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The Current Status of Photovoltaic Panel Power Peak Point Tracking System

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Abstract. As contemporary technologies progress, traditional energy sources have become increasingly constrained by limited resources and environmental concerns. Consequently, there has been a substantial push for the widespread adoption of new energy sources, which offer abundant resources, superior energy quality, and environmental cleanliness. Among these sources, solar energy has gained significant prominence as a key component in the development of new energy in various nations. However, enhancing the power generation efficiency and optimizing the power peak point capture of photovoltaic panels represents a crucial area of current research focus. This article first introduces the principle and structure of the photovoltaic system. Further, the paper proposed the application of artificial intelligence in dual-axis tracking technology and offers a detailed solution for the efficient tracking of power points. Through research, artificial intelligence has optimized parameters in the dual-axis tracking system through remote operation technologies such as WIFI modules so that the dual-axis tracking system can efficiently track the power peak point of the photovoltaic board.

1 Introduction

With the advancement of human society and technology, to solve the problem of increasing consumption of energy, solar energy as renewable energy has great development and utilization value. Researchers have found a good photovoltaic system that tracks the sun, which can increase the efficiency of the entire system by more than 30% [1]. Maximizing the efficiency of power generation is crucial when positioning solar panels directly toward the sun. However, traditional fixed solar photovoltaic systems have proven insufficient in achieving optimal power generation efficiency. The fixed solar panel only made the solar board reaches the corner of the sun at 90 ° at a certain moment. Nowadays, most of the dual-axis tracking technology on the market can make solar panels reach 90 ° to the sun at any time, making the power generation efficient maximize. At the same time, the dual-axis tracking technology is more intelligent in Wi-Fi modules and 5G technology, making solar panels more intelligent and more reasonable in tracking the sun. Use artificial intelligence to intelligently track the peak of photovoltaic board power peak points with the intelligence of double-axis tracking technology. Today, improving the optoelectronic conversion rate of solar energy and the utilization rate of solar is worthy of thinking and research.

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2 Introduction to photovoltaic board power generation

2.1 Basic principles of photovoltaic board power generation

The basic principle of solar photovoltaic panel power generation is: photovoltaic panels are composed of N-type and P-type semiconductor materials. A pure silicon crystal has equal numbers of free electrons (negative charge) and holes (positive charge). In a silicon crystal, each silicon atom has 4 adjacent silicon atoms and shares 2 valence electrons with each silicon atom, forming a stable structure of 8 electrons. The N-type semiconductors are generally made by adding a small amount of pentavalent impurity phosphorus and other elements to pure silicon. One phosphorus atom may easily break away from the bonds of phosphorus nuclei to make free electrons, and a lot of free electrons are produced in N-type semiconductors as a result. This additional electron is released when one phosphorus atom establishes a covalent link with the four silicon atoms around it. P-type semiconductors are generally made by adding a small amount of trivalent impurity boron and other elements to pure silicon. One valence electron is missing from one boron atom when it forms a covalent connection with the four silicon atoms around it. A hole will appear on the covalent bond, where a large number of holes will be generated in the P-type semiconductor. In the P-type region, there are more holes and fewer electrons. There are more electrons and fewer holes in the N-type area. Therefore, there will be a majority carrier diffusion movement on the interface.

The holes in the P pole region flow to the N pole region, and a batch of negatively charged ions doped with impurities will appear in the P pole region. The electrons in the N pole region flow to the P pole region, and a batch of positively charged ions doped with impurities will appear in the N pole region. When the N-type and P-type semiconductors are closely combined, the area connected between the two semiconductors is called a P-N junction. Because in the P-N junction, positive and negative charges are gathered on both sides, a built-in electric field from the positive charge to the negative charge will be generated, also known as the barrier electric field, as shown in Fig.1. When the sunlight shines on the photovoltaic panel, a voltage in an open circuit and a current in a short circuit will be formed inside the solar cell [2]. Then wires are connected to the load from the two metal electrodes, and the P-N junction is connected to the load through the wires to form a closed loop, as shown in Fig. 2. At this time, the photoelectric effect generates current so that the load has power output.

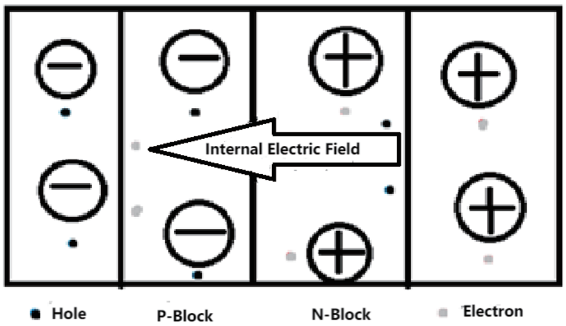

Fig.1.Direction diagram of internal electric field（Picture credit: Original）

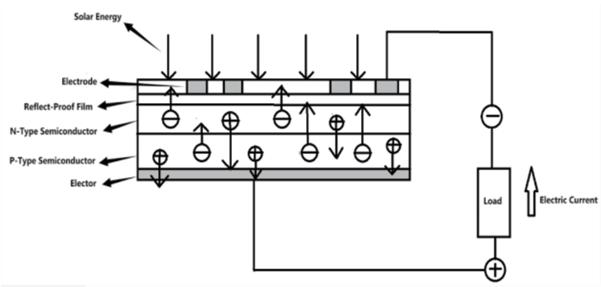

Fig. 2. Schematic diagram of silicon solar cells （Picture credit: Original）

2.2 The benefits and drawbacks of photovoltaic energy production

Benefits of photovoltaic energy production: (1) Flexible and small space occupation: photovoltaic panel power generation equipment is small and suitable for most open-air occasions. Due to the simple structure of photovoltaic power generation equipment, it is easy to install and convenient to install and disassemble. (2) Green and environmental protection: the sunlight used by photovoltaic power generation has no noise, no radiation, no pollution, and a zero-emission power generation process in power generation process. (3) Abundant resources: Photovoltaic power generation uses sunlight, so it is not restricted by region, and photovoltaic power generation equipment can be installed to generate electricity only in places with sunlight. Disadvantages of photovoltaic power generation: (1) Low conversion efficiency: the current domestic average photoelectric conversion efficiency is around 22.8%-23.0% [3], and the conversion efficiency is low, so the power density of power generation is low. (2) Easily affected by weather factors: cloudy, snowy and other bad weather has a great impact on photovoltaic power generation. Dirt will be deposited on the photovoltaic panel to reduce the optical density, resulting in a decrease in photoelectric conversion efficiency. (3) Day and night factors: Photovoltaic power generation mainly generates electricity through sunlight, which is the opposite of people generally using electricity at night.

2.3 The photovoltaic power production system's component structure

A photovoltaic cell array, charge and discharge controller, inverter, battery pack, and load are the typical components of a solar power production system, as shown in Fig.3.

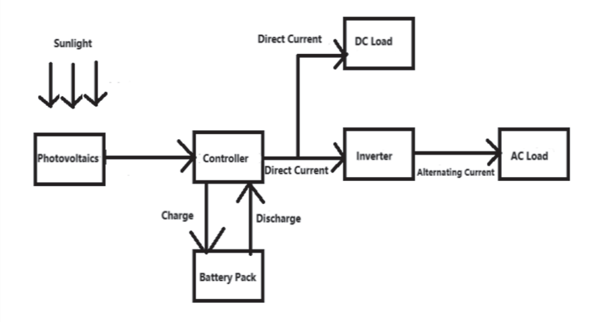

Fig. 3. Basic structure of photovoltaic power generation system （Picture credit: Original）

3 Double-axis tracking system

3.1 Basic structure of the dual-axis tracking device

To more accurately monitor the solar photovoltaic panel's peak power output, biaxial drive electrodes are generally used to adjust the angle between the photovoltaic panel and the sun's rays at 90°, so that the photovoltaic panel reaches the maximum output power point. A general dual-axis tracking device includes a photovoltaic panel, a bracket, a drive motor, and a base, as shown in Figure 4.

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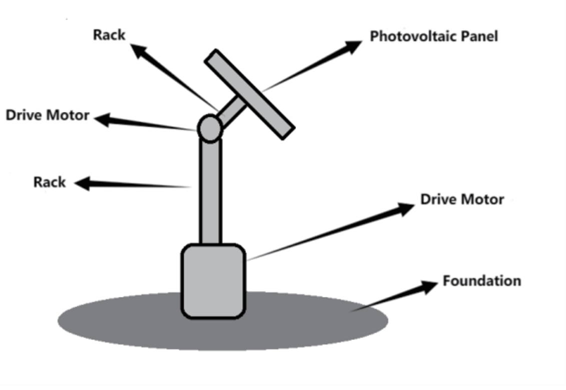

Fig. 4. Dual axis tracking device（Picture credit: Original）

3.2 The dual-axis tracking system's basic idea

At present, two varieties of dual-axis tracking systems exist, active and passive. The active type includes a collection system, a measurement system, a control system, and an execution system. Since the measurement system of the active system is generally in an open-air environment, the existing problem is that it may be affected by harsh conditions. The influence of weather makes cleaning some photosensitive precision components costly for maintenance and cleaning, and it is not suitable for use in harsh long-term environments. It is generally used in closed indoor laboratories [1]. Passive systems generally store edited instructions in the system or transmit new instructions through the network to make the system execute [1].

The dual-axis tracking system can be divided into automatic mode and manual mode. In the automatic mode, the first option is that when the light hits the photovoltaic panel, the voltage value of the photosensitive resistance on the photovoltaic panel is changed to the single-chip microcomputer through the A/D converter, and then the measurement system judges whether it has reached the maximum value. The powerpoint is then fed back to the control system. The control system will drive the motor to run. The photovoltaic panel will reach the ideal position by adjusting the two motors horizontally and vertically [4]. In the automatic mode, the second option is to use the highly accurate and widely applicable SPA (Successive Projections Algorithm) algorithm to calculate the altitude and azimuth angle of the local sun from rising to setting in the daytime according to the local latitude and longitude and latitude and store it in the system. The single-chip microcomputer drives the motor by checking the altitude and azimuth angle data at each moment in a day, assuring the photovoltaic panel can track the sun in real-time [4,5]. For example, Table 1 shows the altitude and azimuth angles calculated by SPA in the daytime from 7:00 to 17:00 in a certain place. It is compared with the altitude angle and azimuth angle given by the Risuo perpetual calendar [4]. Figure 5 shows the average light intensity received by controlling the photovoltaic panels to track the sun through the SPA algorithm from 7:00 to 17:00 during the day. It can be seen from Figure 5 that the SPA algorithm controls the average light intensity received by photovoltaic panels in a day to match the radiation value of the sun in a day [4]. Table 1 shows that there is a very minor relative difference between the sun's altitude angle and azimuth angle measured by SPA and the altitude angle and azimuth angle provided by the queried Risuo perpetual calendar [4]. From this, it can be concluded that the feasibility of tracking the peak power point of photovoltaic panels through this scheme can be obtained.

There are also two options for switching to the manual mode. The first option is to go to the site to adjust some data of the system and check the time so that the photovoltaic panel can track the sun's rays well, or adjust the direction and angle of the photovoltaic panel by pressing buttons [4]. The second option is to install a remote control system for the photovoltaic system, such as a Wi-Fi module, Bluetooth module, 5G module, etc., to realize remote control. People do not have to be on-site to modify data. Through these remote control systems, the data can be transmitted to the PC or mobile terminal in real-time, adjusting the system data online according to the feedback data.

Table 1. Experimental data table [4]

Time	SPA Calculation Data		Risuo Perpetual Calendar	
	Height Angle (º)	Azimuth Angle (º)	Height Angle (º)	Azimuth Angle (º)
7:00	11.60	-82.78	11.56	-82.90
8:00	23.44	-73.14	24.12	-73.07
9:00	40.64	-61.71	39.02	-61.08
10:00	44.53	-47.04	44.29	-46.58
11:00	51.92	-27.31	51.57	-26.92
12:00	55.10	-2.52	55.03	-2.96
13:00	52.94	22.88	53.10	22.65
14:00	46.23	43.71	46.45	44.09
15:00	36.74	59.28	36.86	60.42
16:00	25.74	71.23	25.56	72.40
17:00	14.15	81.14	14.20	81.33

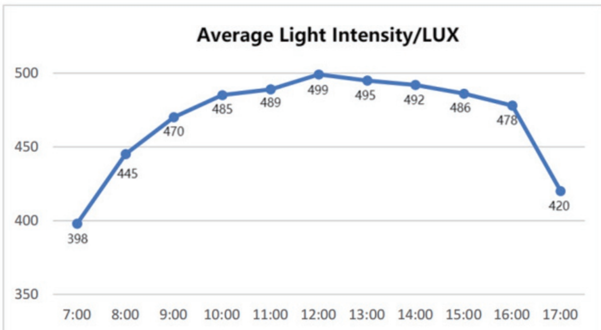

Fig. 5. Changes in the average light intensity [4]

3.3 The advantages of the dual-axis tracking system

Because the altitude and azimuth of the sun will affect the output power of the photovoltaic system, the fixed photovoltaic system in the past could only reach the maximum power output at a certain moment, not continuously. The dual-axis tracking system can better capture the maximum output power point than the previous fixed system. The dual-axis tracking system is designed to continuously align perpendicular to the incoming sunlight with the solar panel by dynamically adjusting the inclination angle through motorized control. This allows the system to consistently track the optimal position for maximum power output, ensuring efficient utilization of solar energy resources. In order to verify that the dual-axis tracking system can harvest energy better than the fixed system, Abdallah and Nijmeh (2004) designed a solar dual-axis tracking system, conducted experiments to measure the energy data collected by the system, and found that the energy collection of dual-axis driven photovoltaic panels is 41.34% higher than that of fixed photovoltaic panels[6, 7].

4 Intelligence of the dual-axis system

4.1 The problem of the existence of the dual-axis tracking system

The intelligence of the dual-axis tracking system is an important part of improving the maximum power point tracking of photovoltaic panels. The dual-axis tracking system tracks the sun's rays irregularly and unreasonably, which will only reduce operating efficiency. For example, when the sun's light density is low in a bad weather environment, the operating system sometimes makes the energy collected during operation far less than the energy consumed during operation. The performance of the dual-axis tracking system in diverse weather conditions and under varying sun densities, as well as its operation modes of tracking the maximum power point and low energy consumption in standby mode, necessitate the establishment of operational criteria for efficient functioning. These criteria encompass the determination of appropriate operational standards that govern the system's behavior and decision-making processes.

4.2 Smart MPPT control method

Most photovoltaic cells now use the maximum power tracking technology, MPPT (Maximum Power Point Track) technology. This technology solves the problem that the photovoltaic panels can output the maximum power, and the DC power produced is effectively stored in the battery. The maximum power point of this technology is captured through the relationship between the photovoltaic cell's output power and the MPPT controller's working voltage. The working principle is that the solar photovoltaic panel's output voltage must be larger than the battery's current voltage in order for it to charge the battery. When the solar photovoltaic panel's output voltage is lower than the battery's current voltage, the transmission current is zero. There are three intelligent control methods based on MPPT technology, such as FLC (Fuzzy Logic Controller), NN (Neural Network), and SMC (Sliding Mode Controller). An algorithm used often in artificial intelligence that uses fuzzy rules is called the FLC control technique. This algorithm uses fuzzy membership functions to improve the tracking speed and tracking accuracy of MPPT [8,9]. A predictive neural network controller is used in the NN control technique, a novel information processing technology type, to process information parameters. A predictive neural network controller is used to optimise and adaptively adjust the controller settings [8,10]. SMC increases the solar system's tracking speed by using the discontinuity of the control to drive the closed-loop system to attain and maintain the desired sliding surface via high-frequency switching [8]. Integral sliding mode control was suggested by Pahari and Subudhiand by conducting experiments to show that the combination of SMC and MPPT technology can improve the tracking of the maximum power point [11].

4.3 Intelligent combination of MPPT technology in the dual-axis tracking system

Nowadays, there are various algorithms to optimize MPPT techniques, such as the imperialist competition method, the genetic algorithm, and the particle swarm optimisation algorithm, etc. [12]. After optimizing the MPPT technology by summarizing the advanced algorithm through artificial intelligence, control the maximum power output point of the photovoltaic panel to the battery to obtain the law. Then get the weather data for the day or the next few days from the local weather station. Finally, let the artificial intelligence compare and summarize the data obtained from the weather station and the data that summarizes the law of MPPT. Use artificial intelligence to optimize and adjust MPPT technology through remote control technology such as Wi-Fi modules, and use artificial intelligence to optimize and adjust MPPT to obtain operating standards for photovoltaic systems in any environment, which can better make the dual-axis tracking system for photovoltaic panels and track the maximum power point.

5 Conclusion

This article briefly introduces the principle, the benefits and drawbacks of solar power production, as well as the makeup and design of photovoltaic systems. And the structure of the dual-axis tracking system is introduced. The advantages of a dual-axis tracking system over traditional stationary photovoltaic systems are presented. Explained that the principle of the dual-axis tracking system is divided into active and passive and can also be divided into automatic mode and manual mode. And analyzed the principle of a dual-axis tracking system using the SPA algorithm in automatic mode and the principle of operation control in manual mode. It demonstrates how the solar panel's maximum power point is tracked using a dual-axis tracking system, which can more accurately follow the sun's rays and maintain the photovoltaic panel's output at its maximum power point. The principle of intelligent MPPT technology and three intelligent control methods based on MPPT technology are described. Finally, artificial intelligence is used to optimize the MPPT controller in the dual-axis tracking system. The intelligent MPPT control method makes it possible to further improve the power generation efficiency of the system. This paper proposes a way to use artificial intelligence to compare and optimize the rules based on the data obtained from the weather station and the rules summarized by the intelligent MPPT technology through the remote control technology of the WIFI module to further track the peak power point of the photovoltaic panel.

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