Efficient solar receiver system based on maximum power tracking

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Abstract. Sunlight is everywhere around the world, and solar cells can be used, the working principle of solar cells is to directly convert solar energy into electricity, which does not need a secondary conversion process, so it has a high conversion efficiency. How to make full use of solar energy for power generation has become a key topic of development research in various countries. In this paper, we design and develop a high-efficiency solar energy receiving system based on maximum power tracking with STM32H750VB microcontroller as the core controller, collect the system current and voltage state parameters through the sampling module, and use the variable step conductance incremental method and combine with the PID control algorithm to control the input lifting and lowering module, so as to control the output power of the solar panel, in order to achieve the goal of tracking the maximum power point at any time. goal to obtain greater effectiveness. As can be seen from the experimental results, the system can quickly achieve the goal of tracking the maximum power point, and has high practical value.

Keywords: Maximum power, High efficiency solar receiving system, Variable step conductance increment method.

1 Introduction

A solar receiving system is a collection of equipment and components used to collect solar energy and convert it into usable energy. Its main function is to receive solar radiation and convert it into usable forms of energy. As a clean and sustainable way of collecting energy, solar receiving systems have received extensive attention and research from various sectors[1].

In solar receiving systems, the Maximum Power Point (MPP) is the operating point at which a solar panel or other energy conversion device can provide the maximum output power under specific conditions. Therefore, it is of great theoretical and practical significance to study the efficient solar receiving system based on maximum power tracking. Analysing the operating state that refers to when the output power of a PV cell reaches its maximum[2], and then accurately tracking and locking the MPP is

© The Author(s) 2024
A. E. Abomohra et al. (eds.), *Proceedings of the 2023 9th International Conference on Advances in Energy Resources and Environment Engineering (ICAESEE 2023)*, Atlantis Highlights in Engineering 29,
https://doi.org/10.2991/978-94-6463-415-0_37

crucial for improving the energy use efficiency and performance of solar receiver systems.

The basic idea of the typical conductance increment method is to detect the parameters of the current working state from the photovoltaic array, compare with the working parameters of the previous state after adjustment, and predict and determine the control amount of the next time period by the working state of the current moment. When tracking the maximum power point, for the rapidity and accuracy.There are many contradictions in beg. To solve this problem, this paper proposes a variable step conductance increment method: the interval uses the maximum power point to increase the convergence rate and the maximum work in the interval close to the maximum power point rate points for tracking search, reduce the range of shocks.

Jin Jian[4] in 2023 conducted research and simulation on tracking technology for the maximum power point of solar photovoltaic (PV) power generation system, and analysed the operating state that refers to the maximum output power of PV cells[3]. Accurately tracking and locking the maximum power point is essential to improve the energy utilisation efficiency and performance of solar PV power generation systems.

Liu Xiangqian[5] explores the maximum power point tracking technology of solar photovoltaic power generation systems to improve the energy utilisation efficiency and performance of the systems in his research on solar photovoltaic power generation and related technologies in 2023.

Jian Chen[6] in solar photovoltaic power generation system in oilfield design using application strategy based on P&O maximum power point tracking algorithm converts solar energy into DC energy, DC-DC converter regulates and matches the electrical energy, and DC-AC inverter converts DC energy into AC energy and outputs it to the grid or power supply equipment[7].

2 Hardware design of solar receiving system

The system consists of circuits such as boost module, lift module, sampling one module, sampling two module and microcontroller module, and its block diagram is shown in Fig. 1, in which a regulated power supply and power resistor in series are used to simulate the photovoltaic cell.

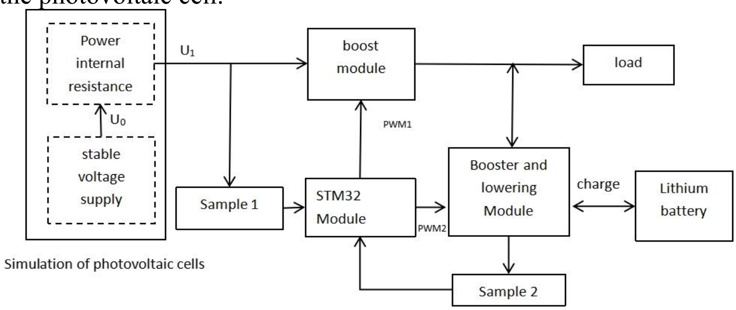

Fig. 1. Hardware design of solar receiving system

The workflow of the hardware system is as follows:

The system is powered up and the STM32 microcontroller outputs a dual PWM wave to enable the system to complete the information initialisation settings[8].

STM32 microcontroller module according to the sampling of the current and voltage values and its law of change, control the boost module to adjust the output voltage to maintain dynamic balance.

The lift-off and voltage module tracks the maximum power point of the system under the control of the STM32 microcontroller module[9]. When the output power of the PV cell is high, the module automatically starts charging operation of the battery to track the maximum power point of the system in real time and store the excess energy; when the output power of the PV cell is low, the module tracks the maximum power point of the system by controlling the battery discharge[10].

3 Maximum Power Point Tracking Algorithm - Variable Step Conductance Increment Method

When the external environment such as light is a fixed value, the power characteristic curve of the PV cell of the PV cell is fixed (as shown in Fig. 2), i.e. the maximum power point is also fixed, i.e. point P on the figure. The following figure divides the PV characteristic curve into six parts according to the distance from the maximum power point P, which are labelled with A~F.

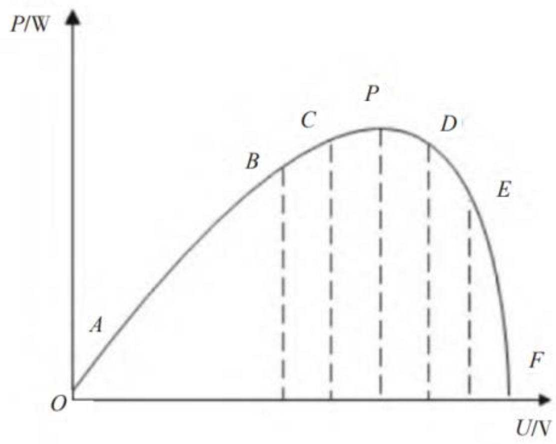

Fig. 2. Power characteristic curve of photovoltaic cell

In the A-P section, the output power tends to rise with the increase of output voltage, and the rising curve is relatively flat; in the P-F section, the output power tends to fall with the increase of output voltage, and the falling curve is relatively steep. As can be seen from the figure, when the voltage reaches the P point, the power reaches the maximum point[11]. Theoretically, at this time $U0 = 2U1$.

For when D1 is low, according to the principle of boosting circuit, MOS opens, capacitance and inductance are charged, at this time to satisfy equation (1).

$$\mathrm{VOUT=VC1=VIN} \tag{1}$$

Derivation of Eq. (1) yields Eq. (2).

$$\frac{\mathrm{dP}}{\mathrm{dU}} = I + U(\frac{\mathrm{dI}}{\mathrm{dU}}) \tag{2}$$

Point P is the point of maximum power with:

$$\frac{dP}{dU} = 0 \tag{3}$$

From (1):

$$I + U(\frac{\mathrm{dI}}{\mathrm{dU}}) = 0 \tag{4}$$

From (4), we can deduce that:

$$\frac{\mathrm{dI}}{\mathrm{dU}} = -\frac{I}{U} \tag{5}$$

In practice, the relationship between the size of $\frac{\mathrm{dI}}{\mathrm{dU}}$ and $-\frac{I}{U}$ can be used to determine the rise and fall of the voltage, and this method is called the conductance increment method. The ordinary conductance increment method has a fixed step size, which makes the system unstable and time inefficient, so in this thesis this problem is analysed using the variable step size conductance increment method[12].

The variable step size conductivity increment method is to choose a fixed large step for the A-B and E-F sections which are far away from the P point, so as to quickly reach the maximum power point near the P point. While the B-E section is closer to the maximum power point, it chooses to calculate the step length according to the slope of the curve, and constantly reduces the step length according to the slope, so as to avoid the phenomenon of crossing the maximum power due to too large a step length as well as the unstable phenomenon caused by repeated corrections near the maximum power point, and the instability problem caused by repeated corrections can be avoided.

Combining the above methods, when the system is tracking at the maximum power point, the variable step conductance incremental method is used, i.e., when the slope changes greatly at the principle maximum power point, i.e., the conductance changes greatly, a fixed large step can be used, such as A-B and E-F in Fig. 2; whereas in the sections of B-C and D-E, the slope changes are small, and if a fixed large step is used it is likely to cause repeated corrections due to the excessive length of the step, and thus the conductance value is set with reference to its Therefore, we set the step size by referring to its derivative value.

4 Results & Discussion

In order to verify the effectiveness of achieving the maximum power tracking of the system, a test system is designed as shown in Fig. 1. The output of the solar cell under different light conditions is simulated by changing the output voltage of the voltage regulator in the solar simulation circuit. Whether the circuit reaches the maximum power point is judged by measuring the correspondence between the measured voltage of the voltage regulator U0 and the output voltage of the solar cell U_1, as shown in Table 1. As shown in Table 1, when the system achieves automatic power tracking, the error rate of the solar cell output voltage is less than or equal to 0.01[13]. Therefore, the maximum power point tracking based on the variable step conductance incremental method can accurately track the maximum power point. In the simulation of the PV cell output voltage changes rapidly, the maximum power point can still be tracked accurately.

Table 1. Correspondence between regulated power supply voltage and photovoltaic cell output voltage.

Regulated power supply U0 /V	70	80	100
Measured value of the output of the photovoltaic cell at maximum power U1 /V	35.002	39.998	49.996
Theoretical value of the output voltage of a photovoltaic cell at maximum power U1 '/V	34.997	40.007	50.005

5 Conclusion

The output of photovoltaic cells fluctuates up and down due to changes in the external environment, so maximum power point tracking is of great significance for new energy utilisation.[16] In order to improve the conversion efficiency of the system, the paper designs a high-efficiency solar receiving system based on maximum power point tracking based on the variable step conductivity increment method[14]. The experimental results show that the system has excellent performance in terms of stability, accuracy and tracking speed, and can track the maximum power point efficiently. In addition. The system adopts a modular structure, which is easy to maintain and has good application prospects[15].

By comparing the measured voltage of the voltage regulator U0 with the output voltage of the solar cell U1, we can find that the maximum power point tracking based on the variable step length gain method also performs well in practical applications. When the light conditions change, the system is able to respond quickly and accurately track the maximum power point.[17] This indicates that the designed test system has a good performance and reliability.

In conclusion, the test system designed in this paper can effectively verify the effectiveness of the maximum power point tracking method. In practice, the maximum power point tracking based on the variable step length gain method can track the maximum power point accurately and quickly, which has high practical value. In future studies, we will continue to optimize the algorithm to improve the tracking performance of the system under different light conditions[18], and provide strong support for the efficient use of solar energy.

To further explore the potential of the maximum power point tracking technology, we will also study the following aspects:

1Optimization algorithm: On the basis of the existing variable step length gain method, a more efficient and accurate maximum power point tracking algorithm is sought to improve the system performance.

System integration: Combine the maximum power point tracking technology with the solar power generation system to achieve efficient and stable solar power generation.

Adaptation of light conditions: study the maximum power point tracking performance of the system under different light conditions to improve the adaptability of the system in different environments.

Hardware design: According to the maximum power point tracking algorithm, the corresponding efficient hardware circuit is designed to reduce the system cost and improve the system reliability.

Through the above research, we look forward to contributing to the development of solar power generation and providing strong support for sustainable development.6 Acknowledgements

This research was funded by Nature Science of Shanxi Province of China(and any supplymentary files).

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