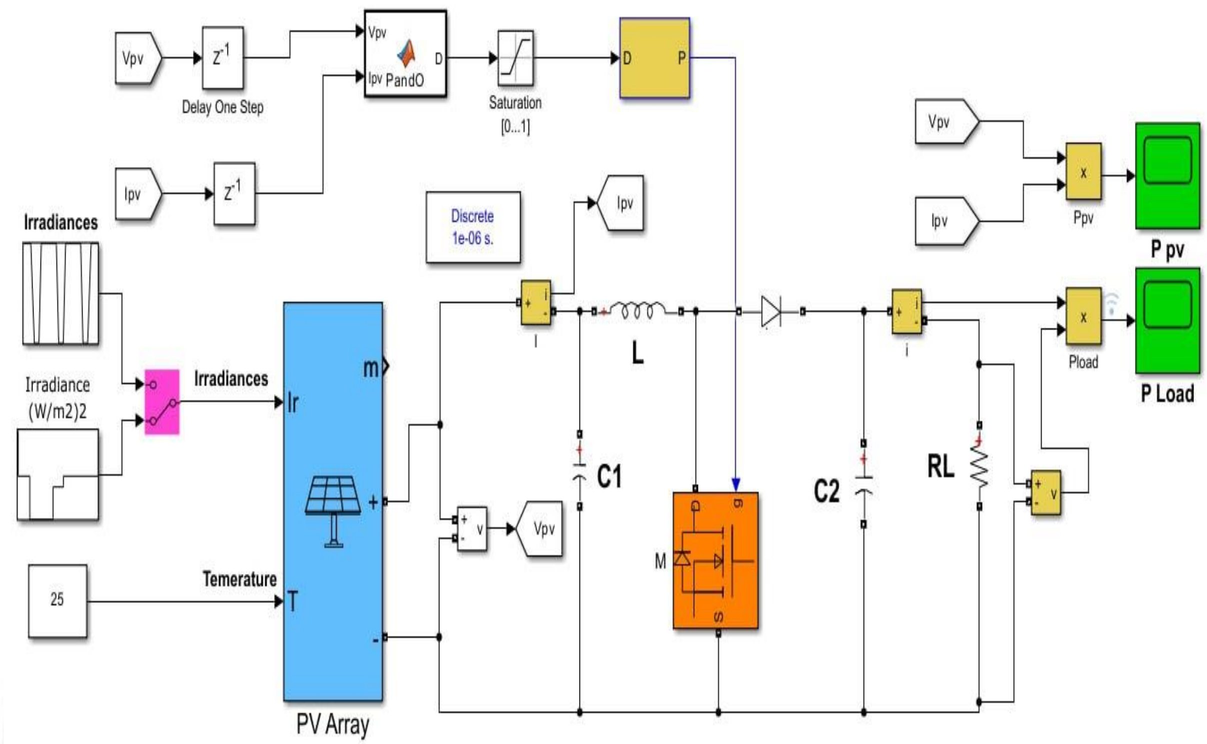
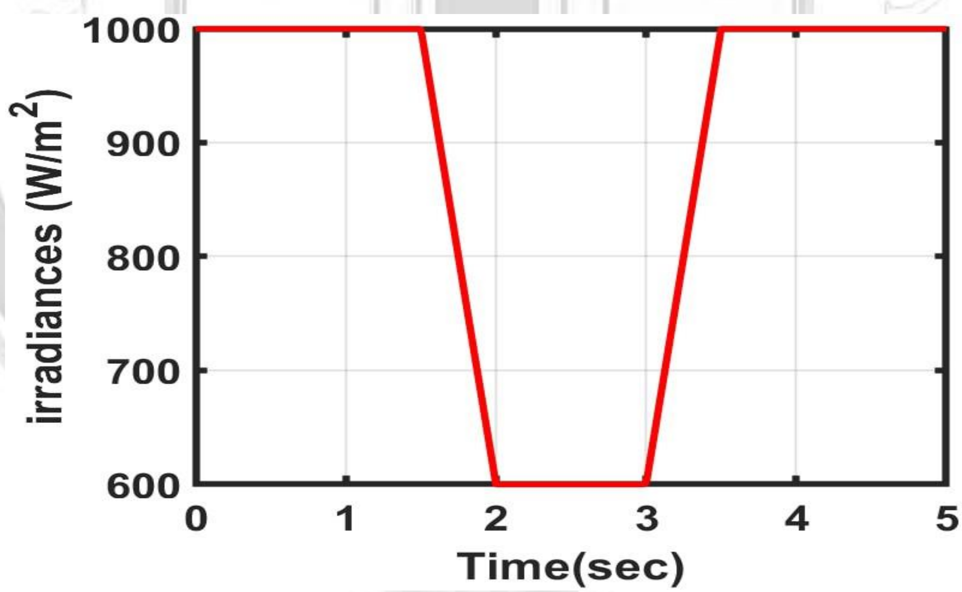
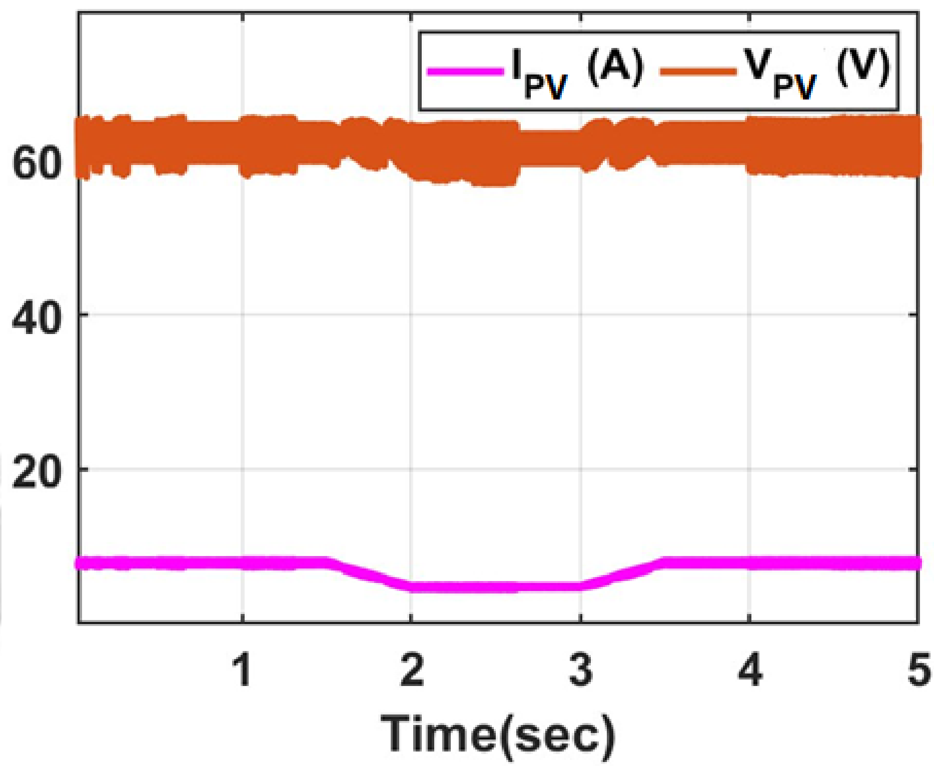


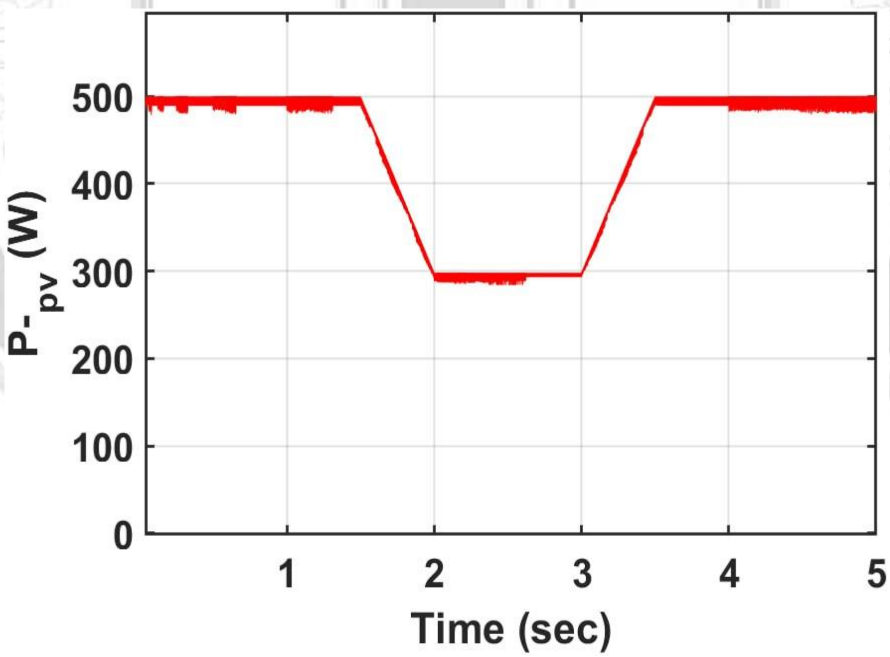
Figure 7: Simulink the operation for propose P&O technique photovoltaic array.



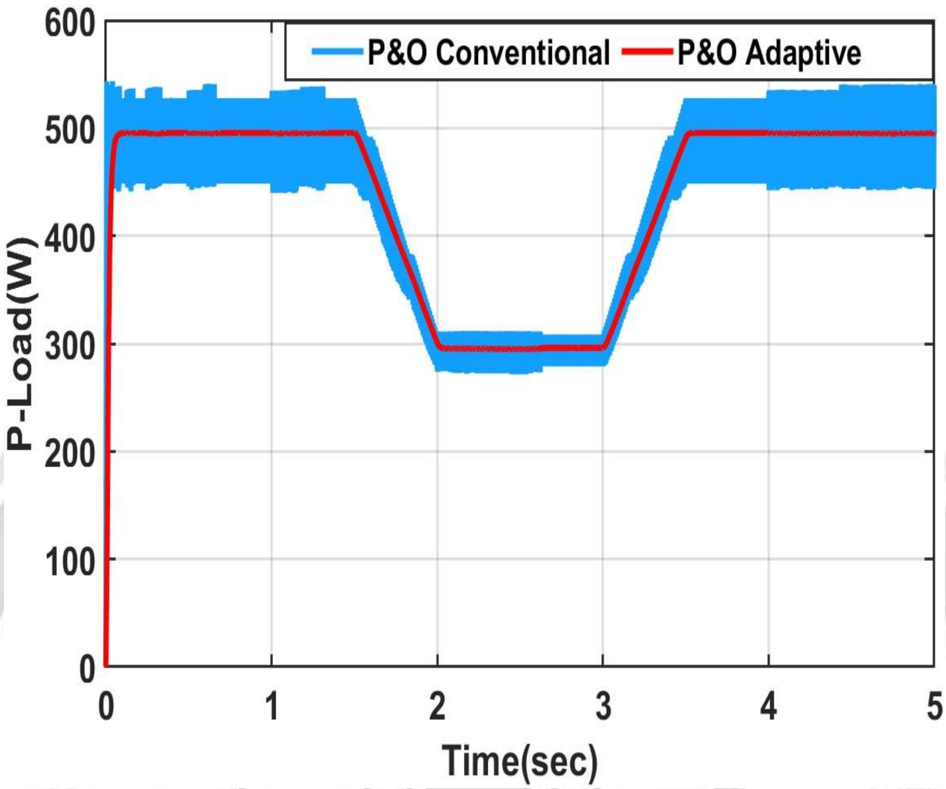
(a)


I_{PV} (A)
V_{PV} (V)
60
40
20
1
2
3
4
5
Time(sec)

(b)

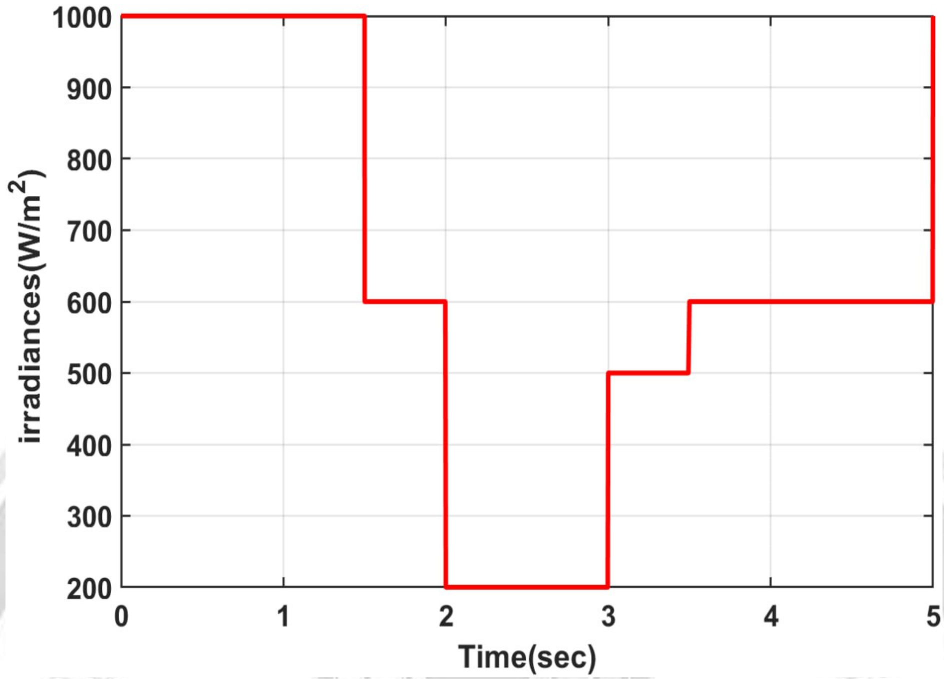

P-$_{pv}$ (W)
500
400
300
200
100
0
1
2
3
4
5
Time (sec)

(c)

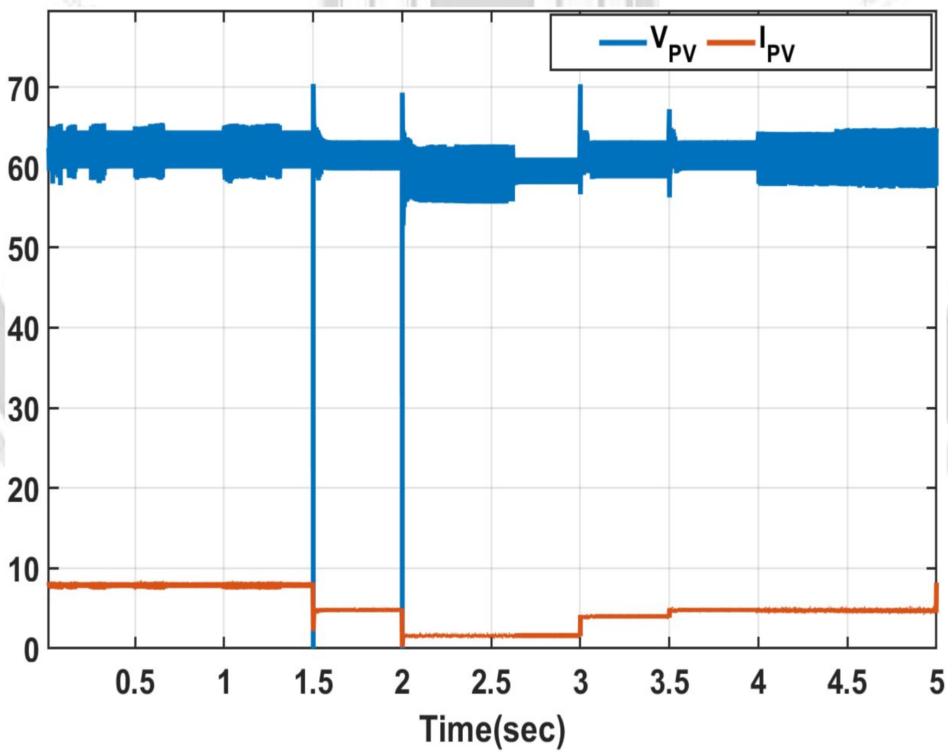


(d)

Figure 8: Graphs for first scenarios (a) change irradiances with time (b) current and voltage of PV- panel (c) Power P_pv with time (d) load power with time use P&O (conventional and adaptive)


1000
900
800
700
600
500
400
300
200
irradiances(W/m^2)
0
1
2
3
4
5
Time(sec)

(a)


V_{PV}
I_{PV}
70
60
50
40
30
20
10
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time(sec)

(b)

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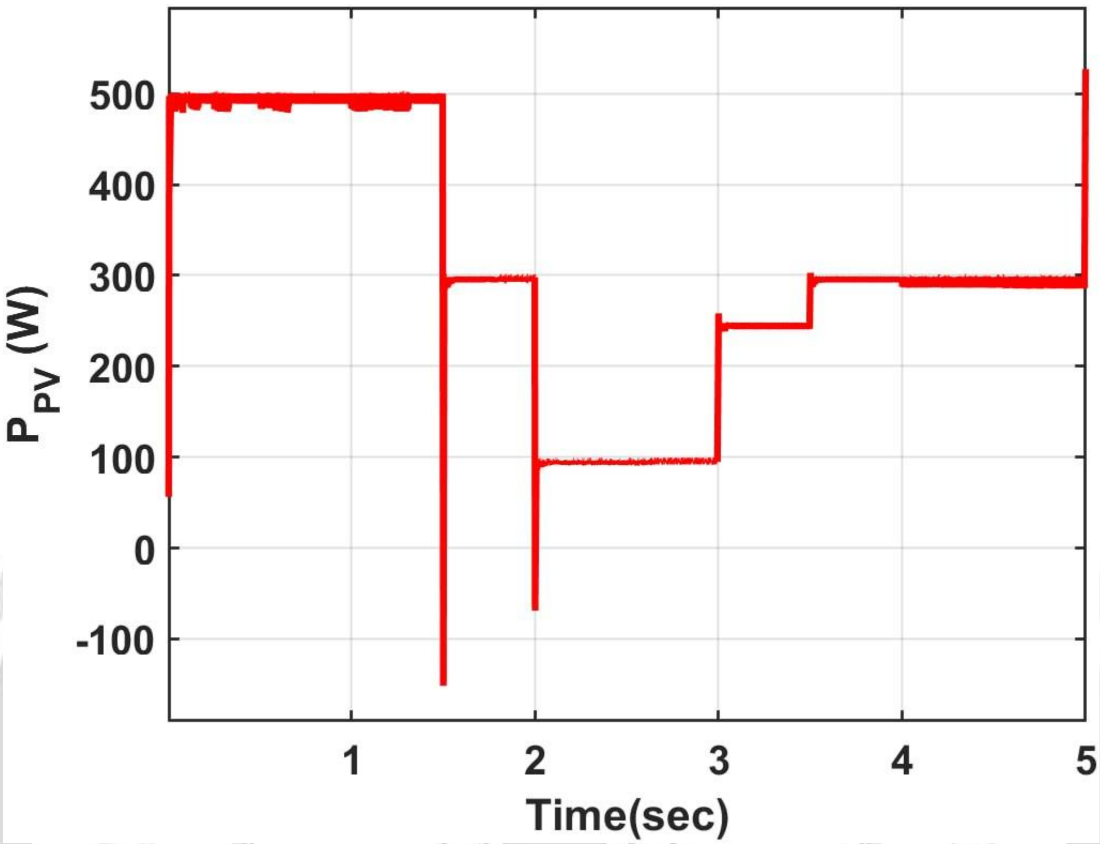
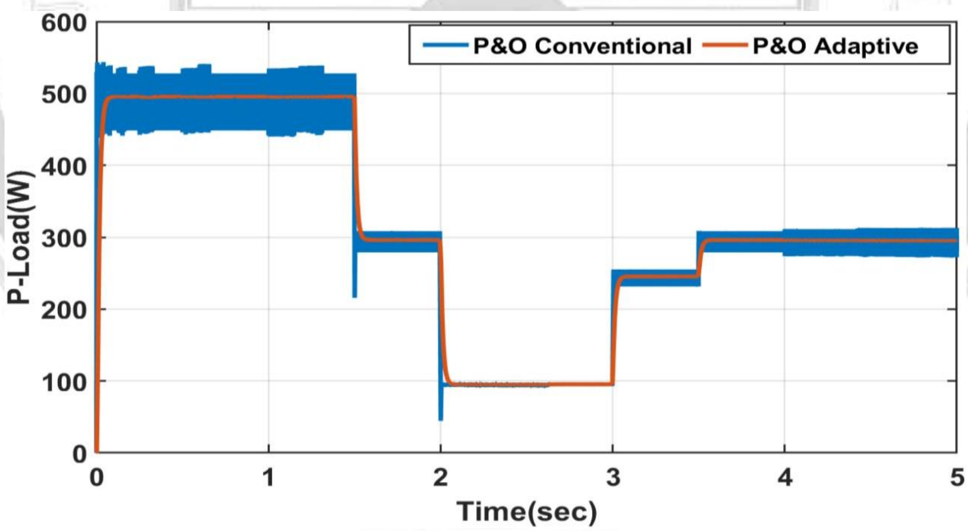


(c)



(d)

Figure 9: Graphs for second scenarios (a) change irradiances with time (b) current and voltage of PV- panel (c) Power P_pv with time (d) load power with time use P&O (conventional and adaptive)

6. Conclusions

A solution for increasing the efficiency through adaptive P&O-based MPPT optimization has been presented. It minimizes the likelihood of divergence from the MPP locus and reduces the steady state oscillation until it becomes very small by dynamically adjusting the perturbation size. In comparison to traditional MPP techniques, thorough simulation results clearly show the behavior of the algorithm and ensure an overall efficiency of 99.2% regardless of environmental changes. Moreover, its benefits include a simple algorithmic structure, fast response, and minimal computation.

7. References

[1] Li, Xianqi, Ye He, and Maojun Li. "Research on Photovoltaic Maximum Power Point Tracking Control Based on Improved Tuna Swarm Algorithm and Adaptive Perturbation Observation Method." Energies 17, No. 12, 2985, 2024, doi.org/10.3390/en17122985.

[2] Abbas, Ali, Muhammad Farhan, Muhammad Shahzad, Rehan Liaqat, and Umer Ijaz. "Power Tracking and Performance Analysis of Hybrid Perturb–Observe, Particle Swarm Optimization, and Fuzzy Logic-Based Improved MPPT Control for Standalone PV System." Technologies (2227-7080) 13, No. 3, 2025, doi.10.3390/technologies13030112.

[3] Saleem, O., S. Ali, and J. Iqbal. " Robust MPPT Control of Stand-Alone Photovoltaic Systems via Adaptive Self-Adjusting Fractional Order PID Controller." Energies. 16 (13): 5039, 2023, doi.org/10.3390/en16135039.

[4] J. K. Udavalakshmi and M. S. Sheik, “Comparative study of perturb and observe and look-up table maximum power point tracking techniques using MATLAB Simulink”, In IEEE international conference on current trends towards converging technologies, pp.1-5, 2018, doi.org/10.1109/ICCTCT.2018.8550835.

[5] Nadeem, A., Sher, H.A. and Murtaza, A.F., “Online fractional open-circuit voltage maximum output power algorithm for photovoltaic modules”, IET Renewable Power Generation” Vo. 14, No. 2, pp.188-198, 2020, doi.org/10.1049/iet-rpg.2019.0171.

[6] M.G. Abdolrasol, A. Ayob, A.H. Mutlag, and T.S. Ustun, “Optimal fuzzy logic controller based PSO for photovoltaic system”, Energy Reports, Vol.9, pp.427-434, 2023, doi.org/10.1016/j.egyr.2022.11.039.

[7] Mahmod Mohammad, Altwallbah Neda, Mohd Amran Mohd Radzi, Norhafiz Azis, Suhaidi Shafie, and Muhammad Ammirrul Atiqi Mohd Zainuri. "An enhanced adaptive perturb and observe technique for efficient maximum power point tracking under partial shading conditions." Applied Sciences 10, No. 11, 3912, 2020, doi.org/10.3390/app10113912.

[8] Mhanni, Youssef, and Youssef Lagmich. "Enhancing solar power harvesting with pinnacle multipoint optimization: a novel technique for maximum power point tracking." Frontiers in Energy Research 13, 1472768, 2025, doi.org/10.3389/fenrg.2025.1472768

[9] A.G. Olabi, M.A. Abdelkareem, C. Semeraro, M. Al Radi, H. Rezk, O. Muhaisen, O.A. Al-Isawi and E. T. Sayed, “Artificial neural networks applications in partially shaded PV systems”, Thermal Science and Engineering Progress, 37, p.101612, 2023, doi.org/10.1016/j.tsep.2022.101612.

[10] A.H. Abdullah, S.M. Alwash, W.M.S. Abed and H.M. Al Abboodi, “Enhanced Maximum Power Point Tracking Using Embedding Deep Networks and Self-Adaptive Genetic Algorithm”, International Journal of Intelligent Engineering and Systems, Vol.18, No.1, 2025, doi.org/10.22266/ijies2025.0229.10.

[11] Fazal Muhammad Rayyan, Zaheer Abbas, Muhammad Kamran, Inzamam ul Haq, Muhammad Naeem Ayyaz, and Muhammad Mudassar. "Modified Perturb and Observe MPPT algorithm for partial shading conditions." Int. J. Renew. Energy Res 9, No. 2, 721-731, 2019, doi.org/10.13140/RG.2.2.10089.54883.

[12] Manna, Saibal, Ashok Kumar Akella, and Deepak Kumar Singh. "Implementation of a novel robust model reference adaptive controller-based MPPT for stand-alone and grid-connected photovoltaic system." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 45, No. 1, 1321-1345, 2023, doi.org/10.1080/15567036.2023.2178550.

[13] A. Jusoh, R. Alik, T. K. Guan and T. Sutikno, “MPPT for PV system based on variable step size perturb and observe algorithm”, Telecommunication Computing Electronics and Control, Vol.15, No.1, pp.79-92, 2017, doi.org/10.12928/telkomnika.v15i1.3160.

[14] N. Hashim, Z. Salam, D Johari and N.F.N. Ismail, “DC-DC boost converter design for fast and accurate MPPT algorithms in stand-alone photovoltaic system”, International Journal of Power Electronics and Drive Systems, Vol. 9, No. 3, p.1038, 2018, doi.org/10.11591/ijpeds.v9.i3.pp1038-1050.

[15] Abdullah, Burhan U. Din, Suman Lata Dhar, Shiva Pujan Jaiswal, Muhammad Majid Gulzar, Mohammad Alqahtani, and Muhammad Khalid. "Hybrid MPPT control using hybrid pelican optimization algorithm with perturb and observe for PV connected grid." Frontiers in Energy Research 12, 1505419, 2025, doi.org/10.3389/fenrg.2024.1505419.

[16] Gopahanal Manjunath, Madhu, Chintamani Vyjayanthi, and Chirag N. Modi. "Adaptive step size based drift-free P&O algorithm with power optimiser and load protection for maximum power extraction from PV panels in stand-alone applications." IET Renewable Power Generation 15, No. 6, 1270-1285, 2021, doi.org/10.1049/rpg2.12105.

[17] Arezki, Saliha, and Dydia Doufene. "Novel Dual P&O MPPT Techniques for Enhancing Power Harvesting." In International Conference on Artificial Intelligence in Renewable Energetic Systems, pp. 162-174, Cham: Springer Nature Switzerland, 2023, doi.org/10.1007/978-3-031-60632-8_14.

[18] Kiran Kumar, B. M., M. S. Indira, and S. Nagaraja Rao. "Performance analysis of multiple gain boost converter with hybrid maximum power point tracker for solar PV connected to grid." Clean Energy 5, No. 4, 655-672, 2021, doi.org/10.1093/ce/zkab037.

[19] Attia, Hussain, and Khaled Hossin. "Efficient maximum power point tracker based on neural network and sliding-mode control for buck converters." Clean Energy 6, No. 5, 716-725, 2022, doi.org/10.1093/ce/zkac048.

[20] Mehadi, Abdullah Al, Misbahul Alam Chowdhury, Mirza Muntasir Nishat, Fahim Faisal, and Md Minhajul Islam. "A software-based approach in designing a rooftop bifacial PV system for the North Hall of Residence, IUT." Clean Energy 5, No. 3 403-422, 2021, doi.org/10.1093/ce/zkab019.

ARTICLE
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تعزيز كفاءة تتبع القدرة في الأنظمة الكهروضوئية المستقلة من خلال تحسين خوارزمية الاضطراب والمراقبة

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الخلاصة :

يُعد تعزيز كفاءة إنتاج الطاقة في الأنظمة الكهروضوئية (PV) تحديًا هندسيًا كبيرًا، لا سيّما في ظل تغيرات الطقس والظروف المناخية المختلفة. توفّر الأنظمة الكهروضوئية مصدرًا نظيفًا وغير قابل للنضوب من الطاقة، إلا أن أداءها يتأثر بشكل كبير بالعوامل المناخية مثل شدة الإشعاع الشمسي، ودرجة حرارة الخلية، والشمس الغائمة جزئيًا. تعتمد خوارزمية تتبع نقطة القدرة العظمى (MPPT) بشكل شائع على تقنية الاضطراب والمراقبة (P&O). ومع ذلك، فعند استخدام خطوة اضطراب كبيرة، قد تؤدي الطريقة إلى تذبذب حول نقطة القدرة العظمى. وعلى النقيض، فإن استخدام خطوة صغيرة يحسن دقة التتبع لكنه يبطئ وقت الاستجابة بشكل ملحوظ، مما يحد من قدرة النظام على الوصول بسرعة إلى نقطة القدرة العظمى الحقيقية في ظل التغيرات البيئية. ولمعالجة هذه المشكلات، تم اقتراح نهج محسّن يعتمد على استخدام خطوات اضطراب تكيفية. تقوم هذه الخوارزمية المحسّنة بضبط نبضة التشغيل مغير الرفع (Boost Converter) بشكل ديناميكي، مما يسمح بتتبع أكثر كفاءة ودقة لنقطة القدرة العظمى تحت الظروف المناخية المتغيرة. تُستخدم وحدة تحكم دقيقة في تنفيذ خوارزمية تتبع نقطة القدرة العظمى (MPPT) على مستوى البرمجيات. وتُعد هذه الوحدة جزءًا من دائرة التحكم، وهي وحدة التحكم في شحن الطاقة الشمسية. تم محاكاة الدائرة المقترحة باستخدام برنامج MATLAB/Simulink إصدار R2024a في نظام توليد الكهرباء الكهروضوئي المستقل عن الشبكة. وقد أظهرت الخوارزمية المحسنة المعتمدة لتقنية الاضطراب والمراقبة (P&O) أداءً أكثر سلاسة وكفاءة أعلى مقارنةً بالخوارزمية التقليدية ذات الخطوة الثابتة.

الكلمات الدالة: الأنظمة الكهروضوئية، خوارزمية الاضطراب والمراقبة (P&O)، تكيف حجم الخطوة