A Modified Perturb and Observe Algorithm in Photovoltaic Maximum Power Point Tracking System

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Abstract: The power output of the photovoltaic (PV) array is nonlinear, and maximum power point tracking (MPPT) is required to boost the efficiency of solar energy generation. The traditional perturb and observe algorithm is frequently used, but it is difficult to comprehensively consider the tracking accuracy and response speed at the same time. Misjudgment occurs when the solar insolation changes drastically. In view of these shortcomings, this paper presents a variable step size threshold search algorithm. The modified algorithm can quickly track the maximum power point and restrain fluctuations near the maximum power point. Matlab is utilized to simulate and prove the effectiveness of this modified algorithm.

Keywords: Photovoltaic array, Maximum power point tracking, Perturb and observe, Variable step size.

1. INTRODUCTION

In today's society of science & technology and rapid economic development, the efficient use of energy and the issue of environmental protection are becoming prominent. As an extensively distributed clean renewable energy, solar energy has broad application prospects. However, the output characteristics of photovoltaic cells are nonlinear due to the influence of insolation, ambient temperature, etc [1]. For the sake to solve this practical problem, it is necessary to track the maximum power point during photovoltaic power generation.

At present, the algorithms of maximum power point tracking mainly include: perturb and observe algorithm, conductance incremental algorithm, fuzzy control algorithm, etc. Perturb and observe algorithm is frequently utilized in practice because it is simple to control or does not require high sensor accuracy. However, the traditional perturb and observe algorithm always oscillates next to the maximum power point, meanwhile the step size is difficult to choose, and the misjudgment will occur when the external environmental conditions change rapidly.

A variable step size threshold search method is presented in the paper, to overcome the perturbation caused by the drastic changes of the external environment on the basis of the traditional perturb and observe algorithm. In addition, the modeling and maximum power point tracking strategies for photovoltaic power generation was established under the Matlab/Simulink platform, and the rationality of the algorithm was validated by simulation.

2. PHOTOVOLTAIC CELL MODELS AND CHARACTERISTICS

Photovoltaic cell is a device that can converts sun's radiant energy into electrical energy directly, and its working principle is mainly the photoelectric effect of semiconductors. That is, when sunlight shines on the P-N semiconductor junction, a new electron-hole pair is created. And under the action of the P-N junction electric field, the holes flow from the P region to the N region, meanwhile the electrons flow from the N region to the P region, and a current is created when the circuit is turned on [2, 3].

When the insolation is constant, the photovoltaic cell can be regarded as a constant current source that can stably produce photocurrent I_{ph}. Under ideal conditions, R_{s} is small and negligible, while R_{sh} is big. The equivalent model for volt batteries is shown in Figure **1** [4].

From the above figure, it is shown below the mathematical model of photovoltaic cells could be obtained by:

$$I = I_{ph} - I_d - I_{sh} = I_{ph} - I_{sat}\left\{\exp\left[\frac{q}{nkT}\left(U + IR_s\right)\right] - 1\right\} - \frac{U + IR_s}{R_{sh}} \quad (1)$$

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E-ISSN: 2410-2199/24

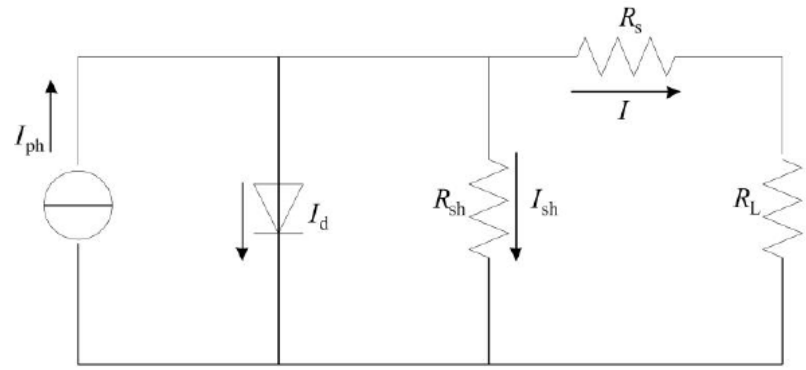

Figure 1: The equivalent circuit for photovoltaic cell.

The volt-ampere characteristics curve for the photovoltaic cell could be obtained from above equation (1), as shown in Figure **2**.

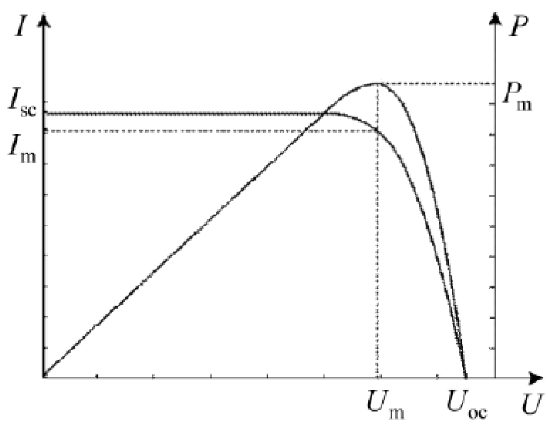

Figure 2: The volt-ampere characteristic curve of photovoltaic arrays.

3. THE BASIC PRINCIPLES OF THE PERTURB AND OBSERVE ALGORITHM

The perturb and observe algorithm is a frequently used algorithm in engineering practice [5]. Its working principle is: first let the photovoltaic cell work at a given working point, and then periodically decrease and increase the voltage and current output (*i.e.*, perturbation), and detect the real-time change trend of the power output from the photovoltaic cell while perturbing. Compare the values before and after the perturbation to determine who will be adjusted for the next cycle. Through this way, the maximum power point for the photovoltaic cell is constantly approached. The traditional perturb and observe algorithm control system has a simple structure and does not require high sensor accuracy, which is easy to implement [6].

However, the perturb and observe algorithm will oscillate back and forth near the maximum power point, causing a partial loss of power. At the same time, the choice of perturbation step size is a difficult problem, can not meet the system response speed and tracking accuracy at the same time. The big step size can accelerate to make response speed faster, but at the expense of tracking accuracy, and can cause oscillation. However small step size, the tracking accuracy in the steady state is increased but sacrifices the response speed. In addition, when the environmental conditions change drastically, there will be the phenomenon of misjudgment, and finally the tracking deviates more and more from the maximum power point.

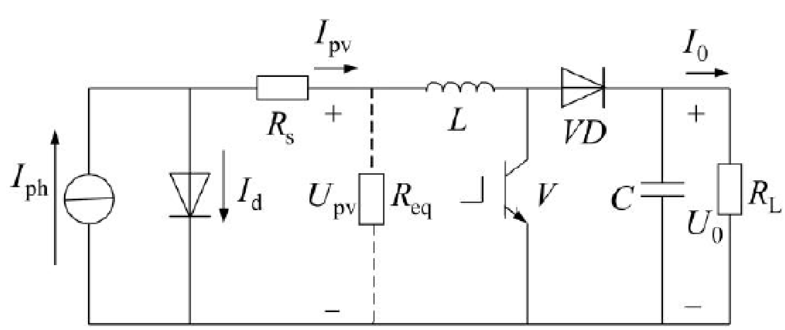

Figure 3: The MPPT implementation circuit.

4. MODIFIED VARIABLE STEP SIZE THRESHOLD SEARCH

The current output from the Boost converter is continuous, smooth, and has little ripple, so the Boost converter was chosen as the implementation circuit for MPPT, and the connection is shown in Figure **3**. By adjusting the duty cycle ratio of this DC/DC converter switch, the output impedance and the load impedance are matched. So that this system is always operating at its best state and providing maximum power to the load.

For a photovoltaic power generation, the method of MPPT adopted in the paper is a modified variable step size threshold search method based on the traditional fixed step size. From the photovoltaic characteristic curve, it is easily to see that the power output ΔP is variable when the perturbation ΔU is constant. When closer it is near the maximum power point, smaller the ΔP becomes. Whereas farther away from the maximum power point, greater the ΔP becomes. If the sampling interval is short enough, $|\Delta P/\Delta U|$ can be thought of as the slope of the curve. $\Delta P/\Delta U$ is constantly changing in real time. The variable step size is M times as large as $|\Delta P/\Delta U|$, and M is an adjustment factor for the step size. The formula of variable step size is as follows:

$$\Delta\lambda = M \times \left|\frac{\Delta P}{\Delta U}\right| \tag{2}$$

Large step size could improve tracking speed, while small step size could increase tracking accuracy. MPPT control is performed by changing the size of the duty cycle ratio according to the change of the power output. Finally, a threshold δ is set, and when the output power changes less than the δ, this system can be regarded as being at the maximum power point in the current environment. The control flow diagram of the system can be observed from Figure **4**.

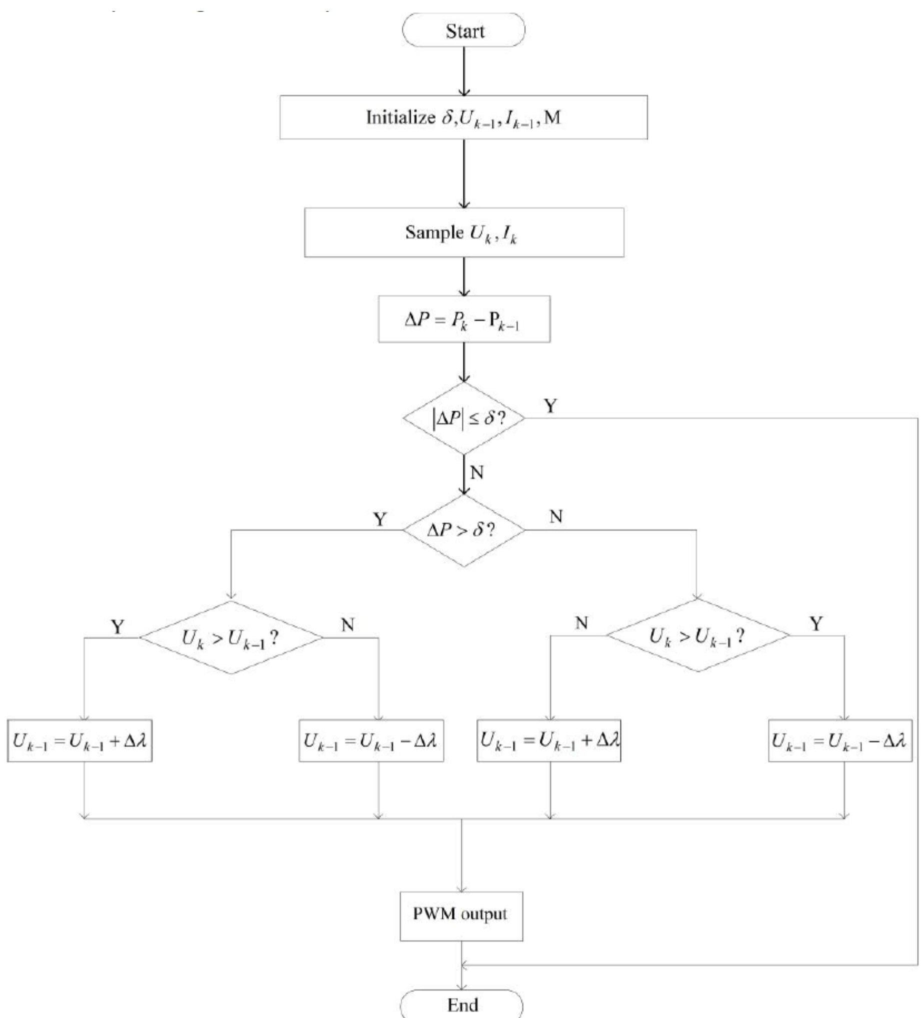

Figure 4: The control flow chart of improved perturbation method.

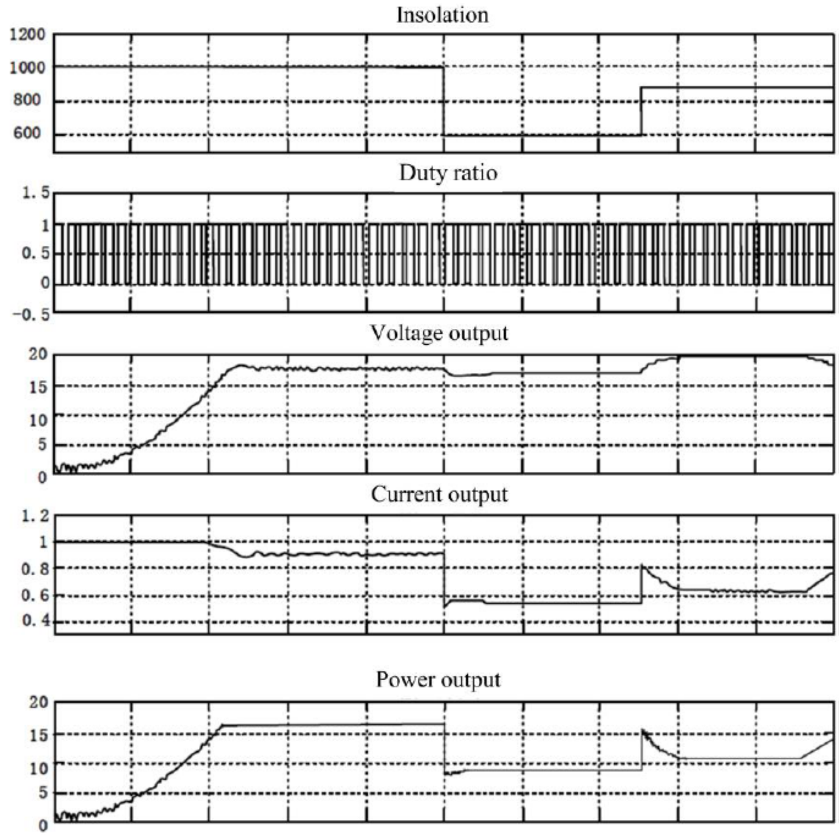

Figure 5: The simulation results.

5. SIMULATION RESULT AND ANALYSIS

For the sake to verify the effectiveness and correctness of the variable step size threshold search method, this paper uses Matlab to establish a system model, and selects the Boost circuit as the DC/DC converter of the model. On Figure **5** shows the simulation results of the system. It can be observed that under the condition that the external environment temperature remains unchanged, when the insolation changes abruptly, in this system the oscillation of the voltage output is very small. And then quickly returns to a stable state, which can quickly identify the changes in the external environment, to adjust the operating state in time. Effectively reduce the oscillation next to this maximum power point, and ensure the maximum power output of the system.

6. CONCLUSION

In view of the shortcomings of the traditional perturb and observe algorithm, this paper proposes a new MPPT algorithm variable step threshold search method, which can effectively avoid oscillation next to this maximum power point. Through simulation, it could be validated that the modified algorithm has the advantage of good static stability, fast dynamic response speed and strong antiperturbation capability, which solves the problem of the maximum power point tracking in the photovoltaic system to some extent.

ACKNOWLEDGMENT

The study is supported by general program of Langfang municipal level science & technology project code number 2023011050.

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Received on 04-04-2024 Accepted on 07-05-2024 Published on 11-05-2024

DOI: https://doi.org/10.31875/2410-2199.2024.11.03