

# An Improved Perturb and Observe Algorithm for Photovoltaic Motion Carriers

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**Abstract.** An improved perturbation and observation algorithm for photovoltaic motion carriers is proposed in this paper. The model of the proposed algorithm is given by using Lambert W function and tangent error method. Moreover, by using matlab and experiment of photovoltaic system, the tracking performance of the proposed algorithm is tested. And the results demonstrate that the improved algorithm has fast tracking speed and high efficiency. Furthermore, the energy conversion efficiency by the improved method has increased by nearly 8.2%.

## 1. Introduction

Photovoltaic (PV) generation system is one of the important renewable energy, which has been widely used in motion carriers such as UAV, bike sharing and internet of things[1]. However, the maximum power point of PV module changes with different solar irradiance and temperature [2]. Therefore, it is necessary to use the maximum power point tracking (MPPT) technique in PV system to obtain high power.

During the past decade, the method of maximum power point tracking technique has developed in a variety of directions, and the typical algorithms are as follows: fraction open circuit voltage/short circuit current [3], incremental conductance (IC) [4], artificial neural network (ANN) [5], perturb and observe (P&O) [6], particle swarm optimization (PSO) [7], genetic algorithm (GA) [8], teaching-learning based optimization (TLBO) [9], fuzzy logic controller (FLC) [10] and sliding-mode controller [11]. Moreover, in low cost practical PV system, perturb and observe is the most used in all these algorithms. However, conventional perturb and observe algorithm has two obvious drawbacks in the case of moving carriers. One is near the maximum power point of PV module, the operating point of PV system is forced to go back and forth around maximum power point[12], results in loss power. The other is that perturb and observe is easy to lose the direction, when the environment is varying [13]. Therefore, the traditional perturb and observe is not suitable for photovoltaic motion carriers.

To obtain high power of PV system, an improved perturbation and observation algorithm is proposed in this paper. The output characteristics of the proposed method are test in simulation and experiment. Moreover, it is found that the energy conversion efficiency of the proposed algorithm has increased by approximately 8.2%.



## 2. The proposed P&O Algorithm

According to the characteristics analysis of the conventional perturbation and observation algorithm [14], it is found that three parameters  $V_{pv}(0)$ ,  $\Delta V_{pv}$  and  $sig$  play a key role in perturbation and observation algorithm, which is depicted in Eq.(1).

$$V_{pv}(k+1) = V_{pv}(k) + sig \Delta V_{pv} \quad k=0,1,2 \dots \dots \quad (1)$$

$$\Delta sig = \frac{\Delta P_{pv}}{\Delta V_{pv}} = \frac{P_{pv}(k) - P_{pv}(k-1)}{V_{pv}(k) - V_{pv}(k-1)} \quad (2)$$

$$sig = \begin{cases} \Delta sig < 0, & -1 \\ \Delta sig > 0, & 1 \end{cases} \quad (3)$$

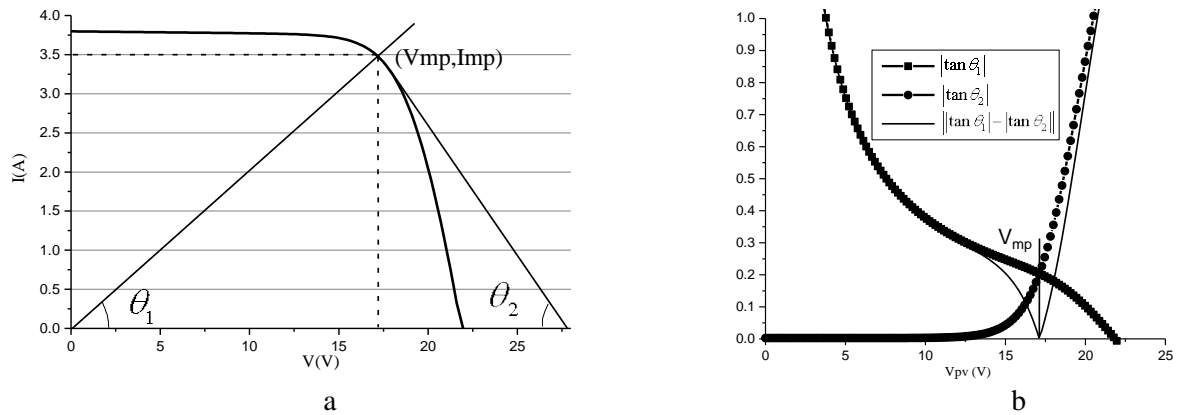
And the estimation of initial voltage  $V_{pv}(0)$  can be given by:

$$V_{pv}(0) = V_{oc,ref} - \left( \frac{n_s I_{sc,ref}}{m_p^2} + \frac{V_{oc,ref}}{m_p n_s R_{p,ref}} \right) R_{s,ref} - n_{ref} V_{th,ref} \ln \left( \frac{n_s n_{ref} V_{th,ref} + \frac{V_{oc,ref}}{n_s} - I_{mp,ref} R_{s,ref}}{n_s n_{ref} V_{th,ref}} \right) \quad (4)$$

The step size  $\Delta V_{pv}$  can be calculated by using tangent error method, as shown in Eq.(5), Eq.(6) and Fig.1.

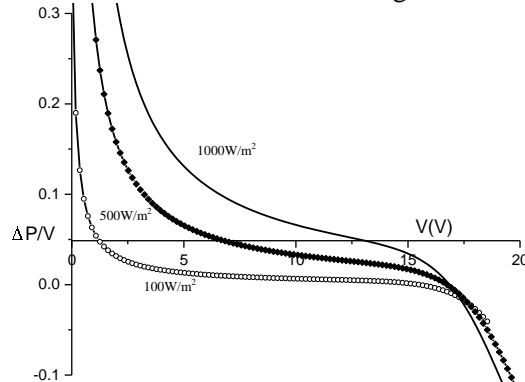
$$\Delta V_{pv}(k) = \beta \Delta V_{pv}(k-1) \quad (5)$$

$$\beta = \left| \tan \theta_1 \right| - \left| \tan \theta_2 \right| \quad (6)$$



**Fig. 1.** The method of  $\Delta V_{pv}$ .

a- the scheme of tangent error method, b- the absolute tangent error at standard test conditions



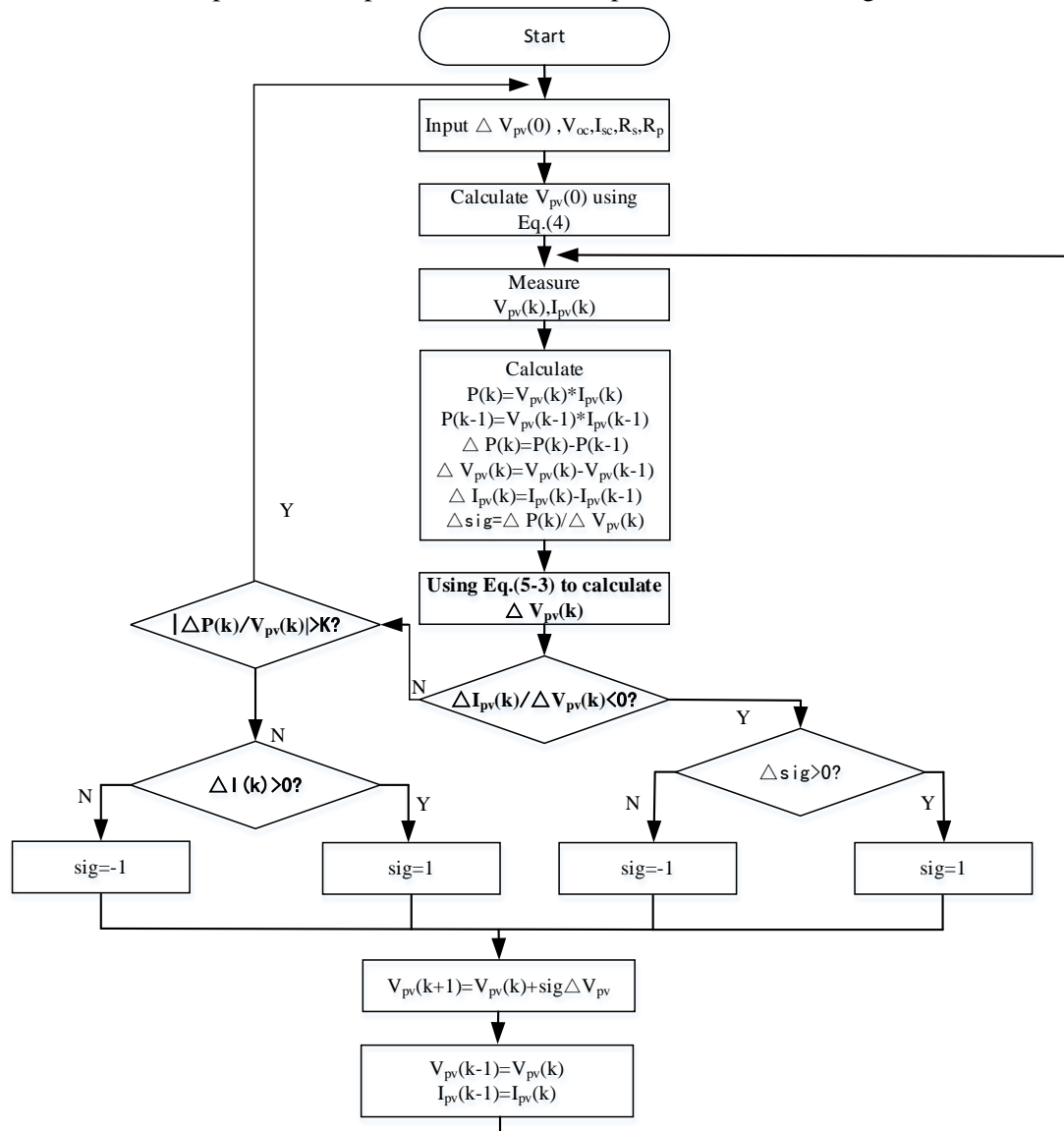
**Fig. 2.** The relationship of  $\Delta P_{pv} / V_{pv}$  under different irradiance levels.

By using Lambert W function [15], the disturbance power  $\Delta P$  can be given by:

$$\Delta P = \frac{Z_2 [R_p (I_L + I_o) - 2V_{mp}]}{R_s + R_p} - \frac{V_{mp} [R_p (I_L + I_o) - 2V_{mp}]}{R_s + R_p} - W \left[ \frac{R_s R_p I_o}{n(kT/q)(R_s + R_p)} \exp \left( \frac{R_p (R_s I_L + R_s I_o + V_{mp})}{n(kT/q)(R_s + R_p)} \right) \right] \quad (7)$$

$$\frac{n(kT/q)V_{mp}}{R_s} + \frac{n(kT/q)Z_2}{R_s} W \left[ \frac{R_s R_p I_o}{n(kT/q)(R_s + R_p)} \exp \left( \frac{R_p (R_s I_L + R_s I_o + Z_2)}{n(kT/q)(R_s + R_p)} \right) \right]$$

Where  $Z_1 = V_{mp} - U$ . According to the Eq.(7), it can be seen that when  $V_{pv}$  converges to the maximum power point,  $\Delta P_{pv}$  becomes very small. If  $V_{pv} = V_{mp}$ , then  $|\Delta P_{pv} / V_{mp}| = 0$ . Similarly, if  $K = |\Delta P_{pv} / V_{mp}|$  exceeds the threshold level  $K$ , it implies that the environment changes rapidly shown in Fig.2. Therefore, the direction of the perturbation and observation  $sig$  can be determined by the value  $\Delta P_{pv} / V_{mp}$ . In summary, the proposed algorithm for photovoltaic motion carriers is illustrated in Fig.3, in which the black boxes are added parts with respect to the traditional perturb and observe algorithm.



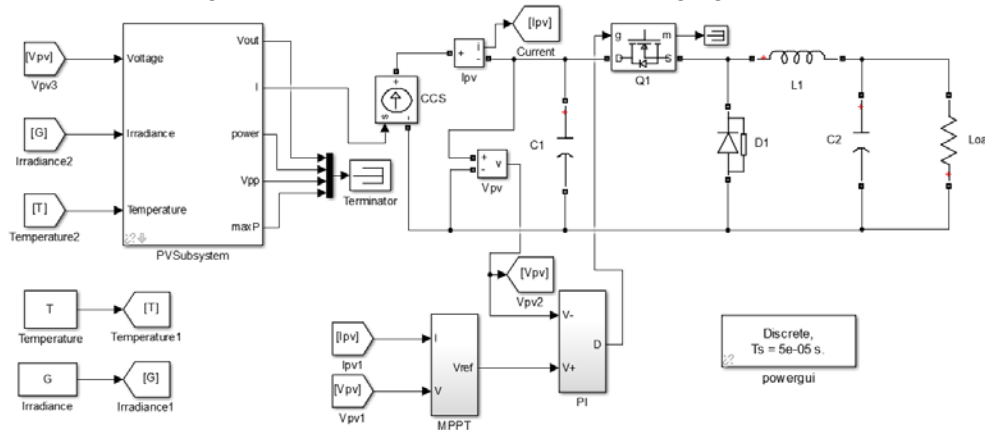
**Fig. 3.** Flow chart of proposed MPPT algorithm.

### 3. Results and Discussion

In this section, simulation and experimental results of the proposed MPPT algorithm are provided to validate the tracking performance in a common platform [16]. Fig.4 shows the simulation diagram of

photovoltaic motion carrier system. And the specifications for the PV system are listed in Table 1. Moreover, the simulation results with different methods of the PV system are depicted in Fig. 5. Besides, experimental results of PV system under varying environment is given in Fig. 6 and Table 2.

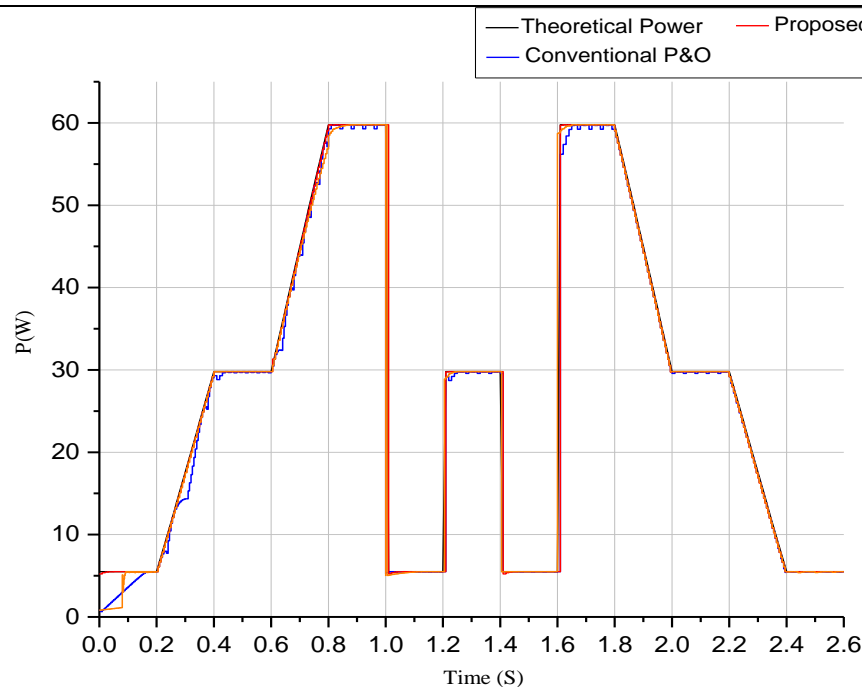
With the Fig. 5, it is easy to see that the proposed perturb and observe algorithm is closest to the theoretical values, which has perfect tracking effect. Compared with the traditional algorithm, it also can be concluded that the proposed method not only has low oscillating power at the stable condition, but also never loses its tracking direction under the fast and slow changing irradiance levels.



**Fig. 4.** Simulation diagram of PV system.

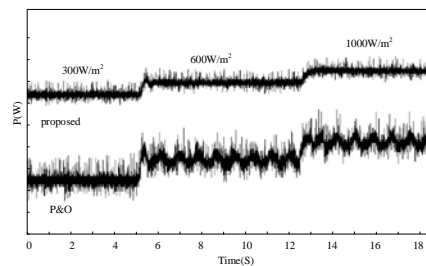
Table 1 Specifications for the PV system.

DC-DC converter				MPPT controller				
$L_1$ (mH)	$C_1$ ( $\mu$ F)	$C_2$ ( $\mu$ F)	$f$ (kHz)	$P$	$I$	$V_{pv}(0)$ (V)	$\Delta V_{pv}(0)$ (V)	$K$ (W/V)
2	470	1000	20	0.5	0.125	16.79	0.0012	0.14



**Fig. 5.** Simulation results of PV system with different methods.

Fig. 6 shows the experimental results obtained from prototype PV system under varying environment, with traditional perturb and observe and proposed method. It is easy to find that the proposed MPPT algorithm not only has higher efficiency but also has faster speed. Moreover, Table 2 reveals that the energy conversion efficiency by the improved method has increased by approximately 8.2%.



**Fig. 6.** Experimental results of PV system with different methods under varying environment.

Table 2 Output power under different irradiances

Item	Proposed			Conventional		
irradiance ( $\text{W/m}^2$ )	300	600	1000	300	600	1000
output power (W)	17.56	35.89	59.77	14.35	34.63	58.09
efficiency (%)	99.96	99.98	99.99	81.67	96.25	97.18

#### 4. Conclusions

This paper proposes an improved perturbation and observation algorithm for photovoltaic motion carriers. By using tangent error method and Lambert W function, a novel technique is proposed to improve the tracking speed and efficiency. Moreover, the tracking performance of the proposed method is evaluated by using simulation and experiment. Comparing with conventional perturb and observe, the proposed method has the best tracking performance, which can be used for motion carriers.

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