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Research Article

MAXIMUM POWER POINT TRACKING OF A SOLAR SYSTEM UNDER PARTIAL SHADOW CONDITION USING GLOBAL CONFIRM PARTICLE SWARM OPTIMIZATION (GCPSO) AND FULL-BRIDGE CONVERTER

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ABSTRACT
As the electrical power production by solar systems depends on temperature and radiation, control of operating point for maximum power production of solar system is necessary. The aim of this paper is to propose a new method to track the maximum power point of a solar system under partial shadow condition using global confirm particle swarm optimization (GCPSO) and full-bridge converter.

Keywords: *Power Point Tracking (MPPT), Photovoltaic Solar Cell, Full-bridge Converter, Global Confirm Particle Swarm Optimization (GCPSO)*

INTRODUCTION
As the people are worried about running out of fossil fuels and environmental problems due to energy consumption, utilization of renewable energies specifically solar panels has been spread out. Besides, solar energy is one of the most important and prevalent supplies for satellites and space-crafts. Solar batteries or solar cells are electronic tools that transform light or futon directly to electrical current or voltage using photovoltaic phenomenon. Nowadays, solar cells are widely used in many applications.
As the maximum power produced of a solar cell is dependent to various non-linear variables, it is necessary to continuously track the maximum power production of the cell using a controller. In recent years many researches has been conducted on methods of maximum power point tracking of solar cells. The most important differences of these methods are: the method used, convergence speed, pulsations around maximum power point, cost and complexity of performance and required measuring tools (Sang-Soo *et al.*, 2009). The proposed method for maximum power point is generally categorized into three groups: 1-direct method 2-artificiall intelligence method 3-indirect method. There are methods like perturb and observe (P&O) (Abdelsalam *et al.*, 2011), hill climbing (Yao and Yu, 2010) and incremental conductance algorithm (INC) (Safari and Mekhilef, 2011) in the first group.
In direct methods like R&O, the maximum power point system deliver data from solar arrays output directly and frequently and track the maximum power point tracking. These methods have agreeable performance and can be easily implemented but on the other hand the second group methods like artificial intelligence have better performance and accuracy but with complicated implementation and need processors with high efficiency. In these methods, the output data of solar system is processed using maximum power point tracking system by intelligence methods with complicated analysis to get to the maximum power point of solar system and then required variations are imposed to the electronic converter. Utilization of such methods requires high efficiency hardware in order to execute the program. Nowadays, these methods are used in different applications due to the reduction in cost and increase in efficiency of digital circuits.
In the third method (indirect methods), the maximum power point tracking system takes the data of solar cells indirectly and these data are stored in advance. The advantages of these methods are the simplicity and simple tools but the limitation to a certain cell and determined parameters is their disadvantage.
One of the methods to track the maximum power point is the particle swarm optimization which is widely used to control the maximum power point due to their simplicity and simple implementation. However, if

these methods estimate improperly, algorithm would be trapped in local minima and cannot reach to global minima. In this paper, the capability of particle swarm optimization method in escaping from local minima trap is enhanced with modifications.

In this paper, a complete maximum power point tracking of a solar system is investigated using GCPSO method and full-bridge DC/DC converter.

General Structure of Photovoltaic System

A maximum power point tracking device is a DC/DC converter which regulates the output of solar cell so that it perform is maximum power point independent of load. The main duty of this device is to regulate the output voltage or current of cell to a value corresponding to maximum power deliverable to the load.

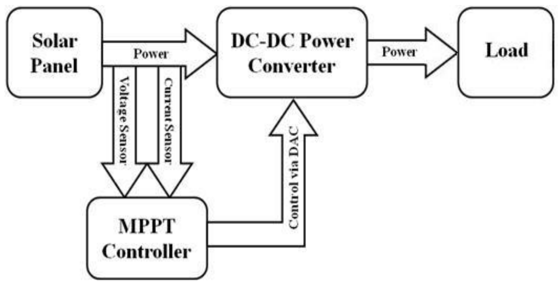

Figure1: Structure of a maximum power point controller system

Each system of solar cell is consisted of three parts: solar arrays, electrical converter and maximum power point tracker (according to Figure 1).

1. Solar Arrays

Each solar array contains solar modules and each module contains solar cells. Output voltage is increased with series connection and output current is increased with parallel connection. Besides, solar cells are named regarding the materials that form them.

When some of solar cells are under shadow condition due to trees or other things, the power produced by them is decreased and hence the output power is reduced. Therefore, various maximum power points would occur. Figure 2 shows global and local maximum power points.

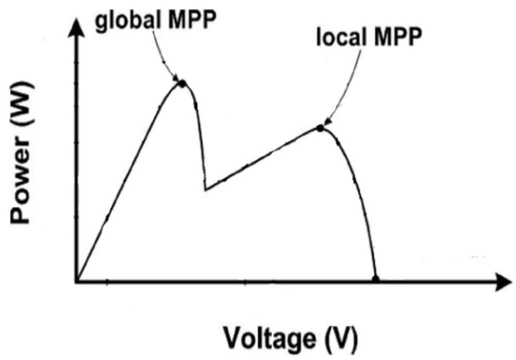

Figure 2: Global and local maximum power points (Eftichios and Frede, 2012)

2. Electrical Converter

Electrical converter transforms the electrical power from solar arrays to the load. These converters are usually Buck, Boost, Buck-Boost type or half-bridge or full-bridge type. Buck converters have higher efficiency compared to other types but they can only decrease the voltage level and as a result they are not used when the voltage level is low. On the other hand, boost converters have lower efficiency but they can increase the voltage level and are used when voltage has to be increased. Besides, half-bridge converter has better efficiency because it uses one switch but their reliability is low. On the other side, full-bridge converter has higher reliability and can increase very low voltage level which makes it appropriate for photovoltaic systems.

3. Maximum Power Point Tracking Device for Photovoltaic System

Maximum possible power is obtained from photovoltaic array using maximum power point tracking system. This is done by changing the electrical operating point of array. Changing the operating point is carried out using an inverter by varying the voltage or current level in order to reach the maximum power. This task is performed by changing the duty cycle of square-wave pulse.

Proposed algorithm: Maximum Point Confirm Particle Swarm

In most of optimization problems, the range of global optimization is not clear. If the estimation is carried out improperly, the algorithm would be trapped in local minima and cannot find global minima. Therefore, in the proposed method in this section mutation and cross-over operators of Genetic algorithm are used to change the movement rules when reaching to local minima and as a result these operators can enhance the efficiency of the Particle swarm optimization algorithm in escaping from local minima.

In each iteration two particles are selected accidentally as parents and then cross-over operator is applied to them and a new particle is added to their set. After that, mutation operator is applied and some particles are spread accidentally in order to find the better optimum point and replace the previous optimum point. It is important to cite that applying these operators can maintain the convergence speed of particle swarm optimization algorithm due to memorable feature of the particles. If a better optimum point is found using these operators, particles would tend toward this point.

If a better optimum point is not found, the movement would not diverge and the convergence speed is maintained due to memorable feature of the particles.

Figure 3 shows proposed GCPSO algorithm.

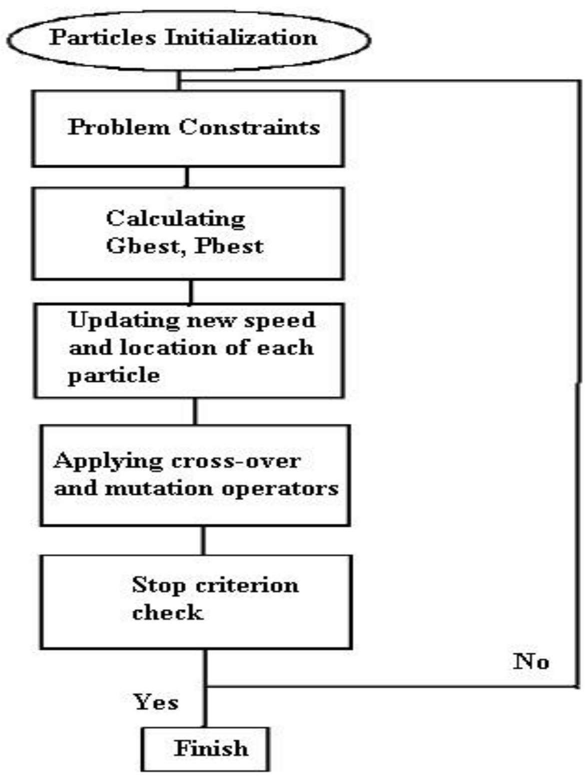

Figure 3: Flowchart for proposed GCPSO algorithm

Simulation

Simulation is done in MATLAB/Simulink which is shown in Figure 4.

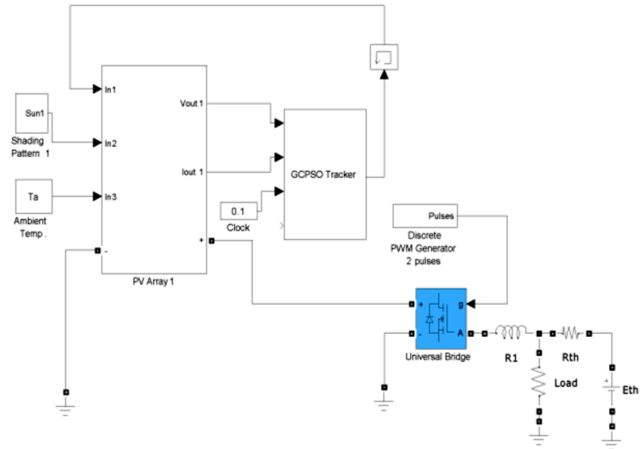

Figure 4: Simulation of maximum power point tracking for solar system under partial shadow condition

This system is consisted on three main blocks: solar arrays, the block for maximum power point tracking and a full-bridge DC/DC converter. The solar array is consisted of three solar modules and each module is consisted of 36 solar cells in series connection.

In order to provide the shadow condition on the solar modules some presumptions values of 1000, 1000 and 600 W/m^2 are considered as radiation on solar module No. 1 and values of 200, 400 and 800 W/m^2 on solar module No.2 (if the radiation value is lower it means that lower radiation reaches to the module surface and more shadow covers it). For example, module No.3 of array No.2 receives 800 W/m^2 and module No.2 of array No.2 receives 400 W/m^2. These values are presumptions and can be varied and the radiation values are varied considering the time that each module is located in the shadow. Besides, temperature of array surface is set to 25 degrees of Centigrade and Table (1) illustrates the defined values in simulation using GCPSO.

Table 1: Defined values in simulation using GCPSO

Parameter	**Value**
PSO population	50
Iteration	10
C_1	2
C_2	2
W_{min}	0.1
W_{max}	1
GCPSO population	5

Each voltage-current diagram has two maximum power points in which the power is maximum. However, among these points the point with highest value is the maximum global power point of the system. In the power-voltage diagram, different points are shown that are obtained by execution in several iteration. In Figure 5, the points on the diagram are maximum power points that are tracked in each step and the point with * is the maximum global power point. Figure 6 shows the diagram of output current to voltage variations of each solar array. At last, the maximum power is obtained P_{out_max}=117.1356 and maximum output current of the array I_{out_max}=3.3872 and maximum output voltage V_{out_max}=34.5821.

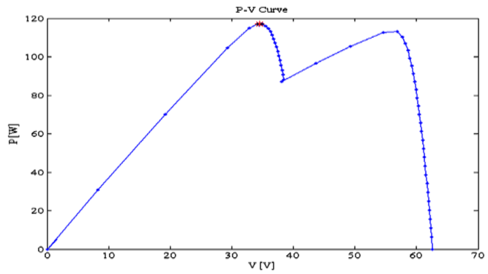

Figure 5: Diagram of solar cell power-voltage

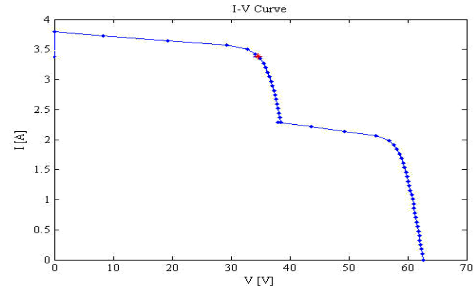

Figure 6: Diagram of solar cell output voltage-current

The block for maximum global power point tracking is the most important block in this system that should track the maximum global power point. This method has better features such as tracking the maximum global power point despite of many local maximum points and escaping from local maximum points by using GCPSO without any limitation in the type of solar cell.

CONCLUSION

In this paper a new method to track the maximum power point of a solar system under partial shadow condition is investigated using global confirm particle swarm optimization(GCPSO) and considering the maximum global power point, this method leads to loss reduction and efficiency increase comparing to systems that uses local maximum points. Besides, the problem of trapping the PSO method in local maximum points is solved.

Full-bridge DC/DC converter is used which has better reliability than the other converters because it uses 4 semi-conductor switches and it also can be used in step-down or step-up mode and even its output polarity can be changed.

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