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Research Paper

A Hybrid (ACO-PSO) Algorithm Based on Maximum Power Point Tracking and its Performance Improvement within Shadow Conditions

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Abstract

In this study, a hybrid Ant Colony Optimization-Particle Swarm Optimization (ACO-PSO) algorithm was proposed to optimally determine the maximum power point tracking (MPPT) parameters. The main goal of current study is to improve the overall performance of the MPPT system.The efforts of oscillation filtering and noise suppression were taken in this design, as well as the time response and the settling time. The proposed method is employed to track the global MPP under different shadow conditions, based on three different irradiation levels to test the ability and accuracy of the proposed method. The results of tracking MPP by the proposed MPPT technique showed that the improved method tracked the MPP for all the tested cases with a reasonable accuracy and in a very short convergence time as compared to the P&O method.

Keywords: *Ant Colony Optimization; Maximum Power Point Tracking; MPPT accuracy; MPPT convergence time; MPPT performance; MPPT settling time; P&O; Particle Swarm Optimization.*

1. Introduction

Photovoltaic (PV) module only converts a relatively low percentage of its incident solar irradiation into electrical energy, which means its efficiency is modest [1]. Main step in increasing the PV cell efficiency is by employing one of the MPPT techniques to obtain the maximum probable power from a varying PV sources. Normally, MPP analytically determined from the power-volt (P-V) characteristic curve and voltage-current (I-V) characteristic curve. Each curve has a unique point named MPP, whereby the module is operating at its maximum efficiency to yield the maximum output power, depending on its operating conditions (radiation and temperature). Therefore, can be defined MPPT method as a technique that constantly tracks the MPP on the characteristic curve of P–V or I–V and to ensure that the PV module can operate at the optimal point where most power is obtained. Different MPPT algorithms have been used previously to achieve that task alongside a DC-DC converter whose duty cycle is varied and is being used on the load side powered by a solar panel [2]. For this purpose, there are different methods used to track the MPP. These methods were deliberated in previous studies.

Perturbation and observation (P&O) technique was used as one of the most well-known algorithms employed to track the MPP [3, 4] . The simplicity and ease of implementation render it an attractive method to use [3]. Nonetheless, one of the major drawbacks of this algorithm is the oscillation around the MPP. Once the algorithm reaches a maximum point (local or global), it will keep oscillating back and forth around it, by a value called Δ*V*. Therefore, perturbation size corresponds to the power oscillation around the MPP. The Incremental Conductance (INC) method can overcome some of the drawbacks of P&O method [5, 6]. It is still a popular method, although it is more complex than the P&O. However, incremental conductance is slightly harder to implement than P&O [7].In addition, these methods still conventional methods and cannot distinguish between the local and global MPP.

Therefore, it has become necessary to implement MPPT techniques dealing with such cases. Particle Swarm Optimization (PSO) algorithm was one of the most widely used [8, 9], since it is a method utilized towards predicting the PV system's MPP accurately [10, 11]. Meanwhile partially shaded I–V curve exhibits multimodal characteristics, PSO methods are envisaged and very effective to track global MPP and distinguish it from the local ones under this condition [12, 13]. Fast changing in the weather condition needs to do iteration fast, but long convergence time is required for PSO based MPPT, which make it less effective in case of rapid weather changes . Ant Colony Optimization (ACO) method is supposed to be one of the most effective methods in the operation of tracking MPP from a PV. This is because it combines a positive feedback appliance, distributed calculating, as well as greedy search method. In the process of searching for the optimal solution, it has a sturdy level of ability like, the positive feedback mechanism which guarantees that the ACO is almost capable in perceiving fast and optimal solution in the early stages. By combining the advantages of both methods, PSO and ACO techniques, a desirous search, adequate results are quickly obtained and efficient MPP results are achieved. In this sense, many numbers of studies have been achieved in the field of MPPT performance improvement. However, there is no study carried out both of the convergence time and accuracy in a time with a reasonable value. Therefore, this study aimed to achieve a high number of accuracy level within a very short convergence time.

In this paper, a new technique based on hybrid ACO-PSO algorithm to track the global MPP for a PV system operates with dif-

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ferent partial shadow conditions and rapid weather change has been presented. It combines both, the simplicity in the search process and accuracy of the acquired results. To verify its validity, the presented technique is then compared with PSO based on P&O MPPT algorithm. The implemented method is simulated and tested using Matlab Simulink software.

2. Materials and Methods

Proposed method

As mentioned earlier, the importance of MPPT techniques dedicated in its ability of achievement the best value of extracted power point from PV panels through any operation condition. Most implemented methods succeed in tracking and extracting the maximum power point. However, each method has its obstacles and implemented in a certain weather condition for a specific system. Also, there is no method considered all available shadow conditions; like shadow conditions with rapid change in the weather conditions.

Therefore, a new method developed in this study to track the global MPP under both rapid and partial shadow conditions. In addition, the presented method combines the simplicity and improve efficiency of the extracted power via different weather conditions. Consequently, the proposed MPPT based on ACO-PSO and variable step size P&O applied and tested through three different shadow conditions. In all these shadow conditions, the MPPT method and optimal PID controller presented a clear enhancement for all oscillation round MPP, the settling time and the response time. The ACO is a combination of positive feedback mechanism, distributed computing, and a greedy search algorithm. It has strong abilities to look for the optimal solution. For instance, the positive feedback mechanism ensures that the ant colony algorithm is able to identify the optimal solution in earlier stage. By using the greedy search, the acceptable solution is quickly found and efficiency of the system is improved. Therefore, the MPPT convergence speed problem in a PV system is solved through modified ACO-based optimization. ACO-based MPPT is applied in this study to find the shortest path, to increase convergence speed. The equation below describes the ant's behaviour towards finding the shortest path to the global MPP point, denoting the amount of pheromone toward the shortest path.

$$Ph_{xy} = Ph_{xy}(1-\beta) + \sum_i \Delta Ph_{xy}^{\;i} \tag{1}$$

Where Ph_{xy} is the amount of pheromone deposited for a state transition xy, β is the pheromone evaporation coefficient, ΔPh_{xy}^i is the amount of pheromone deposited by i_{th} ant.

$$\Delta Ph_{xy}^{\;i} = \begin{cases} K/L_i & \text{if ant } i \text{ uses curve } xy \text{ in its tour} \\ 0 & \text{otherwise} \end{cases}$$

Where L_i is the cost of the i_{th} ant's tour (typically length) and K is a constant. Due to aforementioned merits of using ACO, the problem of slow MPP tracking for PV arrays could be solved via adopting ACO based MPPT [14].

The PSO algorithm relies on population. It uses several possible solutions in order to establish the best one or a combination of solutions to a particular problem. Its objective is to provide the global optimum of the fitness function (the real valued function) ascribed to a particular search space. The P_{best} and G_b must be kept up-to-date at each iteration all through the optimization process. The mathematical form of acquiring the velocity and updating the location of each particle is shown in Eqs. below, individually. The equations below are the basis for computing the position and velocity of individuals.

$$V_n^{\,i+1} = wv_n^{\,i} + \frac{c_1 r_1 (P_{best} - X_n^{\,i})}{\Delta t} + \frac{c_2 r_2 (G_{best} - X_n^{\,i})}{\Delta t} \tag{2}$$

$$X_n^{i+1} = X_n^{\,i} + V_n^i \Delta t \tag{3}$$

Where the subscription n represents the number of used particles; i refers to the number of iterations; V^i_n stands for the velocity vector of the n_{th} particle and X^i_n for location vector, at i_{th} iteration.

The search operation of MPPT within shadow conditions is more difficult, due to multi peaks appearing on the P-V characteristic curve. Different local points and only one global point will be generated on the P-V characteristic curve. A technique of using Perturbation and Observation method (P&O) combined with a Particle Swarm Optimization method (PSO) has shown an efficient result for tracking global MPP and differentiate it from the local ones [15, 16]. However, it has the disadvantage of long convergence time and failure to track global MPP rapidly, especially when the array is exposed to fast changing weather conditions.

Therefore, to overcome these drawbacks, this study proposes a new method of combining the P&O method with a hybrid method of ACO-PSO. This is because the above mentioned merits of PSO in differentiating the global point and tracking it efficiently, the ability of ACO algorithms in adapting to the rapid changes in weather condition and its fast convergence speed [17, 18]. This will lead to producing an accurate MPPT method with fast convergence speed. In this method, DC/DC converter (boost converter) is used to control the maximum global point via employing the proposed MPPT algorithm, which adjusts the duty cycle of boost converter. The schematic diagram of interleaved proposed MPPT controller is shown in Figure 1. In the proposed system, to control the step size, firstly the perturb and observe algorithm are activated. They are used because of the ability to track the first local point and changing the step size of the search in a proper way. In the next step, the calculation process of a hybrid ACO-PSO algorithm is carried out as this can track the global MPP in a very fast convergence speed and efficient mode.

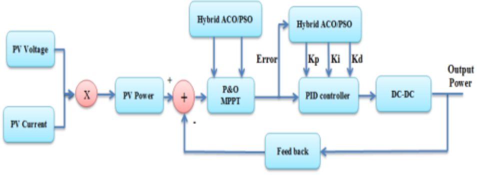


Fig. 1: Block diagram of proposed ACO-PSO based P&O MPPT and PID controller.

As a matter of fact, the performance of any optimization technique depends on the selected objective function or fitness function. The integral time absolute error (ITAE) helps in shrinking the peak overshoot. Also, the integral time square error (ITSE) decreases the settling time, which cannot be achieved with the integral absolute error (IAE) or the integral square error (ISE) based-tuning [19]. Consequently, in this research, ITAE and ITSE are used as objective functions or cost functions to improve the PID design process, as shown in the next Eqs. While the whole combination system shown in Figure 2.

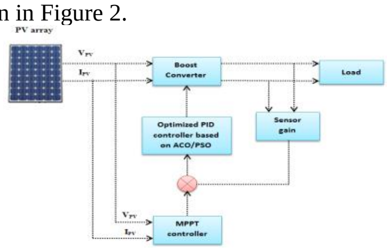


Fig. 2: PV system with proposed MPPT diagram & optimal PID controller.

$$ITAE = \int_{0}^{T} t\,|e(t)|.dt \qquad (4)$$

$$ITSE = \int_{0}^{T} te(t)^{2}.dt \qquad (5)$$

A combination of ACO-PSO algorithm have been used in this study and tuning PID controller for the purpose of attaining steady state condition of extracted power in order to achieve the system stability and reliability. The study algorithm applied on PV system from four PV modules operated in two different show conditions. These processes are represented in Figure 3, which illustrates the block diagram of PV modules system.

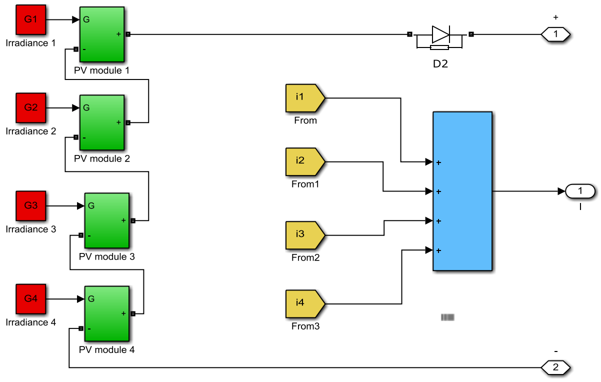


Fig. 4: Block diagram of a PV array with four PV modules.

3. MPPT implementation under Partial Shadows

Under partial shadowing conditions, there are many MPPT techniques introduced and proposed in the literature. However, each method had its restrictions and limitations. Some methods could track the MPP but it so complicated whereas other methods have an oscillation around the MPP, but failed to track MPP within fast changing weather conditions. This is because when the PV system operates under shadow conditions the I-V and P-V characteristic curves will generate many local maximum points and only one global point. Tracking this MPP global point and distinguishing it among the local ones is a big constraint for most MPPT methods. Also, transient issues of extracting power are added up to the limitations facing tracking operation. Therefore, the proposed method serves to resolve the most important issue; which is to track the MPP. To insure the capability of proposed method to treat the most important issue for any change in weather condition, this study was applied in three different shadow conditions to examine the reliability of method used.

3.1. First Case Steady

The first applied shadow condition was as in the following sequence; 400 W/m^2; 400 W/m^2; 800 W/m^2; 800 W/m^2, for each PV module and connected in series. The P–V and I–V characteristic curves of the array of the PV system's array are as presented in Figure 5, the output which represents the general characteristics of the PV model operating in the shadow condition. The results of tracking the MPP using the proposed method and the P&O comparison method are presented and plotted in Figures 6 and 7, which were recorded under two different levels of shadow conditions. The first level is 400 W/m2 and applied on the 1st and the 2nd PV modules, and the second level is 800 W/m2 applied on the 3rd and 4th PV modules, when these four PV modules are connected in a series. The second important issue is the attainment of steady state condition for the extracted power.

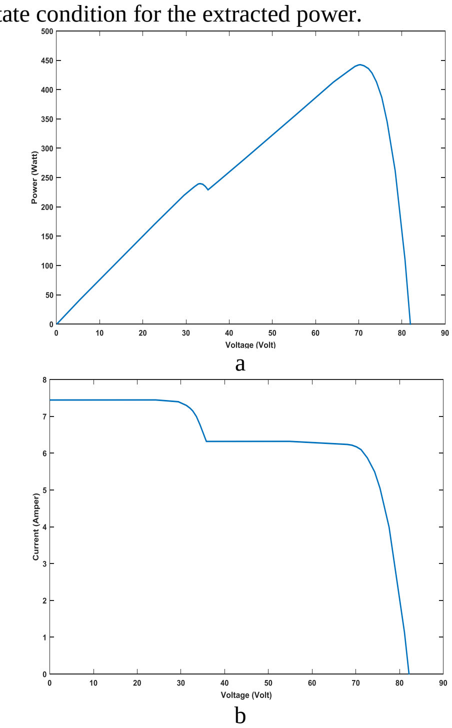


Fig. 4: a: P–V characteristics of the PV array, **b**: I–V characteristics of the PV array operating under shadow conditions, (400 W/m^2; 400 W/m^2; 800 W/m^2; 800 W/m^2).

The effectiveness of the proposed MPPT method was tested and investigated through three different shadow conditions, which represented the most common shadow conditions that could happen on the PV system. Figure 5 displays the extracted power's simulation results through the proposed MPPT technique. Whereas, Figure 6 is displaying the extracted power's simulation results by the P&O comparison method. By using the proposed method, it can be seen that at the thirteenth selection interval, the algorithm tracked the local MPP at a value of 231W and at a time of 0.82 s. The algorithm continued to search until finding the second point which represented the global point. It was tracked accurately at 3.5 s and 447 W. However, in the comparison method (P&O method), the first local point tracked at the eighteenth selection interval with power value ranging from 225 W and 235 W. The global point was tracked at the time of 4.05 s with power value ranging between 443 W and 453 W.

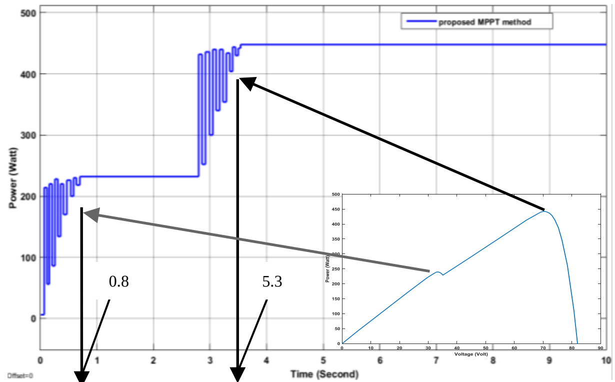


Fig. 5: Extracted power using the proposed method (ACO-PSO), under shadow conditions (400 W/m^2; 400 W/m^2; 800 W/m^2; 800 W/m^2).

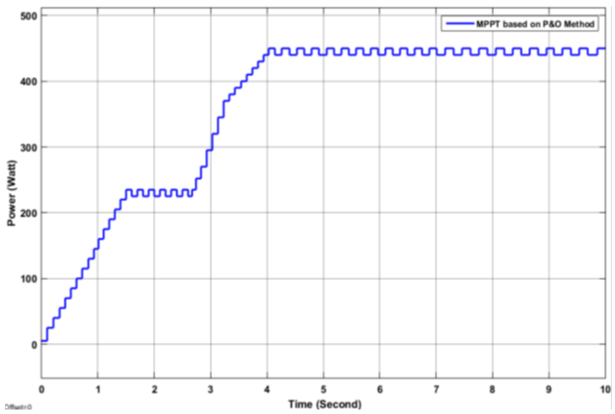
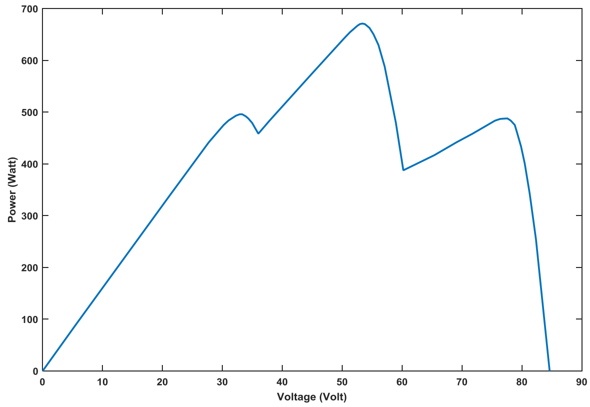


Fig. 6: Extracted power using the proposed method (ACO-PSO), under shadow conditions (400 W/m^2; 400 W/m^2; 800 W/m^2; 800 W/m^2).

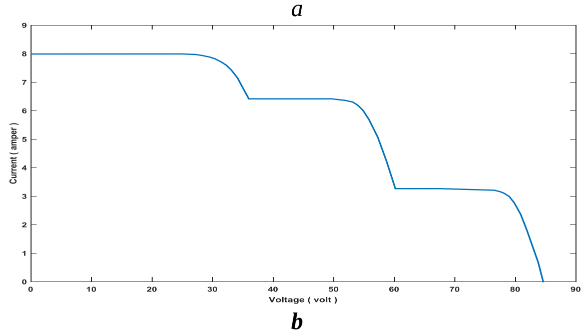
From the two Figures (5 and 6), it can be concluded that in addition to the fast tracking time of the proposed method, it also recorded other advantages in terms of efficiency and time response besides acquiring the steady state condition around MPP value. In the tracking operation of the first shadow condition, settling time of MPP in the proposed method was shorter than the P&O method, which occurred at 3.5 s for global point. However, it took 4.05 s in the P&O method. Furthermore, the other important issue considered in the proposed method is the oscillation pattern around MPP, which was oscillation-free in comparison with the P&O method; ranging from 443 W to 453 W along the time after the global MPP tracking was achieved.

3.2. Second Case Steady

The second case selected shadow condition as per the following sequence: 600 W/m^2; 1000 W/m^2; 1000 W/m^2; 800 W/m^2 and the shape of P–V and I–V characteristic curves of the PV system's array are presented in Figure 8. The output represents the general characteristics of the PV model operating in shadow condition.



a



b

Fig. 7: a: P–V characteristics of the PV array, b: :I–V characteristics of the PV array, for a system operating under shadow conditions, (600 W/m^2; 1000 W/m^2; 1000 W/m^2; 800 W/m^2).

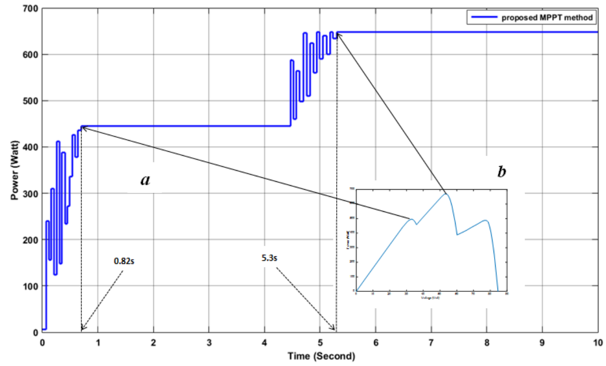


Fig. 8: Extracted power using the proposed method (ACO-PSO), under shadow conditions (600 W/m^2; 1000 W/m^2; 1000 W/m^2; 800 W/m^2).

The result of tracking MPP in second operating condition, using the proposed method is presented in Figure 8 and by using the comparative P&O method presented in Figure 9. In this shadow condition, the same way of tracking the first shadow condition was used. However, in this method, two local points and one global point were taken. In the tracking process, it initially tracked the first local point at 0.82 s and 445 W in the proposed method. Afterward, the searching process continued and it tracked the global point at 5.3 s and 648 W. In the second local point, the tracker maintained the same power value of global point, although the change is observed in the power characteristic curve, as shown in Figure 8. This change is due to the fact that the proposed method tried to maintain the maximum value of extracted power. However, as shown in Figure 9, in the second local MPP, the power extracted in P&O method continued to track the MPP and the value of power plunges very fast. Under this P&O method, the maximum tracked power was at 245 W. However, in the proposed method, it maintained at 648 W.

Another most important comparative point, within the tracking process, is the proposed algorithm, which tracked the first local MPP at the twelfth selection interval of 445 W and 0.82 s. However, in the P&O, it was tracked at power value in the range of 437 W and 447 W and 1.4 s. The tracking process continued searching until it finding the global point at 648 W and 5.3 s. Similarly, in the P&O method, the global point was tracked at 5.88 s with a power value ranging between 640 W and 650 W. In the comparative method, the search continued, resulting in tracking the third MPP point (i.e. the second local point) at 7.4 s with a maximum power value of 245 W. Therefore, the important difference between the proposed method and the P&O method; is that the proposed method was successful in tracking the global point, while P&O failed in tracking it. Contradictorily, the P&O method continued tracking each local point on the power curve, which finally resulted in a decrease in power value at all time values. But, in the proposed method, the focus was on the global point.

As a general comparison between the proposed and P&O method during this tracking process, the proposed algorithm tracked the first local MPP at the tenth selection interval at 0.7 s and 147 W, but the compared P&O method MPP tracked it at 1.35 s and power value ranging from 139 W to 149 W. The second local MPP was tracked at the twelfth selection interval, but in the compared P&O method, it was tracked at the sixteenth selection interval at 3.9 s and power value between 373 W and 383 W. The third MPP (global MPP) was tracked at the fourteenth selection interval, but in the compared P&O method, it was tracked at the nineteenth selection interval of 6.2 s and power value ranging from 451 W to 461 W.

Therefore, for all the case studies tested in this study, the MPPT proposed method recorded fast tracks time as compared to the P&O method which was much slower than the proposed method. In addition to that, the proposed method also depicts other benefits in terms of power efficiency and time response, as well as the steady state occurring around the MPP values. Additionally, in the proposed method, the oscillation pattern around MPP was not found, indicating that it had attained the steady state condition. In comparison with P&O method where the oscillation around MPP was present, the third shadow condition was ranging from 451 W to 461 W, along with the time after the global MPP tracking was attained.

4. Conclusion

In this study, a new MPPT algorithm based on hybrid ACO-PSO algorithm has been developed. The proposed method implemented by referring to the output of the conventional P&O algorithm and nonlinear characteristics of photovoltaic as an input to the PID controller. In addition, the proposed method has been used to track the maximum global power point under shadow conditions. For this purpose, two different shadow conditions were tested as a case studies. The results of tracking MPP by the proposed MPPT technique showed that the improved method tracked the MPP for all the tested cases with a reasonable accuracy and in a very short settling time as compared to the P&O method. It was found that the extracted power had no oscillation around the MPP, when comparing with the P&O method with a noticeable oscillation around the MPP, which resulted in decreasing the efficiency of the extracted power from the PV system.

5. References

[1] A. M. Humada, A. M. Aaref, H. M. Hamada, M. H. Sulaiman, N. Amin, and S. Mekhilef, "Modeling and characterization of a grid-connected photovoltaic system under tropical climate conditions," *Renewable and Sustainable Energy Reviews*, 2017.

[2] R. F. Coelho, F. Concer, and D. C. Martins, "A study of the basic DC-DC converters applied in maximum power point tracking," in *Power Electronics Conference, 2009. COBEP'09. Brazilian*, 2009, pp. 673-678.

[3] N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "A technique for improving P&O MPPT performances of double-stage grid-connected photovoltaic systems," *IEEE transactions on industrial electronics,* vol. 56, pp. 4473-4482, 2009.

[4] M. G. Villalva, J. R. Gazoli, and E. Ruppert Filho, "Analysis and simulationof the P&O MPPT algorithm using alinearized PV array model," in *Power Electronics Conference, 2009. COBEP'09. Brazilian*, 2009, pp. 189-195.

[5] B. Liu, S. Duan, F. Liu, and P. Xu, "Analysis and improvement of maximum power point tracking algorithm based on incremental conductance method for photovoltaic array," in *Power Electronics and Drive Systems, 2007. PEDS'07. 7th International Conference on*, 2007, pp. 637-641.

[6] M. A. Elgendy, B. Zahawi, and D. J. Atkinson, "Assessment of the incremental conductance maximum power point tracking algorithm," *IEEE Transactions on sustainable energy,* vol. 4, pp. 108-117, 2013.

[7] S. Qin, M. Wang, T. Chen, and X. Yao, "Comparative analysis of incremental conductance and perturb-and-observation methods to implement MPPT in photovoltaic system," in *Electrical and Control Engineering (ICECE), 2011 International Conference on*, 2011, pp. 5792-5795.

[8] M. V. Rajkumar, M. Mahakumar, M. Manojkumar, M. Hemaraj, and E. Kumaravel, "A New DC-DC Converter Topology with Grey Wolf MPPT Algorithm for Photovoltaic System," *International Journal of Emerging Technologies in Engineering Research (IJETER),* vol. 5, pp. 54-59, 2017.

[9] H. Renaudineau, F. Donatantonio, J. Fontchastagner, G. Petrone, G. Spagnuolo, J.-P. Martin, *et al.*, "A PSO-based global MPPT technique for distributed PV power generation," *IEEE Transactions on Industrial Electronics,* vol. 62, pp. 1047-1058, 2015.

[10] K. Ishaque, Z. Salam, M. Amjad, and S. Mekhilef, "An improved particle swarm optimization (PSO)–based MPPT for PV with reduced steady-state oscillation," *IEEE transactions on Power Electronics,* vol. 27, pp. 3627-3638, 2012.

[11] F. M. de Oliveira, S. A. O. da Silva, F. R. Durand, L. P. Sampaio, V. D. Bacon, and L. B. Campanhol, "Grid-tied photovoltaic system based on PSO MPPT technique with active power line conditioning," *IET Power Electronics,* vol. 9, pp. 1180-1191, 2016.

[12] K. Ishaque and Z. Salam, "A review of maximum power point tracking techniques of PV system for uniform insolation and partial shading condition," *Renewable and Sustainable Energy Reviews,* vol. 19, pp. 475-488, 2013.

[13] P.-C. Cheng, B.-R. Peng, Y.-H. Liu, Y.-S. Cheng, and J.-W. Huang, "Optimization of a fuzzy-logic-control-based MPPT algorithm using the particle swarm optimization technique," *Energies,* vol. 8, pp. 5338-5360, 2015.

[14] L. L. Jiang, D. L. Maskell, and J. C. Patra, "A novel ant colony optimization-based maximum power point tracking for photovoltaic systems under partially shaded conditions," *Energy and Buildings,* vol. 58, pp. 227-236, 2013.

[15] R. Suryavanshi, D. R. Joshi, and S. H. Jangamshetti, "PSO and P&O based MPPT technique for SPV panel under varying atmospheric conditions," in *Power, Signals, Controls and Computation (EPSCICON), 2012 International Conference on*, 2012, pp. 1-6.

[16] A. R. Reisi, M. H. 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.

[17] A. Besheer and M. Adly, "Ant colony system based PI maximum power point tracking for stand alone photovoltaic system," in *Industrial Technology (ICIT), 2012 IEEE International Conference on*, 2012, pp. 693-698.

[18] 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.

[19] H. Fang, L. Chen, and Z. Shen, "Application of an improved PSO algorithm to optimal tuning of PID gains for water turbine governor," *Energy Conversion and Management,* vol. 52, pp. 1763-1770, 2011.