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To cite this article: Ali Jawad Khadhim Alrubaie *et al* 2020 *J. Phys.: Conf. Ser.* **1432** 012061

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Improved hill climbing algorithm with fast scanning technique under dynamic irradiance conditions in photovoltaic system

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Abstract: The perturb and observe (P&O) algorithm is an easy and effective method used for tracking maximum power point. However, this technique suffers from deviation when irradiation changes suddenly. Moreover, the impact of this deviation is high when the insolation variation is rapid. This error is due to the incorrect decision taken by the conventional P&O method throughout the first step-change in the duty cycle during the increase in irradiation. The proposed P&O is a modified conventional P&O that focuses on using additional dI parameter with variable step size ΔD_n . In this manner, the conventional P&O algorithm is allowed to identify the source of deviation caused by rapid irradiance changes. The efficiency of the proposed P&O is assessed using simulation in MATLAB/Simulink. Results show that the proposed P&O effectively tracks maximum power and prevents deviations in rapidly changing climate conditions within a short time, which is lesser than the conventional P&O method. In addition, the proposed P&O has a rapid dynamic response. A DC–DC boost converter is utilized in this work to validate the proposed P&O algorithm.

Keywords: Photovoltaic, P&O algorithm, DC–DC boost converter, maximum power point

1. Introduction

The world's demands for energy are increased by thirtyfold over the two recent decades because of its rapid development in the industrial field worldwide, as well as the consistent expansion of the complexity of present-day ways of life [1]. Researchers around the world are searching for new energy sources that are more efficient and economical than conventional ones [2],[3]. Renewable energy sources meet urgent energy demands, such as electrical power [4]; among all types of efficient green resources, solar energy is considered the most effective and optimal way of providing efficient solutions for handling difficulties and challenges that obstruct the current society [5]. Solar energy uses photovoltaic (PV) technology because it is an optimal way of extracting electric energy from the sunlight; furthermore, it has high reliability, long effective life, low maintenance cost, and immediate reaction during changes in temperature and irradiance [6],[7],[8]. PV systems have two main limitations. First, a PV system depends on weather conditions, such as the amount of irradiance and changes in temperature [9],[10]. Second, research confirmed that solar cells could convert 20% of sunlight energy into electrical energy because the power conversion efficiency of the PV module is low [11]. Maximum power point (MPP) tracking (MPPT) technique is used to guarantee that the PV systems continuously operate at their MPP [12],[13]. To attract MPP, different algorithms that may be classified into two classes [14], namely, conventional MPPT algorithms (e.g., perturb and observe (P&O) [15], incremental conductance [16], fractional short-circuit [17], and fractional open-circuit [18] and intelligent methods (e.g., fuzzy logic control [19] and artificial neural network) [20], are used

in the MPPT technique. These methods differ in terms of tracking speed, cost, sensor requirements, complexity, time to reach MPP during the variation of irradiation and temperature, efficiency range, and hardware needed during their implementation [21]. Conventional MPPT algorithms have numerous advantages, including simplicity and low implementation cost [22]. Previous studies have stated that the P&O algorithm is the most popular MPPT method. The P&O method is also known as the (hill climbing) method [23], because it climbs the power curve to achieve the MPP. Despite these advantages, the P&O algorithm has drawbacks, among which is the deviation that occurs during quick insolation variations that reduces the proficiency of the P&O algorithm [24]. The current paper provides a precise and easy solution on the deviation issue under dynamic changes in irradiance by assessing another parameter and by altering the current (ΔI) and variable step sizes (ΔD_n). To this end, a DC–DC boost converter is used to validate the proposed P&O algorithm.

2. Modelling of PV Module

Solar cell model

Many solar cell models are available, and every model has distinct behavior under varied weather conditions. Figure. 1 shows the single diode model, which is utilized in the PV module design because of its simplicity [25],[26]. In this circuit, (I_L) is the photocurrent produced by light, (I_D) is the diode saturation current, ($I_{R_{sh}}$) is the shunt current that flows through the shunt resistance, (R_{SH}) is the leakage current, (R_S) is the series resistance that represents the losses caused by the current that flows through it, (V_{OC}) is the open-circuit voltage, and (I) is the PV module current [27].

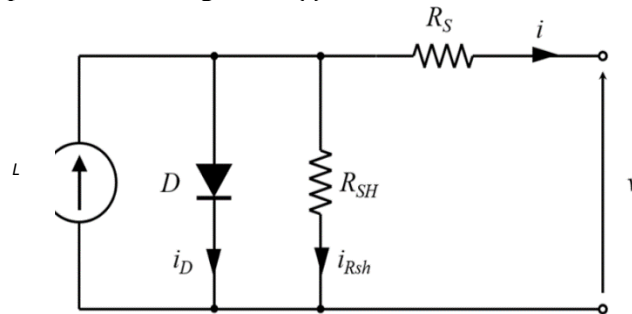


Figure 1. Equivalent Solar PV Circuit Cell Model.

The output current can be expressed by Equation (1).

$$I = I_L - I_D - I_{R_{SH}} \quad (1)$$

In this model, the Shockley equation is used for an ideal diode (Equation (2)):

$$I_D = I_o \left[\exp\left(\frac{V + IR_S}{nV_T}\right) - 1 \right] \quad (2)$$

where n represents the diode ideality factor, and V_T is the thermal voltage, which can be expressed by Equation (3):

$$V_T = \frac{KT_C}{q} \quad (3)$$

Where K is the Boltzmann constant, which is equal to (1.381×10^{-23}) , and q is the electric charge, which is equal to $(1.60217662 \times 10^{-19})$. The current loss that results in shunt resistance is given by Equation (4).

$$I_{R_{sh}} = \frac{V + IR_S}{R_{Sh}} \quad (4)$$

By combining Equations (2, 3, and 4), the final equation of the single diode model is expressed as Equation (5).

$$I = I_L - I_0 \left[\exp\left(\frac{V + IR_s}{nV_T}\right) - 1 \right] - \frac{V + IR_s}{R_{sh}} \quad (5)$$

Figures. 2 and 3 demonstrate the characteristics of $P-V$ and $I-V$ curves under different irradiation and temperature, respectively. $I-V$ and $P-V$ curves of the PV array rely on temperature and insolation cases, respectively.

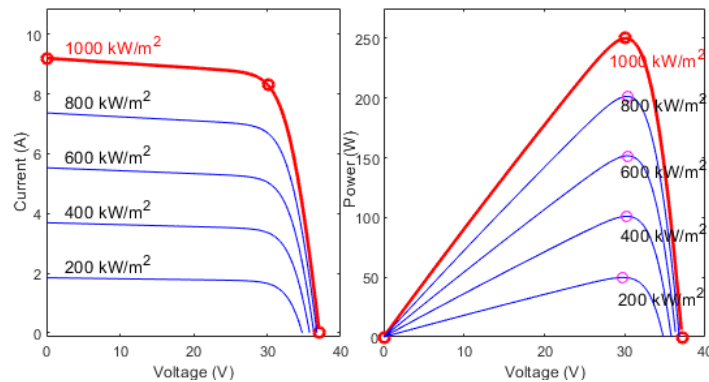


Figure. 2 I-V and P-V curves for different irradiances.

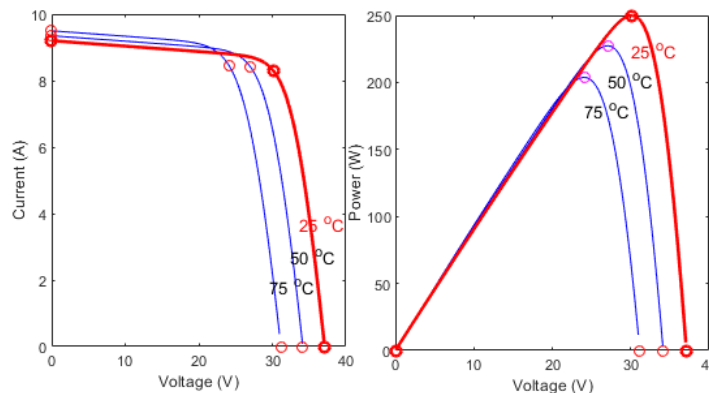


Figure. 3 I-V and P-V curves for different temperatures.

Table 1 shows the parameters of the PV module.

Table 1. Parameters of JWP 250 W desert module and array		
Parameters	PV module	PV array
MPP P_{MPP}	250 W	1000 W
Maximum current I_{MPP}	8.30 A	16.6 A
Maximum voltage V_{MPP}	30.12 V	60.24 V
Short-Circuit Current I_{SC}	9.20 A	18.40 A
Open-Circuit Voltage V_{OC}	37.10 V	74.20 V
Temperature coefficient of V_{OC}	0.318 V/C	-0.318 V/C
Temperature coefficient of I_{SC}	0.065A/C	0.065A/C
Number of cells	60	240

Figure. 4 shows the block diagram of the PV module system with MPPT control.

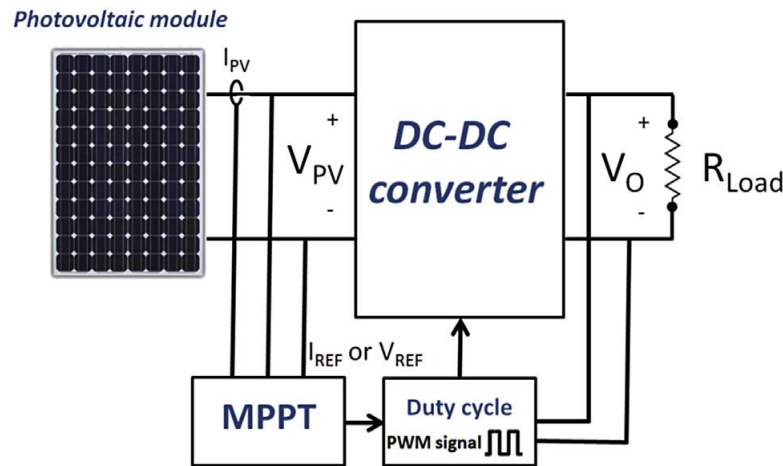


Figure. 4 Block diagram of the PV system with MPPT control.

Boost converter

DC–DC boost converter is used for the testing because of its high effectiveness (Figure. 5). The effectively adapted MPPT controller is utilized to provide and manage a fitting output voltage that has a level that is considerably higher than the input voltage following Equation (6). Converter parameters are given in Table 2.

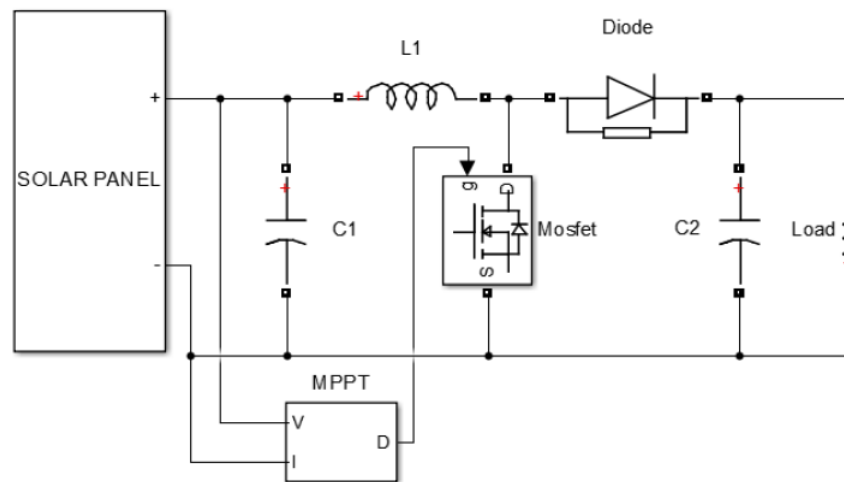


Figure. 5 MPPT system with DC-DC boost converter.

$$V_o = \frac{V_{in}}{(1-D)} \quad (6)$$

where:

V_o : Output voltage of converter

V_{in} : Input voltage of converter

D : Duty cycle

Table 2. DC–DC boost converter parameters.

Parameters	For each module
Inductor	71.13 μ H
Capacitor	23.38 μ F
Input capacitor	470 μ F
Resistive load	65 Ω
Frequency	25 KHZ

3. Proposed P and O algorithm

The proposed P&O MPPT is created on the basis of the observation of ΔP and ΔV . As previously mentioned, conventional P&O algorithm is suffering from deviation because of confusion whenever irradiance shifts. This confusion can be removed by adding parameter ΔI . The deviation phenomena can be prevented by identifying the shift in irradiance based on ΔP , ΔV , and ΔI data.

Case 1: If irradiance decreases when working at Point 2, then a new point in the new irradiance curve, that is, point 3, is reached by the operating point. Then, the algorithm at Point 3 must decide (Figure. 6). At Point 3, the values of ΔP , ΔV , and ΔI are negative. Thus, the negative value of change in power caused by perturbation or irradiance decreases the value of the extra parameter. ΔI can detect this condition. ΔP , ΔV , and ΔI will only be negative if irradiance decreases. Thus, a reduction in irradiance can be detected using the additional parameter ΔI . Thus, the duty cycle is reduced by using a new variable step size ΔD_n by pushing the point near the MPP, where the drift issue can be eliminated (Figure. 7).

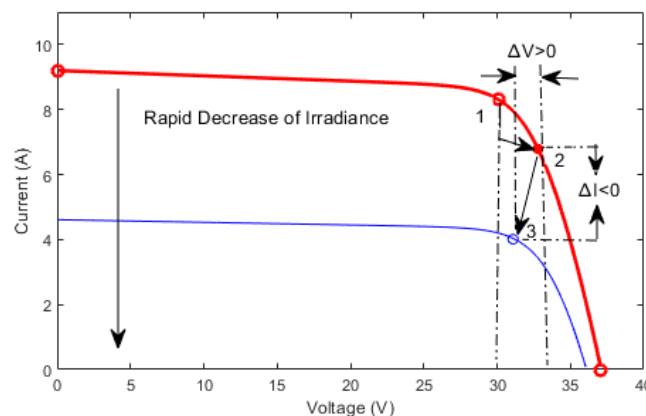


Figure. 6 Observation of change in current.

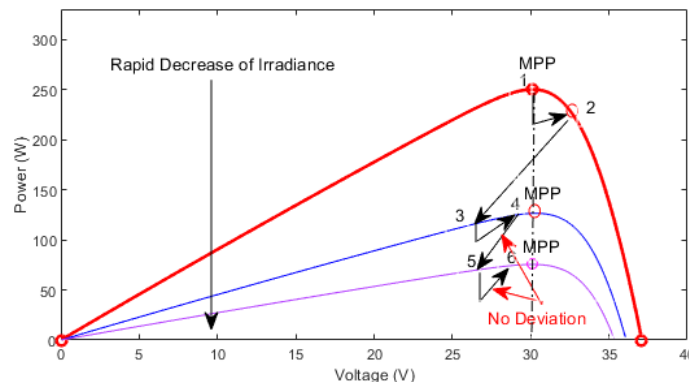


Figure. 7 Rapid decrease in irradiance

Case 2: Case 2 is similar to the increase in Case 1, that is, if irradiance increases when working at Point 3, then a new point in the new irradiance curve, that is, point 4, is reached by the operating point. Then, the algorithm in Point 4 must decide (Figure. 8). At Point 4, the values of ΔP , ΔV , and ΔI are positive. Thus, the positive value of change in power caused by perturbation or irradiance increases the extra parameter. ΔI can detect this condition. ΔP , ΔV , and ΔI will only be positive if irradiance increases (Figure. 9). Therefore, increase and decrease in the duty cycle by ΔD_n can be expressed by Equation (7)

$$\Delta D_n = \pm M \left| \frac{\Delta P}{\Delta I} \right| \quad (7)$$

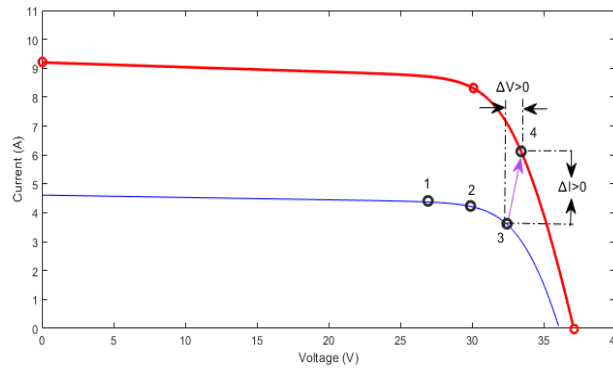


Figure. 8 Observation of change in current in rapid increase in irradiance.

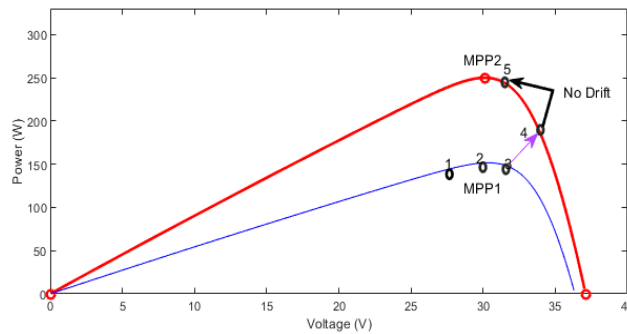


Figure. 9 Rapid increase in irradiance

Figure.10 shows the flowchart of the proposed P&O algorithm, where ΔD_n is the variable step size; and M is a fixed parameter called scaling factor, which is tuned manually.

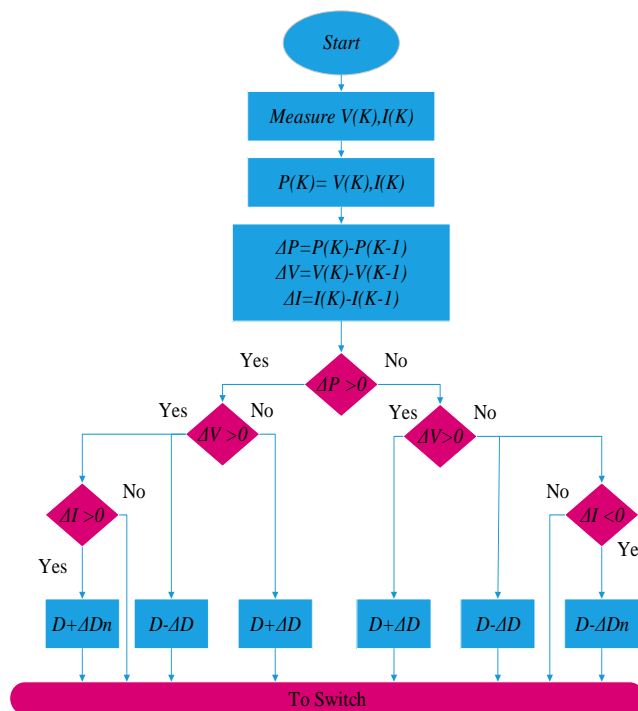


Figure. 10 Flowchart of proposed P&O algorithm.

4. Simulation results for conventional proposed P and O algorithm

Rapid increase in irradiance

In the first case (Figure. 11), the irradiance begins at 200 W/m² until the first second. In the first second, irradiance will be increased from 200 W/m² to 400 W/m² by one step-up of 200 W/m² until the second- second. In the second-second, step-up irradiance will be increased from 400 W/m² to 600 W/m² until the third second by a step size of 200 W/m². In the third second, another step-up change from 600 W/m² to 800 W/m² also occurs by a step size of 200 W/m².

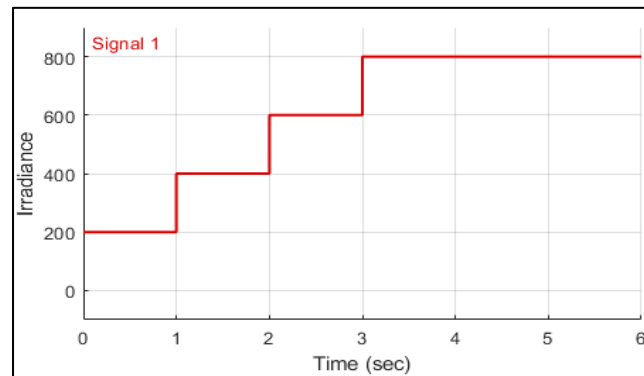


Figure. 11 Irradiance pattern levels in Test 1.

In this case, the response of the proposed P&O algorithm at this change can be observed when irradiance is increased at the first second from 200 W/m² to 400 W/m². The MPP tracking time of the proposed P&O algorithm in this change is only 0.15 sec, and the extracted power is 403.81 W. The proposed P&O algorithm succeeds to reach the MPP within five iterations.

At the second-second, irradiance will be a step-up from 400 W/m² to 600 W/m². The MPP can be reached within a tracking time of 0.08 sec, and the extracted power is 606.13 W. The proposed P&O algorithm also succeeds to reach the MPP of the system within three iterations.

At the third second, irradiance will be a step-up from 600 W/m² to 800 W/m². The MPP can be reached within a tracking time of 0.03 sec, and the extracted power is 805.20 W. The proposed P&O algorithm succeeds to reach the MPP within one iteration.

For the same condition, in an irradiance of 200 W/m², the response of conventional P&O at this change can be observed when irradiance is increased at the first second from 200 W/m² to 400 W/m². The MPP tracking time of the conventional P&O algorithm in this change is 0.30 sec, and the extracted power is 403.40 W. The conventional P&O succeeds to reach the MPP within 10 iterations.

At the second-second, irradiance will be a step-up from 400 W/m² to 600 W/m². The MPP can be reached within a tracking time of 0.23 sec, and the extracted power is 605.10 W. The conventional P&O algorithm succeeds to reach the MPP within eight iterations.

At the third second, irradiance will be a step-up from 600 W/m² to 800 W/m². The MPP can be reached within a tracking time of 0.07 sec, and the extracted power is 798.50 W. The conventional P&O algorithm succeeds to reach the MPP within two iterations.

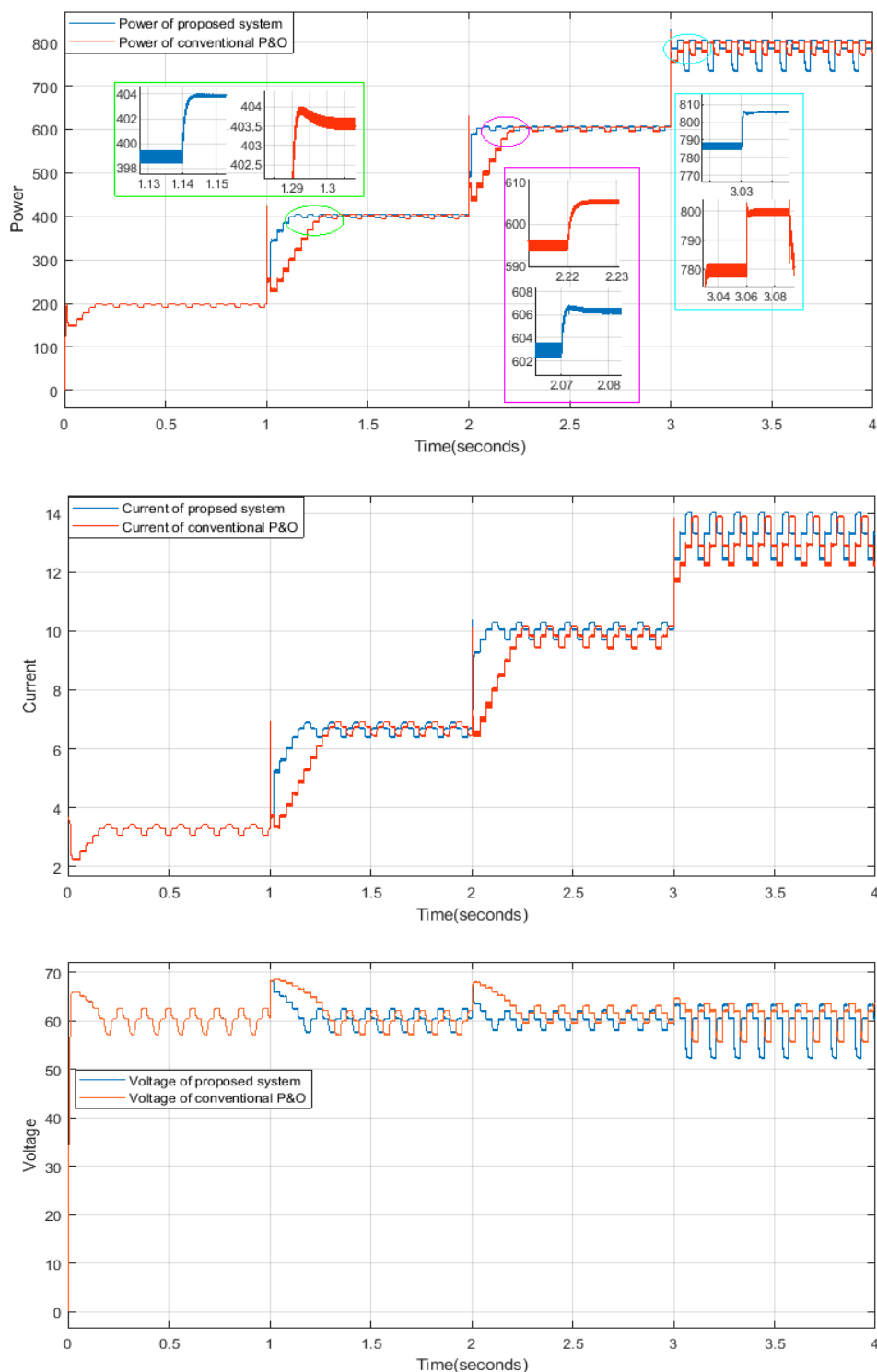


Figure. 12 Comparison of proposed and conventional P&O algorithm during the rapid increase in irradiances on power, current, and voltage in Case 1.

Figure.12 shows that tracking using the proposed method is faster, and it has fewer iterations and lesser deviation when the increase in insolation is faster than the conventional P&O method. Therefore, the proposed method is more effective than the conventional method in this case. Table 3 demonstrates the comparison in tracking the results of the proposed and conventional P&O methods during a dynamic change in irradiance by a step-up size of 200 W/m^2 .

Table 3. Comparison of the tracking results of the proposed and conventional P and O algorithms under dynamic change in irradiance by step-up of 200 w/m² in case 1

A step change in irradiance	From- to (200-400) W/m ²	From- to (400-600) W/m ²	From- to (600-800) W/m ²	
Theory	403.98 W	606.60 W	805.55 W	
Proposed system	Maximum power that can be extracted from PV	403.81 W	606.13W	805.20W
	Tracking time	0.15 s	0.08 s	0.03 s
	No. of iteration	5	3	1
P and O method	Maximum power that can be extracted from PV	403.40 W	605.10 W	798.50 W
	Tracking time	0.30 s	0.23 s	0.07 s
	No. of iteration	10	8	2

Rapid decrease in irradiance

The irradiance in the second case begins at 600 W/m² until the first second (Figure. 13). In the first second, the irradiance will be decreased from 600 W/m² to 400 W/m² by one step-down of 200 W/m² until the second-second. In the second-second, another step-down irradiance will be decreased from 400 W/m² to 200 W/m² also by a step size of 200 W/m².

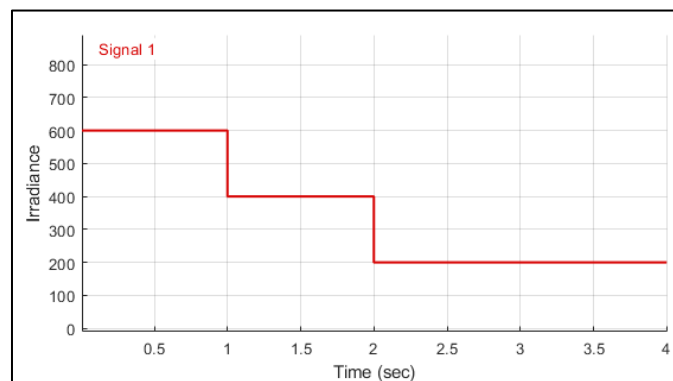


Figure. 13 Irradiance pattern levels in Test 2.

In this case, in an irradiance of 200 W/m², the response of the proposed P&O algorithm at this change can be shown when irradiance is decreased at the first second from 600 W/m² to 400 W/m². The MPP tracking time for the proposed P&O algorithm in this change is only 0.09 sec, and the extracted power is 403.60 W. The proposed P&O algorithm succeeds to reach the MPP within three iterations.

At the second-second, the irradiance will be a step-down from 400 W/m² to the 200 W/m². The MPP can be reached within a tracking time of 0.08 sec, and the extracted power is 199 W. The proposed P&O algorithm succeeds to reach the MPP within three iterations.

For the same condition, in an irradiance of 200 W/m², the response of the conventional P&O algorithm at this change can be observed when irradiance is decreased at the first second from 600 W/m² to 400 W/m². The MPP tracking time of the conventional P&O algorithm in this change is 0.15 sec, and the extracted power is 403.49 W. The conventional P&O algorithm succeeds to reach the MPP within five iterations.

At the second-second, irradiance will be a step-down from 400 W/m² to the 200 W/m². The MPP can be reached within a tracking time of 0.12 sec, and the extracted power is 195.80 W. The conventional P&O algorithm succeeds to reach the MPP within four iterations.

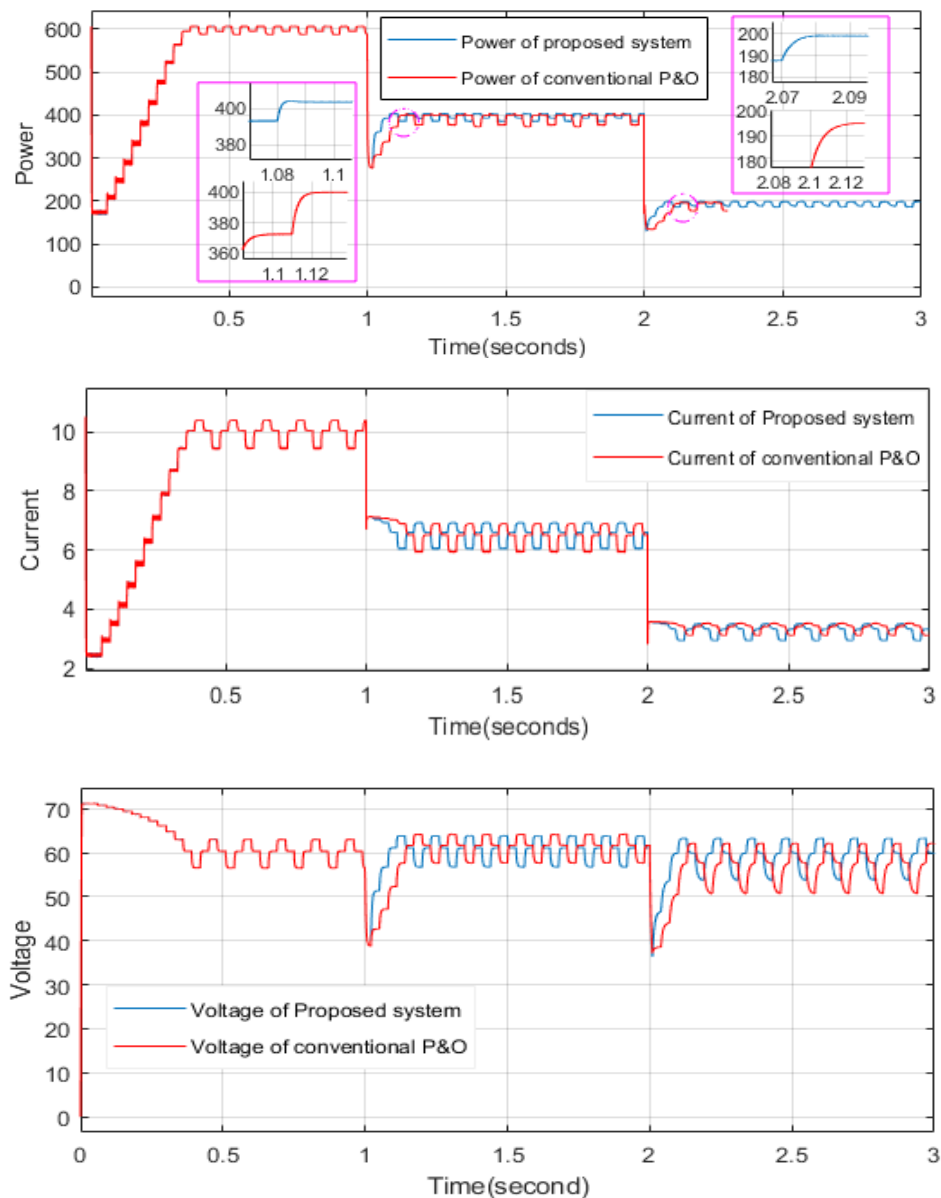


Figure. 14 Comparison of the proposed and conventional P&O methods during the rapid increase in the irradiances on power, current, and voltage in Case 2.

Figure. 14 shows that the tracking using the proposed method is faster and need fewer iterations and lesser drift when the reduction in irradiance is faster compared with the conventional P&O algorithm. Therefore, the proposed method is more effective in this case than the conventional method. Table 4 demonstrates the comparison in tracking the results of the proposed and conventional P&O algorithms during a dynamic change in irradiance by a step-down size of 200 W/m².

Table 4. Comparison of the tracking results of the proposed and conventional P and O algorithms under dynamic change in irradiance by a step-up of 200w/m² in test 2.

A step change in irradiance	From- to (600-400) W/m ²	From- to (400-200) W/m ²
Theory	403.98 W	199.1 W
Proposed system	Maximum power that can be extracted from PV	403.6 W
	Tracking time	0.09 s
		199 W
		0.08 s

		No. of iteration	3	3
P and O	method	Maximum power that can be extracted from PV	403.49 W	195.80 W
		Tracking time	0.15 s	0.12 s
		No. of iteration	5	4

5. Conclusion

The performance of the proposed P&O algorithm is compared with that of the conventional on in all tests to validate its effectiveness in terms of the dynamic changes in irradiance conditions. The results show the efficiency of the proposed P&O algorithm in attracting MPP in a shorter time and with lesser iterations without oscillation around MPP than the conventional P&O algorithm.

Acknowledgments

The authors would like to thank the Universiti Malaysia Perlis and the ministry of higher education (MOHE) Malaysia for providing the facilities and financial support (Fundamental research grant scheme (FRGS) under a grant number of FRGS/1/2018/TK07/UNIMAP/02/1

References

- [1] S. Bana and R. P. Saini, "Experimental investigation on power output of different photovoltaic array configurations under uniform and partial shading scenarios," *Energy*, vol. 127, pp. 438–453, 2017.
- [2] G. K. Singh, "Solar power generation by PV (photovoltaic) technology: A review," *Energy*, vol. 53, pp. 1–13, 2013.
- [3] T. E. K. Zidane, M. R. B. Adzman, M. F. N. Tajuddin, S. Mat Zali, and A. Durusu, "Optimal configuration of photovoltaic power plant using grey wolf optimizer: A comparative analysis considering CdTe and c-Si PV modules," *Solar Energy*, vol. 188, pp. 247–257, 2019/08/01/ 2019.
- [4] A. A. Solomon, D. M. Kammen, and D. Callaway, "Investigating the impact of wind–solar complementarities on energy storage requirement and the corresponding supply reliability criteria," *Appl. Energy*, vol. 168, pp. 130–145, 2016.
- [5] O. Weiss, D. Bogdanov, K. Salovaara, and S. Honkapuro, "Market designs for a 100% renewable energy system: Case isolated power system of Israel," *Energy*, vol. 119, pp. 266–277, 2017.
- [6] M. F. N. Tajuddin, N. H. Ghazali, T. C. Siong, and N. Ghazali, "Modelling and simulation of modified unipolar PWM scheme on a single phase DC-AC converter using PSIM," in *Research and Development (SCOReD)*, 2009 IEEE Student Conference on, 2009, pp. 328–331.
- [7] O. Inganäs and V. Sundström, "Solar energy for electricity and fuels," *Ambio*, vol. 45, pp. 15–23, 2016.
- [8] "Energy Efficiency Constraints in Photovoltaic Power Generation Systems ENERGY EFFICIENCY CONSTRAINTS IN," no. April, 2018.
- [9] B. V Chikate and Y. Sadawarte Assistant Professor BDCOE Sewagram, "The Factors Affecting the Performance of Solar Cell," *Int. J. Comput. Appl. Sci. Technol.*, pp. 975–8887, 2015.
- [10] M. F. N. Tajuddin, N. H. Ghazali, I. Daut, and B. Ismail, "Implementation of DSP based SPWM for single phase inverter," in *Power Electronics Electrical Drives Automation and Motion (SPEEDAM)*, 2010 International Symposium on, 2010, pp. 1129–1134.

- [11] L. Yalcin and R. Ozturk, "Performance comparison of c-Si, mc-Si and a-Si thin film PV by PVsyst simulation," *J. Optoelectron. Adv. Mater.*, vol. 15, no. 3–4, pp. 326–334, 2013.
- [12] H. Islam et al., "Performance evaluation of maximum power point tracking approaches and photovoltaic systems," *Energies*, vol. 11, no. 2, pp. 7–9, 2018.
- [13] M. F. N. Tajuddin, M. S. Arif, S. M. Ayob, and Z. Salam, "Perturbative methods for maximum power point tracking (MPPT) of photovoltaic (PV) systems: a review," *Int. J. Energy Res.*, vol. 39, no. 9, pp. 1153–1178, 2015.
- [14] 2015 Patil & Deshpande, "MPPT based on Fuzzy Logic Controller for Photovoltaic System using PSIM and Simulink MPPT based on Fuzzy Logic Controller for Photovoltaic System using PSIM and Simulink," 2018.
- [15] "Review on widely-used MPPT techniques for PV applications," 2016 1st Int. Conf. Innov. Challenges Cyber Secur. ICICCS 2016, no. Iccics, pp. 270–273, 2016.
- [16] V. K. Viswambaran, "Tracking Algorithms &," pp. 4–7, 2016.
- [17] H. A. Sher et al., "A New Sensorless Hybrid MPPT Algorithm Based on Fractional Short-Circuit Current Measurement," pp. 1–9, 2015.
- [18] S. Baroi, P. C. Sarker, and S. Baroi, "An Improved MPPT Technique – Alternative to Fractional Open Circuit Voltage Method," 2017 2nd Int. Conf. Electr. Electron. Eng., no. December, pp. 1–4, 2017.
- [19] M. Bahrami, R. Gavagsaz-ghoachani, M. Zandi, S. Pierfederici, and F. Meibody-tabar, "Hybrid maximum power point tracking algorithm with improved dynamic performance," vol. 130, pp. 982–991, 2019.
- [20] J. P. Ram, T. S. Babu, and N. Rajasekar, "A comprehensive review on solar PV maximum power point tracking techniques," *Renew. Sustain. Energy Rev.*, vol. 67, pp. 826–847, 2017.
- [21] M. Patil and A. Deshpande, "Design and simulation of Perturb and Observe Maximum Power Point Tracking using MATLAB/Simulink," in 2015 International Conference on Industrial Instrumentation and Control (ICIC), 2015, pp. 1345–1349.
- [22] S. Karthika, K. Velayutham, P. Rathika, and D. Devaraj, "Fuzzy Logic Based Maximum Power Point Tracking Designed for 10kW Solar Photovoltaic System with Different Membership Functions," vol. 8, no. 6, pp. 1015–1020, 2014.
- [23] J. Mahanta, B. Sharma, and N. Sarmah, "A Review of Maximum Power Point Tracking Algorithm for Solar Photovoltaic Applications," vol. 13, no. 4, pp. 1–13, 2018.
- [24] M. Killi and S. Samanta, "Modified perturb and observe MPPT algorithm for drift avoidance in photovoltaic systems," *IEEE Trans. Ind. Electron.*, vol. 62, no. 9, pp. 5549–5559, 2015.
- [25] M. S. Hossain, N. K. Roy, and M. O. Ali, "Modeling of solar photovoltaic system using MATLAB/Simulink," 19th Int. Conf. Comput. Inf. Technol. ICCIT 2016, pp. 128–133, 2017.
- [26] M. B. H. Rhouma, A. Gastli, L. Ben Brahim, F. Touati, and M. Benammar, "A simple method for extracting the parameters of the PV cell single-diode model," *Renew. Energy*, vol. 113, pp. 885–894, 2017.
- [27] A. Chowdhury, T. Rout, and S. Samal, "Analysis of Perturbation and Observation Technique used in Maximum Power Point Tracking for Photovoltaic Systems," *Analysis*, 2017.