AN IMPROVED MAXIMUM POWER POINT TRACKING BASED ANT COLONY OPTIMIZATION METAHEURISTIC ALGORITHM FOR PV SYSTEMS

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Abstract. ***Nowadays, there is an increasing trend in the use of solar energy by using photovoltaic system (PVS). The power generated by a PVS highly relies on solar intensity. Therefore, a Maximum Power Point Tracker (MPPT) is one of the key components of solar electricity generation. It is used to extract the maximum power point (MPP) produced by a PVS. In this paper, we present an intelligent Ant Colony Optimization (ACO) algorithm to track the MPP thereby increasing the performance of the PVS. The proposed ACO algorithm is developed in Matlab/Simulink environment. Furthermore, the results obtained from the ACO algorithm are compared with the well-known conventional Perturb and Observe (P&O) algorithm.***

Keywords— Maximum Power Point Tracking; Photovoltaic System; Swarm Intelligence, Ant colony Algorithm; Perturb and Observe.

1. INTRODUCTION

Due to energy crisis and environmental issues such as pollution and global warming effect, photovoltaic (PV) generation is becoming increasingly important as a renewable source since it exhibits numerous advantages such as inexhaustible, free, cleanness with no noise and little maintenance. Unfortunately, PV panel has an output characteristic which depends on the solar radiation, the temperature and the load, the maximum power point (MPP) is not constant. Therefore, tracking the MPP of a photovoltaic panel is usually an essential part of photovoltaic system since it maximizes the power output of the PV system, and therefore maximizes the PV panel efficiency. Thus, to improve the conversion efficiency of the electric power generation, an MPPT controller is integrated with the PV system so that the PV panel will be able to deliver the maximum power under all variable atmospheric conditions. Thus, since the seventies, several researchers have proposed a significant number of algorithms for MPPT controllers in the literature and industry [1, 2], starting with conventional method (CM) to methods based on artificial intelligence (AIM), basically known as methods based on soft computing [3,4]. The main goal of these MPPT controllers is to extract maximum output power from the PV panel under different temperature and sunlight radiation. Despite the fact that these algorithms are designed for the same objectives, they differ in many aspects, such as the complexity, flexibility, convergence speed, cost, hardware implementation , effectiveness and correct tracking when irradiation or temperature change. Thus, MPPT based conventional methods are simple to implement but exhibit limited accuracy with oscillation around the MPP specially in the case of varying atmospheric conditions In recent years, MPPT based AIM such as, ANN, FLC, GA [5,6,7,8] and more recently swarm intelligence and evolutionary algorithms are attracting huge interest from research communities. These MPPT are developed and used both to improve the energy conversion efficiency under uniform and non-uniform irradiation. In this study, an MPPT based AIM is developed, this MPPT is based on a swarm intelligent algorithm namely Ant Colony Optimization [9], which is used for maximum power point tracking, analyzed and compared with the well-known conventional Perturb and Observe (P&O) [10] MPPT controller. The paper is organized as follows, in Section II; we present the system overview of a PV system. Section III deals with the techniques of MPPT, where the proposed ACO algorithm is presented, followed in section IV by the simulation results. Finally, a conclusion is given.

2. SYSTEM OVERVIEW

The main architecture of a PV system is depicted in Figure.1. It consists of a solar panel for energy extraction from the sun, a DC/DC converter, a resistive load and an MPPT controller.

Fgure.3. shows the equivalent circuit of a solar panel, which is composed of several photovoltaic cells employing parallel, series or series/parallel. The model consists of a current source Ipv, a diode D and a couple of resistances Rs and Rp.

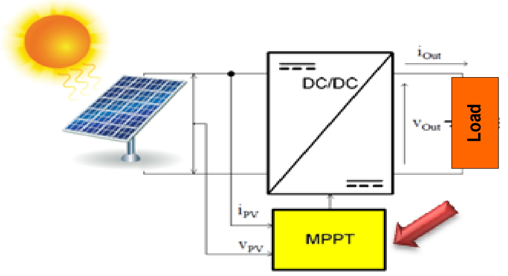


Fig.1 Photovoltaic System architecture

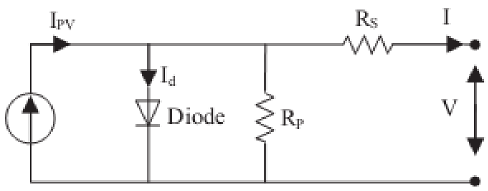


Fig.2 Equivalent circuit of a PV cell

Equation (1) show the current produced by the solar cell.

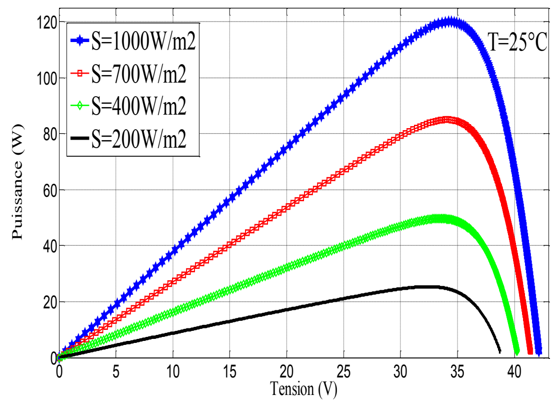
$$I = Ipv - I_0\left[e^{\frac{(V+I.R_s)}{aVt}} - 1\right] - \frac{V+IR_s}{R_p} \quad (1)$$

Where I_{PV} is the PV current, I_0 is the saturated reverse current, Vt is the thermal voltage associated with the cells, "α" is a constant known as the diode ideality factor, and RS and Rp are the series and parallel equivalent resistances of the solar panel respectively. I_{PV} has a linear relationship with light intensity and varies with temperature variations. I_0 is dependant on temperature variations. The I_0 and I_{PV} are calculated as follow:

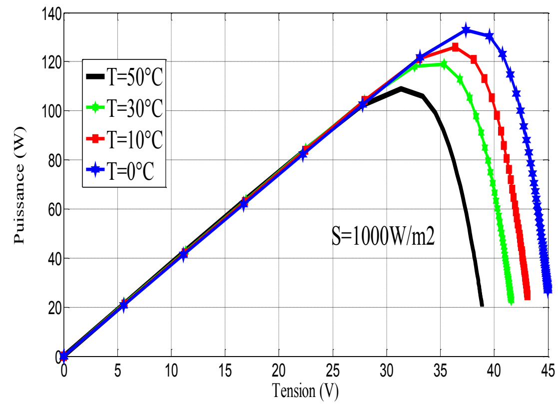
$$I_{PV} = (Ipv,n + K_1\Delta T)\frac{G}{G_n} \quad (2)$$

$$I_0 = \frac{I_{SC,n} + K_1\Delta t}{e^{\frac{(V_{OC,n}+K_v.\Delta T)}{aVt}} - 1} \quad (3)$$

Where, K_1 is the coefficient of short circuit current variation with the temperature, ΔT is the deviation from standard temperature, G is the light intensity and K_v is the ratio of the open circuit voltage to temperature. $I_{PV,n}$, $I_{SC,n}$ and $V_{CO,n}$ are respectively the PV current, the short circuit current and the open circuit voltage under the standard conditions). The PV module operation depends strongly on the load characteristics to which it is connected, under constant uniform irradiance the current–voltage (I–V) characteristic has a unique point on the curve, called the maximum power point (MPP), at which the array operates with maximum efficiency and produces maximum output power. Furthermore the characteristics of a PV system vary with temperature (Tc) and insolation (S), as illustrated in Figures 3 (a) and (b). Thus, MPPT controller is required to track the new modified MPP in its corresponding curve whenever temperature and/or insolation variation occurs.



(a)



(b)

Fig.4. (a) The P-V curves under varying solar irradiance
(b)The P-V curves under under different temperatures.

3. ANT COLONY OPTIMIZATION ALGORITHM

The Ant Colony Optimization Basic Concepts

The ant colony algorithm is a probabilistic algorithm for finding optimal paths based on the behavior of ants searching for food. It was introduced in the early 1990s and was originally used to solve difficult combinatorial optimization problems by Dorigo [7]. Initially, ants randomly move along trails, explore the area to find food. When they move the food to the nest, they leave a chemical pheromone trail on the way. During the moving time, the pheromone quantity increase according to food quantity. This pheromone quantity motivates other ants to follow the path and go to food source by choosing the shorted path in their movement. Mainly, the ACO algorithm have been researched in various aspects and successfully applied to the various combinatorial optimization problems [11, 12]. However, the discrete nature restricts solving continuous problem areas, thus, in recent years, the technique has been extended to continuous optimization, where, many different approaches to find the optimum solution of a continuous problem are presented [13, 16]. One of the most popular ACO based algorithm for continuous domains is ACO_R [15, 16], the solution construction is slightly different from the combinational problem. Where, ACO algorithms for combinatorial optimization problems make use of a pheromone model in order to probabilistically construct solutions. Regarding to ACO_R, the author proposes to use a solution archive to store a finite number of solutions as way of describing the pheromone distribution over the search space, where the solution archive contains a number of complete solutions to the problem and want them to be well chosen and cover the search space smartly, then the archive is used as a base to build new solutions. However, the major difference between ACO algorithms is the technical update of the pheromone. In [17], the author proposed a new ACO algorithm to search for extreme of a continuous function in a given interval mainly based on a new technique for updating the pheromone during the execution. The specific feature of the proposed algorithm is the novel pheromones updating which depends on better solutions so that ants could be directed to better solutions by intensify of the pheromone value.
Figure.5. resumes the basic idea of the ACO algorithm which performs in three main steps.

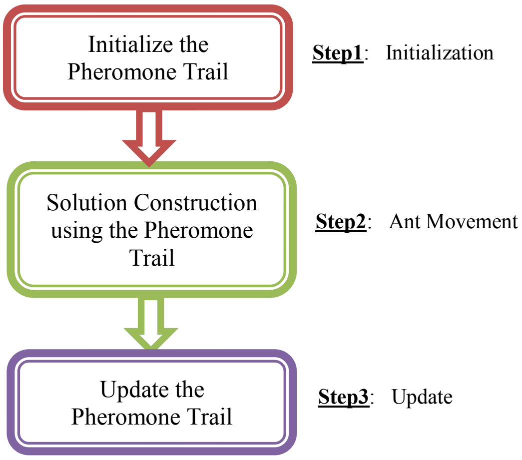


Fig.5. Basic idea of ACO algorithm

Firstly, the archive is initialized using values randomly generated in the interval [a, b] (the search space) and associate each solution to his fitness value calculated by the fitness function F. After the archive solutions is sorted according to fitness values (F), which further helps in choosing the best solutions and to update the archive. The best solutions are selected from the archive, and an ant is assigned to each solution. It is not necessary to have a number of ants equal to the size of the file; however a smaller number is used in most cases. Then ***m*** (number of ants) best solutions in the archive are selected. After this, a pheromone update for each solution is performed.

The Ant Colony Optimization applied to MPPT

This section describes the implementation of the ACO algorithm for solving the problem involved to MPPT controller in PV system. The flow chart of the proposed ACO based MPPT method is depicted in Figure .6, where the different steps of the algorithm are divided into three main parts: Initialization, Ants movement and the archive update. The PV power serves as the target function. The function to optimize is $\mathbf{P_{PV}= f (V_{PV})}$. The algorithm starts by having no previous information about the position of the best value (ant). In the beginning, ant are generated randomly in the interval $\mathbf{[0,V_{co}]}$. For each solution there is a corresponding fitness function. Based on these solutions, the archive is constructed. Depending on the region strength, the transition probability of ants is calculated. In the next iterations, ants move towards a stronger strength position, then, again the attraction strength of every region is calculated. By successive iteration ants move towards the optimized point i.e MPP. Figure.7. a-b and c, depicts the initialization and distribution of ants according to the fitness function, the restrict search space and ants movement towards the optimized point, i.e. the MPP.

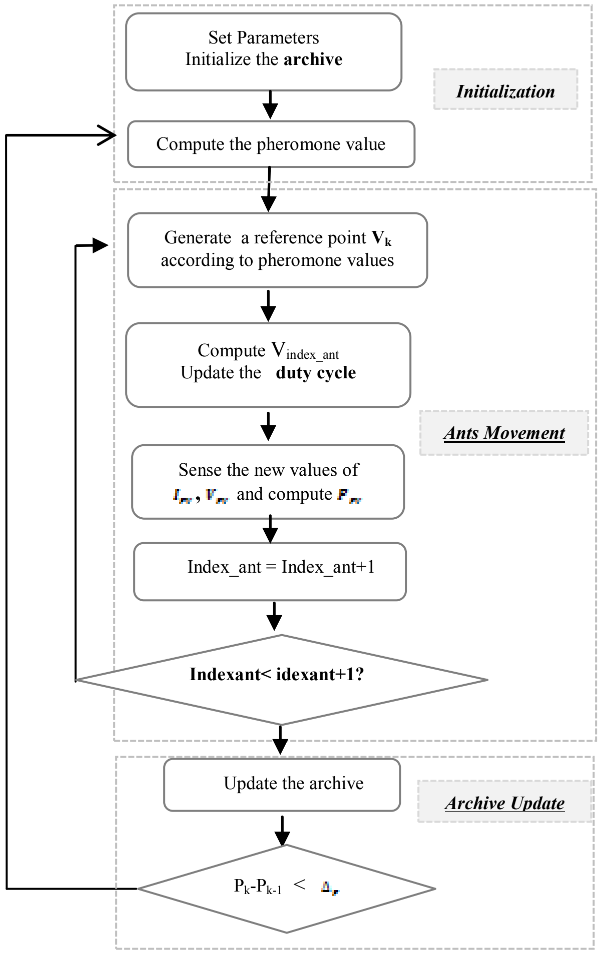
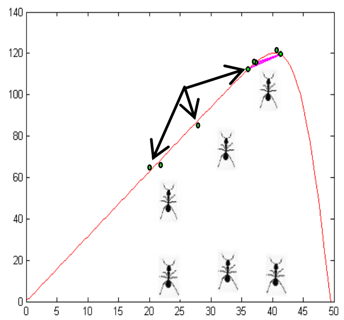
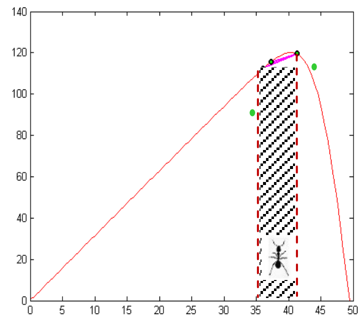


Fig.6. Flow chart of ACO_MPPT controller



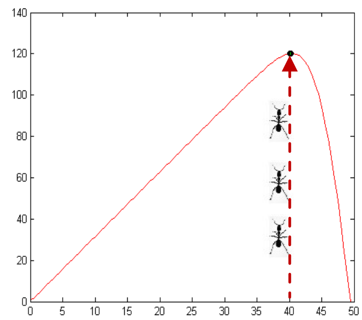
(a)

Fig.7. (a) Initialization and distribution of ants according to the fitness function.



(b)

Fig.7. (b) Restrict search space



(c)

Fig.7. (c) Ants move towards the optimized point, i.e. the MPP

4. SIMULATION RESULTS

For the simulation, we used the Matlab/Simulink environment tools [18]. These facilitate the change of the atmospheric conditions (T°, S) to assess the MPP tracking trajectory, thus several scenarios are developed in order to evaluate the MPPT respond under dynamic operating conditions. Firstly, the two controllers were simulated at standard conditions STCD (1000W/m2, 25°C), then at rapidly changing atmospheric conditions, The temperature is constant at 25°C and the irradiance is varying from 500 to 1000W/m^2.The performance of each MPPT controller was evaluated at steady state condition. Figure.8 illustrates the Simulink model of the PV system, which includes the PV panel with a DC/DC converter and the MPPT control algorithm. The MPPT based ACO algorithm was tested and compared to the well-known Perturb and Observe algorithm P&O.
The photovoltaic module used for the simulation is the Solar BMX 120, the specification of the PV module is shown in Table 1. Figures 9-15 depicts the respective results of these tests.

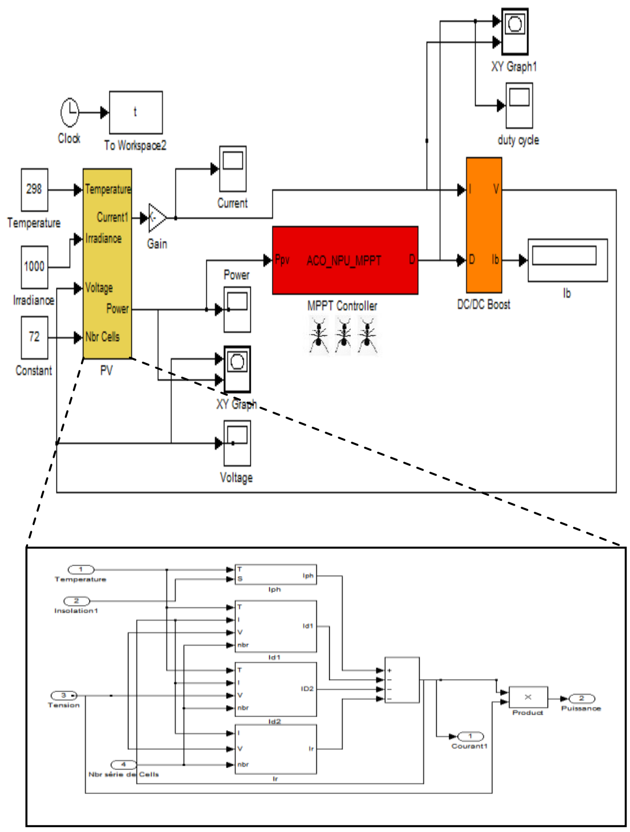


Fig.8. Simulink model of the PV System

TABLE1.Photovoltaic Module Specification

Designation	**BP Solar MSX 120W**
Nominal Power	120W
Voltage at MPP	33,7W/m^2
Current at MPP	3,56A
Short Circuit Curent	3,87A
Open Circuit Voltage	42,1V

Figures 9-11 depicts respectively the progression of the output power delivered to the load for the P&O and ACO algorithms under standard conditions (1000W/m^2 ,25°C). As depicted in figure.9, the P&O MPPT controller converge slowly, the MPP is reached after 8s with a continuous oscillations around the MPP which cause energy losses. Regarding to the MPPT based ACO, results show that the MPP is reached after 1.8s with a short time transition as illustrate in figure 10.

In the case of rapidly changing atmospheric conditions regarding to irradiance, the condition of changing solar insolation was modeled as depicted in Fig.12. The temperature is constant at 25°C and the irradiance is varying from 500 to 1000W/m^2. From these results, it is shown that the ACO controller gives better results compared to P&O controller in terms of power value, time response and oscillations around the MPP. In figure.14, it is clearly shown that at 20s, in the transition of the irradiance from 500 to 1000W/m^2, the ACO MPPT controller follow the variation of the irradiance and track the MPP rapidly, it take negligible time to stabilize with no oscillation around the MPP, whereas the P&O controller, take more time to track the MPP and adjust the value of the power, where the oscillations around the MPP are still not eliminated as illustrate in figure 13.

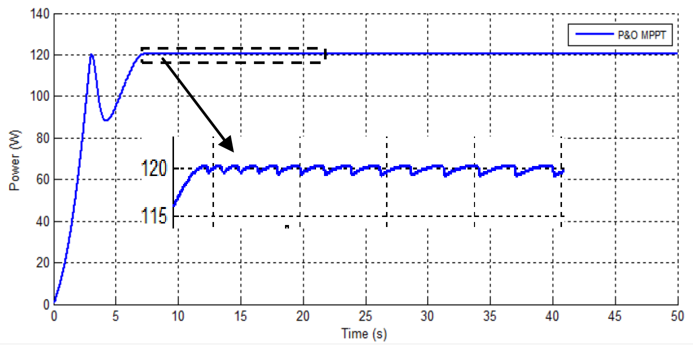


Fig.9. P&O Power curve under STDC (25°C,1000W/m^2)

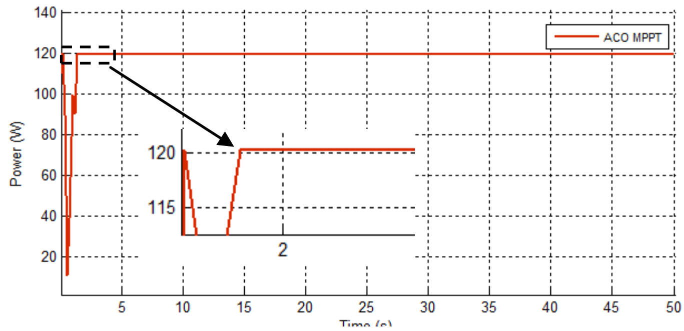


Fig.10. ACO Power curve under STDC (25°C,1000W/m^2)

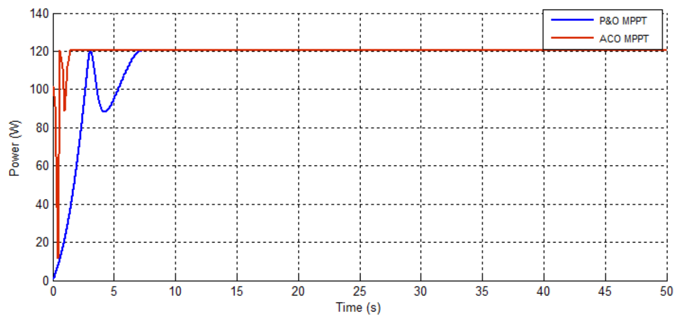


Fig.11. ACO and P&O power progression time

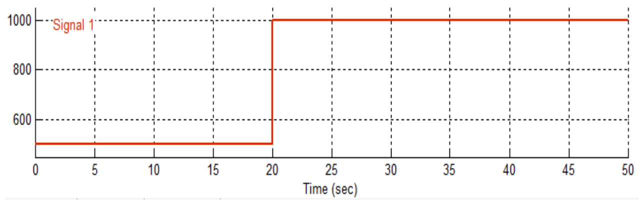


Fig.12. Variation of the irradiance level

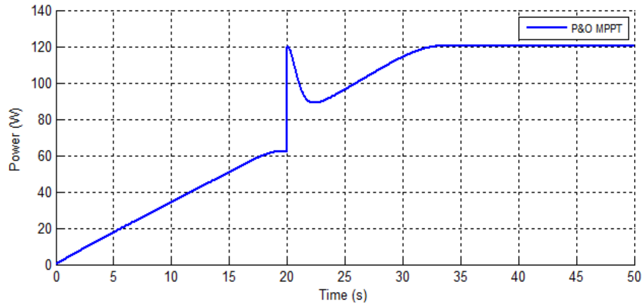


Fig.13. P&O Power curve under rapid variation of irradiance

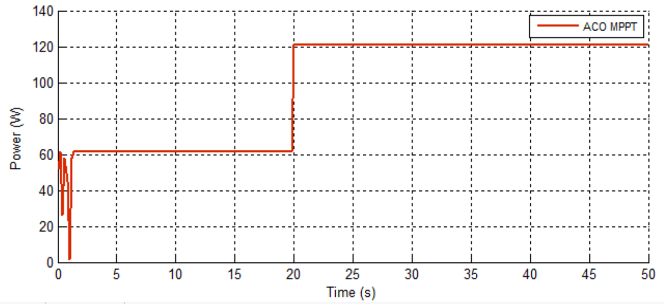


Fig.14. ACO Power curve under rapid variation of irradiance

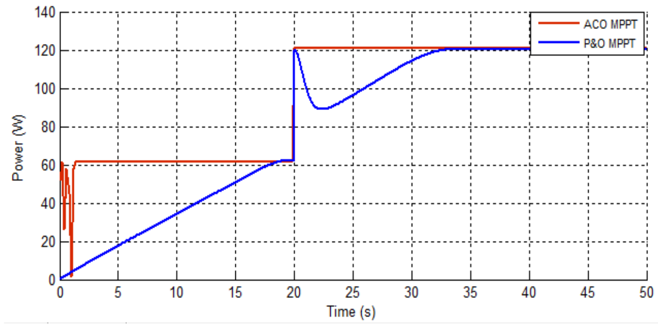


Fig.15. ACO and P&O Power progression time

5. CONCLUSION

In this paper, a swarm intelligent algorithm namely Ant Colony Optimization used for maximum power point tracking is analyzed and compared with well-known conventional Perturb and Observe (P&O) MPPT controller. The results show that Ant Colony Optimization gives better performance; where the controller reached the MPP with accuracy and negligible oscillation around the point. . whereas for the P&O controller, the oscillation around the MPP still constitute the biggest drawback of the method especially under rapid variation of the atmospheric condition. Thus, the ACO can be considered as one of the main competitive algorithms for tracking the maximum power point of a Photovoltaic system under rapid variation of irradiance. As future work we aim to test the proposed algorithm to solve the problem of partial shading.

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