Application of PSO Algorithm Based on Recognition in MPPT Control of Photovoltaic Array

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Abstract. Under the condition of local shadow, the P-U curve of photovoltaic array presents multi peak phenomenon. Traditional MPPT algorithm is easy to fail. PSO algorithm is suitable for the optimization of complex multi extremum system, so it is applied in multi peak global MPPT. In order to solve the problem of low precision and premature in PSO algorithm, this paper proposes a new PSO algorithm based on recognition. Through the introduction of awareness, compared with the set value, the particles with better awareness will directly enter the next better iteration, while the particles with poor awareness will be replaced by their historical optimal location, which continues to maintain the search accuracy and speed in the later stage of particle swarm, so as to improve the accuracy and speed of multi peak global optimization. Through the simulation of MATLAB/Simulink, the results show that under the condition of uniform illumination and variable shadow, the particle swarm optimization algorithm based on recognition can effectively improve the convergence speed and accuracy of system optimization.

1 Introduction

China is rich in solar energy resources and has great potential for photovoltaic power generation. However, in practical applications, the photovoltaic array is greatly affected by the environment, uneven light or some components are covered by dust, or even the parameters of individual battery components are inconsistent, which are collectively referred to as the photovoltaic panel affected by local shadow conditions. In this case, the shaded photovoltaic panel not only does not provide power for the circuit, but also becomes the load consumes the electrical power of the whole system and generates heat. When the heat exceeds a certain degree, it will cause irreversible permanent damage, which is the hot spot effect.[1] Therefore, it is necessary to make full use of the energy of the photovoltaic array through the photovoltaic power generation system MPPT to make the photovoltaic array reach the maximum power output.[2-3]

For multi peak optimization problem, intelligent algorithm is often used to realize global MPPT. In reference[6], genetic algorithm is applied to multi peak MPPT optimization. This algorithm can not stabilize the power near the MPPT, and the algorithm is complex. In reference [7-8], particle swarm optimization (PSO) algorithm is used to optimize multi peak MPPT. The algorithm has fast convergence speed and is easy to
realize. However, PSO algorithm still has some defects, such as long convergence time and low search accuracy with the increase of iterations.

Therefore, this paper proposes a PSO based on recognition, and proves that the algorithm has faster convergence speed and accuracy through MATLAB/Simulink simulation.

2 Photovoltaic array

When the photovoltaic cell under light is connected to the load, the photo generated current will establish the terminal voltage on both sides of the load, and the working circuit of the photovoltaic cell is shown in Figure 1.

\[
I = I_{\text{ph}} - I_0 \left[ \exp \left( \frac{U+IR_{\text{sh}}}{nkT_{\text{ns}}} \right) - 1 \right] - \frac{U+IR_s}{R_{\text{sh}}} \tag{1}
\]

where: \(I_0\) is the reverse saturation current of PN section of equivalent diode; \(q\) is the electronic charge; \(U\) is the voltage of equivalent diode end; \(k\) is Boltzmann constant; \(T\) is the thermodynamic temperature; \(N_s\) is the number of cells in series and \(n\) is the ideal factor of diode.

In engineering practice, photovoltaic modules are composed of multiple single photovoltaic cells in series and parallel, and parameters, \(I_{\text{ph}}, I_0, R_{\text{sh}}\) and \(R_s\) will also change with the change of external environment. Take the engineering mathematical model of photovoltaic cell as the template to build the simulation model of single cell in Matlab/Simulink. The overall photovoltaic array used is composed of 16 photovoltaic panels with the same bypass diode, which are connected into 4x4 series and parallel form, and each substring of the array is connected with an anti reverse diode in series, as shown in Figure 2.
There are two steps in the I-U curve and two peaks in the P-U curve of photovoltaic array under the shadow conditions of two kinds of light intensities. There are four steps in the I-U curve and four peaks in the P-U curve under the shadow conditions of four kinds of light intensities; Therefore, if there are m kinds of light intensity, the I-U characteristic curve will have m steps, and the P-U characteristic curve will have m peaks.

3 Particle swarm optimization

Particle swarm optimization (PSO) is simple in construction and fast in convergence, which is suitable for the optimization of complex nonlinear systems. [11-12] Multiple particles are randomly initialized and distributed in space D, the position of the ith particle is recorded as $X_i = (X_{i1}, X_{i2}, \ldots, X_{iD})$. The velocity can be expressed as $V_i = (V_{i1}, V_{i2}, \ldots, V_{iD})$. The objective function is $f(x_i)$. The local optimal solution searched by the ith particle is recorded as $P_{best}$. The global optimal solution searched by the whole particle swarm is recorded as $G_{best}$. The iterative formula of the position and velocity of the ith particle in the optimization process is as follows:

$$
V_{i}^{k+1} = wV_{i}^{k} + c_1r_1(P_{best}^{k} - X_{i}^{k}) + c_2r_2(G_{best}^{k} - X_{i}^{k}) \tag{2}
$$

$$
X_{i}^{k+1} = X_{i}^{k} + V_{i}^{k+1} \tag{3}
$$

where $k$ is the number of iterations, $w$ is the inertia weight factor, $c_1$ and $c_2$ are the learning factors, which represent the acceleration weight of the particle convergence optimal solution, $r_1$ and $r_2$ are the constraint factors, which increase the randomness of the search, generally taking the value of 1.

4 PSO algorithm based on recognition

Particle recognition is the ratio of the best trajectory value of each particle to the best trajectory value of the whole group, that is

$$
 r_{i}^{k} = \frac{f(P_{best}^{k})}{f(G_{best}^{k})} \times 100\% \tag{4}
$$

$$
X_{i}^{k+1} = \begin{cases} 
  P_{best}^{k} & r_{i}^{k} < \alpha \\
  \frac{X_{i}^{k+1} + X_{i}^{k}}{2} & r_{i}^{k} \geq \alpha 
\end{cases} \tag{5}
$$

From (4) and (5) formulas, it can be concluded that recognition is an objective understanding of the particle through its own knowledge and group communication. Therefore, the recognition $r_{i}^{k}$ is used to judge whether the particle's spatial location is good or bad. Set $\alpha = 50\%$, and the recognition $r_{i}^{k}$ is $[0,1]$. The higher the recognition value is,
the better the particle's own spatial location is, and the closer it is to the maximum value of the whole domain currently searched. On the contrary, the lower the recognition value is, the worse the particle's own spatial location is, and the farther it is from the best location.

The process of PSO algorithm based on recognition is as follows:

① Set the initial values for the parameters of particle number $n$, space location $x_{i1}$ and start velocity $v_{i1}$;
② Calculate the trajectory value $f_{ik}(i)$ of all particles;
③ Calculate the recognition $r^k_i$ of all particles;
④ Formula (4) and (5) are used to replace the search velocity $v_i$ and the space location $v_i$ of particles;
⑤ If the end condition is reached, exit, otherwise return ②.

5 Simulation verification

The array photovoltaic MPPT control system composed of \{3x1\} series photovoltaic panels is built in Matlab/Simulink, as shown in Figure 3.

![Figure 3. Photovoltaic MPPT control system.](image)

1) Uniform illumination simulation
Under the condition of uniform light, set the temperature of three photovoltaic panels as 28 ℃, the light intensity as 820W/m, and the simulation time as 0.5s. The simulation results are shown in Figure 4.

![Figure 4. Optimization curves of two algorithms under uniform illumination conditions.](image)

Under uniform illumination, there is only one peak point (53V, 145W) in the P-U curve of the system. According to the power curve in the analysis diagram, both algorithms can track the maximum power point, of which the traditional PSO algorithm needs 0.27s to track MPPT, and the recognition based PSO algorithm only needs 0.16s to track MPPT, and the oscillation in the optimization process is smaller.

2) Simulation in shadow condition
Shadow changes with time, and can be regarded as constant or variable in a certain period of time. In the following, simulation will be carried out under the conditions of static shadow and dynamic shadow to verify the feasibility of recognition based PSO algorithm.

(1) Static shadow simulation
In the static local shadow environment, because the three panels are connected in series, the maximum number of particles can be three peak points, so the number of particles does not need to be too many. Three wave peak areas, each area of three to four particles, can not only meet the needs of search accuracy, but also meet the needs of tracking speed.

It can be seen from Figure 5 that the traditional PSO algorithm is adopted. In each replacement, although the output power and voltage have small oscillation, they can quickly approach the maximum power point. From Figure 6, it is found that the recognition based improved so algorithm can achieve the best power point in a few iterations, and its stability is enhanced.

(2) Dynamic local shadow simulation
In the real photovoltaic power generation system, cloud occlusion often occurs, which is not always static, and all kinds of emergencies may occur. Therefore, it is particularly important for the dynamic search ability of MPPT in the case of sudden occlusion of photovoltaic array.

Figure 5. Output power of traditional PSO algorithm. Figure 6. Power output of recognition PSO algorithm.

Figure 7. Power and voltage output diagram of traditional PSO method under dynamic condition.
From Figure 7 and figure 8, it can be observed that in the process of searching based on recognition PSO, due to the linear change of inertia factor W in the later stage and the introduction of recognition contrast, particles can quickly aggregate in the later stage of searching for prime, so its characteristic curve is in the stage of finding the best power, which is smaller in vibration and faster in convergence compared with PSO.

6 Conclusion

In this paper, the serial panel of {3x1} is built on the MATLAB/Simulink platform. The traditional PSO method and the recognition based PSO method are used to search the optimal power point respectively. The accuracy and reliability of the improved PSO algorithm are verified under the static local shadow environment and the dynamic local shadow environment respectively. The results show that the PSO algorithm based on recognition is more stable and reliable, which can suppress the oscillation caused by the iteration in the search process, and improve the search performance greatly.

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