Random inertia weight PSO based MPPT for Solar PV under Partial Shaded Condition

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Abstract. Since the power-voltage characteristic curve of a photovoltaic (PV) arrays has multiple peaks under partially shading conditions (PSC), the conventional maximum power point tracking (MPPT) control methods fail to work. In this paper, a PSO algorithm based on random inertia weights is proposed to achieve global maximum power tracking. By improving the inertia weight coefficient of the traditional PSO algorithm and optimizing the search order of the particles, the population size and the number of iterations are decreased, thus finding the MPP (maximum power point) in a shorter time to ensure accurate tracking of the maximum power. By using the same parameters, its tracking performance is compared with traditional perturb and observe (P&O) method and particle swarm optimization (PSO) method, and the existed PSO algorithm is compared with the improved PSO to verify the correctness of the algorithm. The concordance of simulation results prove the advantage of the proposed MPPT method to ensure rapidity and stability of the output PV power.

1. Introduction
At present, photovoltaic (PV) generation system (PGS) is considered to be the most promising technology in the field of renewable energy. When the PV array is partially shielded, the voltage and current of the PV system will fluctuate randomly, resulting in multiple local peaks on the output power curve of the system [1].

Various schemes have been proposed for the maximum power point tracking technology (MPPT) of PGS, and the conventional methods include perturb and observe (P&O) method, and conductance increment method (INC) [2]. And the PV panel will exhibit multiple peaks on the output characteristic curve of the system under partial shadow conditions. Therefore, the traditional the MPPT algorithm is no longer applicable to dynamic systems. In an effort to overcome aforementioned disadvantages, many domestic and foreign experts have proposed new optimization algorithms. In [3], based on the photovoltaic module under partial shielding conditions, a differential evolution (DE) based algorithm is proposed to improve the tracking efficiency. In [4], in order to solve the problem of local maximum power search, an ant colony optimization (ACO)-based maximum power point tracking control algorithm is proposed, which effectively solves the local maximum power point tracking. Literature [5] proposed a maximum power point tracking method based on genetic algorithm (GA), which improves the tracking efficiency of the system and can effectively track the global maximum power. In [6], a firefly algorithm is proposed for the PGS under partial shielding conditions, which effectively improves the tracking performance. Since PSO is based on search optimization, in principle, it should be able to locate the MPP for any type of P–V curve regardless of environmental variations. In [7], the authors have added various extra coefficients in the conventional PSO searching scheme equations,
thus increasing the computational burden of the algorithm. Therefore, the analysis of the implemented PSO algorithm shows that the existing algorithms have serious deficiencies in tracking efficiency and accuracy.

The article first discusses the PGS under local shadow conditions and analyzes its output characteristics. Then, the particle swarm optimization algorithm is optimized and improved by random inertia weighting strategy, and compared with the traditional algorithm to verify the effectiveness of the proposed algorithm. The PGS can quickly and accurately track the maximum power point under partial shadow, and achieve the purpose of maximum power stable operation.

2. Photovoltaic system

Block diagram of the proposed system is shown in Figure 1.

![Block diagram of the proposed system](image)

Figure 1. Block diagram of the proposed system.

Using the control variable method, for the PGS under ideal conditions, the influence of two factors on the PGS is analyzed by changed the temperature and illumination intensity.

Keep the light intensity $G$ of the external environment of the PGS constant and change the temperature $T_i$. The system sets the illumination intensity to 1000W/m$^2$ and the external temperature is 0°C, 25°C, 50°C, 75°C, and observes the output characteristics of the system under ideal conditions. The simulation results are shown in Figure 2.

![Output characteristic curve of solar cell](image)

Figure 2. Output characteristic curve of solar cell under different temperature intensity at light 1000W/m$^2$

Keep the temperature $T$ of the external environment of the PGS constant and change the size of the illumination intensity $G$. The system sets the temperature to 25°C and the global irradiance is 400W/m$^2$, 600W/m$^2$, 800W/m$^2$, 1000W/m$^2$, and observe the output characteristics of the system under ideal conditions. The simulation results are shown in Figure 3.
3. Particle Swarm Optimization

3.1. A brief description of the particle swarm algorithm

PSO has good efficiency for multi-peak optimization problems, and is mainly used for function optimization with multiple local advantages in the system [8]. The extent of particle movement depends on two factors, one is the optimal position of the particle itself, and the other is the best position obtained by other particles. The following mathematical equation gives an update of the velocity and position of the particle.

\[
V_{ti}^{t+1} = \omega V_{ti} + c_1 r_1 P_{best} + c_2 r_2 G_{best}
\]

\[
S_{ti}^{t+1} = S_{ti} + V_{ti}^{t+1}
\]

Where: \(\omega\) is the inertia weight coefficient, and \(c_1\) and \(c_2\) are the acceleration constants, which determine the search ability of the algorithm. \(r_1\) and \(r_2\) are normalized random numbers with values ranging between 0 and 1, \(S_t\) indicates the current position of the particle. The variable \(P_{best}\) is used to store the current optimal position of the i-th particle, and if the formula (3) is satisfied, the position of the particle is updated (4).

\[f\left(S_{ti}^t\right) = f\left(P_{best}\right)\]

\[P_{best} = S_{ti}^t\]  

The particles move in different directions in the search space, and the movement trajectories of the individual physical quantities in a single iteration period are shown in Figure 4:

![Figure 4. The movement of particles in space.](image)

3.2. Application of the improved PSO algorithm in MPPT

The photovoltaic array includes N sub-modules, and each sub-module operates in series and in parallel in an n-dimensional manner. In order to achieve the above tracking scheme, by improved the traditional PSO algorithm, it is assumed that the module has N individuals in the n-dimensional space, the i-th individual is represented by \(N_i\), its position attribute is \(S_i\) and the velocity attribute is \(V_i\). Therefore, each module contains two attribute quantities, which can be expressed by:

\[N_i = [S_i, V_i]\]  

\[i = 1, 2, ..., N\]
Using the unit vector method, the relationship between position and velocity can be expressed as the following vector expression:

\[
V_i = [v_{i1}, v_{i2}, v_{i3} ... v_{in}] \\
S_i = [s_{i1}, s_{i2}, s_{i3} ... s_{in}]
\] (6)

Assuming that the time each particle moves is \(T\), the speed of the particle at the last time can be expressed as:

\[
V^{t-1}_i = [v^{t-1}_{i1}, v^{t-1}_{i2}, v^{t-1}_{i3} ... v^{t-1}_{in}]
\] (8)

The maximum power output position of the module under ideal conditions is:

\[
S^{\text{best}}_i = [s^{\text{best}}_{i1}, s^{\text{best}}_{i2}, s^{\text{best}}_{i3} ... s^{\text{best}}_{in}]
\] (9)

The maximum power output of the entire system under ideal conditions is:

\[
S^{\text{all,best}}_i = [s^{\text{all,best}}_{i1}, s^{\text{all,best}}_{i2}, s^{\text{all,best}}_{i3} ... s^{\text{all,best}}_{in}]
\] (10)

The speed at which the current position of a single module reaches the historical optimal position is:

\[
V^{t'}_{i,\text{best}} = \frac{(S^{\text{best}} - S'_i)}{T}
\] (11)

The speed of the current position of the system to the historical optimal position is:

\[
V^{t'}_{\text{all,best}} = \frac{(S^{\text{all,best}} - S^{\text{all}})}{T}
\] (12)

Find the current speed of the system:

\[
V^{t'}_i = \omega \times (V^{t-1}_i + V^{t'}_{i,\text{best}} + V^{t'}_{\text{all,best}})
\] (13)

When \(V^{t'}_i \geq V^{\text{max}}\), \(V^{t'}_i = V^{\text{max}}\), and when \(V^{t'}_i \leq V^{\text{min}}\), \(V^{t'}_i = V^{\text{max}}\). When the speed is known, the position \(S^{t'+1}_i\) at the next moment can be solved according to the time \(T\) and the current position \(S^{t'}_i\), as shown in the equation (14). This is repeated and the final maximum power is obtained.

\[
S^{t'+1}_i = S^{t'}_i + T \times V^{t'}_i
\] (14)

By improving the inertia weight \(\omega\) of the traditional PSO algorithm, this paper overcomes the shortcomings caused by the linear decrement of \(\omega\) to some extent. For multi-peak PV systems, effectively avoiding local maximum power. The algorithm flow is shown in Figure 5:
4. Results and Discussion
In order to verify the effectiveness of the MPPT algorithm proposed in this paper, and combined with the experimental platform, the mathematical model of the PGS under local shadow conditions is built. The global irradiance is 1000W/m², 800W/m², 600W/m², 400W/m², under the condition of 25℃, make sure the system is working properly. As shown in Figure 6, there are three local peaks (Pbest) and one global peak (Gbest) on the P-V characteristic curve outputted by the PGS under the simulated partial shielding condition.

![Figure 6. P-V curve of the system output under partial shielding conditions.](image)

Particle algorithms based on random inertia weight improvements are applied to the MPPT of PV systems. As shown in figure 7, (a)-(d) show part of the simulation process of the maximum power point of the particle tracking system of the PV array under local shadow conditions.

![Figure 7. Particle running process.](image)

As shown in Figure 8, the output power characteristics of both the conventional PSO algorithm and the improved PSO algorithm are shown. By using the same parameters, the consistency of the simulation results prove the advantages of the proposed MPPT method in ensure rapidity and stability of the output PV power. Furthermore, the searching sequence of particles is optimized to effectively reduce fluctuation of voltage and suppress output power spike.
5. Conclusions

This paper proposes a PSO algorithm based on random weights. The main purpose is to develop an accurate and system-independent MPPT algorithm for centralized-type PGS operating under PSC. Based on the MATLAB/simulink simulation experiment platform, a generalised model of the PV system has been developed. According to the experimental results, the proposed method can obtain the GMPP in all the test cases no matter where the GMPP locates. The proposed technique boasts the following advantages: (1) Compared to other GMPP searching methods, the tracking efficiency of the APSO-based MPPT algorithm is very high. (2) PSO-based method is a good candidate for MPPT algorithms, as it is easy to implement and converges to the desired solution in a reasonable time. (3) The new algorithm is shown to capable of jump out of the current MPPT point and reorient towards new GMPP under rapidly changing partial shading conditions.

References

[1] Z. Li.; S. Kai.; X. Yan. A modular grid-connected photovoltaic generation system based on DC bus[J]. IEEE Trans. Power Electron. 2011, 26, 523-531.
[2] Y. Bo.; L. Wuhua. Design and analysis of a grid connected photovoltaic power system[J]. IEEE Trans. Power Electron. 2010, 25, 992-1000.
[3] Kumari, P.A.; Geethanjali, P. Parameter estimation for photovoltaic system under normal and partial shading conditions: A survey(Review)[J]. Renewable and Sustainable Energy Reviews. 2018, 84, 1-11.
[4] Tolic, Ivan; Primorac, Mario; Milicevic, Krno. Measurement Uncertainty Propagation through Basic Photovoltaic Cell Models [J]. ENERGIES. 2019, 12, 100-107.
[5] Mohamed I. Mosaad.; M. Osama abed el-Raouf. Maximum Power Point Tracking of PV system Based Cuckoo Search Algorithm[J]. Energy Procedia. 2019, 162, 117-126.
[6] A. Guichi.; A. Talha. A new method for intermediate power point tracking for PV generator under partially shaded conditions in hybrid system[J]. Solar Energy. 2018, 170, 974-987.
[7] Li, S.; Liao, H. A MPPT strategy with variable weather parameters through analyzing the effect of the DC/DC converter to the MPP of PV system[J]. Solar Energy. 2017, 144, 175-184.
[8] Martin, Aranzazu D.; Vazquez, Jesus R. MPPT in PV systems under partial shading conditions using artificial vision[J]. Electric Power Systems Research. 2018, 162, 89-98.