Design of Maximum Power Tracking System for Photovoltaic Power Generation

Yuewen LIU\textsuperscript{1,2*}

\textsuperscript{1}Key Laboratory of wind energy and solar energy, Ministry of Education, Inner Mongolia University of Technology, Hohhot 010051, China
\textsuperscript{2}Key Laboratory of renewable energy of Inner Mongolia Autonomous Region, Inner Mongolia University of Technology, Hohhot 010051, China

*81145701@qq.com

Abstract—Solar power generation is related to climatic conditions, and its high cost and low power generation efficiency have become the main factors restricting its development. Realizing the maximum power tracking of solar photovoltaic power generation through power electronic technology and control technology is an effective measure to increase the power generation of photovoltaic power generation systems, reduce power generation costs, improve solar energy conversion efficiency, and widely promote photovoltaic power generation technology. According to the illumination characteristics of solar cells, using a single-chip microcomputer to control the DC-DC converter and conductance increment method as the control algorithm, a solar maximum power tracking system is designed.

1. Introduction:
The solar cell is a nonlinear DC power supply. Its P-V output characteristic has nonlinear characteristic, which is affected by the intensity of sunlight, ambient temperature and load conditions. Under certain sunshine intensity and ambient temperature, photovoltaic cells can work at different output voltages, but only at a certain output voltage value, the output power of photovoltaic cells can reach the maximum value \cite{1}. At this time, the working point of photovoltaic cells reaches the highest point of the output power voltage curve, which is called the Maximum Power Point (MPP). In the photovoltaic power generation system, it is an important way to improve the overall efficiency of the system to keep the output power of photovoltaic cells at the maximum state through the maximum power point tracking technology. The output power of the photovoltaic cell is detected in real time, and the possible maximum power output of the photovoltaic cell under the current working condition is predicted through a certain control algorithm, so as to change the current impedance and adjust the working point of the photovoltaic cell to make it always work near the maximum power point, so as to improve the efficiency of the photovoltaic power generation system \cite{2-4}.

2. Hardware design of photovoltaic power generation maximum power tracking system

2.1. The basic composition of the maximum power tracking system
As the photovoltaic cell array is changing with different sunlight intensity and ambient temperature, the output power will also change greatly when its terminal voltage changes. As mentioned in the introduction, it is neither a constant current source nor a constant voltage source. Add a DC/DC
converter between the solar cell array and the load to adjust and control the solar cell array to work at the maximum power point by changing the conductivity of the power switch in the DC/DC converter, so as to achieve the maximum power tracking control and improve system efficiency [5-6].

Fig. 1 structure diagram of maximum power tracking system

2.2. The hardware part of photovoltaic power generation system

2.2.1 Design of DC/DC converter

Vin is the input voltage, V₀ is the output voltage, and i₁ is the current flowing through the inductor. Assuming that the switching period of the Boost circuit is T and the duty cycle is D, the equivalent circuit during the on-time of the switch is shown in Fig. 2, and the equivalent circuit during the off-time of the switch is shown in Fig.3.

During the on time of the switch tube, \( i_L \) increases linearly, and the increment is:

\[
\Delta i_L (+) = \frac{V_o}{L} DT
\]  

(1)

The \( i_L \) decrease during the off time of the switch tube, the decrease is:

\[
\Delta i_L (-) = \frac{V_o - V_{in}}{L} (1 - D) T
\]  

(2)

When the system is in steady state, the changes of these two currents are equal, \( \Delta i_L (+) = \Delta i_L (-) \), that is:
\[ \Delta i_L (+) = \frac{V_{in} DT}{L} = \Delta i_L (-) = \frac{V_o - V_{in}}{L} (1 - D) T \]  

Voltage increase

\[ M = \frac{V_o}{V_{in}} = \frac{1}{1 - D} \]  

### 2.2.1.1 Selection of energy storage inductor \( L \)

There are two basic requirements for the inductor design in the Boost circuit: one is to make the circuit work as far as possible under the current continuous working state, and the other is to ensure that the inductor cannot be saturated when the peak current flows. The energy storage inductor \( L \) can be selected according to formula (5).  

\[ L = \frac{V_{in} \cdot t_{on}}{1.4 I_{in}} = \frac{V_o^2 DT}{1.4 V_o I_o} = \frac{V_{in} (V_o - V_{in})}{1.4 fV_o^2 I_o} \]  

### 2.2.1.2 Selection of filter capacitor \( C \)

When the switch tube \( Q \) is in the on state, the capacitor \( C \) supplies power to the load; when \( Q \) is in the off state, the induced electromotive force in the inductor \( L \) forces the diode \( D \) to turn on, one side supplies power to the load, and the other side supplements the reduce charge on the capacitor \( C \) when the switch is turned on. When the circuit enters a steady state, the average current flowing through the capacitor \( C \) is 0, and the pulsation of the output voltage \( \Delta V \) is equal to the voltage change caused by the discharge of the capacitor \( C \) to the load during the conduction of the switch \( Q \). In order to meet the requirements of the relative value of the output ripple voltage, the filter capacitor \( C \) is determined by the following formula (6):

\[ C \geq \frac{V_o DT}{\Delta VR} \]

### 2.2.2 Design of control circuit

The output voltage and current of the photovoltaic array are sent to the MPPT controller after sampling A/D conversion for maximum power point tracking control. The controller outputs PWM wave to drive the switch tube to change the output voltage of the Boost circuit \( V_o \), that is, the output voltage of the photovoltaic array \( V_{PV} \) to match the voltage corresponding to the maximum power point of the photovoltaic array, so that the photovoltaic array always outputs the maximum power. The core part of the controller is the specific control algorithm of the control circuit which can use the various methods discussed in this article. The core part of the controller is the control circuit. Because the output power of the solar cell is constantly changing under the influence of the environment, in order to track its maximum power point, this requires the system to respond quickly, and the control circuit is the core of the whole system. In order to track and control the maximum output power point of photovoltaic cells, the system requires strong real-time performance and fast response speed, so the system uses advanced 80C196KC chip as the main controller. The control circuit is mainly composed of sampling circuit, MOSFET drive circuit, 80C196KC chip, 74LS373 latch and 2864 memory [9].

### 3. Software design of photovoltaic power generation maximum power tracking system

#### 3.1 Maximum power tracking algorithm

The program flow chart of the conductance increment method is shown in Figure 4. \( U_n \) \( I_n \) is the current voltage and current value of the photovoltaic array detected, \( U_{n-1} \) \( I_{n-1} \) is the sampling value of the previous control cycle. After reading the new value, first calculate the voltage difference and...
judge $du$ whether it is zero (because the denominator must not be zero when the division is done later); If it is not zero, then judge whether it is true. If it is true, the slope of the power curve is zero and reaches the maximum power point; If the conductance change is greater than the negative conductance value, it means that the slope of the power curve is positive and $U_r$ will increase; Otherwise, $U_r$ will decrease. Let's discuss the case that the voltage difference is zero. At this time, you can leave $U_r$ alone and proceed to the next cycle of detection until it is detected that the voltage difference is not zero.

![Program flow chart of conductance increment method](image)

**Fig. 4** Program flow chart of conductance increment method

### 3.2 System software design

In the software design of this system, the modular design method is adopted. Each module is relatively independent. Each subprogram completes certain functions and is called by the main program when necessary. This can make the program structure clear and facilitate further expansion of the system in the future. The main program of the system is mainly composed of the following parts: setting initial voltage, battery voltage signal sampling, maximum power point tracking, and control loop switch program. When the initial voltage is set, the predetermined value is set for the single chip microcomputer. The signal sampling will send the sampled photovoltaic battery voltage, current and other external signals to the single chip microcomputer. The control loop switch is the
state of the main circuit switch after the input external signal processing end is determined by the single-chip microcomputer.

The system software process is shown in Figure 5. The current and voltage of the solar photovoltaic cell array are sampled by the Hall sensor and then sent to the 80C196KC chip. The terminal voltage and current of the battery are sampled by the Hall sensor and sent to the 80C196KC chip. Then according to the program, the high-speed output port HSO.2 is controlled to generate a PWM wave to drive the MOSFET power switch of the Boost circuit and the MOSFET power switch of the discharge controller to control the working state of the system circuit.

![System software flow chart](image)

Fig. 5 System software flow chart

4. Conclusion
Research on the maximum power point tracking of photovoltaic power generation system, compares the advantages and disadvantages of various tracking methods, selects an efficient and simple control method, uses boost converter as the main hardware part of the MPPT controller to achieve maximum power point tracking. The control circuit is introduced and analyzed in detail. By controlling the duty cycle of the DC/DC converter to realize the tracking of the maximum power point, it is an effective measure to improve the power generation capacity of photovoltaic power generation system, reduce the power generation cost, improve the solar energy conversion efficiency, and widely promote the photovoltaic power generation technology.
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References:
[1] Zhao Yuwen. Strategic Thinking on the Development of my country's Solar Photovoltaic Industry in the 21st Century [A]. Proceedings of the 6th China Photovoltaic Conference (CSES) [C], 2007:257-261.
[2] Feng Duosheng et al. The principle and application of solar power generation [M]. Beijing: People's Posts and Telecommunications Press, 2007.
[3] Wang Zhaoran, Huang Jun. Power electronics technology [M]. Xi'an: Mechanical Industry Press. 2005.107～108
[4] Liang Heqing, Liang Tao. MCS-96 Series MCU User Manual [M]. Beijing: Publishing House of Electronics Industry, 1995
[5] Huang Yao, Huang Hongquan. The conductance increment method realizes the maximum power point tracking control of the photovoltaic system[J]. Modern Electronic Technology, 2008, 22(285): 18-19
[6] Solodovnik E V, Liu S, Dougal R A. Power controller design for maximum power tracking in solar installations[J]. Power Electronics IEEE Transactions on, 2004, 19(5):1295-1304.
[7] Song L, Wang X, Liu W, et al. Research of Perturbation and Observation Method for MPPT of PV Arrays[J]. Semiconductor Optoelectronics, 2012, 33(4):455-462.
[8] Liu C X, Liu L Q. An improved perturbation and observation MPPT method of photovoltaic generate system[C]// IEEE Conference on Industrial Electronics & Applications. IEEE, 2009:2966-2970.
[9] Zan B L, Song Y D, Wang L, et al. An Improved P&O MPPT Method for Photovoltaic Power System[J]. Advanced Materials Research, 2013, 805-806:45-51.
[10] Pilakkat D, Kanthalakshmi S. An improved P&O algorithm integrated with artificial bee colony for photovoltaic systems under partial shading conditions[J]. Solar Energy, 2019, 178(JAN.):37-47.