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To cite this article: Ying-bo Chai and XIE Pu 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **295** 042006

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Variable step-size incremental conductance method used in PV power system

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Abstract. The paper presents a new control strategy on MPPT as a result of the disadvantages of the present variable step-size incremental conductance method on MPPT, which is simulated in MATLAB/Simulink. The simulation results show that the new control strategy is obviously better than the previous in terms of the tracing velocity, which is the expected result.

1. Introduction.

As a kind of new energy, solar energy has the advantages of clean, pollution-free and almost inexhaustible, and it is one of the important ways to solve the problem of energy shortage in the world. In the way of using solar energy, in addition to oil, coal and other solidified solar energy, photovoltaic cells are one of the important means. However, the output characteristics of photovoltaic cells are nonlinear, which is mainly affected by light intensity and external temperature, and these factors change frequently, so the output power of photovoltaic cells is also constantly changing. On the certain illumination and temperature conditions, the output of photovoltaic cells has the only maximum Power point (MPP). In order to maximize the use of solar energy resources, it is of great significance to achieve the maximum power point tracking (MPPT).

At present, there are many methods to realize MPPT, which can be divided into indirect control method based on parameter selection, direct control method based on voltage and current detection and artificial intelligence algorithm based on modern control theory [1]. The commonly used direct control algorithm contains perturbation and observation method, incremental conductance method, etc. The precision of this kind of control algorithm is higher than the indirect control method, carrying on the real-time MPPT control, satisfying the requests of general occasion [2][3]. Compared with artificial intelligence algorithm, this kind of method is simpler and does not require complex conditions such as a large number of samples, so it is most widely used in practice.

The incremental conductance method in the direct control algorithm is one of the most commonly used methods, which tracks the changing of the output voltage of the photovoltaic cell dynamically, and its main characteristics are high control precision, good stability, and independent of the output characteristics and parameters of the photovoltaic cell [4].

2. Modelling and analysis of photovoltaic cells

Considering changes in solar radiation and temperature effects [5],

$$I = I_{sc}(1 - C_1(\exp(\frac{V - DV}{C_2V_{oc}}) - 1)) + DI$$

Among it,



$$DI = DT \alpha R / R_{ref} + (R / R_{ref} - 1) I_{sc}$$

$$DV = -\beta DT - R_s DI$$

$$DT = T_c - T_{ref}$$

Among them,

R_{ref} , T_{ref} —solar radiation and photovoltaic cell temperature reference values, generally taken as 1000 W/m^2 , $25 \text{ }^\circ\text{C}$;

α —the change coefficient of current temperature under the reference light intensity;

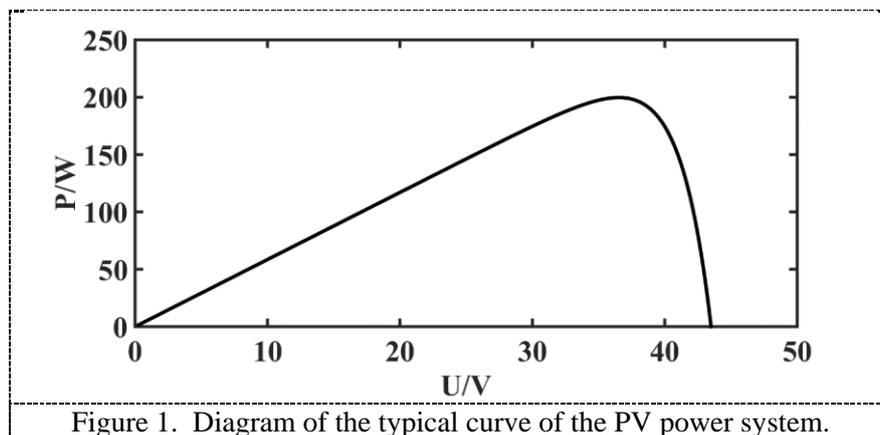
β —the voltage variation temperature coefficient under the reference temperature;

R_s —series resistors for photovoltaic modules.

3. The variable step-size incremental conductance method

3.1. The disadvantages of the existing slope-based variable step-size incremental conductance method

The fixed step incremental conductance method has the advantages of simple control logic and easy implementation, but it has great contradiction in control precision and tracking speed, and may fluctuate near the maximum power point. The variable step-size MPPT algorithm can adjust the duty cycle change step length of the boost circuit, so as to overcome the contradiction to a certain extent, and reduce the fluctuation. A control method based on the absolute value of P-U curve slope is proposed in literature [6], because of the characteristics of the curve itself, when the maximum power point is far away, the curve slope value is larger, and the step size is larger, and the tracking speed is improved; and when it is near the maximum power point, the curve slope value is smaller, and the step size is smaller, which improves the tracking accuracy and reduces the shock near the maximum power point [7].



3.2. The improved step-size incremental conductance method

The basic idea of the algorithm is, in the area far from the maximum power point, that is to say, without exceeding the boundary of Marginal Area, the tracking step is increased gradually; when the that boundary is exceeded, it is considered to be close to the maximum power point and the step size is replaced with a smaller step length, as shown in Figure 2.

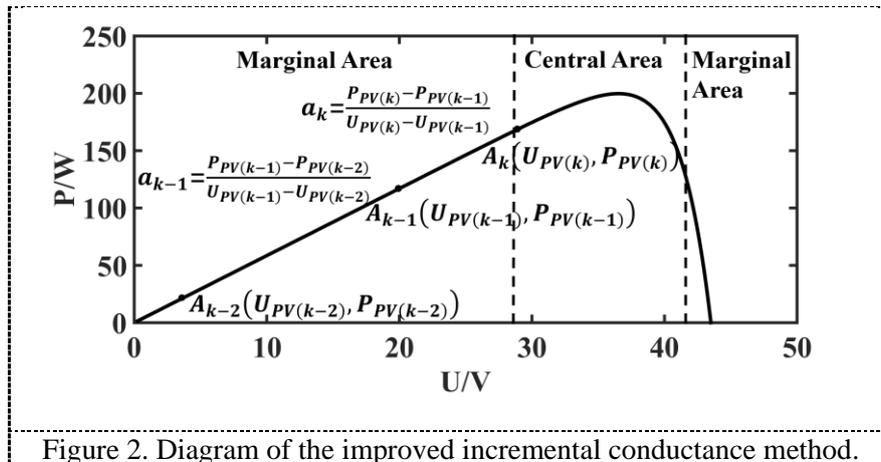


Figure 2. Diagram of the improved incremental conductance method.

The following is illustrated in conjunction with Figure 2, firstly, dividing the P-U curve into two parts, namely the Marginal Areas and the Central Area, the boundary between the two parts is not fixed, but determined by the parameter ε , when the slope of adjacent three points $A_{k-2}(U_{PV(k-2)}, P_{PV(k-2)})$, $A_{k-1}(U_{PV(k-1)}, P_{PV(k-1)})$, $A_k(U_{PV(k)}, P_{PV(k)})$, a_k , a_{k-1} , the difference of absolute value of which is greater than $\varepsilon(U_{PV(k)} - U_{PV(k-2)})$, that is, the A_k point is considered to be beyond the boundary of the Marginal Area, located in the Central Area. Two regions use different tracking strategies: in Marginal Areas, the method of gradually increasing step length is used to increase the tracking speed. The algorithm holds that as long as the A_k point is located in the Marginal Area, the tracking speed is low, the step size needs to be increased, the degree of increase is related to the slope a_k , a_{k-1} , and in the Central Area, the tracking accuracy is increased by using the method of minimum variable step length, and the step size is related to a_k and β . When the absolute value of a_k is less than δ , it is considered that the MPP is tracked, which can solve the problem caused by the tracking accuracy, which may lead to a concussion near the MPP. The algorithm involves 4 parameters, namely α , β , δ , ε , of which α is the Marginal Area step adjustment factor, β is the Central Area step adjustment factor, ε is the regional boundary adjustment factor, δ is the tracking precision adjustment factor, 4 parameters can be adjusted to meet the requirements of tracking speed and accuracy. The flow chart is shown in Figure 3.

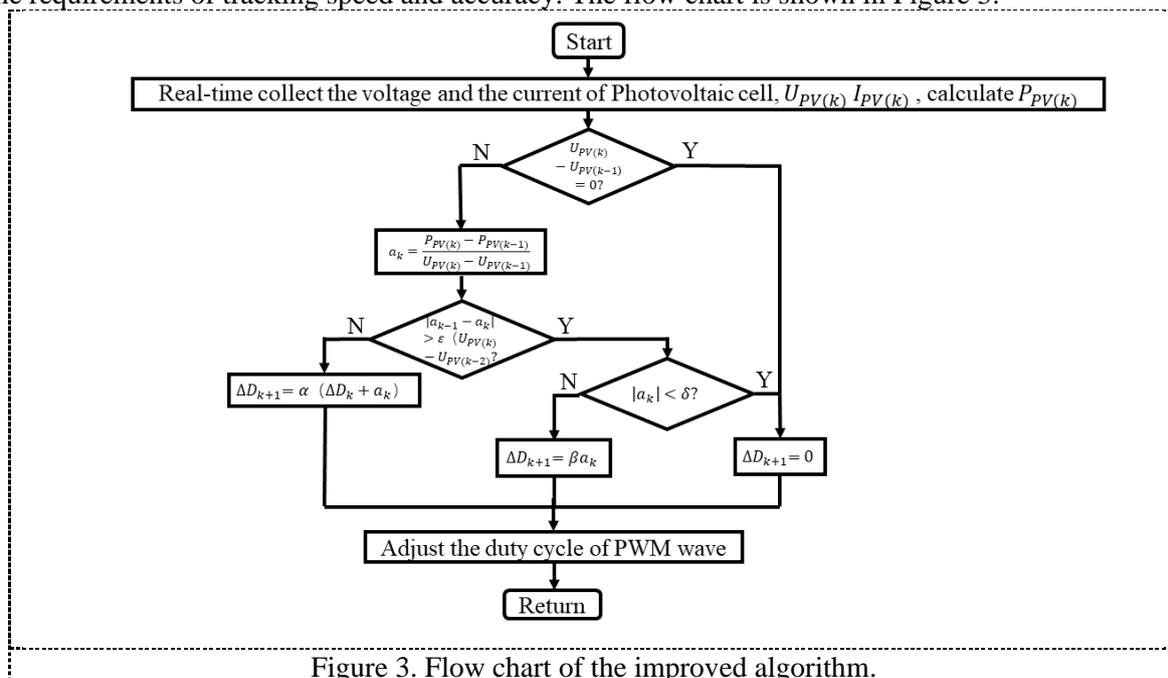


Figure 3. Flow chart of the improved algorithm.

4. Simulation verification and analysis

In order to verify the correctness and feasibility of the proposed algorithm, the algorithm and the improved algorithm are modelled and simulated in MATLAB/Simulink software. The main structure of the circuit is the boost transformation circuit, which is shown in Figure 4 [8].

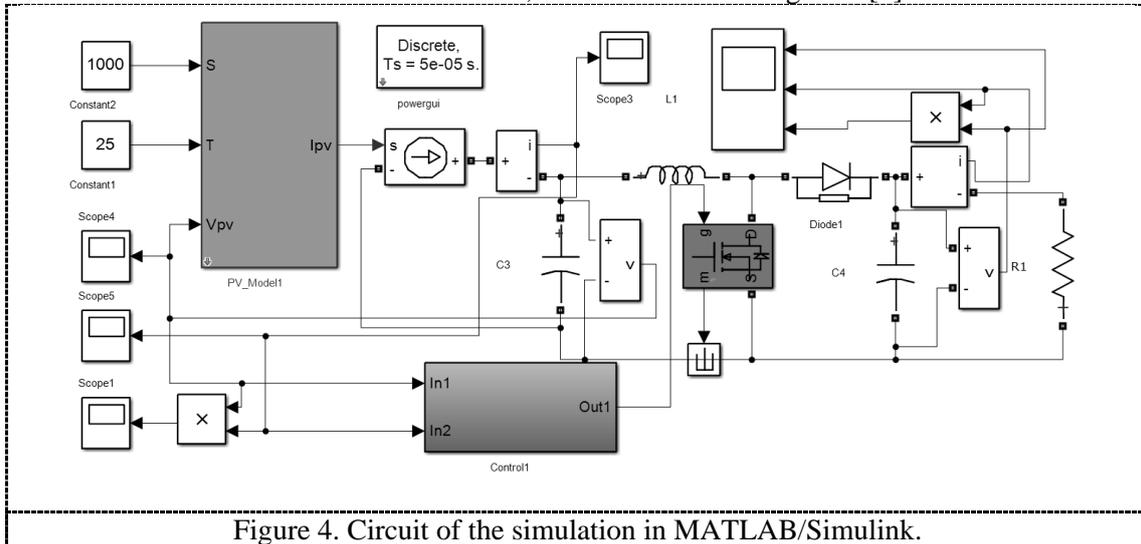


Figure 4. Circuit of the simulation in MATLAB/Simulink.

Its basic working process is that, the Photovoltaic cell module is a DC source, by detecting its output voltage U and output current I , its output state determined, and the output information is fed into the control subsystem of the MPPT module for processing, and finally the switch device duty cycle D of the original signal is obtained, and then through the PWM generation link, finally, the PWM control signal can be directly sent to control the switching device, and through the adjustment of the duty cycle D of the boost circuit, which can change the equivalent input impedance of the circuit to realize the impedance matching between the load and the source, so the MPP is finally tracked [9]. The simulation condition is set to typical conditions, that the illumination intensity $1000\text{W}/\text{m}^2$, temperature is 25°C , and the load is pure resistance. In the algorithm, 4 controllable parameters, α , β , δ , ε , are set to suitable values. The simulation adopts ODE45 algorithm, the simulation type is discrete type, the sample time is $5 \times 10^{-5}\text{s}$, and the simulation time is 0.1s . For the previous algorithm, the step length adjustment coefficient is consistent with β in the algorithm which is improved, and eventually the output power of the two is shown in Figure 5.

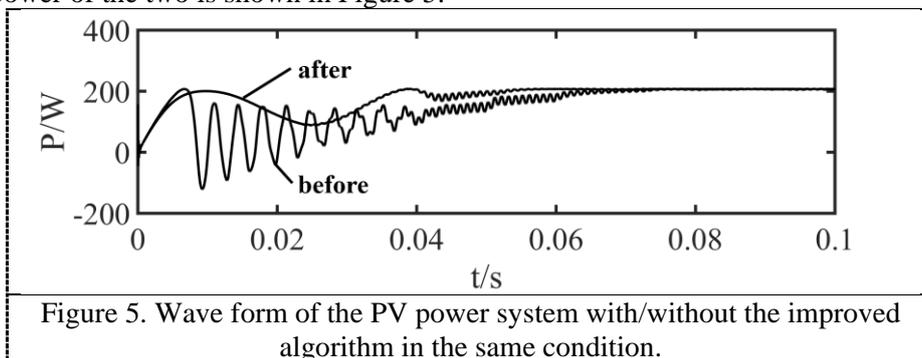


Figure 5. Wave form of the PV power system with/without the improved algorithm in the same condition.

According to the figure, under the same conditions, after the improvement is taken, in tracking speed, the number of fluctuations is less before the output power reached stable, the fluctuation amplitude is smaller and has reached a stable in 0.04s , better than the 0.06s of the previous, which is a great increase; In tracking accuracy, due to the use of the same step adjustment coefficient, Therefore, the tracking accuracy of the them is close.

Under dynamic conditions, the control variable method is adopted. Firstly, the output of photovoltaic cells varying with the intensity of illumination under the condition of constant

temperature is analysed. Set the conditions for, simulation time 0.4s, temperature of 25°C, illumination intensity at 0s for 1000W/m², in 0.1s, 0.2s, 0.3s respectively into 900W/m², 800W/m², 1200W/m². Eventually the output power of the two is shown in Figure 6 and Figure 7.

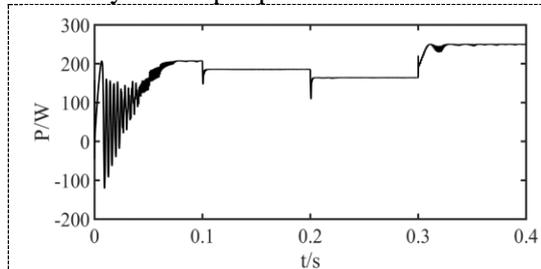


Figure 6. Wave form with the light intensity change of the PV power system without the improved algorithm.

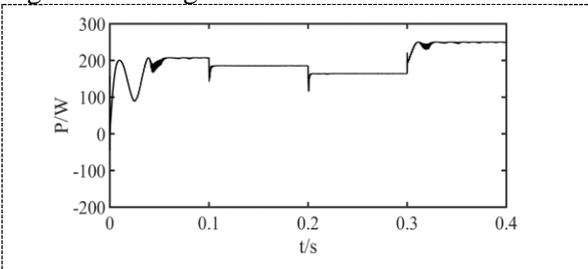


Figure 7. Wave form with the light intensity change of the PV power system with the improved algorithm.

According to the figures, when the illumination intensity changes, the designed algorithm can control the circuit to produce the corresponding action, tracking the MPP faster than the previous algorithm. Their accuracy is same, but the improved one shocked slighter in the light mutation.

After that, under the condition that the illumination remains constant, the photovoltaic cell output varying with temperature is analysed. The simulation time is 0.4s, the illumination intensity is 1000W/m², the temperature is 25°C in 0s, and at 0.1s, 0.2s and 0.3s, it becomes 30°C, 35°C, 15°C respectively. Eventually the output power of the two is shown in Figure 8 and Figure 9.

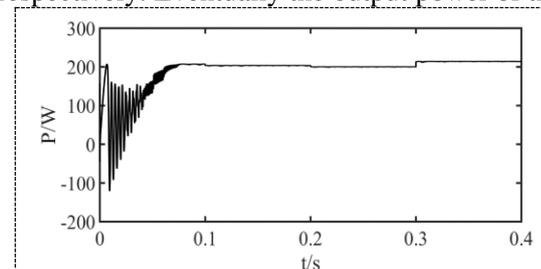


Figure 8. Wave form with the temperature change of the PV power system without the improved algorithm.

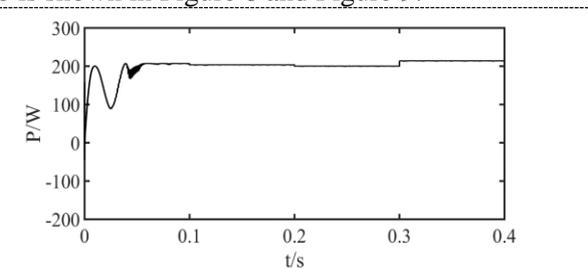


Figure 9. Wave form with the temperature change of the PV power system with the improved algorithm.

According to the figure, when the temperature changes rapidly, the designed algorithm can control the circuit to produce the expected action, quicker adjust the photovoltaic cell output to the MPP than the previous one, and their accuracy is the same, but the improved one performs a small oscillation.

5. Conclusions

Aiming at the problem that the tracking speed of variable step incremental conductance method based on slope is not enough, this paper presents an improved variable-step length incremental conductance method, and uses MATLAB/Simulink to model and simulate, and the simulation results show that under static conditions, the algorithm can increase the tracking speed, reduce the oscillation, enable photovoltaic cell output to reach the MPP faster and has better tracking accuracy. Under dynamic conditions, compared with the previous algorithm, the improved algorithm can respond to the rapid changes of temperature, illumination intensity and other influencing factors timely, with high precision at the same time, without producing a large oscillation. Simulation results show that the algorithm is feasible and efficient, and solves the problem of the previous slope-based variable step-size incremental conductance method.

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