Photovoltaic Array Maximum Power Point Tracking Based on Improved Perturbation and Observation Method

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Abstract. The output characteristics of photovoltaic cells are strong non-linearity, and maximum power point tracking technology can improve the efficiency of photovoltaic systems. Based on improved perturbation and observation method, this paper takes the advantages of both long and small steps to realize the maximum power tracking of the photovoltaic system. Firstly, the absolute value of the real-time power rate of change is used as a reference for the automatic variable step size, and the maximum power is quickly tracked with a large step when the external conditions change. Then, after reaching the maximum power point, the system automatically becomes a small step to reduce the power oscillation loss. Finally, average calculation module is added to the power sampling to reduce the impact of clutter on the system and prevent the "sharp peak" of power. The results of the maximum power point tracking example show that the model has significantly improved the tracking speed of the maximum power point and the range of oscillation near the maximum power point.

1. Introduction

Current photovoltaic power generation equipment and algorithms rely heavily on the environment, and solar energy utilization efficiency is low. The main reasons for this are the photovoltaic cell materials and the control algorithms for the photovoltaic power generation system. The main performance of photovoltaic cell materials is to absorb solar energy and convert it into electrical energy. To improve the material for photovoltaic cells, countries must invest a lot of money and time, but the effect was not significant. Then, improving the maximum power point tracking algorithm in photovoltaic power generation systems has become the best way to significantly increase the efficiency of photovoltaic power generation systems.

The current maximum photovoltaic power tracking (MPPT) methods include: fixed voltage method, perturbation observation method (P&O), incremental conductance method (INC) [1] and fuzzy control [2]. Tao Feng shows in the literature [3] that the use of fixed voltage method and admittance increment method to achieve photovoltaic MPPT. Ling Ren describes the use of perturbation observation method to achieve the control of photovoltaic MPPT system in the literature [4]. The algorithm is simple. It is easy to implement modularized. It has less parameters to be measured and less demanding on the accuracy of the sensor. It is also more commonly used. However, there are certain difficulties in choosing the step size of this algorithm. when the step size is large, the maximum power tracking speed is fast, but there will be a large power oscillation near the maximum power point; when the step size is small, the power near the maximum power point oscillation will be significantly reduced, but
the system's ability to respond to changes in the external environment will be degraded, resulting in loss of power, and also have a greater impact on power quality [5].

To solve the above problems, this paper proposes an improved modified MPPT algorithm. The new variable-size P&O method proposed in the paper can adjust the step size according to the change of external conditions. It can solve the contradiction between tracking speed and steady-state accuracy. At the same time, in order to eliminate the influence of misjudgment and clutter on the system, an average calculation module is added in power sampling. The results show that this method can effectively avoid the occurrence of misjudgment and has good dynamic and steady state performance.

2. Perturbation Observation Method

The basic principle of photovoltaic power generation is a technology that the photovoltaic effect of the semiconductor surface is used to directly convert light energy into electrical energy. The photovoltaic cell is a non-linear DC power supply. When the light intensity and temperature are constant, the output power characteristics of the photovoltaic system are as follows:

\[
\begin{align*}
\frac{dP}{dV} > 0 & \quad \text{Left of maximum power point} \\
\frac{dP}{dV} = 0 & \quad \text{maximum power point} \\
\frac{dP}{dV} < 0 & \quad \text{Right of maximum power point}
\end{align*}
\]

A disturbance is firstly given in one direction of the system to detect the output power of the photovoltaic cell, when P&O seeks the maximum power point. The direction of the next system disturbance is determined according to whether the output power becomes larger or smaller, and the photovoltaic cell eventually works at the maximum power point by continuous disturbance. In the traditional disturbance observation method, since each disturbance time is the same, in order to achieve a maximum power change, the number of disturbances with small steps is much larger than the number of large steps, so it will make small the long step tracking time cannot track the maximum power in time [6]. However, for a large step size, when the maximum power reaches a certain period of time, it will be difficult to oscillate at the closest position of the maximum power due to a large change in the perturbation of the large step, resulting in a large shock and energy loss.

2.1. Variable Step Perturbation Observation Method

Due to the drawbacks of traditional P&O, the overall power generation efficiency of the photovoltaic system is reduced. Based on this problem, this paper designs a modified scheme for observation of variable step size disturbances. From ‘figure 1’, it is not difficult to find that when the external
conditions suddenly change, the load power is in a relatively large growth stage, and then the amplitude gradually decreases until reaching the maximum power point.

According to this intrinsic characteristic of photovoltaic cells, the constructive duty cycle disturbance expression is:

\[
D_{\text{ref}} = D_{\text{ref}} + \frac{dP}{dV} = D_{\text{ref}} + \alpha \frac{P(k) - P(k-1)}{P(k) - P(k-1)}
\]  

(2)

In the formula, \( \alpha \) is a positive number. It is a variable step speed factor for adjusting the tracking speed. It can be seen from equation (2) that when the PV array operating point is far away from the maximum power point, the tracking step length is large, and the step length is small. When the PV array operating point approaches the maximum power point, it approaches 0. The value of \( \alpha \) can be estimate by equation (3):

\[
\alpha \leq \frac{V_{\text{step max}}}{|dP/dV|_{\text{max}}}
\]  

(3)

In the formula, \( V_{\text{step max}} \) is the maximum step size allowed by the fixed step perturbation observation method. The \( |dP/dV|_{\text{max}} \) can be calculated according to the characteristics of the PV array (as shown in ‘figure 1’).

Development of the process shown in ‘figure 2’.

**Figure 2. Flow chart of variable step perturbation observation method.**

### 2.2. Model establishment

Through data analysis, it is found that when the power curve tends to the maximum power point, the slope of power \( P \) (the derivative of \( P \) versus time, \( dP/dt \) ) gradually goes to 0, and the slope is larger when the power curve is farther away from the maximum power point, which meets the requirement of the ideal step length in this paper. Therefore, the absolute value of the real-time power change rate is used as the reference variable of the automatic variable step size. The simulation module for auto-changing the step length using Matlab/Simulink is shown in ‘figure 3’.
In addition, the absolute value of the power change rate may reach infinity and the minimum may be 0. In order to avoid the influence of the automatic variable step size on the accuracy and stability of the system, the system may not be able to timely make changes to the external environment. In response, this article limits the maximum and minimum values of the final step size. In this paper, the step size in the simulation is limited to 0.001~0.05.

The avg1 is used to reduce the influence of clutter in the circuit (such as the clutter of the DC-DC switching circuit) on the system and prevent the power from appearing a "spike" (a sudden change in the power curve within a short period of time). Influencing, the average calculation module added in the power sampling of this simulation is shown in 'figure 4'.

In the actual simulation process, it can be found that the tracking speed of the improved P&O tracking is close to a large step, the step length gradually decreases when it reaches a steady state, and finally stabilizes, and the steady-state oscillation approaches the effect of a small step. On the whole, the system combines the advantages of large steps and small steps. So it can effectively avoids the shortcomings of the two, and effectively improves the overall efficiency of the photovoltaic system using the disturbance observation method.

3. Analysis of examples
In order to verify the effectiveness and superiority of the improved variable-step perturbation observation method, based on Matlab/Simulink simulation software, the above-mentioned traditional P&O method and variable-step P&O method were respectively constructed as shown in ‘figure 5’, which is based on the boost circuit simulation model. Then, under the conditions of maintaining the environmental parameters of temperature 25°C and light intensity of 500W/m² unchanged, the simulation results of the improved front and back perturbation observation methods (step size is 0.03 and 0.003) are shown in ‘figure 6’.
Automatic variable-step P&O method for maximum power tracking simulation, as shown in Figure 6: (1) Variable step length in climbing the time spent in the first half and the fixed step length 0.03 is almost the same, but in the latter half due to close to the maximum power point so the step length automatically decreases. So that the tracking speed is reduced, the total length of time is greater than the 0.03 step size, but it is still much less than the tracking time of the small step of 0.003. (2) After the steady state is reached, the oscillation amplitude of the step power at this time is basically the same as the small step size of 0.003, but it is obviously smaller than the power oscillation amplitude of 0.03 step size.

After data analysis, it can be seen from ‘table 1’ that when the step size of the traditional perturbation observation method is increased by 10 times, the tracking speed is increased by about 3.2 times, but the steady-state oscillation rate is also increased by about 8.8 times; the variable step size perturbation observation method The tracking speed is 62.3% faster than the small step perturbation, 19.4% slower than the large step perturbation, and the steady-state oscillation rate is 74.9% smaller than the small step perturbation. It is 97.1% smaller than large step disturbance.
Table 1. Simulation data analysis.

| Step size          | Steady-state time (s) | Steady-state minimum power (W) | Steady-state oscillation rate (%) |
|--------------------|-----------------------|-------------------------------|----------------------------------|
| 0.003              | 0.114                 | 190.7                         | 189.1                            | 0.839                           |
| 0.03               | 0.036                 | 190.6                         | 176.5                            | 7.398                           |
| variable step size | 0.043                 | 190.8                         | 190.4                            | 0.210                           |

It can be seen that the variable step-rate perturbation is obviously superior to the single-step-long traditional perturbation observation method in comprehensive performance, and can better solve the shortcomings in speed and steady-state power oscillation.

4. Conclusion

Based on the establishment of the photovoltaic cell model, this paper analyzes the advantages and disadvantages of the traditional perturbation observation method. And it proposes an improved perturbation observation method with automatic variable step size. Then an improved MPPT simulation module is built by the relationship between the expected step change and the power change. Finally, the feasibility of the improvement is verified by simulation. The method has fast response speed and stability. On the basis of the original solar cell manufacturing process and the premise of the original system cost, this paper maximizes the utilization of solar energy, effectively solves the problem of low conversion efficiency of the photovoltaic system and achieves the goal of full use of solar energy. This method has obvious economic value and social significance.

References

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