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An Advanced MPPT Based on Artificial Bee Colony Algorithm for MPPT Photovoltaic System under Partial Shading Condition

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ABSTRACT

Maximum power point tracking (MPPT) algorithms are employed in photovoltaic (PV) systems to make full utilization of PV array output power, which have a complex relationship between ambient temperature and solar irradiation. The power-voltage characteristic of PV array operating under partial shading conditions (PSC) exhibits multiple local maximum power points (LMPP). In this paper, an advanced algorithm has been presented to track the global maximum power point (GMPP) of PV. Compared with the Perturb and Observe (P&O) techniques, the algorithm proposed the advantages of determining the location of GMPP whether partial shading is present.

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1. INTRODUCTION

Photovoltaic (PV) system has received a great attention, as it appears to be one of the most promising renewable energy sources. It has a complex relationship between solar irradiation, total resistance and temperature and has been commercialized in many countries due to its potential long-term benefits. The electrical energy produced by a photovoltaic system stored or used directly by static converters is not maximized. To ensure the optimal utilization of large PV arrays, maximum power point tracker (MPPT) is employed in conjunction with the power converter DC/DC by adjusting the operating point of the PV array. In this context, an increasing interest is given to the methods of tracking the maximum power of the PV system named Maximum Power Point Tracker (MPPT) [1],[10]. Among these techniques, The perturb and observe approach [2]-[3] and the incremental conductance [4]-[5] are most utilized.

Most MPPT techniques are based on the assumption that all cells in the same module and all modules in the same string receive the same irradiance. The classical algorithm can accurately track the MPP under uniform illuminating conditions. However, in some cases, PV modules are subjected to partial shade conditions (PSC), and the power voltage curves are characterized by the apparition of multiple local peaks, which are due to the activation of bypass diodes avoiding shaded cells from damage [6].

In this paper, an intelligent approach using artificial bee colony controller has introduced to track the maximum power point of the photovoltaic panel under shading condition. The PV system constituted of a photovoltaic generator, boost DC-DC converter to adjust a resistive load to PV array. This converter is controlled by a PWM signal delivered by ABC controller. The system is presented in Figure 1.

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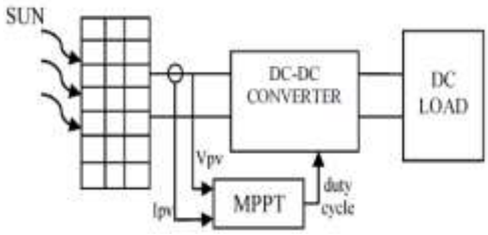


Figure 1. General diagram of the photovoltaic system.

2. PHOTOVOLTAIC SYSTEM MODEL

2.1. Characteristics of PV module

The studied PV module includes 36 PV cells connected in series. Therefore, a PV cell is modelled by an electrical circuit based single diode as shown in the following Figure 2.

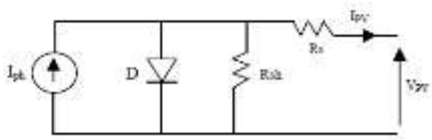


Figure 1. Equivalent circuit of a PV cell

$$I_{PV} = n_p I_{Ph} - n_p I_s \left[\exp\left(\frac{V_{Pv}+R_s I_{Pv}}{nsV_{th}}\right) - 1\right] - \frac{V_{Pv}+R_s I_{Pv}}{R_{sh}} \quad (1)$$

$$I_s = I_r \left(\frac{T}{T_r}\right)^3 \text{expo}\left(\frac{qE_g}{KqA}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right) \quad (2)$$

$$I_{Ph} = [I_{Sc} + K_I(T - T_r)]\frac{G}{1000} \quad (3)$$

Where

Table 1. Parameters of a PV

IPV	Output current
VPV	Output voltage
T	Cell temperature (K).
G	Solar irradiance (W/m2).
IPh	Light-generated current.
Is	PV cell saturation current.
Ir	saturation current at Tr.
Isc	Short-circuit current at reference condition.
Tr	Reference temperature.
KI	Short-circuit temperature coefficient.
q	Charge of an electron.
K	Boltzmann's constant.
Eg	Band-gap energy of the material.
A	Ideality factor.

Equation (1) expressing the mathematical model of a PV cell is basically derived from the electrical circuit schematized above in Figure 2. The behavior of the PV module is shown in two characteristics IPV (VPV) and PPV (VPV), which are obtained when a varying resistance is connected directly to the PV module. The following Figures (Figure 3 and Figure 4) give an example of these characteristics for two different irradiance (G) and temperature (T).

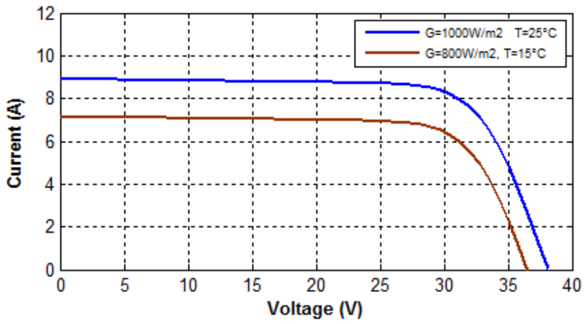


Figure 3. IPV (VPV) characteristic

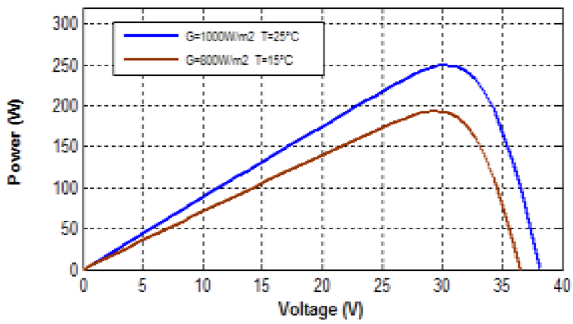


Figure 4. PPV (VPV) characteristic

The specification of the photovoltaic module used are (for G=1000W/m2 and T=25°C).

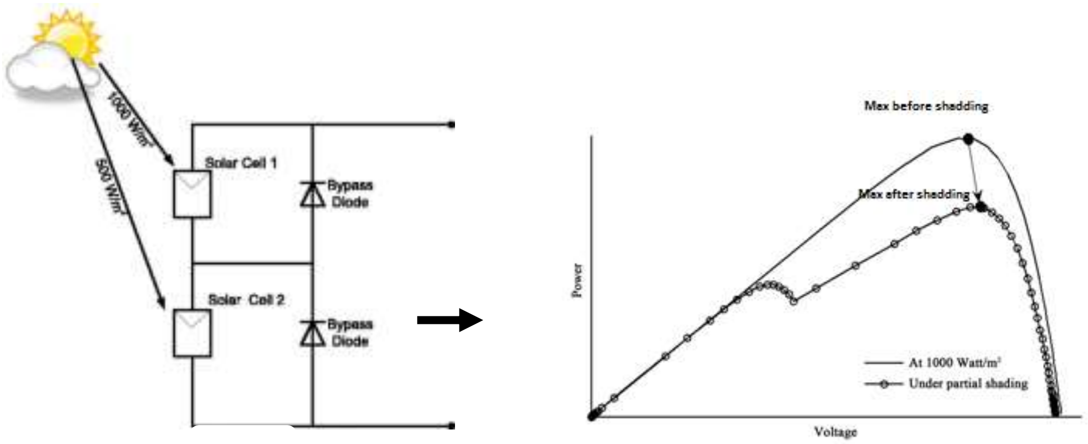
Table 2. Specification of PV Used

Pmax (W)	250.0W
Voc (V)	37.6V
Isc (A)	8.81A
Vmp(V)	30.5V
Imp(A)	8.27A

2.2. PV Systems Working under Partial Shading Condition

Figure 3 presents a PV array formed by two series connected PV modules [7]. If one of the PV modules is shaded, it acts as a load instead of a power source. Under uniform insolation, the bypass diodes are reverse biased and have no impact. When the PV module is shaded, the bypass diode across the PV module is forward biased and the current passes through the diode instead of the PV module as shown in Figure 3(b).

However, P-V curves will be transferred into complicated shape characterized by multiple peaks as shown in Figure 3. So, in order to extract the maximum power from the PV array, the system should be operated at the global maximum power point (Gmpp).thus, in order to achieve optimal energy harvesting from the PV array, an intelligent and efficient MPPT method should be used.



(a) (b)

Figure 3. (a) Operation of PV under PSC, (b) The Resulting P–V Curves For operation of PV array under PSC

3. MAXIMUM POWER POINT TRACKING

Maximum power point tracking (MPPT) technique is used to extract the maximum power delivered by the solar panel. Indeed, there are several algorithms to extract the maximum power. The most famous is Perturb and Observe (P & O). In this section, we offer a new controller based on ABC under shading condition.

3.1. Perturb and observe

Perturb and observe algorithm is the most used method to pursue the maximum power point of a photovoltaic generator. The principle is to disrupt the voltage or duty cycle and calculating the power terminal of the PV module.

a. When p(k-l)<p(k), the voltage is increased.
b. When p(k-l) > p(k), the voltage is decreased.

3.2. ABC Controller Optimization Applied to Track the MPP under Partial Shading Condition :

3.2.1. Fundamental of ABC Optimization Algorithm

In the ABC model, the colony consists of three groups of bees: employed bees, onlookers and scouts. It assumes that there is only one artificial employed bee for each food source. The employed bees go to their food source and come back to hive. They share this data with onlooker bees by dancing in the designated dance area inside the hive. The nature of dance is proportional to the nectar content of food source just exploited by the dancing bee. The onlooker bees are waiting in the hive for the data, watching the dances of employed bees and choosing food sources depending on dances. Therefore, good food sources attract more onlooker bees compared to bad ones. Whenever a food source is exploited fully, all the employed bees associated with it abandon the food source, and become scout. Scout bees search randomly for new food sources [8]. The flowchart of the proposed ABC algorithm is given in Figure 4 [9]:

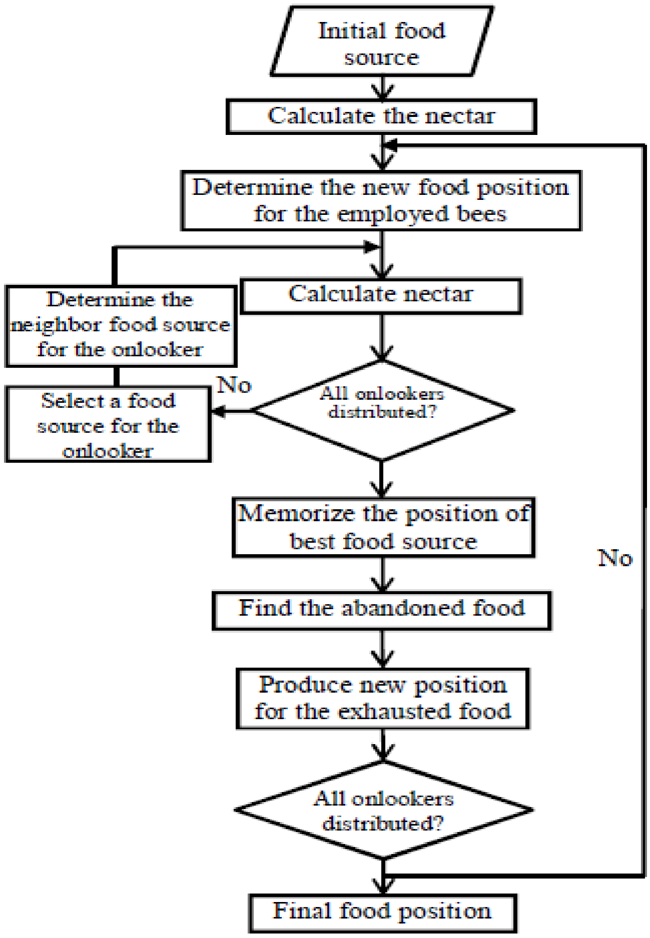


Figure 4. Flowchart of the ABC Algorithm

The steps of the ABC algorithm are outlined as follows:

a. Employed bees: Initial food sources are randomly generated for all employed bees within its limits according to the Equations.

$$x_i = x_{min} + rand\,[0,1]*(x_{max} - x_{min}) \quad (4)$$

Where x_{min} and x_{max} represent respectively the minimum and the maximum, $i \in \{1, 2, 3 \ldots SN\}$ with SN is the number of candidate. After initialization, the population of the solutions is subject to repeated cycles C = 1, 2. . . MCN, of the search processes of the employed bees, the onlooker bees and the scout bees. For each cycle, every employed bee leaves to a food source and locates a neighbor source V_i (Equation 2), then estimates its nectar value and dances in the hive.

$$V_i = x_i + \phi_i*(x_i - x_k) \quad (5)$$

Where $k \in \{1, 2. . . SN\}$ is randomly chosen. $\Phi_i \in [0,1]$

b. Onlooker bees: Each onlooker bees finds new solution Vi within the neighborhood of xi based on the probability value Pi defined as:

$$P_i = \frac{Fit_i}{\sum_{n=1}^{SN} Fit_n} \quad (6)$$

Where fit is the fitness value of the solution xi.

c. Scout: Abandoned food sources are located and are exchanged with the new food sources found by scouts.

d. Best food: At the end of each search cycle, the algorithm memorizes the best solution achieved so far and repeats the procedure from the employed bees phase until the maximum cycle number (MCN).

3.2.2 Application of ABC algorithm to the MPPT

To realize the direct control ABC-based MPPT, each solution is defined as the duty cycle value d of the DC–DC converter. Equations (4) and (5) become:

$$d_i = d_{min} + rand[0, 1](d_{max} - d_{min}) \quad (7)$$

$$new\text{-}d_i = d_i + \phi i\,(d_i - d_k) \quad (8)$$

The fitness of each solution (duty cycle) is chosen as the generated power P_{pt} of the PGS. Then, Equation (6) become :

$$P_i = \frac{P_{Vi}}{\sum_{n=1}^{SN} P_{Vn}} \quad (9)$$

Where Pv_i is the power of photovoltaic array for the corresponding duty cycle di. To evaluate the duty cycles, the digital controller successively outputs the PWM signal according to the value of di, and then the PV voltage Vpvi and current Ipvi can be measured and the corresponding power (Ppvi) of each duty cycle di can be calculated

4. RESULT AND DISCUSSION

In this section, the both search algorithms of maximum power point tracking (perturb & observe and ABC) are simulated with the software matlab/simulink under shading condition. The power-voltage characteristic of PV arrays used in simulation which formed by two series connected PV modules. One of them is shaded and acts as a load instead of a power source. The P-V characteristic exhibits multiple local maximum power points (LMPPs) (Figure 5).

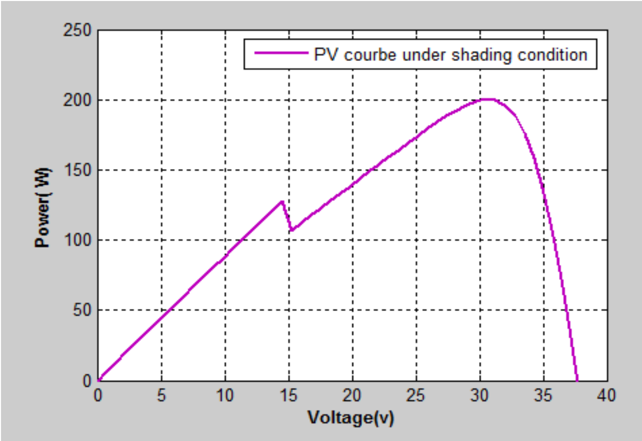


Figure 5. P-V curve under shading condition (G1=1000w/m^2 and G2=800W/m^2)

In a situation where the PV array is under partial shading condition, P&O algorithm hasn't the capability of finding the global peak (200W) and it uses perturbation to check if the current operating point is the MPP. If the current operating point is not the MPP, P&O needs perturbation in order to move to the operating point to the MPP. Too small a perturbation size makes the convergence time to the MPP too long and may also make it vulnerable to sensor noise. Large perturbation size will cause oscillation around the MPP.

However, in this algorithm (ABC), the number of candidate solutions SN (bees) influences the convergence speed and the performance of the algorithm. More of bees makes easier to find the global MPP with a good accuracy and very quicly.

The voltage starts randomly by 32 then, by comparaison of the candidate solution, is reduced into 30 which correspond on the maximum power point (MPP) at t=0.004s (Figure 6-7-8) . The ABC algorithm can track the MPP very quickly and effectively without any oscillations in the steady state. During a change in temperature or irradiation, the ABC algorithm resets (we control the fluctuation of weather conditions through Equation (10) then converges to the new maximum power, which makes our more robust algorithm.

$$\frac{P_{pv(new)}-P_{pv(Old)}}{P_{pv(new)}} \geq \Delta P \qquad (10)$$

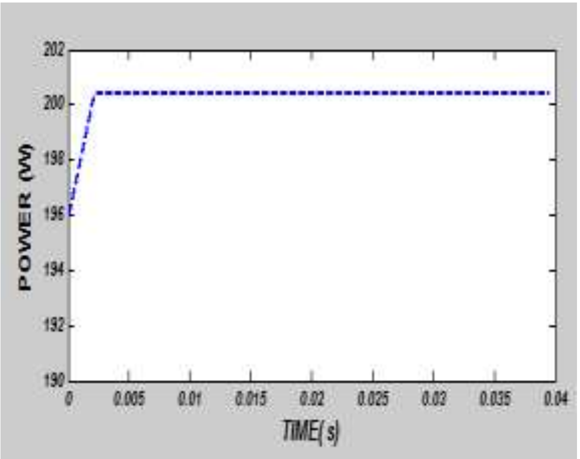


Figure 6. Trend of P_{PV} for ABC method.

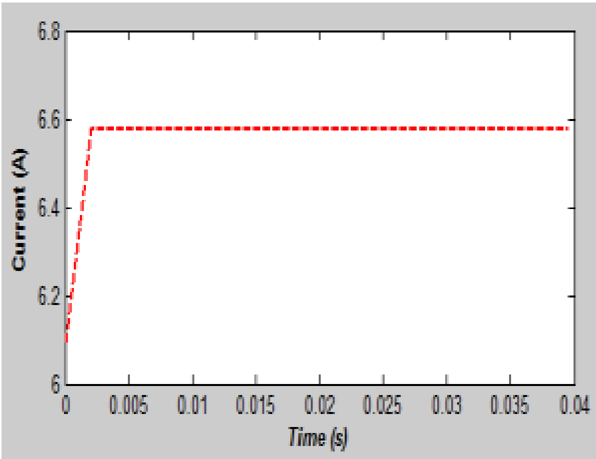


Figure 7. Trend of I_{PV} for ABC method.

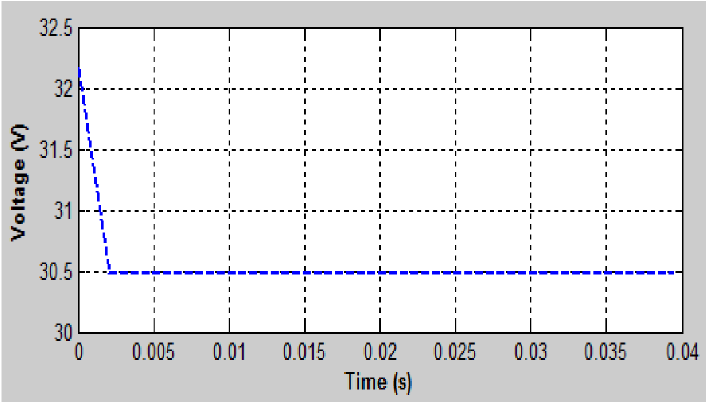


Figure 8. Trend of V_{PV} for ABC method.

5. CONCLUSION

In this work, we present an optimization of the energy produced by a PV module by an improved ABC algorithm. This technique is necessary to mark the point of maximum power when there are more than one maximum point in the I-V characteristic of the PV module. The simulations results show the effectiveness of this method to the different climate changes, which demonstrates that the optimized settings are correct.

Beside all of that, it provides just one optimal value of duty cycle and can track the MPP very quickly and effectively without any oscillations in the steady state. In contrast, when there are more than one maximum point in the I-V characteristic of the PV module, P&O find many values of duty cycle, which causes in the end of their convergence an instability and oscillations. This oscillation is due to the unstable values of duty cycle « d » which does not allow the algorithm to lead the PV module to reach the maximum power point effectively.

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