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Improving MPPT system performance through improved Perturb and Observe algorithm in solar power plant system

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ABSTRACT

This study evaluates the performance of Maximum Power Point Tracking (MPPT) algorithms using conventional and modified Perturb and Observe (P&O) methods in photovoltaic systems. Tests were conducted across irradiance levels of 200-600 W/m². Results demonstrate that the modified P&O method significantly reduces oscillations and improves convergence speed compared to the conventional approach. At 600 W/m² irradiance, the modified method achieves MPP in 325 ms with 9.85 W power output, while the conventional method requires 345 ms, producing 8.775 W. Increased irradiance correlates positively with power output and negatively with MPP tracking time. This research validates the effectiveness of the modified P&O method in enhancing efficiency and stability of MPPT systems in photovoltaic applications.

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1. INTRODUCTION

The use of fossil energy as fuel for power plants in Indonesia continues to increase, causing a shortage of fossil energy and significant environmental and air pollution impacts. To reduce dependence on fossil energy, one solution that can be taken is the use of alternative energy such as solar energy [1]-[3]. Solar energy can be converted into electrical energy through solar panels, where the power generated depends on the intensity of radiation and the temperature of the sun received by the panel. These factors are key in maximizing the capacity of solar energy received to be converted into electrical energy [4].

To achieve and maintain the position of the maximum power point (Maximum Power Point), the Maximum Power Point Tracking (MPPT) method is used [5]. There are various types of MPPT, including conventional MPPT, Intelligence MPPT, and Hybrid MPPT, each with its own advantages and disadvantages. Conventional MPPT, for example, is often difficult to adapt to environmental changes, while Intelligence MPPT requires high resources to run complex systems, and Hybrid MPPT requires complex algorithms and more complicated circuits [6]-[16].

This research focuses on the development of conventional MPPT methods, one of which is the Perturb and Observe (P&O) method. The P&O method works by detecting disturbances in the photovoltaic output power and evaluating the output power by taking into account previous perturbations [13]. The advantage of this method is its ability to independently regulate the duty cycle to reach the maximum power point [17]-[25]. In addition to the MPPT algorithm, photovoltaic optimization can also be done through a DC-DC converter. This converter not only helps MPPT performance, but is also able to increase or decrease the voltage value as needed [4]. This study uses a Boost Converter, which can increase the output voltage of solar panels. This Boost Converter is connected to the MPPT, so that the MPPT voltage can be controlled using PWM (Pulse Width Modulation) [23].

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2. METHOD

The design in this study aims to find and analyze the maximum power point of the solar panel output connected to the Boost Converter power circuit using the Perturb and Observe algorithm. The output of the solar panel will be compared in its performance with the Perturb and Observe algorithm both conventionally and modified, in order to obtain optimal results. The MPPT system block diagram can be seen in Figure 1 below.

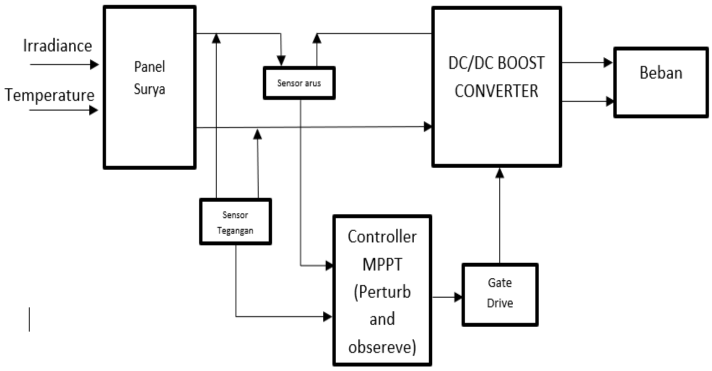


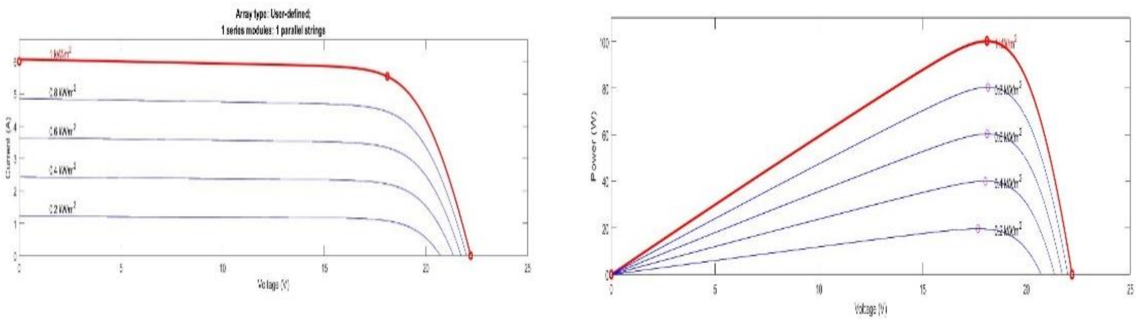
Figure 1. MPPT system block diagram

In Figure 1 Solar panels receive temperature and solar irradiation which are converted into electrical energy. The PV output produces unstable voltage and current due to the influence of irradiation and changing temperature. This current and voltage are controlled by the Arduino microcontroller using the P&O method to regulate the duty cycle on the boost converter. The photovoltaic module used is the MSP-100 W type with a maximum power of around 100 W. Full specifications are given in Table 1.

Table 1. Specifications of PV MSP-100W

Parameter	Variable	Value
Maximum Power	Pmax	100 W
Voltage at P_{max}	Vmp	18.1 V
Current at P_{max}	Imp	5.54 A
Open sirkuit voltageV_{oc}	V_{oc}	22.2 V
Short circuit current	I_{sc}	6.00 A
Temperature coefficient Voc	Kv	-(0.40)%/°C
Temperature coefficient Ioc	K_i	-(0.65)%/°C
Number of cells and connections	n_s	72 (4 x 18)

The PV characteristic curves are shown in Figure 2. Figure 2a shows the characteristic curve of voltage change against current, Figure 2b shows the characteristic curve of voltage against power affected by solar radiation.



(a) (b)

Figure 2. PV characteristic, (a) Voltage versus current characteristic curve
(b) Voltage versus power characteristic curve.

2.1 Boost Converter

Boost converter or commonly called Step Up Converter is a power supply converter that can increase the output voltage greater than the input voltage [15]. The components used in this power supply topology include Mosfet, Inductor, Diode, Capacitor, and Resistor. When the switch is in the ON position, current will flow from the source to the inductor so that the inductor voltage will be the same as the input voltage [1]. When the switch is in the OFF position, the current stored in the inductor will flow to the load through the diode so that the boost output voltage is greater than the input voltage [17]. Figure 3 shows the boost converter topology.

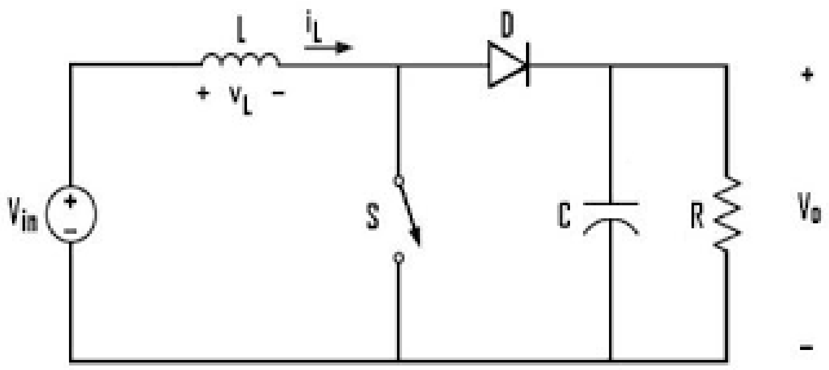


Figure 3. Topology Boost Converter

The relationship between Vin, Vout, and D of boost converter can be written as :

$$D = \frac{V_{in}}{V_{out}} \tag{1}$$

The capacitance value of the boost converter needs to be designed so that it helps reduce the voltage ripple at the output, which is stated in the following equation.

$$L = \frac{V_{in}\,D}{\Delta I_L\,f} \tag{2}$$

The inductor value in the boost converter needs to be designed so that it helps in limiting the input current ripple which is stated in the following equation :

$$C = \frac{I_{out}D}{\Delta V_o\,f} \tag{4}$$

Based on the equation above, we can obtain parameter values that can be used to design a boost converter .

Table 2. Boost converter design parameter values

Parameter	Symbol	Value
Voltage input	Vin	18 V
Voltage output	Vout	38 V
Resistor	R	50 ohm
Switching frequency	f	62500 Hz
Duty cycle	D	0.47
Ripple current	ΔI	1 %
RippleVoltage	ΔV	1 %
Inductor value	L	2.2 mH
Capasistor value	C	100 µF

2.2 Perturb and Observe Algorithm

The working principle of P&O is to increase or decrease the PV output voltage and compare the previous cycle power with the current cycle power. The voltage value will change as the power increases. MPPT will continue to track the position of the maximum power point. Otherwise, the operating point will change in the opposite direction. Figure 4 show the P&O algorithm.

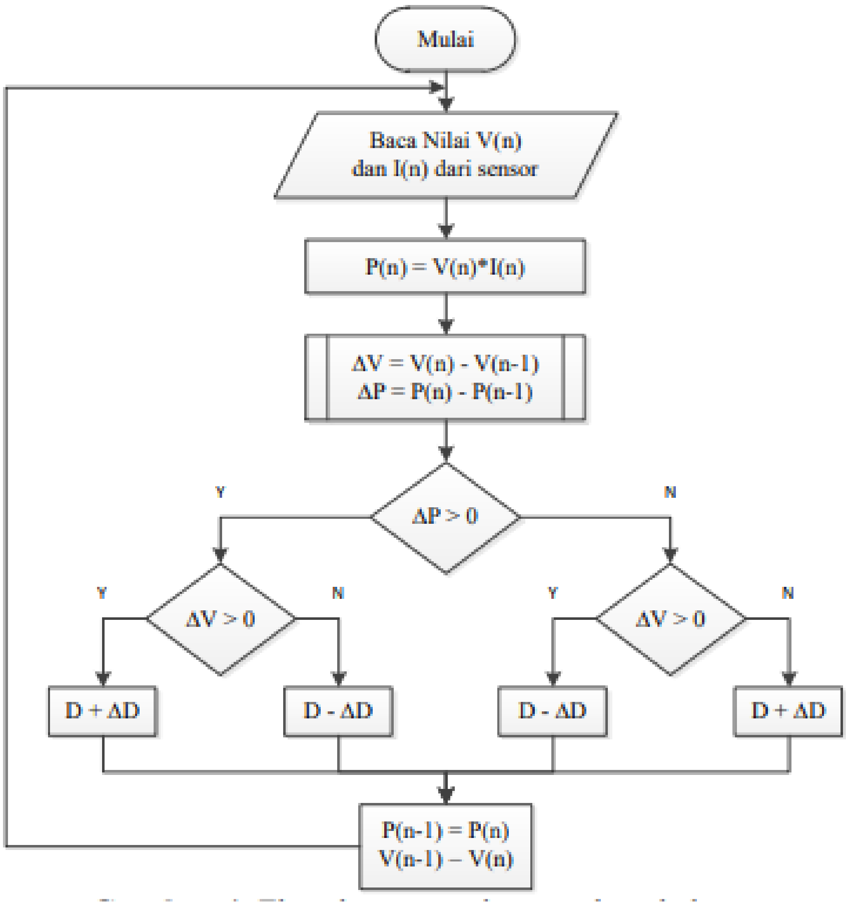


Figure 4. Flowchart of Conventional P&O Algorithm

This process will produce oscillations around the MPP, so that this process will lose efficiency. In addition, the conventional P&O algorithm takes a long time to reach the maximum point (MPP). So in overcoming the problem of oscillations around the MPP point and the speed of reaching the MPP point, modifications are needed to the P&O algorithm, so that the system can produce higher and more stable efficiency. The perturb and observe algorithm has several parameters, including the initial initialized value and the size of the step value change that occurs during each iteration. To maintain the capability of the boost converter, duty cycle limitations are also needed to run this algorithm. The delay time to run the program in one iteration is set to provide a feedback response if the duty cycle value changes. Table 3 shows the parameters used in the perturb and observe algorithm.

Table 3. Perturb and observe algorithm parameters

Perturb and Observe Algorithm Parameters	
Duty cycle	0.1 – 0.8
Step size	0.01
Delay	500

2.3 Modified Perturb and Observe Algorithm

To overcome the shortcomings of conventional P&O, modifications are made by changing the value of ΔD used. After finding the maximum power point, the value of ΔD will be multiplied by a constant value between 0-1, so that the value of ΔD will be smaller. Figure 5 show the modified P&O algorithm.

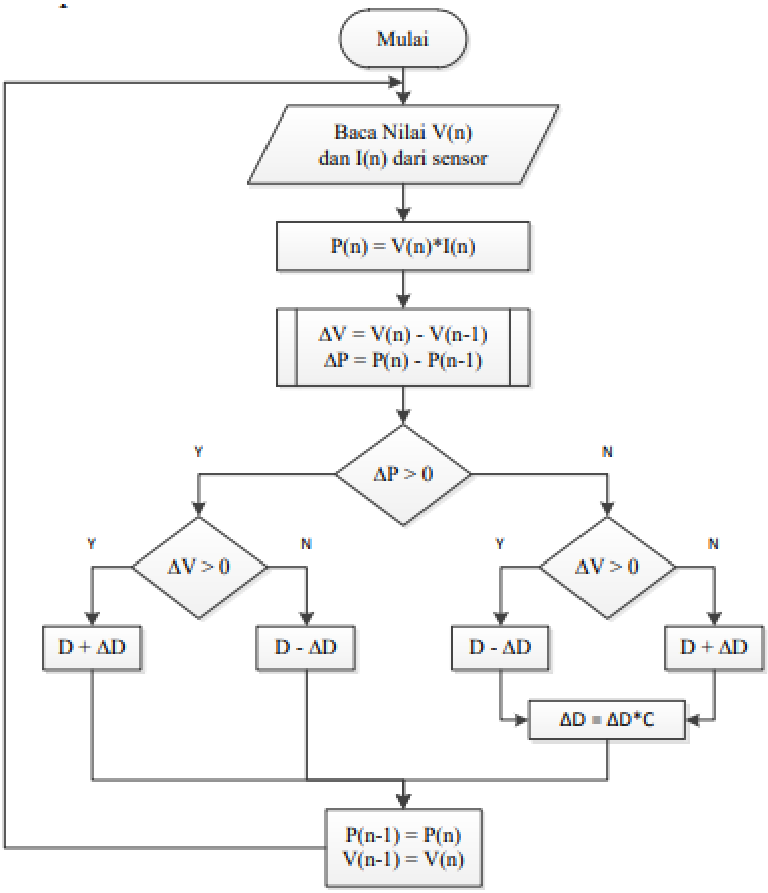


Figure 5. Flowchart of Modified P&O Algorithm

The perturb and observe algorithm also has a step size value that is changed and observed. The algorithm has several parameters, including initialization of the initial value and the amount of change in the step size value for each iteration. The step size value of the algorithm is changed and observed and will change according to the system response. The constant value C is used to set how much the step size (ΔD) changes at each iteration, so that the system can be responsive to changes in environmental conditions. In addition, the duty cycle value is limited to maintain the boost converter's capability. The delay time to run the program in one iteration is set to provide a feedback if the duty cycle value changes. Table 4 shows the parameters used in the modified change and observation algorithm.

Table 4. Parameters of the Perturb and Observe Modification Algorithm

Perturb and Observe Modified Algorithm Parameters	
Duty Cycle	0.1 – 0.8
Delta D	0.02
Konstanta	0.99
Delay	100 ms

3. RESULTS AND DISCUSSION

This study evaluates the performance of MPPT Algorithm with conventional and modified P&O methods. Experiments were conducted by varying the irradiance levels in the range of 200 W/m², 400 W/m², and 600 W/m², and gradually decreasing from 600 W/m² to 400 W/m² and 200 W/m². A resistive load of 50 ohms was used in the test. The following Figure 6 illustrates the comparative results of the two approaches studied. Figure 6 shows the results of waveform measurements from the implementation of the conventional P&O method. Analysis of the output waveform reveals significant oscillations around the MPP point, as well as suboptimal tracking duration and MPP achievement. These characteristics indicate that the conventional P&O method still has potential for improvement, especially in terms of stability and convergence speed to the MPP.

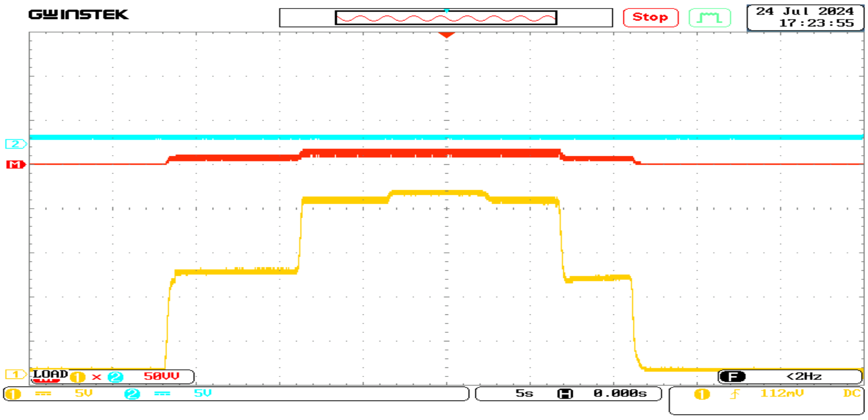
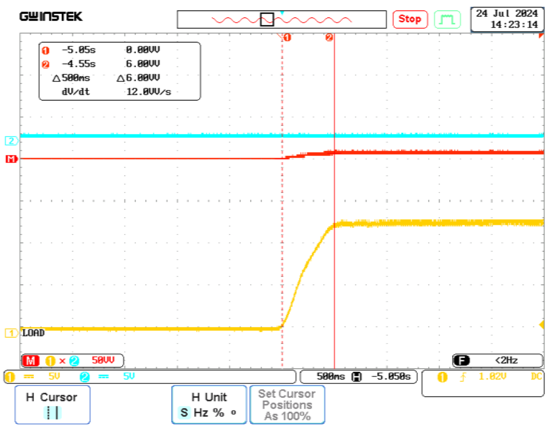
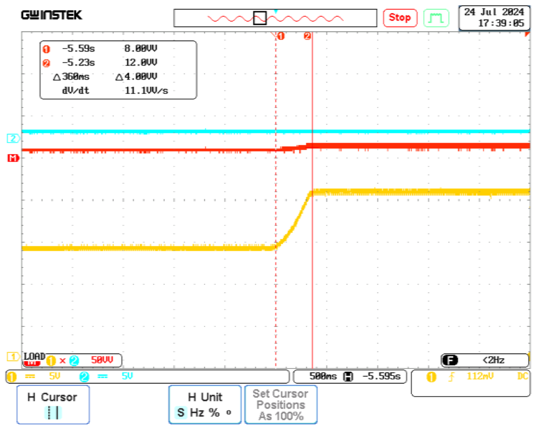


Figure 6. Conventional P&O Input Waveform Test Results

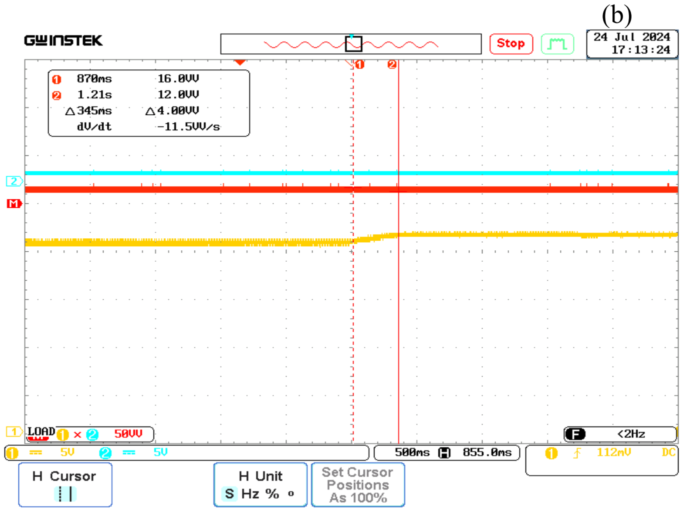
At low irradiance (0-200 W/m²), the system takes 500 ms to reach MPP, with a maximum power of 2.95 W. At medium irradiance (200-400 W/m²), the system takes 360 ms, with a maximum power of 7.03 W. At high irradiance (400-600 W/m²), the system reaches MPP in 345 ms, with a maximum power of 8.775 W, as shown in Figure 7.



(a)



(b)



(c)

Figure 7. Experimental results of conventional P&O algorithm. a) irradiance 0 -200 W/m^2, b) irradiance 200 – 400 W/m^2, c) irradiance 400 – 600 W/m^2

Figure 8 shows the results of waveform measurements from the implementation of the modified P&O method. Analysis of the output waveform shows a significant reduction in oscillations around the MPP point. At 0-200 W/m² irradiance, the system takes 385 ms to reach MPP, with a maximum power of 3.294 W. At 200-400 W/m² irradiance, the tracking time is reduced to 310 ms, with a maximum power of 7.52 W. At 400-600 W/m² irradiance, the system reaches MPP in 325 ms, with a maximum power of 9.85 W. At irradiance of 600-400 W/m², the system takes 305 ms to reach MPP, with a maximum power of 7,708 W.

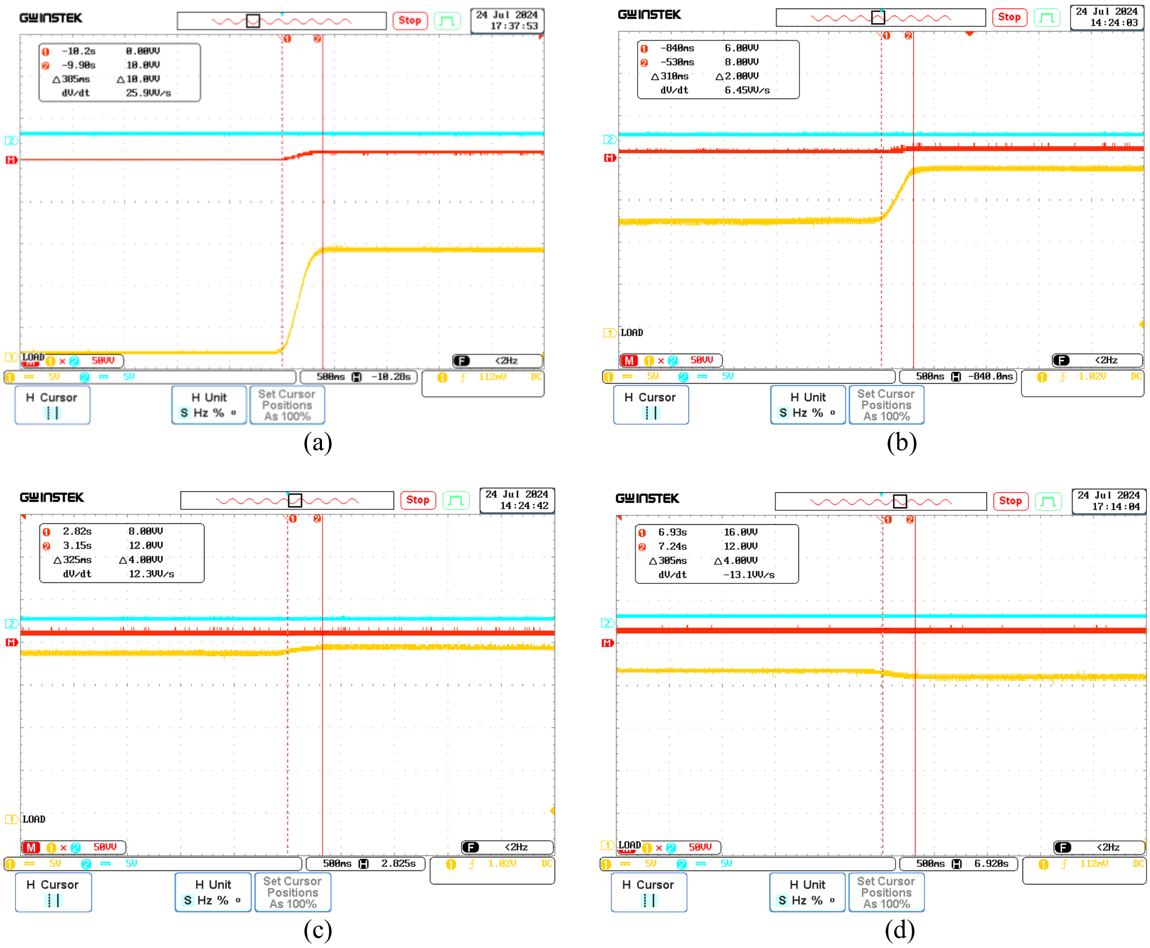


Figure 8. Modified P&O algorithm result. a) irradiance 0 -200 W/m^2, b) irradiance 200 – 400 W/m^2, c) irradiance 400 – 600 W/m^2, d) irradiance 600 – 400 W/m^2

4. CONCLUSION

This study examines the effectiveness of the Maximum Power Point Tracking (MPPT) algorithm using the Perturb and Observe (P&O) method and its modification variations on a photovoltaic system connected to a Boost converter. The results show that the P&O algorithm is able to achieve the maximum power point (MPP) well under stable solar radiation conditions, but shows less than optimal performance under conditions of rapid radiation changes. Modification of the P&O algorithm by setting the step size value using the constant C is proven to improve the algorithm's ability to adjust to changes in environmental conditions, making it more efficient in maintaining MPP. The use of a Boost converter is effective in increasing the output voltage of the solar panel, which ultimately increases the overall efficiency of the system. In addition, the duty cycle value regulated through PWM (Pulse Width Modulation) in the Boost converter provides more precise control over the output voltage, thereby increasing system stability.

For further research, some suggestions that can be considered are implementing other MPPT algorithms such as Fuzzy Logic or Neural Network to be compared with the P&O algorithm in various environmental conditions, conducting tests in various weather conditions and solar radiation intensities to validate the performance of the modified P&O algorithm in more diverse situations, and integrating real-time monitoring and control systems to improve the responsiveness and adaptability of the MPPT algorithm to dynamic environmental changes. In addition, developing and testing a larger photovoltaic system prototype to measure the scale of system efficiency and reliability in real-world applications, as well as examining the impact of the constant C value used in the algorithm modification on the overall system performance, and finding the optimal value for a particular application, are also important to do. This research provides an important contribution in efforts to improve the efficiency and stability of photovoltaic systems through MPPT algorithm optimization, especially the modified P&O method.

REFERENCES

[1] K. S. Tey and S. Mekhilef, "Modified Incremental Conductance Algorithm for Photovoltaic System Under Partial Shading Conditions and Load Variation," *IEEE Transactions on Industrial Electronics*, vol. 61, no. 10, pp. 5384-5392, Oct. 2014, doi: 10.1109/TIE.2014.2304921.

[2] Asnil, Krismadinata, E. Astrid., and I. Husnaini, "Enhanced Incremental Conductance Maximum Power Point Tracking Algorithm for Photovoltaic System in Variable Conditions," vol. 57, no. 1, pp. 33–43, 2024.

[3] Asnil, Krismadinata, I. Husnaini, and E. Astrid, "Characteristics Of Photovoltaic Modules In Various Configurations For Partial Shading Conditions," *Journal of Theoretical and Applied Information Technology*, vol. 99, no. 22, 2021

[4] M. Alsumiri, "Residual Incremental Conductance Based Nonparametric MPPT Control for Solar Photovoltaic Energy Conversion System," *IEEE Access*, vol. 7, pp. 87901-87906, 2019, doi: 10.1109/ACCESS.2019.2925687.

[5] M. Dhimish, "70% Decrease of Hot-Spotted Photovoltaic Modules Output Power Loss Using Novel MPPT Algorithm," *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 66, no. 12, pp. 2027-2031, Dec. 2019, doi: 10.1109/TCSII.2019.2893533.

[6] H. Li, D. Yang, W. Su, J. Lü, and X. Yu, "An overall distribution particle swarm optimization MPPT algorithm for photovoltaic system under partial shading," *IEEE Trans. Ind. Electron.*, vol. 66, no. 1, pp. 265–275, Jan. 2019, doi: 10.1109/TIE.2018.2829668.

[7] M. Lasheen, A. K. A. Rahman, M. Abdel-Salam, and S. Ookawara, "Adaptive reference voltage-based MPPT technique for PV applications," *IET Renew. Power Gener.*, vol. 11, no. 5, pp. 715–722, Apr. 2017, doi: 10.1049/iet-rpg.2016.0749.

[8] I. F. Sanul and M. Yuhendri, "Sistem Kendali MPPT Panel Surya Dengan Menggunakan Algoritma Jaringan Saraf Tiruan," *JTEIN J. Tek. Elektro Indones.*, vol. 4, no. 1, pp. 345–352, 2023.

[9] S. Tang, "An enhanced MPPT method combining fractional-order and fuzzy logic control," *IEEE J. Photovolt.*, vol. 7, no. 2, pp. 640–650, Mar. 2017, doi: 10.1109/JPHOTOV.2017.2649600.

[10] L. Shang, H. Guo and W. Zhu, "An Improved MPPT Control Strategy Based on Incremental Conductance Algorithm," *Protection and Control of Modern Power Systems*, vol. 5, no. 2, pp. 1-8, April 2020, doi: 10.1186/s41601-020-00161-z.

[11] W. Jinpeng, Y. Qinxue, Z. Bo, Jeremy-Gillbanks and Z. Xin, "Study on MPPT Algorithm Based on an Efficient Hybrid Conjugate Gradient Method in a Photovoltaic System," *IEEE Access*, vol. 11, pp. 4219-4227, 2023, doi: 10.1109/ACCESS.2022.3233826.

[12] M. Yuhendri and G. S. Putra, "Implementasi Sistem Kendali MPPT Panel Surya Berbasis Algoritma Incremental Conductance," *JTEIN J. Tek. Elektro Indones.*, vol. 1, no. 2, pp. 218–223, 2020, doi: 10.24036/jtein.v1i2.72.

[13] S. Xu, R. Shao, B. Cao and L. Chang, "Single-phase grid-connected PV system with golden section search-based MPPT algorithm," *Chinese Journal of Electrical Engineering*, vol. 7, no. 4, pp. 25-36, Dec. 2021, doi: 10.23919/CJEE.2021.000035.

[14] O. Abdel-Rahim and H. Wang, "A new high gain DC-DC converter with model-predictive-control based MPPT technique for photovoltaic systems," *CPSS Transactions on Power Electronics and Applications*, vol. 5, no. 2, pp. 191-200, June 2020, doi: 10.24295/CPSSTPEA.2020.00016.

[15] D. C. Huynh, T. N. Nguyen, M. W. Dunnigan, and M. A. Muller, "Dynamic particle swarm optimization algorithm based maximum power point tracking of solar photovoltaic panels," in *Proc. IEEE Int. Symp. Ind. Electron. Conf.*, May 2013, pp. 1–6.

[16] H. Masrepol and M. Yuhendri, "Implementasi MPPT Panel Surya Berbasis Algoritma Perturbasi & Observasi (PO) Menggunakan Arduino," *JTEIN J. Tek. Elektro Indones.*, vol. 2, no. 2, pp. 162–167, 2021, doi: 10.24036/jtein.v2i2.155.

[17] S. Lyden and M. E. Haque, "Comparison of the perturb and observe and simulated annealing approaches for maximum power point tracking in a photovoltaic system under partial shading conditions," in *Proc. IEEE Energy Convers Congr. Expo.*, Sep. 2014, pp. 2517–2523.

[18] K. Ishaque, Z. Salam, M. Amjad, and S. Mekhilef, "An improved particle swarm optimization (PSO) based MPPT for PV with reduced steady-state oscillation," *IEEE Trans. Power Electron.*, vol. 27, no. 8, pp. 3627–3638, Aug. 2012.

[19] A. Lindo and M. Yuhendri, "Sistem Kendali Daya Maksimum Panel Surya Berbasis Fuzzy Logic Controller," *JTEIN J. Tek. Elektro Indones.*, vol. 3, no. 1, pp. 102–110, 2022, doi: 10.24036/jtein.v3i1.207.

[20] H. Renaudineau et al., "A PSO-based global MPPT technique for distributed PV power generation," *IEEE Trans. Ind. Electron.*, vol. 62, no. 2, pp. 1047–1058, Feb. 2015.

[21] Q. Zhu, X. Zhang, S. S. Li, C. Liu, and H. Ni, "Research and test of power loop based dynamic multi-peak MPPT algorithm," *IEEE Trans. Ind. Electron.*, vol. 63, no. 12, pp. 7349–7359, Dec. 2016.

[22] Y. Zhou, C. N. M. Ho and K. K. -M. Siu, "A Fast PV MPPT Scheme Using Boundary Control With Second-Order Switching Surface," *IEEE Journal of Photovoltaics*, vol. 9, no. 3, pp. 849-857, May 2019, doi: 10.1109/JPHOTOV.2019.2899470.

[23] H. D. Tafti, C. D. Townsend, G. Konstantinou and J. Pou, "A Multi-Mode Flexible Power Point Tracking Algorithm for Photovoltaic Power Plants," *IEEE Transactions on Power Electronics*, vol. 34, no. 6, pp. 5038-5042, June 2019, doi: 10.1109/TPEL.2018.2883320.

[24] 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, Jun. 2007.

[25] S. Sajadian and R. Ahmadi, "Model predictive-based maximum power point tracking for grid-tied photovoltaic applications using a Z-source inverter," *IEEE Trans. Power Electron.*, vol. 31, no. 11, pp. 7611–7620, Nov. 2016.