Particle swarm optimization algorithm with compression factor is used to solve complex shading MPPT problem

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Abstract: In photovoltaic power generation systems, pv arrays are often affected by local shadow phenomena, resulting in the unstable operation of the system and the reduction of output power. In addition, pv array's p-u characteristic curve will show multiple peaks, and the traditional maximum power point tracking (MPPT) algorithm cannot complete the tracking of the maximum power point because it can only find the single peak. Particle swarm optimization (PSO) algorithm has good global optimization ability of multi-peak, which is widely used in tracking the maximum power point of local shadow. However, PSO algorithm has the shortcoming of insufficient convergence speed and low search accuracy. Therefore, a particle swarm optimization (YSPSO) algorithm with compression factor is proposed to effectively improve the global search ability and local improvement ability of the whole algorithm.

1. Introduction

In the actual use of the photovoltaic system, the shadow formed by the dust on the surface of the photovoltaic array, surrounding buildings, trees and clouds will greatly reduce its power generation efficiency. Under local shadow conditions, the pv array's p-u curve will have multiple maximum power values, which makes the conventional maximum power point tracking algorithm easily fall into local maximum value instead of global maximum value. Therefore, conventional algorithms, such as perturbation observation and incremental conductance method, cannot accurately track the maximum power point. At present, the maximum power point tracking method under shadow conditions can use genetic algorithm, particle swarm optimization (PSO) method and so on.

In this paper, PSO algorithm is improved. In the operation process, particle swarm optimization (YSPSO) of particle swarm algorithm with compression factor is formed. The improved algorithm can effectively improve the global search ability and local improvement ability of the whole algorithm, thus improving the tracking speed and accuracy of the system.

2. The photovoltaic cell model is established

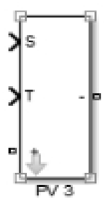

Figure 1. Encapsulation module.

In fact, photovoltaic cells use their photovoltaic effect to generate electromotive force, and their equivalent circuit is composed of a constant current source and some resistances. The mathematical model of photovoltaic cell is obtained by the output characteristic formula of photovoltaic cell and some environmental modification methods. Figure 1 shows the encapsulation module of the model and encapsulates the U_m, U_{oc}, I_m and I_{sc} parameters internally. Parameters of solar cell model were

23.36V, 18.47V, 2.8A and 3A, respectively. Where V and I are the actual voltage and current of the model, S and T are the actual sunshine intensity and environmental temperature respectively.

In Simulink, with two batteries in series, were measured in the standard conditions (temperature 25 ℃, light 1000 w/m^2) and shade (temperature 25 ℃, light 1000 w/m^2 respectively, and 400 w/m^2) of the output characteristic curve.

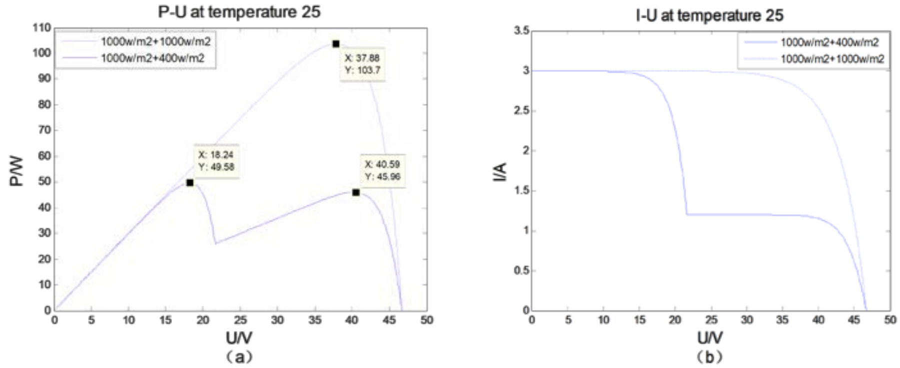

Figure 2. Comparison of standard and partial shading output characteristics.

As can be seen from figure 2, when the two components have the same light, the P-U curve has only one maximum value and the I-U curve has only one inflection point. When the light intensity of the two components is different, that is, the shadow appears, the P-U curve will have two maximums, and the i-u curve will have stepped state. The results show that the output power of pv array decreases under local shadow conditions. Different light intensity leads to multiple peaks in the output voltage of the series module, which leads to multiple extreme points in the total output power of the pv array. As a result, the conventional single-peak MPPT algorithm is no longer applicable at this time. The following is verified through simulation.

3. Perturbation observation

P&O uses feedback and requires fewer measurement parameters. The main idea is to periodically apply a step length disturbance voltage (current) to the output voltage (current) of the photovoltaic cell, and according to the variation of the output power of P before and after the disturbance. If one is positive, the original direction of disturbance remains unchanged. If Δ P is negative, change the direction of the disturbance to keep the photovoltaic cell's operating point close to MPP. According to the realization process, the obvious defects of the traditional P&O method are :(1) constant step disturbance causes constant amplitude oscillations near MPP, resulting in certain power loss; (2) when the illumination changes rapidly, it is easy to be followed less than the time or misjudgment.

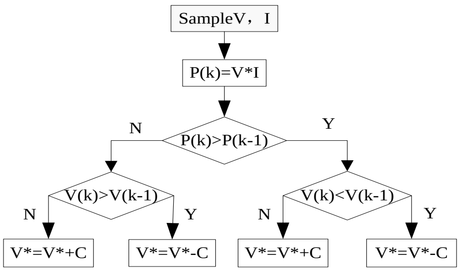

Figure 3. Flow chart of perturbation observation method

4. Particle swarm algorithm with compression factor

4.1. Traditional particle swarm optimization algorithm

PSO is a new evolutionary algorithm that has been rapidly developed in the past decade and has been widely used. It has simple structure, high optimization accuracy and high speed, and is very suitable for searching the optimal value of discontinuous nonlinear and combinatorial optimization problems.

PSO is easy to understand. Suppose there are n particles, randomly distributed in the n-dimensional space, and the position of each particle is X_i (i = 1,2... n),The corresponding speed is v_i and the objective function is f (X_i). The optimal position of the particle in the spatial search process is P_{besti} and the global optimal position is G_{best}. The iterative formula is as follows:

$$v_i^{k+1}=wv_i^k + c_1\text{rand}\ (P_{besti} - X_i^k) + c_2\text{rand}(G_{best} - X_i^k) \quad (1)$$

$$X_i^{k+1} = X_i^k + v_i^{k+1}$$

Among them: w is the weight coefficient of the particle; c_1 and c_2 are learning factors; Rand is a random number between (0,1); k is the number of iterations.

4.2. Particle swarm algorithm with compression factor

The performance of PSO depends largely on the control parameters of the algorithm, such as particle number, maximum velocity, learning factor, inertia weight and so on. The learning factors c_1 and c_2 determine the influence of the empirical information of the particle itself on the motion of the particle, and reflect the information exchange between particle groups. Setting a larger value of c_1 will cause the particle to wander in the local range too much, while a larger value of c_2 will cause the particle to converge to the local minimum prematurely.

In order to effectively control the particle's flight speed so that the algorithm can achieve an effective balance between global detection and local mining, the PSO algorithm of shrinkage factor is introduced. Its speed update formula is as follows:

$$v_i^{k+1}= \varphi\{v_i^k + c_1 rand(P_{besti} - X_i^k) + c_2 rand(G_{best} - X_i^k)\} \quad (2)$$

$$\varphi=\frac{2}{|2-C-\sqrt{C^2-4C}|}\ ,C=c_1+c_2$$

In order for the algorithm to proceed smoothly, c_1+c_2 must be greater than 4. Typical methods:

(1) $c_1=c_2=2.05$,at this time C is 4.1, contraction factor φ is 0.729, which is equivalent to w= 0.729 in form, the basic PSO method of $c_1 = c_2 = 1.49445$;

(2)particle size N=30, $c_1=2.8$, $c_2=1.3$,at this time C is 4.1 , contraction factor φ= 0.729.

The following figure is the algorithm flow chart of YSPSO.

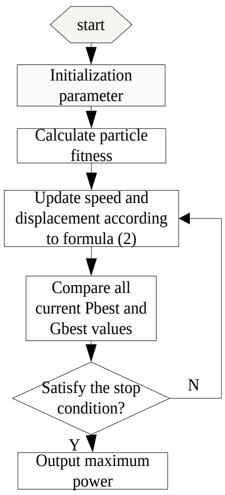

Figure 4. Algorithm flow chart of YSPSO

5. Analysis of simulation results

In order to verify the optimization effect of YSPSO relative to the perturbation observation method under standard and partial shading conditions, a model was established in Matlab/Simulink to verify that this method not only has the ability of global search, but also has a short tracking time and a small oscillation.

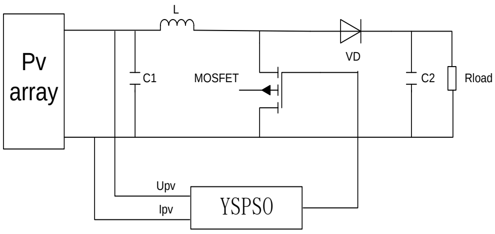

Figure 5. Photovoltaic array MPPT system

5.1 Comparison of output results of YSPSO and disturbance observation under standard conditions

When the light is uniform (1000w/m^2), the two batteries are strung together for Simulation. It can be seen from FIG. 2 that the P-U diagram has only one peak value with a value of 103.7w under uniform illumination. The following figure shows the simulation results. From the figure, we can see that the perturbation observation method starts to output stable power at 0.1306s, and can also trace the maximum power to 103.3w, but the early fluctuation is very large. YSPSO began to output stable power at 0.03272s, with a value of 103.8. So, both methods can trace to the maximum. However, YSPSO is obviously fast and has little fluctuation.

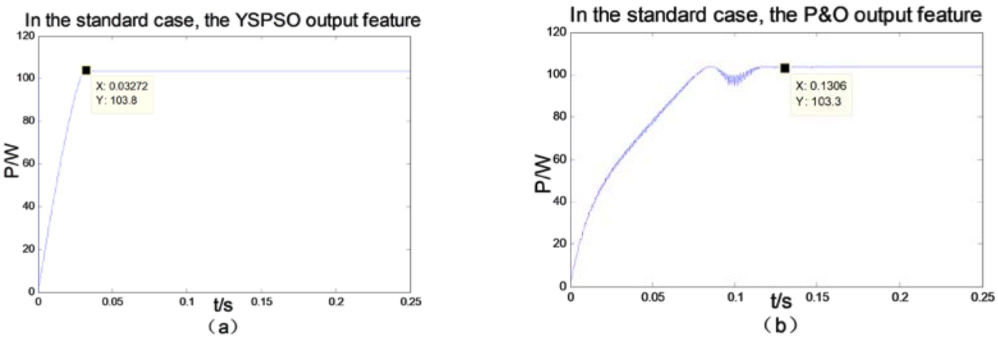

Figure 6. Two methods output characteristics under standard conditions

5.2 Comparison of output results of YSPSO and disturbance observation under partial shading conditions

In partial shading (1000w/m^2, 400w/m^2), the two batteries were strung together for simulation. Similarly, it can be seen from FIG. 2 that when partly shaded, the P-U diagram has two peaks, with values of 49.58w and 45.96w, respectively. The following figure shows the simulation results. From the figure, we can see that the disturbance observation method starts to output stable power at 0.0617s and tracks the maximum power at 45.85w, falling into local extreme value and fluctuating greatly in the early stage. YSPSO began to output stable power at 0.0591s, with a value of 49.59w.Therefore, in partial shading, the traditional MPPT method will fall into local extreme values. At this point, YSPSO not only tracked to the maximum value, but also fluctuated slightly.

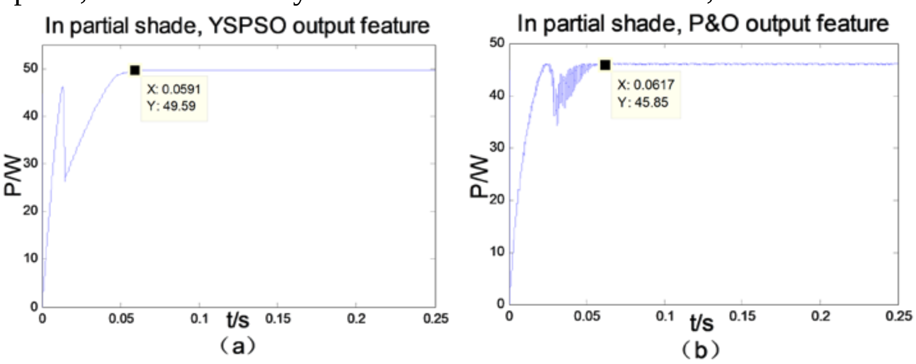

Figure 7. Output characteristics of the two methods under partial shading conditions

6. Conclusion

For some shade condition, the traditional MPPT method could fall into the local extreme value cause the failure of optimization, this paper proposes a particle swarm optimization (YSPSO) with shrinkage factor, by controlling the shrinkage factor to control the particle speed make the algorithm to achieve balance in the relationship between global exploration and local exploitation, and set up in Matlab/Simulink model, verify the accuracy and rapidity.

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