Photovoltaic Cells Mppt Algorithm and Design of Controller Monitoring System

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Abstract. This paper combined the advantages of each maximum power point tracking (MPPT) algorithm, put forward a kind of algorithm with higher speed and higher precision, based on this algorithm designed a maximum power point tracking controller with ARM. The controller, communication technology and PC software formed a control system. Results of the simulation and experiment showed that the process of maximum power tracking was effective, and the system was stable.

1. Introduction

Solar energy as a kind of inexhaustible and low pollution energy, it has aroused widely attention and is being studied. Photovoltaic power generation is the most effective way to use and store solar energy. How to improve the efficiency of Photovoltaic power generation has become the core issue of solar power [1]. The PV cell output characteristic is non-linear, which not only affected by the light and temperature, but also by the load when the light intensity and temperature are fixed. According to its output characteristics, changing the output voltage will realize the maximum power point tracking (MPPT) [2]. In this paper, the algorithm combined the advantages of the common algorithms of Constant Voltage, Perturb & Observe and Incremental conductance, take constant voltage method first, then Perturb & Observe, the last incremental conductance to make the process of MPPT rapid and accurate. Through the simulation, the algorithm is more effective than the other algorithms used alone. The solar energy maximum power tracking controller was designed with this algorithm, improving the efficiency of PV cells. The control system consisted of the controller, communication technology and the PC software. The purpose of this system was to monitor and control processes of power generation of PV, MPPT and charge of storage battery.

2. PV Output Characteristics

PV module equivalent circuit diagram as Figure 1.
The output characteristic equation is:

\[
I_L = I_{ph} - I_0 \left( \frac{g(U_L + I_L R_s)}{A k T} \right) - \frac{U_L + I_L R_s}{R_{sh}}
\]  

(1)

In this formula, \(I_L\) - photovoltaic battery output current; \(I_{ph}\) - Photoproduction current; \(I_0\) - reverse saturation current of photovoltaic cells; \(g\) - quantity of electric charge constant; \(k\) - Boltzmann constant; \(U_L\) - photovoltaic battery output voltage; \(R_{sh}\) - bleeder resistor; \(R_s\) - the internal resistance of the photovoltaic (PV); \(A\) - ideal factor (the characteristics of the diode factor, usually between 1 to 3).

Under the standard conditions (light intensity of 1000W/m², battery temperature \(T_{ref}=25\,^\circ C\)), selecting a photovoltaic cells with the open circuit voltage \(U_{oc}=22.5V\), short circuit current \(I_{sc}=2A\). The relationship between \(I\) and \(V\), \(P\) and \(V\) as Figure 2 and Figure 3.

Curves in the figure showed the I-V characteristics of PV and P-V characteristics of PV. Point ‘a’ correspond to two curves, they are I-V characteristic curve and P-V characteristic curve of PV in a value of light intensity. Before point ‘a’, as voltage increases, current change little, power increase as voltage; after point ‘a’, as voltage increases, current and power decreases sharply. When voltage came to voltage of ‘a’, output power will come to maximum. If try to improve PV output power, take some measures to make the working point at point ‘a’, ‘a’ is the maximum power point (MPP).
3. Photovoltaic MPPT Algorithm

To achieve maximum power output of PV cell, the most practical way is continuously to acquire output current and voltage of the battery, after calculation, controlling DC-DC circuit and changing the output voltage of photovoltaic battery until to the maximum power point. There are many kinds of maximum power point tracking algorithm, common and practical algorithms include Constant Voltage(CV), Perturb & Observe(P&O), Incremental conductance(INC), etc [3].

3.1 Advantage and Disadvantage of Traditional Algorithm. Each algorithm has its feature: the CV(Figure 4(a)) is simple and easy to implement, has good reliability and stability, but PV cells I-V characteristic is influenced by environment, so CV is only applicable when environmental factor is stable; P&O (Figure 4 (b)) is simple, less accused parameters, easy to implement, hardware system need is simple, but P&O perturbation step size is not easy to be determined, too large step size cannot guarantee accuracy, too small step size lead to low speed, using P&O near the maximum power point is easy to cause misjudgment; INC(Figure 4 (d)) is one of the highest accuracy algorithm can be not affected by environmental conditions, INC algorithm is relatively complex, has large amount of calculation, the hardware requirement is high [3][4].
\[ \text{Init} \]

\[ \begin{align*}
\text{Collect } U, I \\
P &= U*1, \text{ let } P = P1
\end{align*} \]

\[ \begin{align*}
U2 &= U + \Delta U \\
P2 &= U2*I2
\end{align*} \]

\[ P2 > P1? \]

\[ \begin{align*}
U &= U - \Delta U \\
U &= U + \Delta U
\end{align*} \]

Figure 4(a). Algorithm flow chart of CV

\[ \text{Init} \]

\[ \begin{align*}
\text{Collect } U(k), I(k) \\
P &= U*1, \text{ let } P = P1
\end{align*} \]

\[ \begin{align*}
U(k+1) &= U(k) + \Delta U \\
P2 &= U(k+1)/I(k+1)
\end{align*} \]

\[ P2 > P1? \]

\[ P1 = P2 \]

\[ P1 = P3 \]

\[ \text{Keep } P1 \]

\[ \begin{align*}
U(k+1) &= U(k) - \Delta U \\
P3 &= U(k+1)/I(k+1)
\end{align*} \]

\[ P3 > P1? \]

\[ P1 = P3 \]

\[ \text{Keep } P1 \]

\[ P1 = P? \]

\[ \text{end} \]

Figure 4(b). Algorithm flow chart of P&O
3.2 New Algorithm of CV-P&O-INC. In algorithms, control the output voltage changes every time, we call the change of the value of voltage $\Delta D$ compensation factor, the compensation factor is determined by the output voltage as $U_L$ and step length $\Delta D$. In the buck and the boost circuit, adjust output voltage by changing the duty ratio D of PWM wave, every time adjust the duty ratio D, the size of the duty ratio $D$ is called step length $\Delta D$. During the control, long $\Delta D$ lead to high speed, but the precision is not easy to guarantee; small step length lead to high precision but low speed. So choose the right step is a key factor to improve the algorithm efficiency.

The algorithm used in this article combined advantages of above algorithms, bypassed the shortcomings of each algorithm, put forward a modified CV-P&O-INC (FIG.3(c)). In general,
photovoltaic maximum power point voltage is 65% to 85% of the open circuit voltage $U_{oc}$, therefore, after initialization of algorithm, let the PV voltage fixed to 75% $U_{oc}$, it’s easy to realize by using the DC - DC circuit. When voltage is steady, the algorithm will enter P&O, the algorithm adopted in this paper has some differences with the general P&O, in order to prevent the inaccurate judgement caused by disturbance in a single direction, the part of P&O in this algorithm (in this paper, we call it Sliding Comparison(SC)) adopts two-direction disturbance, the SC add disturbance before and after the selection point when enter the process of calculate, the way to add disturbance is to amplify or diminish the output voltage, and it will get three different output voltage value point, compare the three get the biggest value point of power, it will gradually close to the maximum power point after repeated comparison. Sliding comparison in the process of the method aimed at achieving high speed to arrived point near the maximum power point so choose the larger step length $\Delta D=0.008$, step size determines the change of voltage each time as $\Delta U=\Delta D*U_L$. When output power come to the maximum power point, algorithm turn into INC for more detailed tracking, then the step size $\Delta D=0.004$ After calculation and the algorithm control DC - DC circuit can realize the tracking of maximum power point quickly and accurately.
Figure 5. Simulation result of each algorithm

In Figure 5, (a) is the CV simulation result, (b) is the P&O simulation result, (c) is the INC simulation result, and (d) is the CV-P&O-INC simulation result. The results showed that CV could keep voltage to a certain value, can’t reach MPPT; P&O could reach MPPT, but it was unstable and had a wave, INC was smooth but it used more time; Comprehensive comparison showed that the CV-P&O-INC was better than others. See the CV-P&O-INC curve, it could be divided into three parts. The first part of CV process, voltage fast approached 75% Uoc; once the voltage have not change obviously, algorithm entered into the second part of P&O, this part of the algorithm calculation speed was moderate, it could roughly close to the MPP; the third part of INC would keep voltage fixed to the maximum power point. Simulation results proved that the CV-P&O-INC algorithm of MPPT is fast and precise.

4. The Design of The Controller and System

Based on the research on algorithm above, we designed a controller. The controller structure was as shown in Figure 6, included DC - DC circuit, communication module, power supply module, display module, test module, protection module, etc. The ARM produced PWM wave to control DC - DC circuit to change the output voltage so the controller could change the output power. DC - DC contains buck and the boost circuit, buck circuit used for buck, its relationship between the output voltage and input voltage: \( U_o = U_i \times D \); voltage boost circuit used for boost, its relationship is \( U_o = U_i \times (1-D) \). The key of the algorithm control the controller was changing the duty ratio(D) of PWM wave. The controller also has communication module and display module. Communication module used 485 serial communication and wireless communication based on the IEEE 802.15.4, 485 communication was mainly used for the distribution of the multipoint Photovoltaic power generation, controller embedded MODBUS protocol, connect to PC, wireless communication has solved occasions the signal line cannot go directly. 12864 OLED display module show information, the module was a kind of low power that display 4 lines, used to display the input, output voltage and current of the power.
generation efficiency [5].

After finished the controller, we built a system as Figure 7, this system includes solar panels, the MPPT controller, storage battery and PC and Communication module. The PV cell converted light energy into electrical energy, electric energy sent to the storage battery through the MPPT controller, the controller display module display voltage, current and efficiency, etc. Multiple MPPT controllers and PC machine and the use of 485 communication can form 485 network. PC software was based on the QT framework for C++ language was a PC monitoring analysis software, it was used for real-time monitoring the MPPT controller for solar energy network and analysis the state.

5. Conclusion

This paper analyzed the advantages and disadvantages of the commonly used algorithm in photovoltaic power generation, combined the advantages of three algorithms namely CV, P&O and INC and put forward a modified algorithm. Result of simulation prove the characteristics of the algorithm was fast and accurate. The MPPT controller was designed based on the algorithm, this controller was an important part of the photovoltaic power generation system. The system would improve the PV cells efficiency and had a vital significance.

References

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