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Performance Comparison of Maximum Power Point Tracking Method of Human Psychology Optimization (HPO), Artificial Bee Colony (ABC) and Fuzzy Logic Controller (FLC) on Flyback Converter Under Partial Shading Condition

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A B S T R A C T

Maximum Power Point Tracking (MPPT) is a method to track the power point of an energy source with the intention to generate maximum power. The surface of the Solar Panel has the possibility of being blocked when it receives sunlight. The barrier can be in the shape of shadows of objects that are nearby solar panels. The problem causes the power generated to be not optimal and makes more than one MPPT peak on the characteristics of P-V. This paper compares several methods of MPPT such as Human Psychology Optimization (HPO), Artificial Bee Colony (ABC), and Fuzzy logic Controller (FLC) under partial shading conditions, the comparison of three method by simulation. This algorithm hooks up to a flyback converter to provide MPP. From the results of MPPT accuracy in partial shading situations, the ABC and HPO approach methods can achieve GMPP with more than 82.22 % accuracy. For convergence, ABC needs extra time to discover GMPP. From the results, the Fuzzy approach can track however nevertheless trapped on LMPP.

INTRODUCTION

These days, the global recognition of solar panel (PV) strength era is increasing each day in residential in addition to commercial regions, due to its specific blessing as fuel loose, zero pollution, easy installation, the absence of shifting or rotating components, and so forth. In each instance, customers have attempted to extract or run at the maximum power point (MPP), which is the simplest possible via the use of the MPPT algorithm. The reason for the MPPT set of rules is extraction and presenting maximum power to the load, which is best viable by way of determining well the managed parameter of the interfacing tool, inclusive of the converter of duty cycle [1].

In the use of solar panels, the requirement of load modules may be connected series or parallel [2], [3]. Solar power may be absorbed and used by Photovoltaic to be a supply of electrical power. Photovoltaic has trouble while the sun irradiation acquired through the floor can't produce optimally because blocked with of an object around PV. The depth of daylight that is partially blocked via item effects within the emergence of more than one peak, Global Maximum Power Point is actual power (GMPP) and Local Maximum Power Point (LMPP) is not real power [4]. The energy acquired isn't the maximum electricity when trapped in LMPP, in partial shading conditions, the characteristic PV curve will deliver up a top of most power point [5]. The conventional approach is possibly trapped in LMPP and can't reach GMPP or actual energy because it is not able to differentiate between GMPP and LMPP. Conventional MPPT can only work well in ideal conditions and the climate does not change [6]. Conventional MPPT has a slow response reaction to reach MPP and in partial shading conditions, it can't work optimally.

The artificial intelligence method can work best because it has long flexibility to manipulate renewable energy MPPT, the weak point of the artificial intelligence method is determining parameters and complexity in coding [7]. This research will evaluate some approaches this is Human Psychology Optimization (HPO), Artificial Bee Colony set of rules (ABC), and Fuzzy logic Controller (FLC). This algorithm applies to a Flyback Converter that manages the usage of a microcontroller to produce a duty cycle along with buck or boost mode [5].

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METHOD

Photovoltaic (PV) Module

Photovoltaic (PV) is needed to convert solar energy into electrical energy. Three factors that affect the performance of solar panels are irradiation, shadow, and temperature. Commonly, each sun Photovoltaic has 36 or 72 cells. Every module has an equal circuit including a diode in parallel with a current source [8]. in this research, two solar panel are connected in series, information for the datasheet of solar panels is in Table 1.

Table 1. PV Module Specification

SHARP PV 80 WP	
P_{max} (Maximum Power)	80 Watt
V_{mp} (Voltage at MPP)	17.3 Volt
I_{mp} (Current at MPP)	4.63 Ampere
V_{oc} (Open-circuit voltage)	21.6 Volt
I_{sc} (Short-circuit current)	5.15 Ampere
Maximum Voltage	540 V
Dimension	1200 × 537 × 46 mm
Test Condition	1000W/m^2, 25^{o}C

Modelling of Flyback Converter

The output of the PV is lowered by the flyback converter. The output of the PV module is connected to the flyback via a switch to the transformer as shown in Figure 1 [10]. The layout of the magnetic circuit of a transformer is carried out like an inductor that stores energy. there is a filter and rectifier on the secondary side of the transformer to get a good output voltage. The flyback converter has one type of ordinary transformer because the normal transformer is under load In the electric current, the primary and secondary windings are almost balanced due to simultaneous behavior, flyback converter is like two magnetically coupled inductors [11], [12]. The parameters are calculated in equation (1) to equation (3).

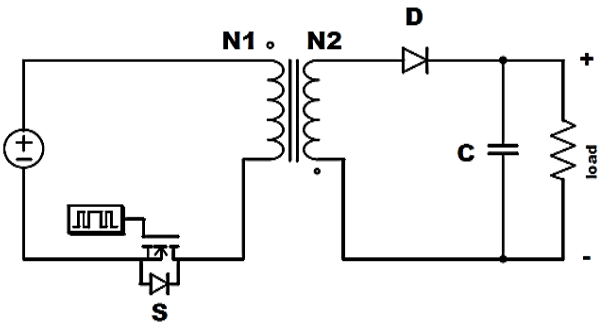

Figure 1. Flyback Converter Circuit

$$V_o = V_s \times \frac{D}{(D-1)} \times \frac{N1}{N2} \quad (1)$$

$$L_m = \frac{(V_s \times D_{max})^2}{2 \times P_{in} \times fs \times K_{RF}} \quad (2)$$

$$C_o = \frac{V_o \times D}{R \times \Delta V_o \times fs} \quad (3)$$

There are 2 modes on the flyback converter, namely working in the 'ON' and 'OFF' mode switch. The flyback converter works when the source voltage is kept at magnetizing inductor when the switch is on and then transmits it to the load when the switch is off, thus, we obtain the set of equations for generating state space analysis (SSM) [13-14]. For SSM, we keep the following assumptions in mind:

- We consider all components to be ideal.
- Turn ratio $\frac{N1}{N2} = 1$ for simplicity purpose.

For equations of the flyback converter can be found (1-3). And parameters and values components of the Flyback converter are shown in Table 2.

Table 2. Parameters of Flyback Converter

Parameters	Values	Unit
Input Voltage (V_{in})	34.6	V
Switching Frequency (*fs*)	40	kHz
Output Voltage (V_o)	14.4	V
Voltage Ripple (ΔV_o)	0.1%	V
Induction Magnetic (L_m)	176	μH
Duty Cycle (D = D_{max})	50	%
Capacitor (C_o)	6800	μF

MPPT Partial Shading Algorithm

According to principle, the maximum power point tracking in particular consists of voltage feedback technique, strength remarks technique, disturbance voltage method, conductivity increment technique, linear approximation approach, and others [15]. Various algorithms are used to get the maximum PV power. However, not all methods can work well when partial shading conditions. Artificial intelligence (AI) is an effective method in overcoming these problems. [9]. This Paper, the usage of 3 technique there are HPO, ABC and FLC set of rules. Figure 2 is pattern of shading.

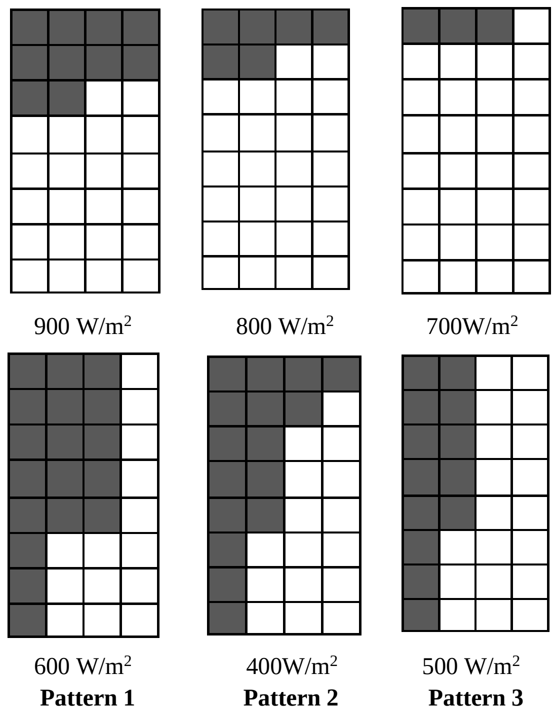

Figure 2. Pattern of shading

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a) Human Psychology Optimization (HPO)

HPO is stimulated by using the intellectual and mental of goal-oriented man or woman in undertaking the entirety [1]. In solving problems, they have effective energy. The positive power comes from excitement, self-motivation, inspiration, and lesson. The expression can be validated in equations (3-6) [5].

Excitement;

$$U_j^{i+1} = \Omega \times (e^{-1\frac{i\times e^{-\frac{i}{I}}\times \sin(i\times\pi)/2l)}{I}}) \times \frac{aD_j^i}{J} \quad (3)$$

Self motivation;

$$S_j^i = \Psi \times (m_j^i - D_j^i) \quad (4)$$

Inspiration:

$$N_j^{i+1} = \frac{\sum_{t=1}^{aD_j^{i-1}} (\beta(aD_j^i,t)\times(M_{\Re i}^i - D^{\frac{i}{j}}))}{aD_j^i - 1} \quad (5)$$

Lesson:

$$L_j^{i+1} = \frac{\sum_{t=1}^{J}(aD_j^i+1), aD_j^i \neq J^{(\xi(aD_{j,t}^i \times (M_t^i - P_j^i))}}{J - aD_j^i}) \quad (6)$$

HPO formula For Update duty cycle using equation (7)[1].

$$D_j^{i+1} = D_j^i + \lambda_1 \times U_j^{i+1} + (1-\lambda_1)\times S_j^{i+1} (1-\lambda_2) \times L_j^{i+1} \quad (7)$$

b) Fuzzy Logic Controller (FLC)

Fuzzy logic Controller (FLC) generally made an algorithm that includes 3 tiers: rule base, fuzzification, and defuzzification. The input to be managed from this technique is the error version and the delta error can be determined via the following equations (8) and (9) [6]. The result is a duty ratio variation DC/DC Converter.

$$e(t) = \frac{\Delta P(t)}{\Delta V(t)} = \frac{P(t)-P(t-1)}{V(t)-V(t-1)} \quad (8)$$

$$\Delta e(t) = e(t) - e(t-1) \quad (9)$$

For fuzzification used 5 triangular membership functions for all inputs and outputs. The inputs and variables were converted to linguistic values. In this work, five subsets were used which are: Negative Large (NL), Zero (Z), Negative Small (NS), Positive Large (PL), and Positive Small (PS). Figure 3-5 is the membership function of inputs and output [16].

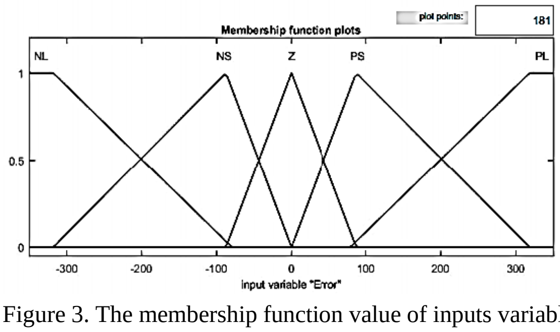


Figure 3. The membership function value of inputs variable "Error"

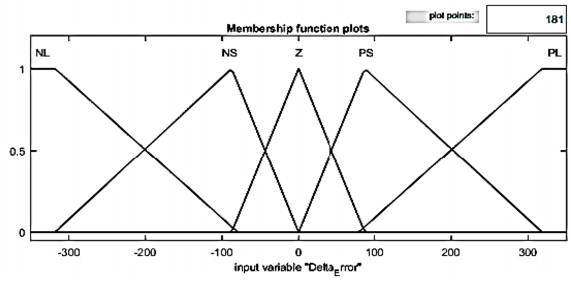


Figure 4. The membership function value of inputs variable "Delta Error".

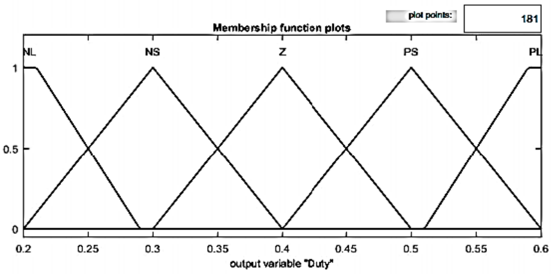


Figure 5. The membership function value of inputs variable "Duty"

Table 3 Shows fuzzy rule base, using 25 fuzzy control rules for determining the task ratio as fuzzy output.

Table 3. Fuzzy Rule Base

e /Δe	**NS**	**NL**	**Z**	**PL**	**PS**
NL	NL	NL	NL	NL	NL
NS	NS	NS	NS	NS	NS
Z	Z	Z	Z	Z	Z
PS	PS	PS	PS	PS	PS
PL	PL	PL	PL	PL	PL

c) Artificial Bee Colony Algorithm (ABC)

The artificial Bee Colony (ABC) set of rules is stimulated via bee colony behavior. It changed into proposed by means the Karaboga crew in 2005 to optimize algebra troubles [17]. The usual ABC set of rules divides the synthetic bees into the subsequent 3 classes: employed bees, onlooker bees, and scouts. The purpose of the whole colony is to locate the biggest source of nectar [18].

Application of the artificial Bee Colony method on MPPT, the PV output power can be called nectar, and the food source of the ABC algorithm is the ratio of the duty cycle [19]. To reduce conversion time on GMPP is ABC without bee scout segments for GMPP tracking Steps using ABC [20]:

1) initialization: first, all bees are positioned on a special food asset (duty cycle ratio dc – dc converter is run through random values) use the following equation:

$$d_i = d_{min} + rand\,[0.1]\,(d_{max} - d_{min}) \quad (10)$$

2) evaluate the amount of Nectar: The Initialization method will repeat until it reaches the specified maximum number of cycles. Each initialization cycle, there is a process of evaluating the amount of nectar and methods of determining the location of food sources. Calculation of output power using PSIM software and the appropriate block [21].

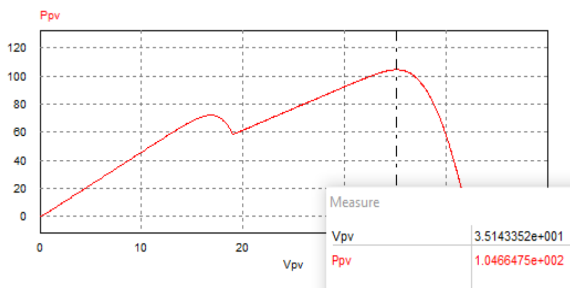
3) search for new food supply positions: for the GMPP tracking cycle in PV structures there are two phases.
worker bee phase: worker bee segment: each bee in this environment uses the following equation:

$$d_{i(k+1)} = d_i + \phi\ (d_i - d_k)$$

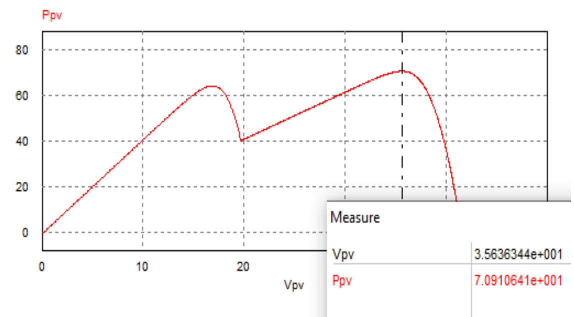
in which k is a range of iteration, variable ϕ are random numbers generated among [-1,1], if there is likely to be a growth in the quantity of food, the worker bees will test the food-dependent supply at the new location and the food source will be replaced with a new one. In any other case, they will go back to the position preceding foods, as an example [21].

$$(d_{i(k+1)} = d_{i(k)})$$

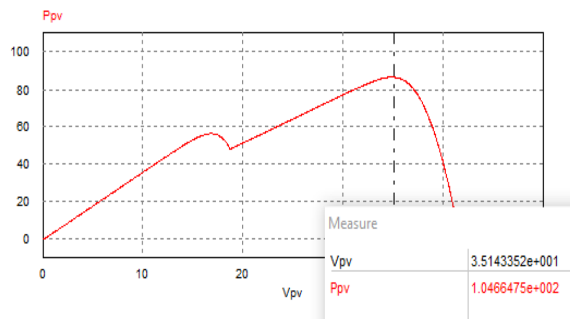
4) end section: in the end, after the PV output power does not increase and the MCN reaches its highest value. The DC-DC converter will work with high quality duty cycles of all techniques that have been surpassed [22].



(a)



(b)



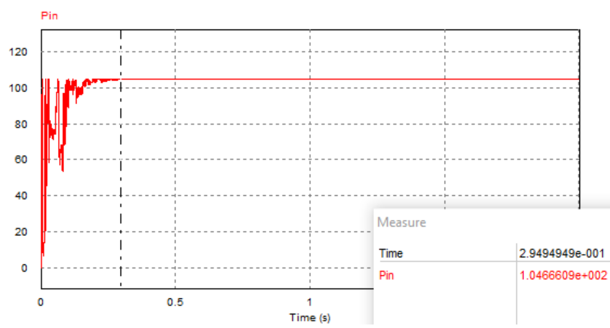
(c)

Figure 6. (a), (b) & (c) P-V characteristic curve in partial shading condition.

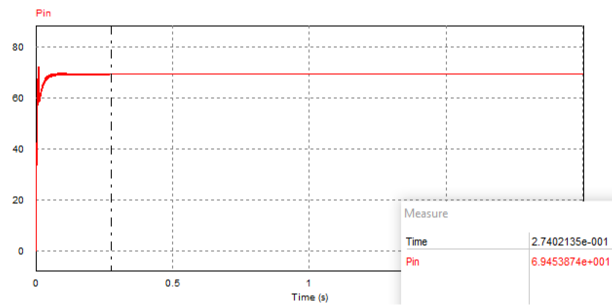
RESULTS AND DISCUSSION

To see the results of all methods in finding GMPP or LMPP with a predetermined pattern, a simulation of the PSIM software program is used with different irradiation received by each PV module. In this paper, two photovoltaic (PV) with a maximum power capacity of 80 watts are connected in series and the output of the PV is connected to a DC-DC converter (flyback converter). The PV parameter values are shown in Table 1, the predetermined shading pattern can be seen in Figure 2 and P-V characteristic curve in partial shading condition can be seen in Figure 6 (a), 6(b), 6(c).

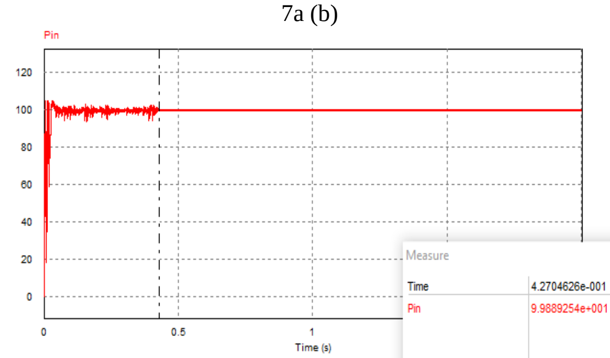
Figure. 6 is the resulting curve of P-V under partial shading (a) pattern 1, (b) pattern 2, (c) pattern 3, with different irradiation. There are two peaks in the characteristic curve because of partial shading condition, kind of peaks is the true peak (GMPP) and not real peak (LMPP), MPPT conventional usually trapped in LMPP, can't reach GMPP, 3 techniques are used to reach GMPP, with PV modules connect with flyback converter. The result simulation of MPPT under partial shading is proven in Figure 7.



7a (a)



7a (b)



7a (c)

Figure 7a. Result of simulation on pattern 1 (a) HPO, (b) Fuzzy and (c) ABC

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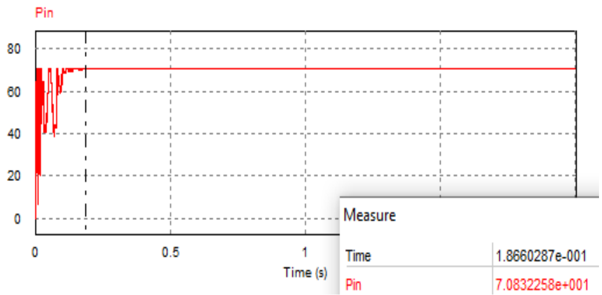
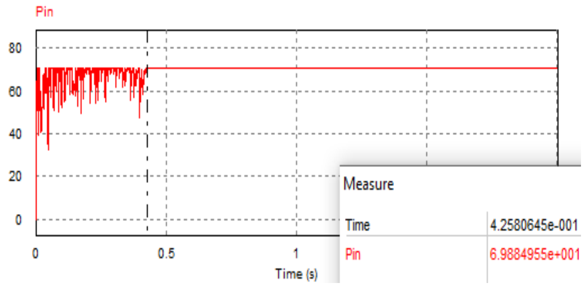
Table 4. Comparison Results Of HPO, Fuzzy And ABC

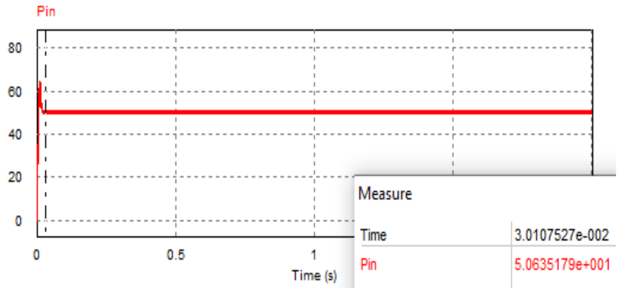
Patterns	Power MPPT (W)				Accuracy (%)			Tracking (s)		
	Target	HPO	Fuzzy	ABC	HPO	Fuzzy	ABC	HPO	Fuzzy	ABC
1	110	104.6	69.4	99.88	95.09	63.09	90.80	0.29	0.27	0.42
2	86	70.83	50.6	69.88	83.33	59.52	82.22	0.18	0.30	0.42
3	96	86.49	48.15	84.39	90.09	50.15	87.90	0.20	0.34	0.43



7b (a)

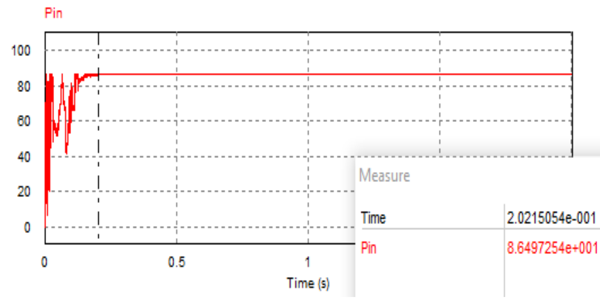


7b (b)

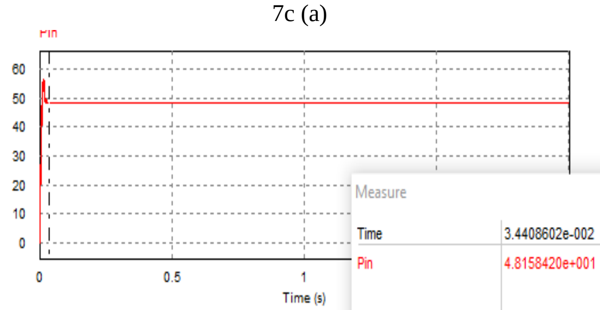


7b (c)

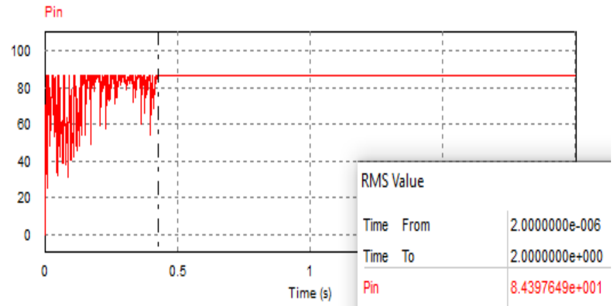
Figure 7b. Result of simulation on pattern 2 (a) HPO, (b) Fuzzy and (c) ABC



7c (a)



7c (b)



7c (c)

Figure. 7c. Result of simulation on pattern 3 (a) HPO, (b) Fuzzy and (c) ABC

Figures 7(a) - 7(c) are the results of partial shading simulation with different irradiation values. Good results reach GMPP conditions which show maximum power without trapping at LMPP. Simulations that have been done by the PSIM software show that the performance of all methods is compared to obtaining the maximum output power with different irradiations. For more details, all method performance power, accuracy and convergence, method comparison results are shown in Table 4. According to the information in Table 4, the accuracy of the MPPT partial shade using the three methods, the fuzzy method has a low accuracy of 50.15%. The HPO method and the ABC method can achieve GMPP well. The HPO method has an accuracy of up to 95.09% and the ABC method has an accuracy of up to 90.80%. For convergence, the ABC method requires extra time to find the GMPP. When testing the simulation under partial shade, the Fuzzy method cannot find the GMPP. From the simulation results, the Fuzzy method can track but is still stuck at LMPP.

CONCLUSIONS

This paper has already presented three methods Human Psychology Optimization (HPO), Artificial Bee Colony (ABC), and Fuzzy logic Controller (FLC) used to achieve MPPT under partial shading conditions. Overall, it can be concluded that the performance of the fuzzy MPPT under partial shading conditions is not very good, meanwhile HPO method is the best solutions in partial shading conditions with the fastest tracking and best accuracy. The ABC method is good after the HPO method in achieving GMPP, but bad convergence to reach GMPP.

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NOMENCLATURE

D_j^i = Duty Cycle I

λ_1, λ_2 = Random variable, the value between 0-1

U_j^{i+1} = Excitement Factor

Ω = Enthusiasm Factor

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aD_j^i = Total of duty cycle

S_j^{i+1} = Self-Motivation factor

Ψ = Sprint factor, $\Psi = 2 \times \omega$

m_j^i = Best duty cycle

N_j^{i+1} = Inspiration factor

L_j^{i+1} = Lesson factor

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