Maximum Power Point Tracking Control Based on Variable Step Size Perturbation Observation Method

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Abstract

In the whole life cycle of the evaluation, construction, grid connection, operation and maintenance and sale of power plant projects, the calculation of power generation with artificial intelligence technology as the core is the top priority. Maximum power points tracking techniques are widely utilized in photovoltaic systems to operate at the peak power of PV array which depends on solar and ambient temperature. the perturbation observation method algorithm is the most applied maximum power point tracking control scheme in photovoltaic applications for its simplicity and ease of implementation. But conventional perturbation and observation method suffers from steady state oscillations. To avoid this, this paper emphasizes on a variable step perturbation and observation which can able to track the maximum power point rapidly with less steady state oscillation as compared with conventional perturbation and observation algorithm. The efficacy of the proposed method is verified considering both simulation and experimental results by modelling.

Keywords: *Maximum Power Point Tracking, Variable Step Size Perturbation Observation, Hybrid PV-Battery System*

1 INTRODUCTION

Renewable energy-based solar photovoltaic (PV) generation is the best alternative for conventional energy sources because of its natural abundance and environment friendly characteristics. Therefore, it has been widely used in various battery charging systems, household appliances, satellites, and other fields.

However, the problem of high investment cost and low efficiency of photovoltaic power generation is the main bottleneck restricting the development of photovoltaic power generation industry, thus, in the process of photovoltaic power generation application, how to improve the utilization efficiency of solar energy has become a prominent problem in photovoltaic power generation system, in which the maximum power point tracking (MPPT) technology is one of the keys in photovoltaic conversion technology. Since the I-V characteristic of the PV module changes with irradiation and temperature, the MPP also changes. Therefore, it is difficult for the PV module to operate at MPP under different weather conditions [1]

MPPT should be designed in such a manner that it should extract maximum power accurately and quickly with less steady state oscillations. Among all classical MPPT controller perturbation and observation (P&O) is a simple and effective controller which is most popularly used. But the major problem with the conventional P&O MPPT is that it suffers from steady state oscillations and is sluggish in nature. To overcome this many improvised P&O MPPT algorithms have been designed. [1]

2 MODELING PHOTOVOLTAIC CELLS

Photovoltaic cell is a kind of photoelectric semiconductor sheet that directly converts light energy into electric energy through photoelectric effect, with crystal silicon solar cell as the main stream. Once there is direct illumination of light, photovoltaic cell will immediately generate voltage and current in the circumstance.

Photovoltaic cells are commonly used to describe their internal structure as shown in the equivalent circuit diagram of Figure 1. As shown in the figure 1, there are four currents, I_{ph}, I_d, I_{sh} and I. I_{ph} is the photovoltaic

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current, in which the photo-generates current when the photovoltaic cell receives light, which can be changed by external factors. According to the application of KCL in equivalent circuit, I_{ph} is divided into three parts, the larger proportion is load current I; The current of the remaining two parts, part of which I_d is the current flowing through the equivalent diode, has a small value. The other part is the current in the resistor R_{sh} of the equivalent circuit, because of its high resistance value, the current I_{sh} in the resistor R_{sh} is also small. Therefore, the current output from the equivalent circuit to the load accounts for a major portion of the photo-generated current I_{ph}.

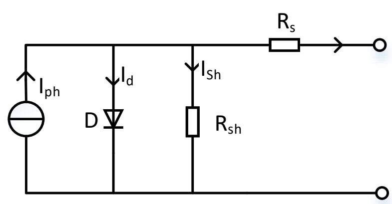

Figure 1 Photovoltaic cell equivalent circuit

Through the equivalent circuit model of photovoltaic cell, the output current of the photovoltaic panel can be listed like eq. (1)-(4) [6]

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

$$I_d = I_0 \left\{ exp\left[\frac{q(V+IR_S)}{AKT}\right] - 1 \right\} \quad (2)$$

$$I_{sh} = \frac{V+IR_S}{R_{sh}} \quad (3)$$

$$I = I_{ph} - I_0 \left\{ exp\left[\frac{q(V+IR_S)}{AKT}\right] - 1 \right\} - \frac{V+IR_S}{R_{sh}} \quad (4)$$

In these formulas, I represent the output current of photovoltaic cell, I_{ph} is the photo-generated current, which is determined by light intensity, contact area and its own temperature. The specific gravity of I_d and I_{sh} is small. I_0 [2] represents the reverse saturated current of the diode (it typically takes 104A as the order of magnitude); A is a constant called the ideal factor of P-N junction and T is the absolute temperature. Q is the electronic charge equals 1.6×10-19coulombs, K is Boltzmann constant equals 1.38×10-18erg/K.

The voltage and power are obvious non-linear changes in figure 2. It is not difficult to obtain such results by comparing the voltage and current in the I-U curve.

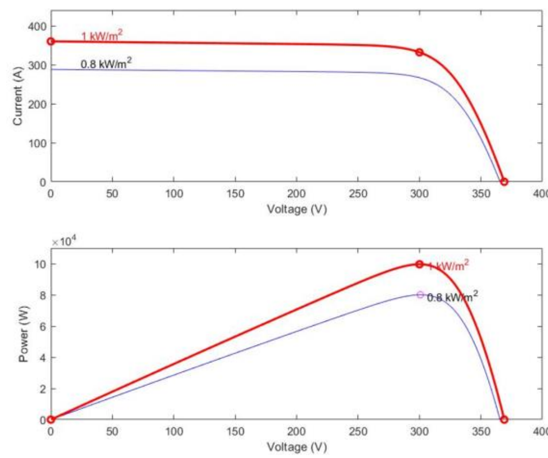

Figure 2 The characteristic curve of photovoltaic cell

The I-U curve gives the process in which I changes with U. Although U does not affect current at first, when the voltage increases to 300V, a sudden decrease in current occurs and the output P decreases sharply. During this change, the P-U relationship has a peak value. It can be seen from the P-U curve that the output P will gradually increase with the change of U, but it will start to decrease substantially after U reaches 300V.

3 VARIABLE STEP SIZE PERTURBATION OBSERVATION ALGORITHM

MPPT algorithm actually makes the system operate stably at the maximum power point, but the maximum power is not a fixed value, it will change with the changes of surrounding environment or other factors. Therefore, when the maximum power point changes, how to continuously find the maximum power point of the power generation system has become the focus to improve the efficiency of the whole system and reduce the cost.

At present, in engineering practice, it is through the maximum power point of solar photovoltaic power generation. Tracking to improve the power generation efficiency of photovoltaic power generation systems. Commonly used MPPT methods are constant voltage control method, the P&O method and conductivity increment method [3].

The P&O is based on whether the system is operating at the maximum power point, if it is not, the step size is adjusted to keep the operating point is constantly close to the maximum power point. It can be seen that when the output working point of the photovoltaic cell is in the left half of the maximum power point, $\frac{dP}{dV}>0$; In the right half, $\frac{dP}{dV}<0$; At the peak point, $\frac{dP}{dV}=0$. However, performances of the P&O are dependent on the tracking step-size; the larger step-size is, the better the speed of tracking response will be, but a larger step-size selection results in oscillations at steady state. [4] It must be pointed out that it is difficult to set the step size by comprehensively considering the tracking accuracy and corresponding speed.

Variable step size P&O has the advantages like simple control, few parameters and easy implementation. Its control idea is: when the operating point of the system is far from the maximum power point, it adopts a larger step size, which can make the operating point quickly approach the maximum power point, and in the process of approaching, the step size of disturbance will be reduced accordingly. This method ensures not only the response speed, but also the tracking accuracy, and it is worth mentioning that variable step size P&O method reduces the energy loss caused by oscillation at the maximum power point, and thus greatly improves the efficiency.

An adjustment is added to the system in this paper to optimize the change in step size, the perturbation step size of the system is no longer a fixed stride size or small step size, but changes with the distance between the operating point and the maximum power point and the change of the external environment so as to satisfy the system simultaneously dynamic steady-state characteristics of the system [5]. The mathematical model is shown in Eq. (5)

$$\alpha(k+1) = \frac{|dP|}{\alpha(k)} \tag{5}$$

α(k) is the adjustment step of interference voltage U, which varies between 0 and 1; dP/α(k) is the change value of power; when the value of dP/α(k) is small, it can be considered that the change of P is mainly caused by adjusting step size D. The next step size α(k+1) is very small, which avoids oscillation at the maximum power point. When the value of dP/α(k) is large, it can be considered that the change of P is mainly caused by environmental factors. As long as the step size α(k+1) is increased, another new maximum power point can be quickly tracked [5].

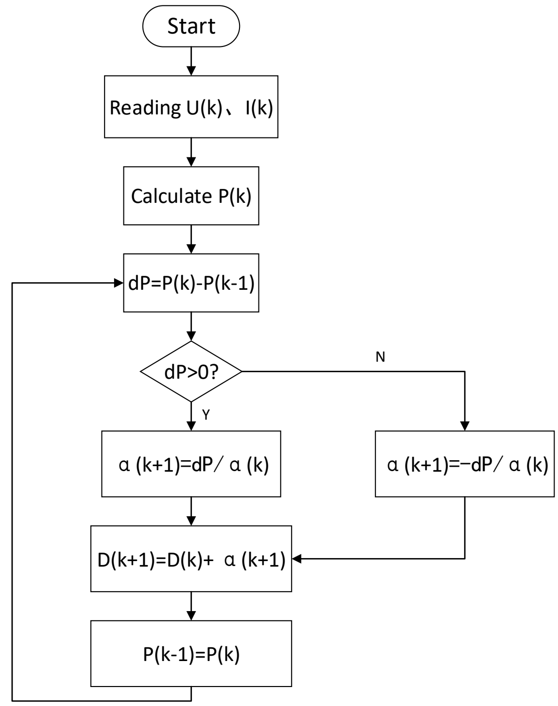

Figure 3 Flow chart of Variable step size perturbation observation method

4 VERIFICATION OF MPPT

The model of variable step size P&O was set up in Simulink in figure 4-5.

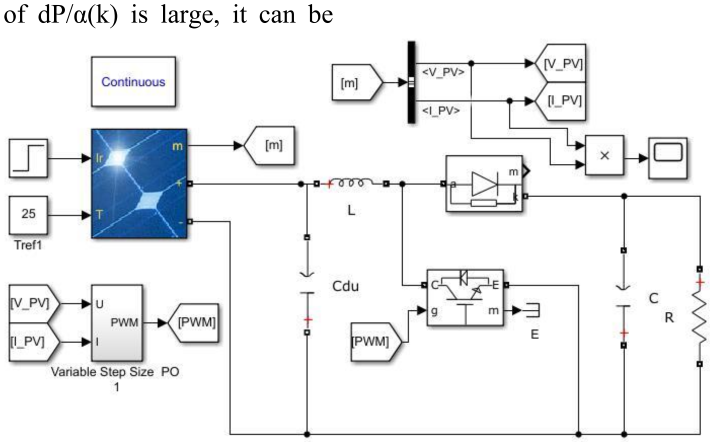

Figure 4: Model of variable step size P&O

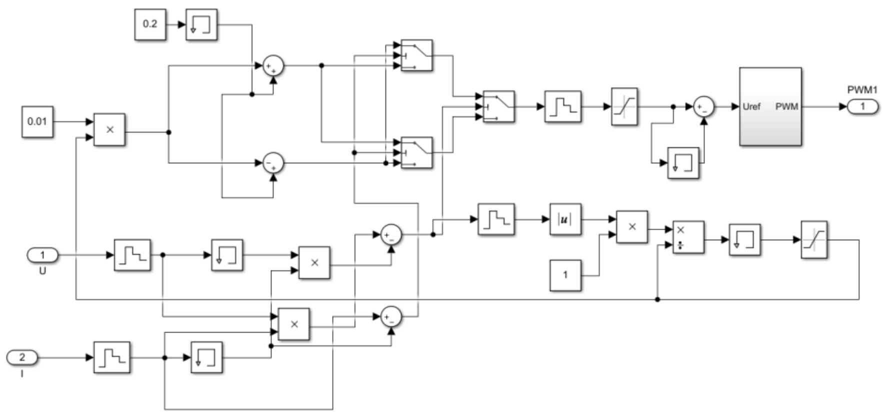

Figure5: PWM model

The performance index of the system was judged by the speed and accuracy of detection. The simulation results are shown in figure 6-7.

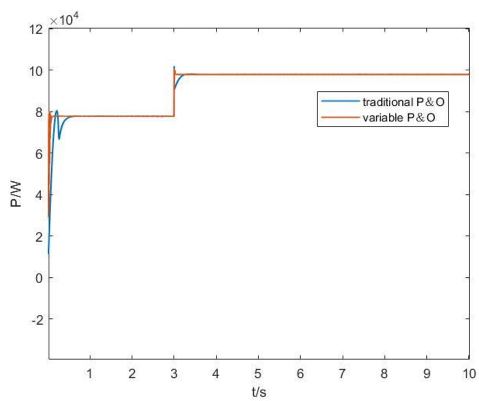

Figure 6: PV power output curve when the light intensity changes

Figure 6 shows the PV power output curve when the light intensity changes, the initial condition is that the light intensity is 800W/m^2, then jumps to 1000W/m^2 in the third second, and the temperature is set at 25℃. It can be seen that when the light intensity is 800W/m^2, the variable step size P&O spends 0.1s, while the traditional P&O uses 0.6s, to track the maximum power point and runs stably at this point. When the light intensity changed to 1000W/m^2, the variable step size P&O spends 0.05s to achieve the new maximum power point, and the traditional P&O uses 0.6s.

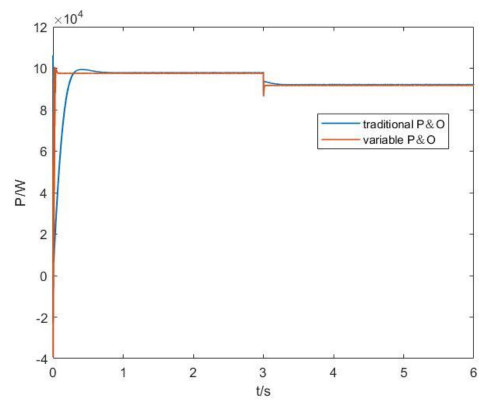

Figure 7: PV power output curve when the temperature changes

Figure 7 shows the PV power output curve when the temperature changes, the initial condition is that the temperature is 25℃, then jumps to 35℃in the third second, and the temperature is set at 1000W/m^2. It can be seen when the temperature is 25℃the variable step size P&O spends 0.05s, while the traditional P&O uses 0.8s, to track the maximum power point and runs stably at this point. When the temperature changed to 35℃, the variable step size P&O spends 0.025s to achieve the new maximum power point, and the traditional P&O uses 0.3s.

This result illustrates the variable step size P&O method can track the maximum power point faster than the traditional P&O-MPPT, with shorter time-consuming and higher efficiency, and make up for the shortage of oscillation when the traditional one tracks the maximum power point.

5 CONCLUSION

Aiming at the problems existing in the traditional perturbation observation method, a variable step size P&O is proposed. In addition, a simple step size decision is added to the variable step size P&O, which can solve the velocity problem earlier. The traditional and Variable step size P&O are simulated by MATLAB/Simulink. Simulation results show that the proposed method can quickly track the maximum power point under rapidly varying irradiance, and it achieves higher output power than the traditional P&O.

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