GMPPT approach for photovoltaic systems under partial shading conditions using a genetic algorithm

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Article Info

ABSTRACT

In this paper a new global maximum power point tracking (GMPPT) approach is proposed for a photovoltaic (PV) module using a genetic algorithm (GA) system under partial shading conditions. The partial shading condition is one of the adverse phenomena that the PV system experiences, it is difficult to track true peaks because of existence of multiple peaks in a PV array (partially shaded based). The conventional GMPPT algorithms met in the literature, the initial value of reference is approximated arbitrarily for various conditions of irradiation and temperature and they can't distinguish between the local and global peaks if partial shading occurs, what reduces the performances of the tracking of the point of optimal operation of PV systems. So, to improve these performances, we proposed a nonlinear based GMPPT method to estimate the initial optimal operating point. To compare with conventional GAs methods, the global peak (GP) tracking process is accomplished after follow the far fewer power perturbation steps. This approach made a possible to largely improve the GP tracking in the PV system, improve the accuracy of the GMPPT algorithms, and accelerate the convergence speed. This GMPPT method is checked for different shading profiles through the simulation and verification.

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1. INTRODUCTION

Under the conditions of partially shading, the current pass throughout a photovoltaic (PV) module is inadequated due to nonuniform irradiation. The current generated from its highest shaded module helps to reduce the output power of the overall PV array [1]. Furthermore, during partial shading conditions the power-voltage characteristic of PV arrays exhibits multiple local of maximum power points and making it difficult to find the GP using traditional tracking methods [2]. In literature, several methods and algorithms have been reported for a global maximum power point tracking (GMPPT). Different conventional GMPPT algorithms are modified hill-climbing perturbation and observation (P&O) method, incremental-conductance method, fractional short circuit current method, fractional open-circuit voltage method. These techniques have advantages of their simplicity.

However, due to the failure to track exact GP under partial shading conditions and trap at local maximum power points, modifications are required [3]. For accurate GP tracking which increases the efficiency of the PV systems, other authors proposed several GMPPT techniques to track GP under partial shading conditions by using evolutionary techniques and artificial intelligence techniques like fuzzy, artificial neural network (ANN), particle swarm optimization (PSO) and, genetic algorithm (GA) [4]-[6]. These techniques are able to track the GP when the PV system characteristics exhibit a single MPP. However, the

need for extensive computation, rule setting and knowledge base and the need for a large amount of data for training are some of the drawbacks of artificial intelligence-based algorithms application to GMPPT in PV systems [7]. Among these various GMPPT techniques, the genetic algorithm (GA) has a better potentiality to control the optimization problem of the GMPPT based networks. The GA can fix the stochastic nonlinearity problems and extract the accuracy of GP [8]. Nevertheless, for GMPPT, the traditional GA is not convenient for its operational complexity, which lowers the accuracy and decreases the convergence speed under the partial shading conditions [9]. Therefore, to accelerate the convergence speed and enhance the veracity of the GMPPT algorithms, we have proposed a nonlinear approach for integrating a modified GA to estimate the initial optimal operating point in this paper. Result shows, the proposed algorithms have quick time response with higher accuracy under partial shading conditions.

2.   PERFORMANCE OF PV ARRAY UNDER PARTIAL SHADING

The electric diagram is equivalent of a module statement is given by Figure 1. Where I_L represents the photocurrent creates in the photovoltaic cells by the solar radiation. I_L is proportional to illumination received and opposed to the current of equivalent diode D. I_d represents the current of the diode to the darkness. R_s is resistance series, due mainly to the difficulty in collecting the loads on the photosensitive surface. R_P is parallel resistance; it is a consequence of the surface quality along the peripheral of the photovoltaic cells. R_L represents the electric charge. The electric characteristic of a module statement under illumination is given by the relation of current (I) and tension (V) of load [1]:

$$I = I_L - I_O \left[EXP\left(\frac{V + R_s.I}{V_T} \right) - 1 \right] - \frac{V + R_S.I}{R_P}$$

(1)

where I_o is the opposite saturation current of the diode, V_T is the thermodynamic potential. A module statement of ideal characteristics is such as R_s is null and R_p becomes infinitely large. The output current:

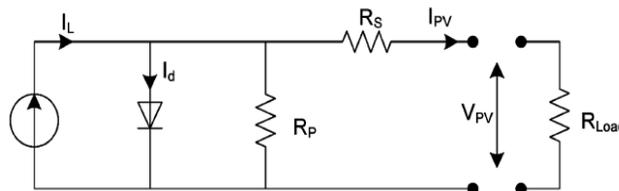$$I = I_L - I_O \left[EXP\left(\frac{V}{V_T} \right) - 1 \right]$$

(2)

Figure 1. Equivalent electric diagram of a PV array

Under partial shading operation, the voltage of the shaded PV array drops due to the interruption of trees, clouds, neighboring buildings, and other circumstances shown in Figure 2(a) (see Appendix). As a result, it acts as a load rather than working as a generator [2], [10]. To ensure the safety of a particular shaded module a bypass diode is equipped to the PV array. The modules connected in parallel can cause a mismatch in the voltage profile. Therefore, under such conditions, a blocking diode is equipped for further protection. The bypass diode starts to conduct when some part of the module is under shading conditions [11], [12]. Accordingly, current-votage and power-voltage characteristics shown in Figures 2(b) and (c) (see Appendix), we do not acquire a single maximum power point but get multiple local maximum power points and a GP. It is quite challenging to decide a GP out of multiple local maximum power points from a partially shaded PV array [13].

3.   SYSTEM OPERATION

A block diagram of MPPT converter for a optimum power transfer PV is presented in Figure 3. A buck converter switch, S is a MOSFET transistor which has a low internal resistance, R_{on}. A PWM signal based generation circuit is used to control the MOSFET that has a microcontroller. To reduce the expansion among the optimal power and the operating power, the MPP and tracking are searched in the event of bad weather situations in order to track the operating point of the PV module and control the circuit of buck converter periodically [11]-[13]. The rating of output current and voltage of PV modules is acquired and

controlled using this data to accelerate or drop off the duty cycle, *d* of the PV array converter by changing its operating point. The load voltage of MPPT converter is given by:

$$\frac{V_{Load}}{V_{pv}} = \frac{I_{pv}}{I_{Load}} = \frac{t_{on}}{T} = d$$

(3)

where t_{on} is turn-on time cycle of switch, S and *T* is its total time cycle.

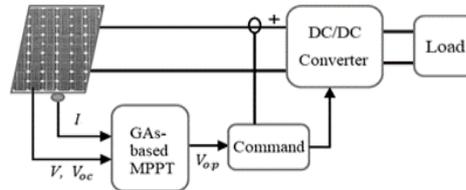Figure 3. MPPT buck converter diagram

4. PROPOSED METHODOLOGY

The GMPPT technique helps to track the optimum point denoted with the optimum voltage V_{op} correspond with a maximum PV power. A GAs can maintain the flow of current and manage the PV panels active to have the maximum power. Figure 3 represents a GAs type MPPT PV system. The steps of the genetic algorithms (selection, crossover, mutation, and insertion) are described using a flow chart shown in Figure 4 to get a maximum optimal function (fitness function) [14]-[18]. The steps used in the flow chart algorithm are explained as:

- Step 1: produce an initial population of individuals which has the solution of the problem. In our algorithm, the initial population is the open circuit voltage given by (11).
- Step 2: carry out the following steps until the stop criterion is satisfied: (i) using the fitness function a rate of fitness is defined for every individual in the population. The fitness function has the ability to contend to the remaining individuals which delivers a score of the fitness to every individual. The individual probability has to be chosen to regenerate the fitness score so that proposed algorithm gives the maximum power for each optimal individual [19]-[21]. The evaluation of each PV voltage (individual) is provided in proportion to the equivalent power, P = V.I; (ii) design the latest individuals population by using the subsequent generic operators. These operators are applied to selected members of the population with a probability chosen on the aptitude: (i) Selection: choose the individuals fittest to reach the genes in the upcoming production. Regeneration for an existing individual by copying it in the new production. For regeneration, the chances are higher to be selected with the individuals of high fitness; (ii) Crossover: creating new individuals using existing individuals; and (iii) Mutation: from an existing individual, creating a new individual causes to undergo a mutation.
- Step 3: the algorithm terminates if it is significantly disparate compare to the prior generation (i.e, not produce the offspring). The individual which is designated is presented here as the best solution.
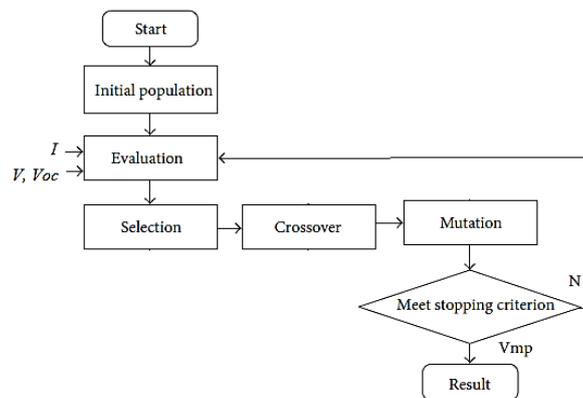

Figure 4. Flow chart of genetic algorithms based GMPPT

The estimate of the point of initial operation will make it possible to improve the performance of the tracking of the MPP. Two methods were published to carry out this estimate, the first is based on the measure of the short-circuit current and the second is based to the measure of the tension of the open circuit [18]-[22]. These methods present the current of short-circuit and the tension of the open circuit as being the point of optimal operational linear function. This approximation reduces the precision of the estimate of the point of initial operation. This led us to propose a nonlinear approach for the estimate of the initial value of reference according to the tension of the open circuit [23]-[25].

The P_{op} useful maximum power = $V_{op}.I_{op}$, is get by cancelling the power derivative.

$$\left(\frac{dP}{dI}\right) = \left(\frac{dVI}{dI}\right) = 0 \tag{4}$$

We obtain:

$$\left(\frac{dV}{dI}\right)_{op} = -\frac{V_{op}}{I_{op}} \tag{5}$$

The relation the derivative in (5) gives:

$$\frac{V_{op}}{I_{op}} = -\frac{V_T}{(I_{cc}+I_0-I_{op})} \tag{6}$$

According to the article [4],

$$I_{op} = K.I_{CC} \tag{7}$$

of (6) and (7):

$$V_{op} = \frac{V_T.I_{op}}{\left(1-\frac{1}{K}\right)I_{op}-I_0} \tag{8}$$

The tension of the PV modules open circuit can be written as:

$$V_{co} = V_T \ln\left[\frac{I_{CC}}{I_O} + 1\right] \tag{9}$$

(5) of (6) and (9):

$$I_{op} = K.I_O\left[EXP\left(\frac{V_{CO}}{V_T}\right) - 1\right] \tag{10}$$

(7) of (8) and (10):

$$V_{op} = \frac{V_T\left(\exp\left(\frac{V_{co}}{V_T}\right)-1\right)}{(1-\frac{1}{K})\exp\left(\frac{V_{co}}{V_T}\right)-1} \tag{11}$$

5. RESULTS AND DISCUSSION

In this paper the Matlab-Simulink software was used to analyze, simulate and establish the proposed method under partial shading condition as shown in Figure 5. This proposed GMPPT based with nonlinear approach to estimate of the initial optimal operating point was distinguished with tracking efficiency, tracking speed and steady-state performance to the conventional GAs methods. Figure 6 and Figure 7 demonstrate the efficacy of the proposed GMPPT compare to conventional GAs methods. The simulation results show, the proposed GMPPT techniques demonstrates the better result as compared to the conventional methods. With the proposed algorithm, the problem of oscillation is not present and the GP tracking process is accomplished after 2 s. However, the GP tracking process is accomplished after 3 s with the traditional methods and the problem of oscillation is present because the maximum power point is tracked point by point.

GAs-based GMPPT techniques under different partial shading patterns have been illustrated in Figures 8 and 9. The solar radiation levels are 800 W/m^2, 600 W/m^2, and 400 W/m^2 considered in the first shading scenario Figure 8(a). The GP tracking process is accomplished after 2.5 s. The GP is positioned on the P–V curve at the first point under the first scenario as shown in Figure 8(b). In Figures 8(a) and 8(b), one can see that the proposed GMPPT approach avoids the second and the third points and catches the first point.

The solar radiation levels are 1000 W/m^2, 800 W/m^2, and 600 W/m^2 considered in the second shading scenario Figure 9(a). With this scenario, the GP is positioned on the P–V curve at the second point. One can see that the proposed GMPPT approach catches the GP with 1.5 s as shown in Figure 9(b). Therefore, the proposed GMPPT approach improves feedback time of operation within higher accuracy under different partial shading.
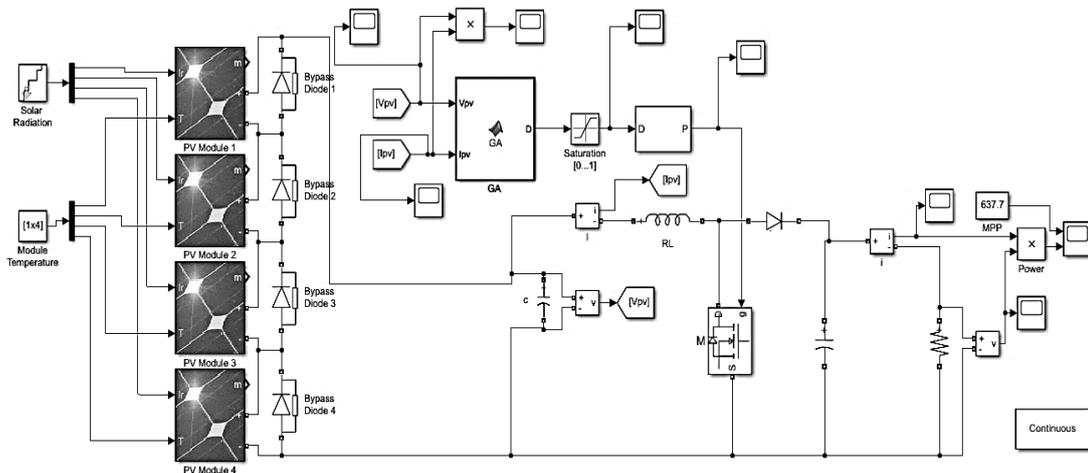

Figure 5. PV module under partial shaded conditions with proposed GMPPT algorithms
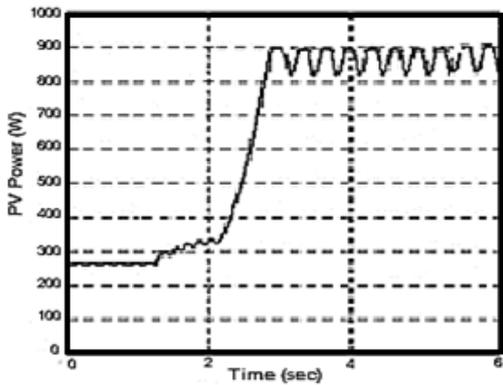

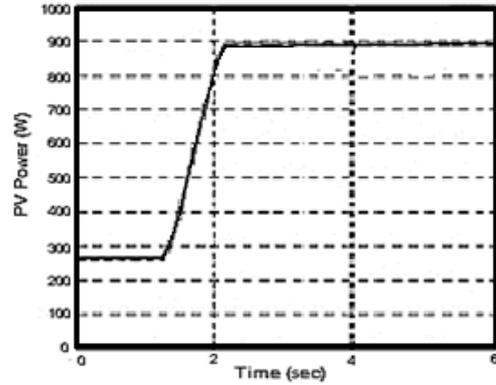Figure 6. Conventional GAs methods
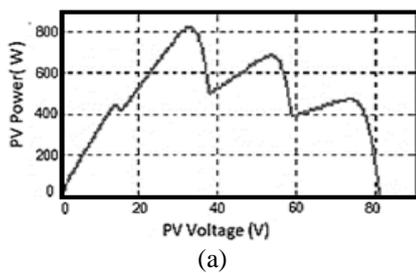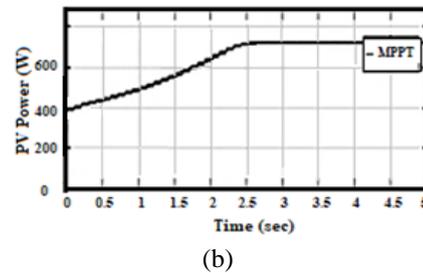

Figure 7. Proposed GMPPT

(a)

(b)

Figure 8. PV array P–V curve for shaded scenario 1

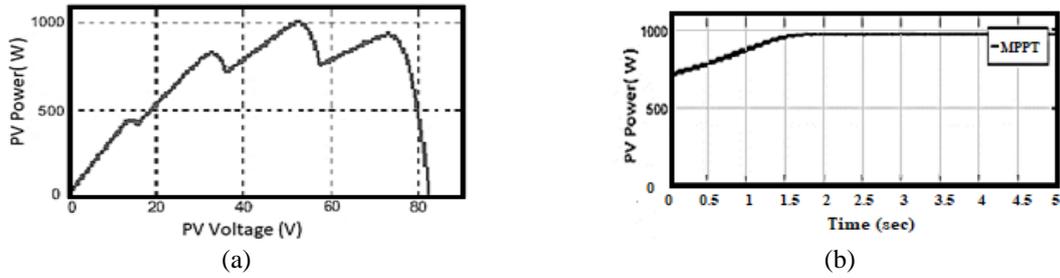(a)   (b)

Figure 9. PV array P–V curve for shaded scenario 2

6.   CONCLUSION

The GMPPT algorithm was invented in this paper to track the power of PV during partial shading. The difference between the proposed GMPPT algorithm and the existing GMPPT algorithms was that the individuals were configured with the voltage of open circuit using a non-linear nonlinear approach for the estimate of the initial optimal operating point where each individual of initial fitness is determined. Using the MATLAB/Simulink, the configuration of the GMPPT algorithm was designed, simulated, and evaluated. To study the capability of GMPPT under partial shading conditions, the performance of the GMPPT algorithm was compared with other techniques described in the literature. The results show, 94.5% of tracking accuracy was achieved using the buck converter technique. Under partial shading conditions the PV tracked power was influenced with the tracking speed. The obtained results with a nonlinear approach for the estimate of the initial optimal operating point proved that the proposed GMPPT method showed better efficacy in terms of complexity, accuracy and time tracking under partial shading conditions compared to other techniques.

APPENDIX

(a)

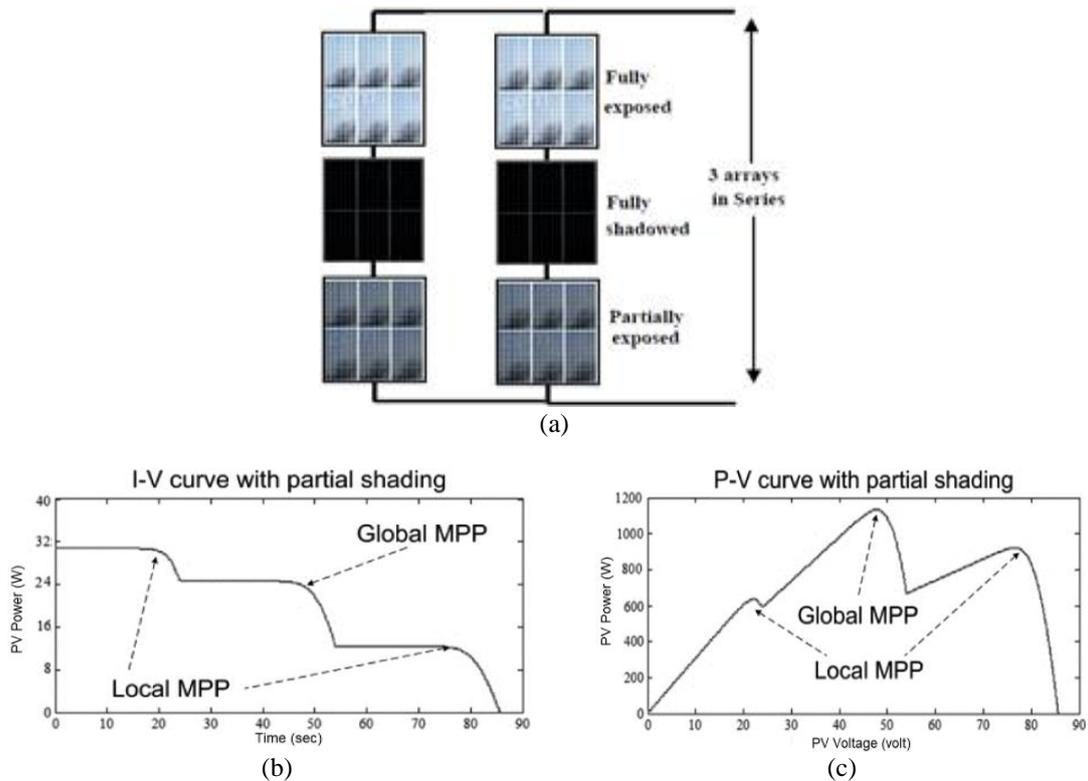(b)   (c)

Figure 2. PV array characteristic during partial shading condition: (a) PV array configuration, (b) V-I characteristic of PV array, and (c) V-P characteristic of PV array

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