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Research Article

An Intelligent Maximum Power Point Using a Fuzzy Log Controller under Severe Weather Conditions

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This study is aimed at providing a comparison between fuzzy systems and convectional P&O for tracking MPP of a PV system. MATLAB/Simulink is used to investigate the response of both algorithms. Several weather conditions are simulated: (i) uniform irradiation, (ii) sudden changing, and (iii) partial shading. Under partial shading on a PV panel, multipeaks appeared in P-V characteristics of the panel. Simulation results showed that a fuzzy controller effectively finds MPP for all weather condition scenarios. Furthermore, simulation results obtained from the FLC are compared with those obtained from the P&O controller. The comparison shows that the fuzzy logic controller exhibits a much better behavior.

1. Introduction

Due to global warming along with high prices of fossil fuel and its hazards on the environment, searching for other renewable green sources of energy drew the attention of the world. Solar energy is considered the main source of renewable energy. Solar energy is a permanent, nonpolluting, and low-running-cost source of energy. Photovoltaic (solar cell) systems are one of the most favorable systems, and their installation is spreading widely. Photovoltaic (PV) systems can be connected to a grid or can be used as stand-alone systems [1, 2]. The power generated from a PV panel depends on the amount of solar irradiance, cell temperature, and load [3–5].

Maximum power point tracking is essential to keep the system operating at its optimal power. Up to date, the overall PV efficiency reaches around 15%. Raising the power generated from PV systems can be achieved by tracking the maximum power point of the output power-voltage curve. This curve may contain multilocal maximum points under partially shaded conditions [6]. Employing MPPT techniques is considered the most economic way of improving the overall efficiency of the system compared with methods that rely on improving solar cell fabrication [7].

Several methods for finding MPP are developed over the last three decades [7–14]. These methods vary in terms of requiring sensors, cost, efficiencies, complexity, correct tracking when sudden shading or temperature changes, and convergence speed. Esram and Chapman presented a review of 19 methods for finding MPP [8]. Generally, the techniques are classified into three classes: offline, online, and hybrid methods. Offline methods are the short-circuit current (SCC) method, open-circuit voltage (OCV) method, look-up table method, and curve-fitting-based [9] and artificial intelligence (AI) algorithms. Online methods are the extremum seeking control (ESC) method, ripple correlation control (RCC) method, hill climbing (HC) method [10], incremental conductance (IC) method, and perturbation and observation (P&O) method [11] and modified P&O [12, 13].

As mentioned previously, when a PV system is subjected to a partially shaded condition, multiple peaks appeared in the P-V curve. Conventional methods such as P&O, hill climbing, IC, direct search algorithm, and line search algorithm with the Fibonacci sequence method could miss the global MPP [8, 14–16]. To overcome the problem with the conventional methods, several researchers have proposed several improvements. Because of the fact that the P&O method uses a fixed step size when tracking MPP, variable

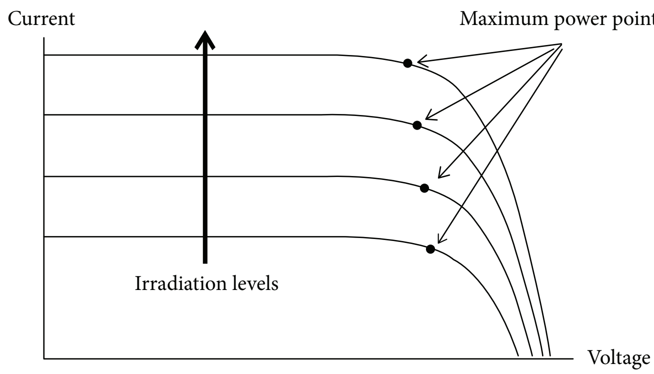


FIGURE 1: Effect of irradiance changes on I-V characteristics.

step size methods are developed to improve the steady-state performance and dynamic response of the PV system [17]. It has been shown that the small step size causes low oscillations during steady-state weather conditions but with a slower response. On the other hand, a larger step size leads to a faster response but with higher oscillations at steady-state conditions. Moreover, the performance of such systems reduces significantly due to the random nature of weather conditions. Tafticht et al. proposed a new method that combines nonlinear expression that is based on the open-circuit voltage with the P&O method to improve the tracking efficiency of MPP [18]. Recently, a new approach has been suggested by Heydari-doostabad et al. based on extremum seeking control (ESC) [19]. It takes the advantage of a band-pass filter (BPF) using a high-pass filter (HPF) and a low-pass filter (LPF) by only passing input power frequencies that include derivatives of PV with respect to its voltage, and so the system will operate at the global maximum point. Noguchi et al. [20] proposed a short-circuit pulse-based MPPT with fast scan on the P-V curve to identify the proportional parameter which is commonly used in a current-based MPPT [21]. Although the proposed method successfully found the global maximum point, momentary power loss is accompanied with additional extra cost. To avoid this extra power loss, Kazmi et al. proposed a controller that fluctuates the converter's duty cycle from zero to one to measure the open-circuit voltage and the short-circuit current and then computes the optimum voltage and current [22]. Based on the computed values, in single step, the operating point is moved to the optimal operating point. The conventional hill climbing algorithm is utilized to keep the system operating around the maximum point. Although the system finds global maximum, significant loss in power is experienced. Utilizing the particle swarm optimization algorithm under abnormal weather conditions results in a long computation time to reach the maximum operating point [23].

Intelligent systems such as neural networks (NN) and fuzzy logic controllers (FLC) have been used successfully in tracking the maximum power point of PV to decrease computation power requirement, while increasing the speed and efficiency of the tracking [2]. They are robust and relatively simple to design. However, they require complete knowledge of the operation of the PV system by the designer. Othman et al. validated the ability of FLC to find MPP compared to the P&O algorithm [24]. Punitha et al. used a modified IC method with NN to supply V_{ref} and compared the results with those of the FLC and P&O approach to validate their proposed method [25]. Results showed the highest performance with the least response time when using ANN with IC. Subiyanto et al. presented a new method using a Hopfield neural network (HNN) to tune FLC parameters to enhance robustness and accuracy [26, 27]. Although fuzzy control has a good ability dealing with the nonlinear system, its main drawback is the generation of cumulative error due to continuous integral calculus. Most FLC-based MPPT techniques take the error ($e(t)$) and the change in error ($de(t)/dt$) as inputs. However, the requirement of differentiation not only increases the complexity of calculation but also may induce large amounts of errors from merely small amounts of measurement noise. The main objective of this study is to compare between conventional P&O and fuzzy logic controller MMPT algorithms under several extreme weather conditions. To carry out the comparison, computer-aided simulations are used to validate the results.

2. PV Modeling and Characteristics

Detailed description of PV modeling can be found in [2]. I-V nonlinear characteristic curves are shown in Figure 1. Partial shading occurs when radiation is not equally distributed on PV cells. The current generated by shaded cells is decreased. This leads to the reduction in the overall power generated from the PV system. In order to understand such phenomena, a PV array system with modules connected in series is considered. Under partial shading conditions, multiple peaks are presented in the P-V characteristic (see Figure 2).

3. MMPT Algorithm

In this section, a brief description about the P&O controller and fuzzy logic controller is given.

3.1. P&O Controller. A detailed description of the P&O controller can be found in [28–30]. The flow chart of the P&O algorithm is shown in Figure 3. The basic idea of this controller is to provoke perturbation by acting (decrease or increase) on the PWM duty cycle and observing the effect on the output PV power. The algorithm can be summarized as follows;

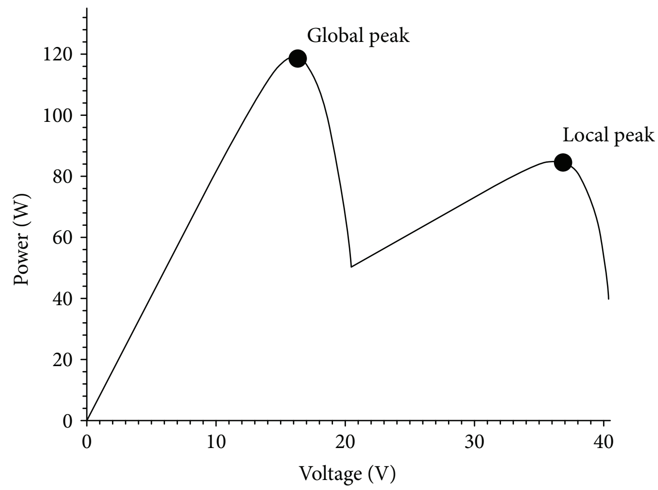


Figure 2: Characteristic curves of PV under partial shading.

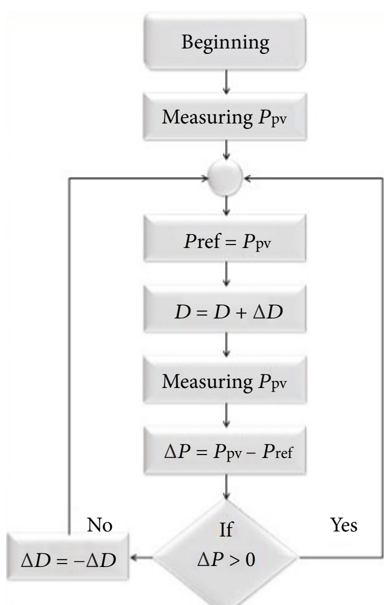


Figure 3: Flowchart of the P&O algorithm.

after recording the present power levels produced by the system, the algorithm performs a perturbation to the operating point by means of changing the duty cycle and measures the resulting power accordingly. If there is an increase in the power levels, another iteration is performed in the same direction. Otherwise, iteration in the reverse direction is carried out. The peak is detected when the power oscillates about a certain value; i.e., increasing and decreasing the duty cycle result in less power levels.

To generate maximum power, a DC-DC boost converter is used and placed between the source and the load. To simulate the P&O algorithm, the PV system composed of a PV panel, a boost DC-DC converter, MPPT, and resistive load is built as shown in Figure 4. In this work, a boost converter controlled by the MPPT algorithm is used to track MPP. Voltage gain of the converter is given as [31]

$$\frac{V_o}{V_s} = \frac{1}{1-D}. \tag{1}$$

The minimum values of inductance and capacitance of the converter necessary for stability (listed in Table 1) are given as [31]

$$L_{\min} = \frac{DR(1-D)^2}{2F_s}, \qquad C_{\min} = \frac{V_o D}{F_s \Delta V_o R}. \tag{2}$$

The P&O algorithm has been implemented in a Simulink model to control the duty cycle of the switching signal of the converter. ΔV and ΔP are used to detect irradiation variations, and the algorithm determines the value of the duty cycle necessary to attain the maximum power point on the load. It changes the duty cycle value by a step size (s) which is determined by the designer.

3.2. Proposed Fuzzy Logic Controller. The proposed FL MPPT logic diagram shown in Figure 5 has two inputs (power and ΔV) and one output (D). Triangular shape membership functions have been used. The fuzzy inference is carried out using a Mamdani-type system. The defuzzification uses the center of gravity to compute the output of this FLC which is the duty cycle:

$$D = \frac{\sum_{j=1}^{n} \mu(D_j) - D_j}{\sum_{j=1}^{n} \mu(D_j)}. \tag{3}$$

The proposed fuzzy rules of the system are shown in Table 2. These two input variables and the control action for the tracking of the maximum power point are illustrated in Figure 5.

Based on the results of the Simulink model, tuning of the rules is performed to design the fuzzy logic controller. Values

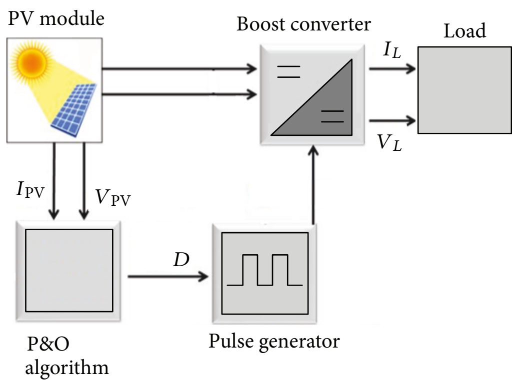


Figure 4: Schematic diagram of the PV system with MPPT.

Table 1: DC-DC booster converter design values.

Electrical characteristic	Values
Inductance	9×10^{-4} H
Output capacitor	0.001 F
Input capacitor	1×10^{-9} F
Resistance load	28.18 Ω

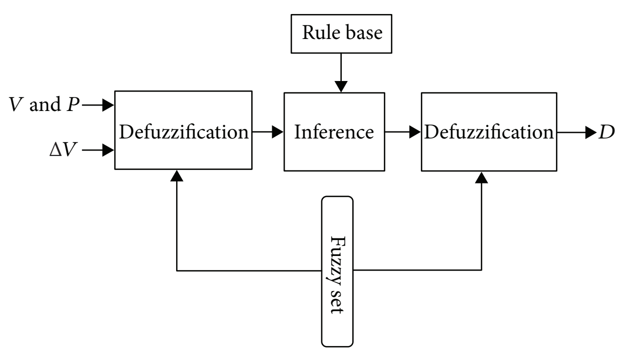


Figure 5: General diagram of a fuzzy controller.

of fuzzy controller inputs are compared with twenty-five rules of the system and are implicated with the membership functions. The implication has been chosen to be an "and" operator that chooses minimum values of membership functions. The implicated rules were aggregated using a maximum method. Figure 6 shows the surface view for the relation between fuzzy inputs and output. A centroid method has been selected for defuzzification by calculating the center of mass of the aggregated membership function. The crisp value represents the duty cycle of the switching signal that triggers the IGBT in the boost converter.

4. Simulation Results and Discussion

The performance of the proposed FLC is evaluated using MATLAB/Simulink. The electrical specifications of the PV cell are $I_{sc} = 4.75$ A, $V_{oc} = 0.6$ V, and $R_s = 5.1 \times 10^{-3}$ Ω. The simulated model consists of 72 cells connected in series to form a PV module. A partially shaded model is simulated by connecting two modules in series allowing each module to receive different levels of irradiation. The P&O MPPT controllers and FLC were simulated under the following tests: (i) uniform irradiation, (ii) sudden changing, and (iii) partial shading. The values of power listed in Table 3 demonstrate that a significant increase in the power output is obtained by using FLC.

Table 2: Rules of the fuzzy controller.

$\Delta V\downarrow \backslash P\rightarrow$	Very low	Low	Medium	High	Very high
Very low	Very low	Very low	Medium	High	Very high
Low	Very low	Very low	High	High	Very high
Medium	Medium	Medium	Medium	Medium	Very high
High	Medium	Medium	High	Medium	Very high
Very high	Low	Low	Medium	High	Very high

Figure 7 shows that the FLC has a great ability to find MP in extremely short time when a PV panel is subjected to sudden changes of irradiation (full shading conditions). To accurately investigate the performance of the FLC, the tracking error and tracking efficiency are defined [3]:

$$\begin{aligned} \text{efficiency} &= \frac{P_{\text{pv}}}{P_{\text{mpp}}} \times 100\%, \\ \text{error} &= \frac{P_{\text{mpp}} - P_{\text{pv}}}{P_{\text{mpp}}} \times 100\%. \end{aligned} \tag{4}$$

Power values on the load after applying FLC have been compared with the nominal values of the maximum power points for several cases of uniform irradiation and partial shading. Results listed in Table 4 show that the FLC has efficiently found the MPP for all uniform irradiation and partial shading scenarios studied.

To further prove the ability of FLC to track the MPP under partial shading, a comparison between the proposed algorithm and the P&O algorithm is conducted. Results listed in Table 5 show that the P&O algorithm is trapped at local peaks while the fuzzy controller finds the global peak. Figure 7 shows the output power for the fuzzy controller compared with the P&O algorithm at different cases. The irradiation applied on the simulated model at this case is equal on the whole panel and suddenly decreased partially at 0.2 s. The fuzzy controller found the peak at the first part with accuracy greater than that of the P&O algorithm. After partial shading being applied on 36 cells of the PV panel, the fuzzy controller tracked the global maximum power point while the P&O algorithm is trapped at the local peaks. The fuzzy controller has reached the global point with an efficiency of 99% while the P&O controller failed to reach this point. The fuzzy controller detects irradiation changing by detecting changes in voltage and power values of the PV system. This controller has the ability to change the duty cycle by a precise difference depending on membership functions. P&O changes the value of the duty cycle by a fixed step every time irradiation changes. Because of the fixed step value, it does not reach the necessary precise value of the duty cycle to get a maximum power from the system and gets trapped

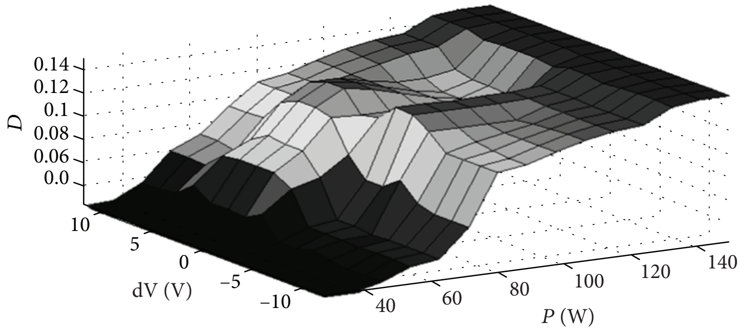
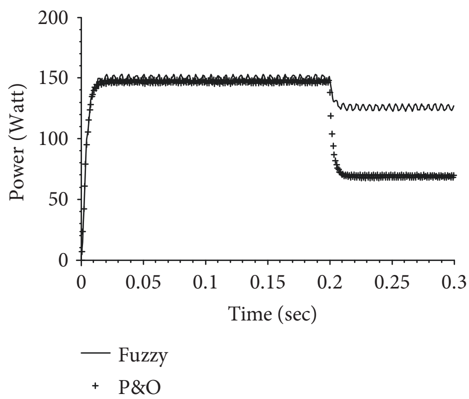


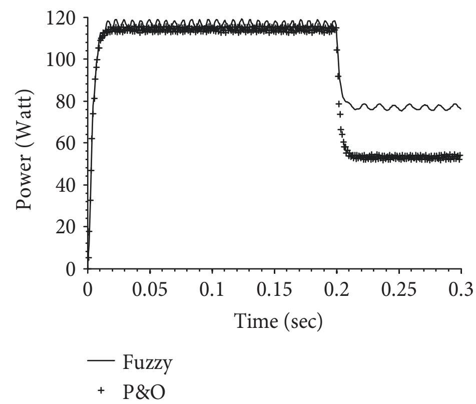
Figure 6: Surface view for fuzzy inputs (P, dV) vs. output (D) (adappted from Allataifeh et al. [2]).

Table 3: Comparison between output power values with and without MPPT.

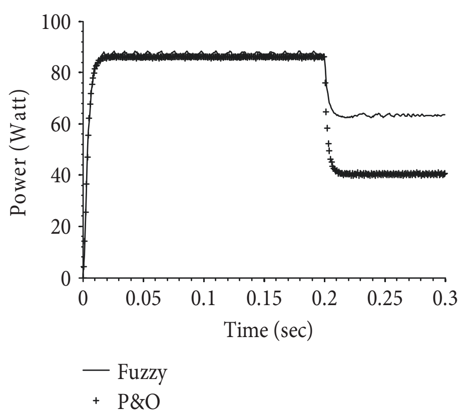
Case no.	Irradiance level (W/m^2)	Output power (W) (without MPPT)	Output power (W) (with MPPT)	% increase
1	800	102.5	123.2	20.7%
2	600	64.9	87	34%
3	500	45	70.8	57%
4	300	21.4	38.7	80%



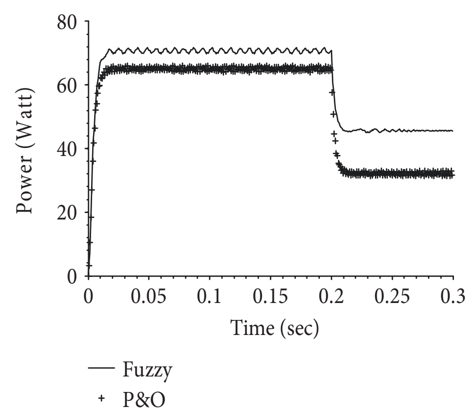
(a) Partial shading—1000 to 800 W/m^2



(b) Partial shading—800 to 500 W/m^2



(c) Partial shading—600 to 400 W/m^2



(d) Partial shading—500 to 300 W/m^2

Figure 7: Comparison between fuzzy and P&O partial shading.

Table 4: Values of model outputs.

Case no.	Condition	Ir1 (W/m^2)	Ir2 (W/m^2)	Nominal power (W)	Power after fuzzy (W)	Efficiency
1	Uniform irradiation	1000	1000	149	149	100%
2	Uniform irradiation	900	900	133	133	100%
3	Uniform irradiation	800	800	118	117.5	99.6%
4	Uniform irradiation	700	700	102.5	101.5	99%
5	Uniform irradiation	600	600	87.2	87	99.8%
6	Uniform irradiation	500	500	71.3	70.8	99.3%
7	Uniform irradiation	400	400	56.5	56	99%
8	Uniform irradiation	300	300	41.5	41	99%
9	Uniform irradiation	200	200	26.6	24.5	92%
10	Partial shading	1000	800	126.3	126	99.8%
11	Partial shading	900	600	95.7	94	98%
12	Partial shading	800	500	79.5	79	99.4%
13	Partial shading	700	500	78.2	78	99.7%
14	Partial shading	600	400	62.3	62	99.5%
15	Partial shading	900	300	61.4	60	97.7%
16	Partial shading	700	300	48	47.5	99%
17	Partial shading	500	300	46.3	46	99.4%

Table 5: Comparison between the fuzzy controller and P&O.

Ir1 (W/m^2)	Ir2 (W/m^2)	Local peak (W)	Global peak (W)	Output of P&O (W)	Output of fuzzy (W)
1000	800	71.24	126.3	68	126
800	500	55.7	79.5	53	79
600	400	41.5	62.3	39	61
500	300	34	46.3	31	46

at local maximum under partial shading conditions due to its way of tracking by looking for the first peak in power values.

5. Conclusions

In this study, the fuzzy logic controller (FLC) for maximum power point tracking (MPPT) of a photovoltaic system under variable insolation conditions has been developed to track the maximum power point of the PV system. A MATLAB/Simulink model consists of a PV panel and a boost converter with FLC connected to a resistive load that has been built in order to evaluate the performance of the proposed controller. The proposed system showed its ability to recover from sudden changes and maintain stability under partial shading conditions. A comparison between the performance of the proposed FLC and perturbation and observation controller has been made. The results show that the fuzzy logic controller has reached the global point with an efficiency of 96% while the P&O controller failed to reach this point.

Nomenclature

- A: Ideal factor of the diode
- C_{min}: Minimum capacitance value (F)
- D: Duty cycle
- dV: Voltage difference (V)
- FF: Fill factor
- F_s: Switching frequency (Hz)
- I_m: Maximum current (A)
- I_{pv}: Photovoltaic current (A)
- I_s: Saturation of dark current (A)
- L_{min}: Minimum inductance value (H)
- P_m: Maximum power (W)
- P_{max}: Maximum power (W)
- P_{pv}: Photovoltaic power (W)
- R: Resistance (Ω)
- R_s: Series resistance (Ω)
- R_{sh}: Shunt resistance (Ω)
- V_o: Output voltage (V)
- V_{pv}: Photovoltaic voltage (V)
- V_s: Input voltage of the converter (V)
- η: Efficiency (%).

Data Availability

The FLC training data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

There is no conflict of interest regarding the publication of this article.

References

[1] K. Bataineh and D. Dalalah, "Optimal configuration for design of stand-alone PV system," *Smart Grid and Renewable Energy*, vol. 3, no. 2, pp. 139–147, 2012.

[2] A. A. Allataifeh, K. Bataineh, and M. Al-Khedher, "Maximum power point tracking using fuzzy logic controller under partial conditions," *Smart Grid and Renewable Energy*, vol. 6, no. 1, pp. 1–13, 2015.

[3] C. F. Lu, C. C. Liu, and C. J. Wu, "Dynamic modelling of battery energy storage system and application to power system stability," *IEE Proceedings - Generation, Transmission and Distribution*, vol. 142, no. 4, p. 429, 1995.

[4] H. J. Möller, *Semiconductors for Solar Cell*, Artech House, Inc, Norwood, MA, 1993.

[5] R. Gottschalg, M. Rommel, D. G. Ineld, and H. Ryssel, "Comparison of different methods for the parameter determination of the solar cell's double exponential equation," in *14th European Photovoltaic Science and Engineering Conference (PVSEC)*, pp. 321–324, Barcelona, Spain, 1997.

[6] Y. Cuia, W. Yaoa, and J. Luoa, "A research and improvement on a maximum power point tracking method for PV system under partially shaded conditions," *Procedia Engineering*, vol. 29, pp. 2583–2589, 2012.

[7] Z. Salam, J. Ahmed, and B. S. Merugu, "The application of soft computing methods for MPPT of PV system: a technological and status review," *Applied Energy*, vol. 107, pp. 135–148, 2013.

[8] T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Transactions on Energy Conversion*, vol. 22, no. 2, pp. 439–449, 2007.

[9] P. Bhatnagar and R. K. Nema, "Maximum power point tracking control techniques: state-of-the-art in photovoltaic applications," *Renewable and Sustainable Energy Reviews*, vol. 23, pp. 224–241, 2013.

[10] C.-H. Lin, C.-H. Huang, Y.-C. Du, and J.-L. Chen, "Maximum photovoltaic power tracking for the PV array using the fractional-order incremental conductance method," *Applied Energy*, vol. 88, no. 12, pp. 4840–4847, 2011.

[11] A. Reza Reisi, M. Hassan Moradi, and S. Jamasb, "Classification and comparison of maximum power point tracking techniques for photovoltaic system: a review," *Renewable and Sustainable Energy Reviews*, vol. 19, pp. 433–443, 2013.

[12] E. Mamarelis, G. Petrone, and G. Spagnuolo, "A two-steps algorithm improving the P&O steady state MPPT efficiency," *Applied Energy*, vol. 113, pp. 414–421, 2014.

[13] R. Ahmed, A. Namaane, and N. K. M'Sirdi, "Improvement in perturb and observe method using state flow approach," *Energy Procedia*, vol. 42, pp. 614–623, 2013.

[14] J. W. Kimball and P. T. Krein, "Discrete-time ripple correlation control for maximum power point tracking," *IEEE Transactions on Power Electronics*, vol. 23, no. 5, pp. 2353–2362, 2008.

[15] M. Miyatake, T. Inada, I. Hiratsuka, H. Zhao, H. Otsuka, and M. Nakano, "Control characteristics of a Fibonacci-search-based maximum power point tracker when a photovoltaic array is partially shaded," in *Power Electronics and Motion Control Conference, 2004. IPEMC 2004. The 4th International*, vol. 2, pp. 816–821, Xi'an, China, 2004.

[16] T. L. Nguyen and K. S. Low, "A global maximum power point tracking scheme employing DIRECT search algorithm for photovoltaic systems," *IEEE Transactions on Industrial Electronics*, vol. 57, no. 10, pp. 3456–3467, 2010.

[17] K.-H. Chao and C.-J. Li, "An intelligent maximum power point tracking method based on extension theory for PV systems," *Expert Systems with Applications*, vol. 37, no. 2, pp. 1050–1055, 2010.

[18] T. Tafticht, K. Agbossou, M. L. Doumbia, and A. Chériti, "An improved maximum power point tracking method for photovoltaic systems," *Renewable Energy*, vol. 33, no. 7, pp. 1508–1516, 2008.

[19] H. Heydari-doostabad, R. Keypour, M. R. Khalghani, and M. H. Khooban, "A new approach in MPPT for photovoltaic array based on extremum seeking control under uniform and non-uniform irradiances," *Solar Energy*, vol. 94, pp. 28–36, 2013.

[20] T. Noguchi, S. Togashi, and R. Nakamoto, "Short-current pulse-based maximum-power-point tracking method for multiple photovoltaic-and-converter module system," *IEEE Transactions on Industrial Electronics*, vol. 49, no. 1, pp. 217–223, 2002.

[21] M. A. S. Masoum, H. Dehbonei, and E. F. Fuchs, "Theoretical and experimental analyses of photovoltaic systems with voltage and current-based maximum power-point tracking," *IEEE Transactions on Energy Conversion*, vol. 17, no. 4, pp. 514–522, 2002.

[22] S. Kazmi, H. Goto, O. Ichinokura, and H. J. Guo, "An improved and very efficient MPPT controller for PV systems subjected to rapidly varying atmospheric conditions and partial shading," in *Power Engineering Conference, 2009. AUPEC 2009. Australasian Universities*, pp. 1–6, Adelaide, SA, Australia, 2009.

[23] M. Miyatake, M. Veerachary, F. Toriumi, N. Fujii, and H. Ko, "Maximum power point tracking of multiple photovoltaic arrays: a PSO approach," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 47, no. 1, pp. 367–380, 2011.

[24] A. M. Othman, M. M. M. el-arini, A. Ghitas, and A. Fathy, "Realworld maximum power point tracking simulation of PV system based on fuzzy logic control," *NRIAG Journal of Astronomy and Geophysics*, vol. 1, no. 2, pp. 186–194, 2012.

[25] K. Punitha, D. Devaraj, and S. Sakthivel, "Artificial neural network based modified incremental conductance algorithm for maximum power point tracking in photovoltaic system under partial shading conditions," *Energy*, vol. 62, pp. 330–340, 2013.

[26] S. Subiyanto, A. Mohamed, and M. A. Hannan, "Intelligent maximum power point tracking for PV system using Hopfield neural network optimized fuzzy logic controller," *Energy and Buildings*, vol. 51, pp. 29–38, 2012.

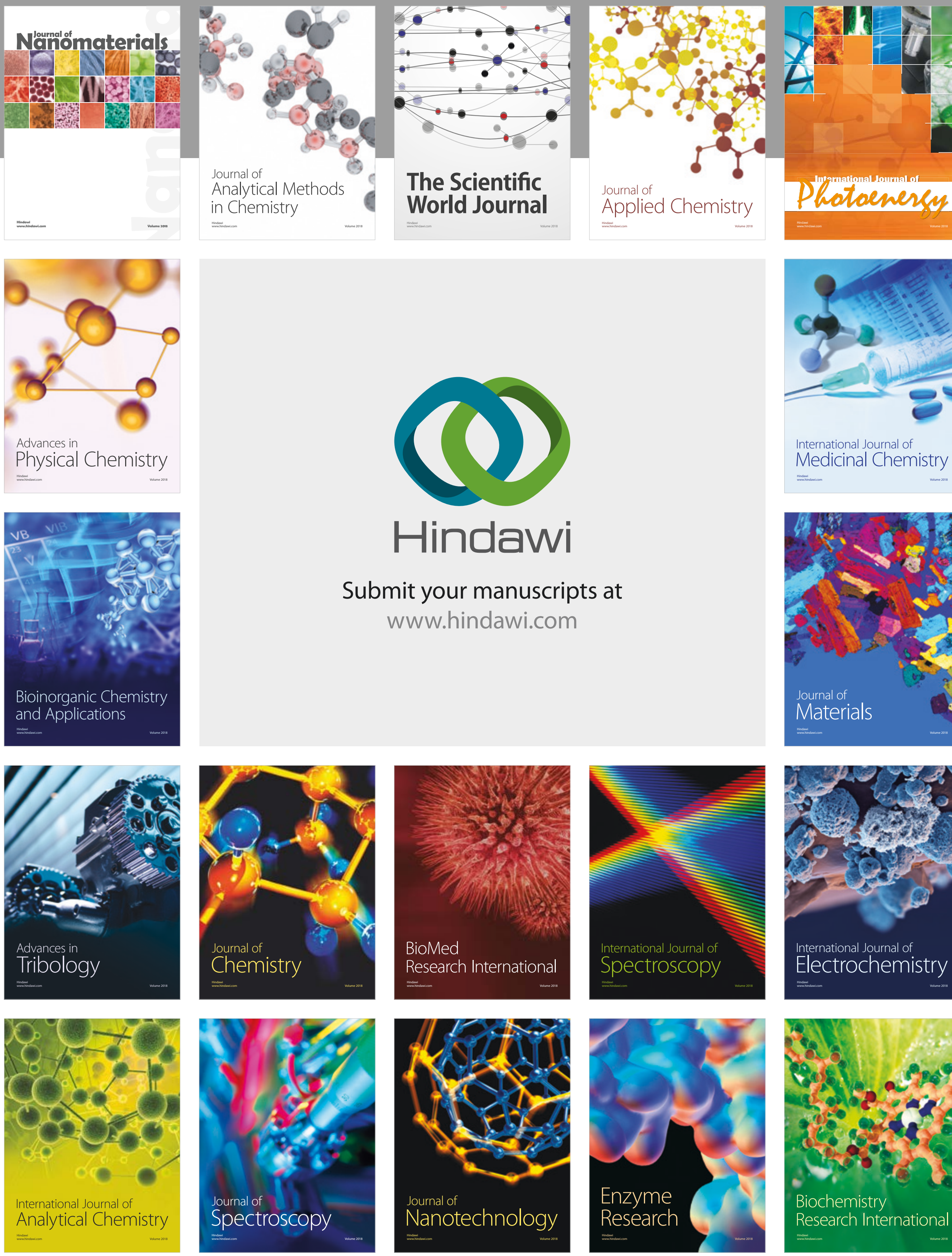
[27] M. Seyedmahmoudian, S. Mekhilef, R. Rahmani, R. Yusof, and E. Renani, "Analytical modeling of partially shaded photovoltaic systems," *Energies*, vol. 6, no. 1, pp. 128–144, 2013.

[28] J. L. Santos, F. Antunes, A. Chehab, and C. Cruz, "A maximum power point tracker for PV systems using a high performance boost converter," *Solar Energy*, vol. 80, no. 7, pp. 772–778, 2006.

[29] X. Liu and L. A. C. Lopes, "An improved perturbation and observation maximum power point tracking algorithm for PV arrays," in *2004 IEEE 35th Annual Power Electronics Specialists Conference (IEEE Cat. No.04CH37551)*, pp. 2005–2010, Aachen, Germany, June 2004.

[30] G. J. Yu, Y. S. Jung, J. Y. Choi, and G. S. Kim, "A novel two-mode MPPT control algorithm based on comparative study of existing algorithms," *Solar Energy*, vol. 76, no. 4, pp. 455–463, 2004.

[31] R. Kharb, M. D. Ansari, and S. Shimi, "Design and implementation of ANFIS based MPPT scheme with open loop boost converter for solar PV module," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 3, pp. 2320–3765, 2014.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