Adaptive Perturb & Observe MPPT Algorithm of PV Array Based on Hysteresis Comparison

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Abstract

The perturbation and observation (P&O) method has a very broad application in MPPT control of PV system because of its simple structure. Aimed to oscillation and misjudgment phenomenon of the (P&O) method, this paper presents a new adaptive perturb & observe MPPT algorithm based on hysteresis comparison in order to improve the output efficiency of PV generation system. Using the software Matlab/Simulink, a model of PV generation system with MPPT control based on adaptive perturbation and observation method is obtained. The MPPT control is realized by means of Matlab simulation.

Keywords

PV array; perturbation and observation (P&O) method; hysteresis comparison

1. The output characteristics of photovoltaic cells

Photovoltaic cell is a component that can convert solar energy into electricity via the photovoltaic effect. Its output characteristic mainly depends on three factors[1]: light intensity G,cell temperature T,load resistance R. Using the software Matlab/Simulink, a model of PV generation system that can reflect its output characteristics is obtained. The output characteristics are shown in Fig.1,and U_{oc}=22.5V,$I_{sc} = 4.3A$,$U_m = 18.75V$,$I_m = 3.9A$,P_m=73. 125W.

In the same temperature, the higher is the irradiance, the bigger is the output current, and the output power increased gradually. As the temperature is increased, the output voltage and maximum power point decrease gradually in the same irradiance [2].

At a particular load impedance, photovoltaic cells reached the maximum output power that is known as the maximum power point. Traditional PV system with MPPT control is achieved by connecting the DC/DC circuit which is generally for the Boost circuit. Its output voltage is given by $U_o = U_d(1 - D)$.In order to realize MPPT control of photovoltaic system, the equivalent input impedance matches the photovoltaic output impedance by changing the duty ratio D of the circuit.

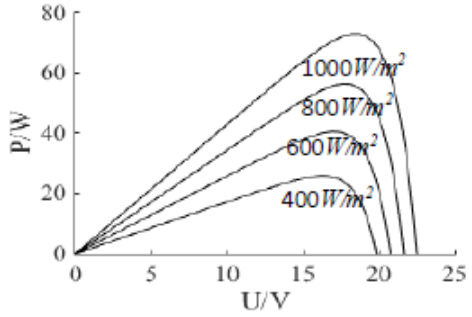
2. Traditional perturbation and observation(P&O) method

The perturbation and observation (P&O) method has a very broad application in MPPT control of PV system because of its simple structure. Increasing or reducing the output voltage of PV array produces interference every once in a while, then the measured values of the power change judge output voltage adjustment direction of the next period of time. If $\Delta P > 0$, voltage adjustment direction remains the same; and if $\Delta P < 0$, voltage adjustment direction need to have the Invert adjustment. In the process of application, the P&O method has two major defects.

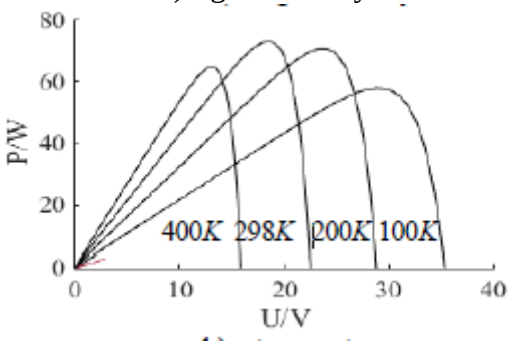
(1) oscillation phenomenon: When the system completes the search to reach the MPP point, the working point of photovoltaic cells will have continuous oscillation near the P_{max} , which causes energy loss as shown in figure 2a. Assuming that the current working point is P_1, the output voltage $U_1 = U_4 + \Delta U$,and $P_1 > P_4$, the working point is in the left side of P_{max}, and then the system don't change the direction of the disturbance. When voltage increases to $U_2 = U_1 + \Delta U$, the working point

will be in the right side of P_{max}. If $P_2 < P_1$, the direction of the disturbance will be changed and $U_3(U_1) = U_2 - \Delta U$. Assuming that light intensity and temperature remain the same, and the power $P_3 = P_1 > P_2$,continuing to reduce voltage to U_4 and $P_4 < P_3$ will make system re-adjust the direction of the disturbance.

(2) misjudgment phenomenon: In Fig.2b, increasing the reference voltage to $U_2 = U_1 + \Delta U$ and the working power point is P_2 ($P_2 > P_1$), if the system working point P_1 in light intensity under the condition of a. The direction of reference voltage will remain the same. If light intensity decreases suddenly from a to b, the actual working point corresponding to U_2 is P_2', and $P_2' < P_1$.The P&O method will produce a misjudgment and change the direction of the disturbance.

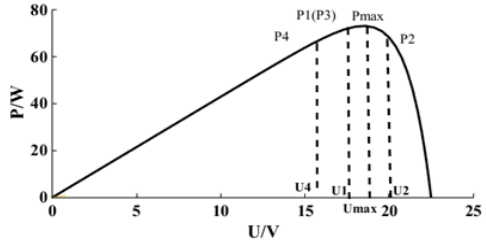


a) light intensity

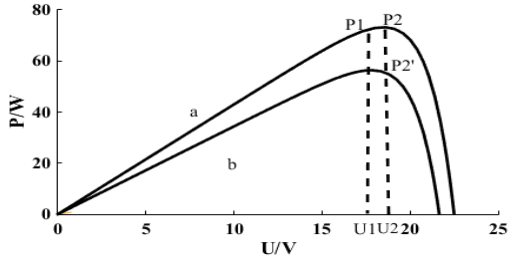


b) temperature

Fig.1 The output characteristics of photovoltaic cells with the change of light intensity and temperature



a) oscillation phenomenon



b) misjudgment phenomenon

Fig.2 oscillation and misjudgment phenomenon of the P&O method

3. The adaptive P&O method based on hysteresis comparison

The oscillation and misjudgment phenomenon of the P&O method in the process of application cause energy loss of the PV system. The hysteresis comparison can restrain effectively oscillation phenomenon, and misjudgment phenomenon can be seen as a dynamic oscillation process under the condition of the external environment of rapid change.

Assuming that the current working point makes a disturbance to the point B according to the judgement of perturbation direction, and then makes a disturbance from B to C in reverse(the power point corresponding to A, B, C is the point P_A, P_B, P_C),some comparison results of the power value are as shown in Figure 3.When the initial flag bit $t = 0$,$P_A > P_C$,it will be marked as "+",$t = t + 1$,or "-",$t = t - 1$;when $P_B \geq P_A$, it will be marked as "+",$t = t + 1$,or "-",$t = t - 1$. Because the essence of MPPT is that the system changes the duty ratio of the Boost circuit by changing voltage. This paper sets up the duty ratio as a direct disturbance quantity. The initial flag bit t has 3 kinds of possible values, and it gets the disturbance rules: 1) when $t = 2$,the direction of the disturbance will be not changed; 2) when $t = -2$, the direction of the disturbance will be changed in reverse .3) when $t = 0$, it shows that the external environment changes quickly or the system reaches the MPP point, so the duty ratio will be the same.

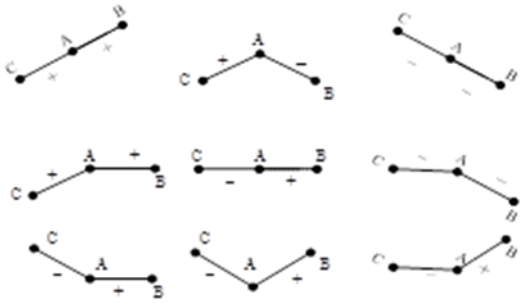


Fig.3 The comparison diagram of 3 power points

Usually, the search step length of the hysteresis comparison has a great influence on the speed and accuracy of the MPPT control. If the search step length is too big, the working point will be stay away from the MPP point for a long time. When the system starts having a search, the search time will increase because of small step length.

Therefore, the hysteresis comparison method of fixed step in the MPPT control is difficult to meet the requirements on the speed and accuracy at the same time.

This paper adopts the way of duty ratio perturbation, and introduces the adaptive strategy. The system changes the search step length constantly in the process of perturbation. According to the P-V characteristics of photovoltaic cells, the absolute value of the slope $k = dP/dU$ reduces gradually when the working point approaches the MPP point. The absolute value at the MPP point is 0. Therefore, the system can change the search step length constantly according to the characteristic. Assuming that $\Delta D = -d * (\frac{dP}{dU})$, speed factor of variable step length d,search step length will increase when the working point stay away from the MPP point, whereas the step length will decrease. In order to avoid that the step length is too big or too small, it needs to set boundary value. If $|\Delta D| \leq \Delta D_{max}$ and $|\Delta D| > \Delta D_{max}$, $\Delta D = -\text{sign}\left(\frac{dP}{dU}\right) * \Delta D_{max}$ .The algorithm process of adaptive perturbation and observation method is as shown in Figure 4.

4. Simulation analysis

There is a model of PV system with MPPT control based on adaptive perturbation and observation method under the software Matlab/Simulink. In Fig.5, $C_1 = 100\mu F$,$L = 4mH$,$C_2 = 400uF$,$R_L =$

20Ω,and the PV array is controlled by the P&O method, the hysteresis comparison method and the adaptive hysteresis comparison method. The simulation results are as shown in Figure 6.

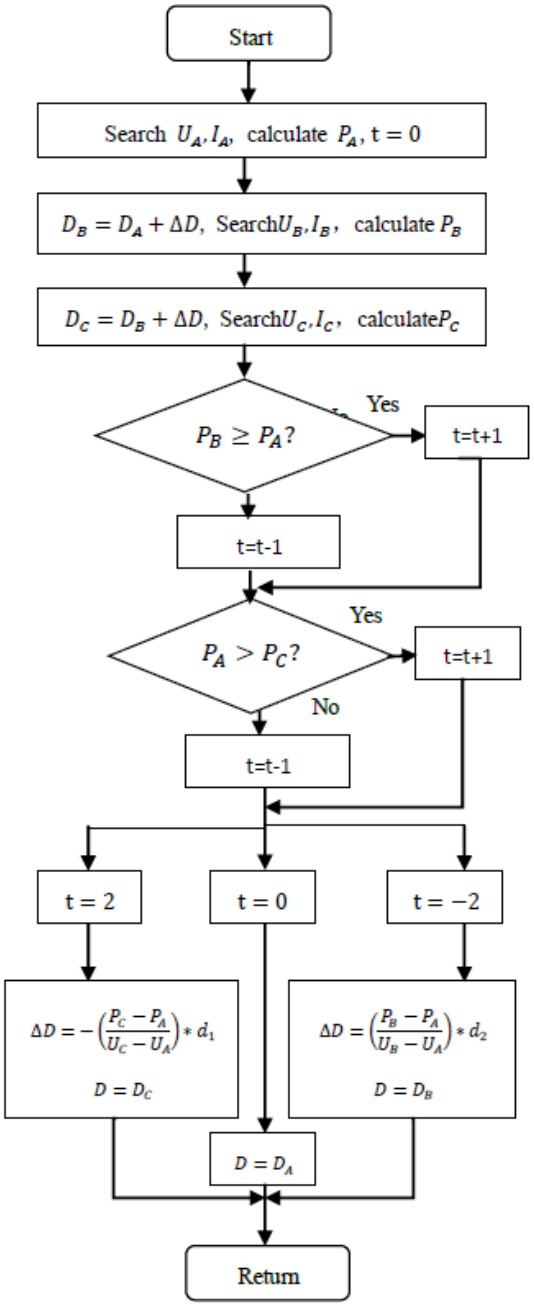


Fig.4 The flow chart of adaptive hysteresis comparison method

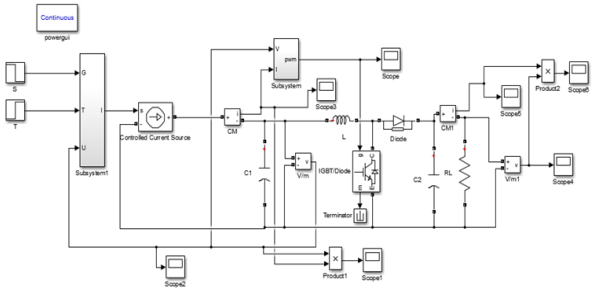
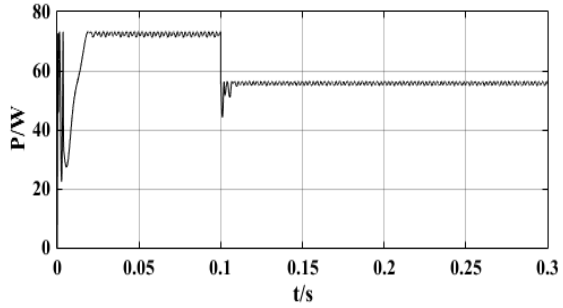
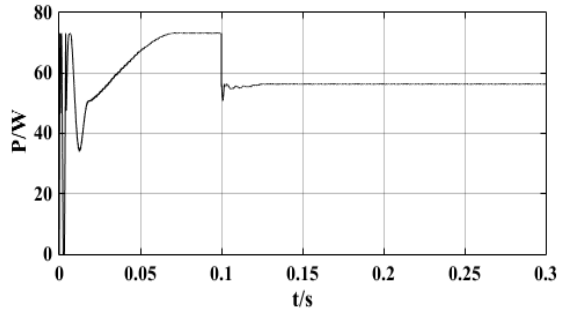


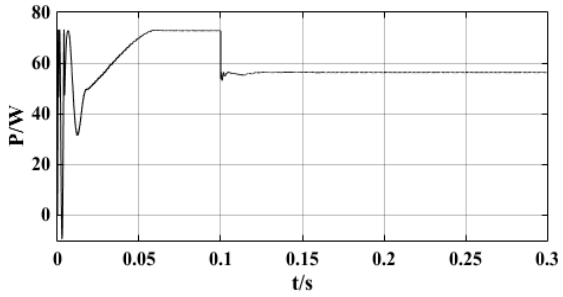
Fig.5 The model of PV system with MPPT control



a) the P&O method



b) the hysteresis comparison method



c) the adaptive hysteresis comparison method

Fig.6 The simulation results of three algorithms

In Fig.6 (a), PV array adopts the P&O method that its search step length is 0.003 and its initial duty ratio is 0.1.There is a sudden decrease in irradiance from 1000W/m^2 to 800W/m^2 at 0.1s. The simulation result shows that the system reaches the MPP point at 0.02s and has continuous oscillation for some time, but the P&O method produces misjudgment. Fig.6 (b) shows tracking of MPP for the hysteresis comparison method for sudden decrease in irradiance. On account of the feature of bidirectional perturbation, the search time will increase if the step length of algorithms is used. Therefore the system search with 0.008 step length and its duty ratio D=0.3. At 0.065s, the system completes the search. Relative to the P&O method, the hysteresis comparison method's oscillation and misjudgment reduces significantly. Fig. 6(c) shows the simulation results of the adaptive hysteresis comparison method. The algorithm sets initial duty ratio as 0.3, and the picture shows that the system reach MPP at 0.057s and the oscillations around MPP are minimized. The misjudgment phenomenon at 0.1s is suppressed at the same time. Compared to conventional MPPT algorithms, performances of the adaptive hysteresis comparison method is superior.

5. Conclusion

This paper analyzes the output characteristic of the photovoltaic cells with changing temperature and light intensity. Meanwhile, there is some detailed analysis of the traditional perturbation and observation of oscillation and misjudgment phenomenon. A novel adaptive P&O method based on hysteresis comparison is proposed to track the maximum power point of PV system. The algorithm

adjusts the load impedance constantly by changing the duty ratio D directly. The adaptive hysteresis comparison method has not only simple structure, but also good performances.

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