Study on the Design of the Two-axial Solar Tracking System

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Abstract:

In this paper, research on the design of a dual-axis solar tracker was conducted. The designed dual-axis solar tracker has a simple structure, reliable operation characteristics, and superior power generation characteristics compared to a fixed type solar panel. Also, since the control circuit is composed of individual elements, it is much easier to manufacture and repair than other dual-axis solar trackers in case of malfunction during operation. Due to these characteristics, the dual-axis solar tracker proposed in this paper is likely to be widely used in solar power generation systems using sunlight tracking in a wider range.

1. Introduction

A PV module/panel/array or solar concentrator converts solar energy into electric or thermal energy [1]. To extract the maximum output power from a PV module or solar concentrator, a solar tracker can be used to track the sun direction where sunbeam is perpendicular to the face of the PV module or solar concentrator, and the maximum value of solar energy captured. [2][3]. For PV systems, past studies showed that approximately 20–50% more extrasolar energy could be obtained depending on the geographic location by adding a solar tracker to a PV system [4]. Solar trackers divided into two types: single-axis and dual-axis [5]. The single axis of a single-axis solar tracker aligned along the local north meridian, it has only one freedom degree, so it can only track the sun in one direction which is the daily path of the sun [6]. A dual-axis solar tracker has two freedom degrees, so it can track the sun path in two directions which are, daily and seasonal motions of the sun [7]. A single-axis solar tracking system improves the everyday output energy of the PV module up to nearly 20% compared to a fixed PV module [8]. Dual-axis solar tracking system is also accurate to track the sun direction compared to a single-axis type [9]. The output energy of a PV module can be enhanced up to approximately 33% compared to a fixed PV module by utilizing a dual-axis solar tracker [10]. Through the prior literature, it can see that the solar panel having the solar tracking device exhibits superior performance over the electric production by the fixed solar panel. Also, in the selection of the solar tracking device, it can be seen that the performance of the dual-axis solar tracker is superior to that of the single-axis solar tracker and can produce more power.

It can see from the previous documents that the central direction of the study was focused only on the control characteristics of the dual-axis solar trackers already being designed and operated, and the contrast analysis on the circuit configuration and operation status. These trackers are superior in terms of installation area and volume of the circuit because the circuit designed using integrated devices. However, from the characteristic of the integrated circuit, there are difficulties in repair, such as the replacement parts and the program input to the integrated element when a malfunction occurs during operation. Therefore, in this paper, we will look at a dual-axis solar tracker designed with a discrete device control circuit that can quickly solve the difficulties described above.

2. A simple theory on the solar tracking system

Solar panels must always be installed perpendicular to the sun to maximize the efficiency of the solar panels. This can realize by the solar tracking system. There are many ways to track the sun, but nothing more than these two methods: photoelectric tracking and tracking according to the movement of the sun. The latter tracking method can divide into dual-axis tracking and single-axis tracking [11].

2.1.Photoelectric tracking

The photoelectric tracking devices include gravity photoelectric tracking devices and electromagnetic photoelectric tracking devices, and an electric photoelectric tracking device. Photoelectric tracking devices all use photosensitive sensors, such as silicon photocells, which are close to the shading plate, adjust the position of the shading plate so that the shading plate aimed at the sun, and the silicon photocell is in the shadow area. When the sun moves westward, the shadow of the shading plate moves with it. The solar sensor receives direct sunlight, outputs a positive value of micro current, emits a deviation signal, amplified by an amplifier circuit, and controls the tracking device to aim at the sun to complete tracking. The advantages of photoelectric tracking are high sensitivity and convenient structure design. The disadvantage is that it is greatly affected by the weather. If dark clouds cover the sun for a long time, the sun rays often cannot shine on the silicon solar sensor, resulting in the tracking device not being able to aim at the sun, or even causing the actuator to malfunction. The following briefly introduces the two methods commonly used for photovoltaic tracking of solar panels [11] [12].

2.2.Solar panel light intensity comparison method

Two identical solar panels are connected into a "human" shape at a certain angle. They are used not only as photoelectric conversion batteries but also as photosensitive devices. When the sunlight irradiates the ground vertically, the energy flow density of the sunlight obtained on the two battery boards is the same, and the magnitude of the generated photocurrent is equal. At this time, the motors controlling their orientations do not work. If the energy flow density of the solar panel obtained by the solar panel A is higher than that obtained by the solar panel B, the photocurrent intensity generated by the solar panel A is higher than that of the solar panel when the angle between the incident sunlight and the ground changes, the motor rotates by using this signal. The advantage is that the adjustment is more precise, and the circuit is relatively simple, but the angle between the two battery plates always exists, and it can never reach the true vertical [13].

2.3.Solar sensor light intensity comparison method

Using the principle that the resistance of the solar sensor changes when exposed to light, two identical photo resistors are placed below the east-west edge of a panel. If the sunlight irradiates the solar panel vertically, the light intensity received by the two solar sensors is the same, so their resistance values are quite equal, and the motor does not rotate at this time. When there is an angle between the direction of sunlight and the vertical direction of the battery panel, the resistance of the solar sensor that receives much light intensity decreases, and the drive motor rotates until the light intensity on both solar sensor is the same. The advantage is that the control is more precise, and the circuit is relatively easy to implement [12]. To confirm the possibility of introducing the solar tracking system to the wind power generator, we designed the simple solar tracking system by using the solar sensor light intensity comparison method in the paper.

3. Design of the solar tracking system

3.1 The solar tracking system structure

The solar tracking system is composed of a sensor control circuit, an azimuth tracking mechanism, an altitude tracking mechanism, and actuator. The sensor control circuit for making the solar tracking system as follows. As shown in the picture above, the circuit consisted of four control circuits, one DC supply circuit, four relays, and two drive motors with worm reducer [Fig.1]. The detection and operation characteristics of the solar tracking system and the tracking time is given by the features of the driving motor with the control circuit and reduction gear. In the control circuit, a 5528 type light receiving element used.

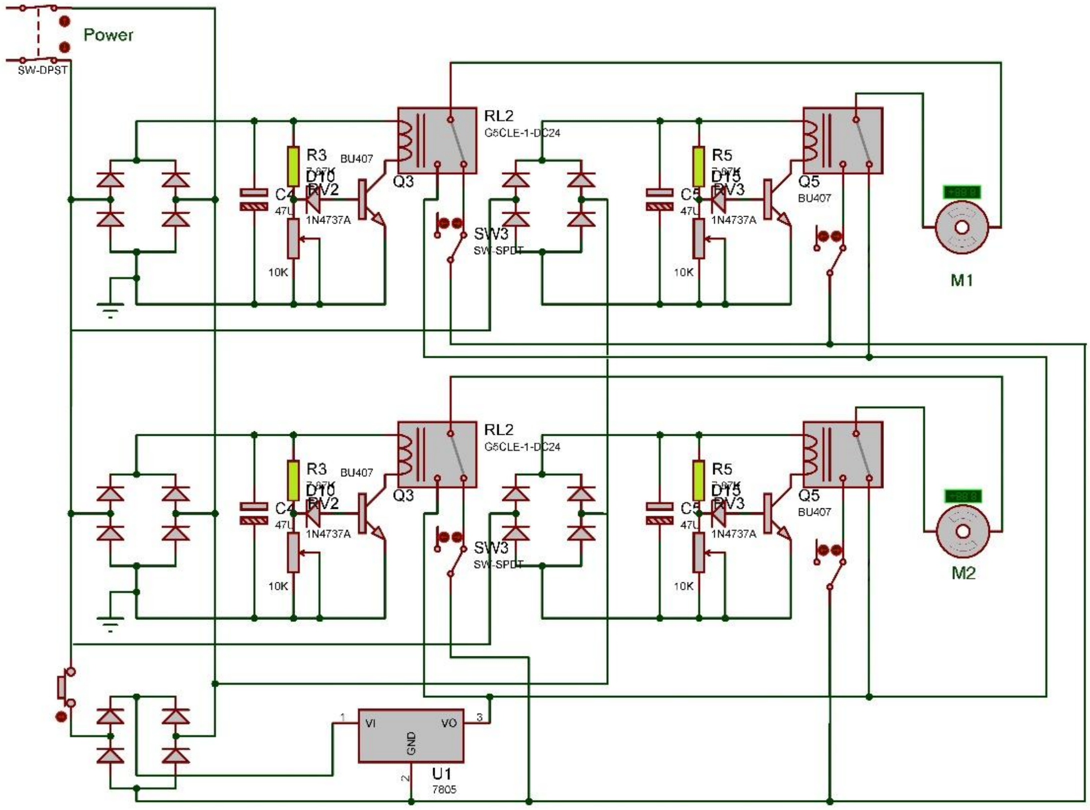
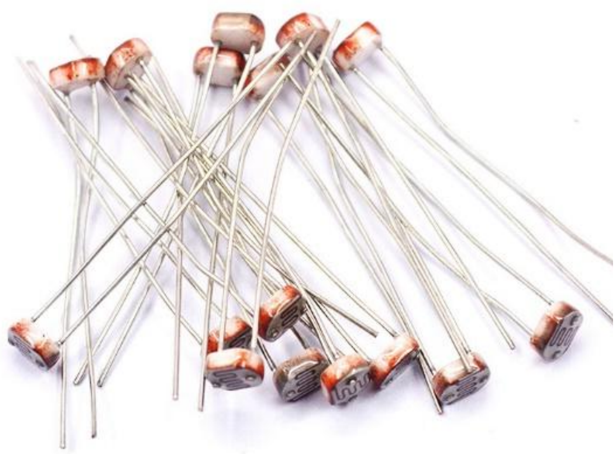


Fig.1.The sensor control circuit for making the solar tracking system

The appearance of the 5528-type light-receiving element and drive motor and their operating characteristics presented in the figure and table below. (Fig.2, Table1, Table2)



A）Light-receiving element

B）Driving motor

Fig.2. Used light-receiving element and driving motor (Source： Author shooting)

Table1. 5528 Light-sensing element and its operating characteristics

Characteristic	Values
Product number	5528
Maximum voltage (VDC)	150
Maximum power consumption (mW)	100

Ambient temperature (°C)	-30 ~ +70
Spectral peak (nm)	540
Bright resistance (Thousand ohms)	10-20
Dark resistance (Megohm)	2
Response time (ms)	Rise 20, Fall 30

Table2. Operating characteristics of drive motor

Characteristic	Values
Rated Voltage	DC 12V
No-load current	0.1A
No-load speed	7 rpm
Suitable voltage	6-12V (3.5-7 rpm)
Weight	87g

The main flow chart of the sun tracking system is as follows.

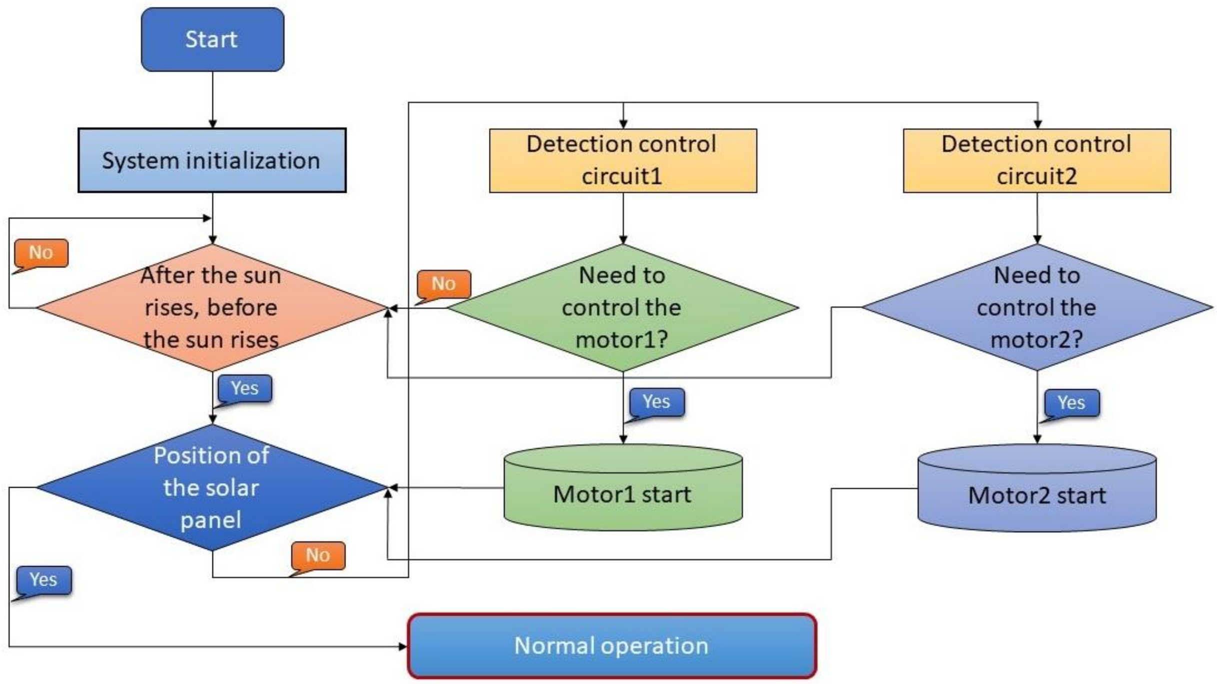
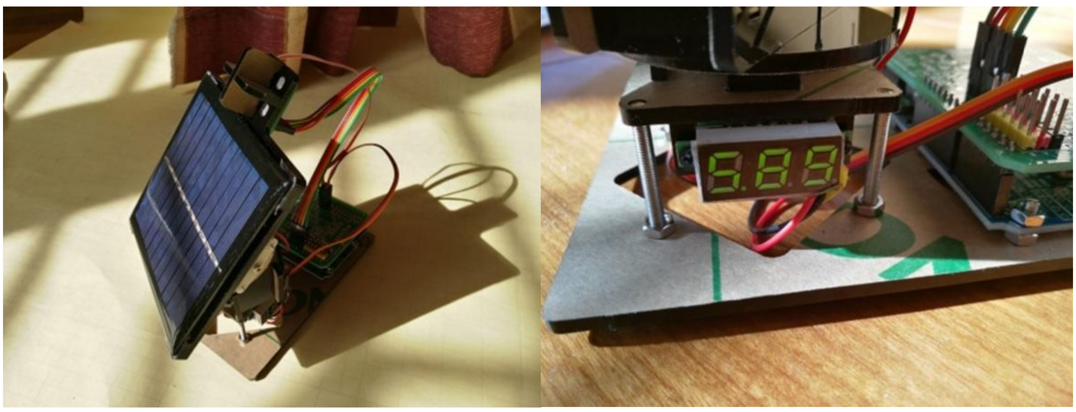


Fig.3.The main flow chart of the sun tracking system



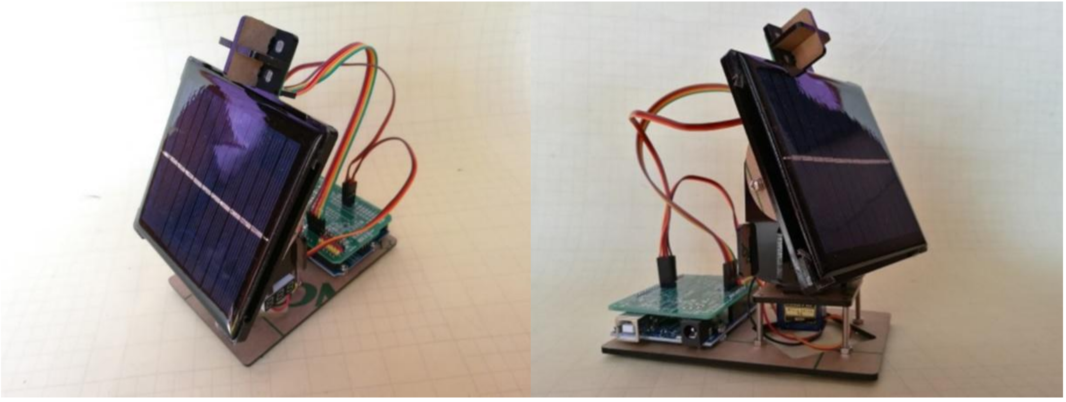


Fig.4.The actual model of the created solar tracking system

The following Fig.4 shows the actual model of the solar tracking system created by the control circuit, transmission, and basic flow chart.

Table3. Parameter characteristics of the fabricated solar tracking system

Parameter	**Characteristics and values**
System form	2-axis solar tracking system
System circuit operating voltage	5~12V
Motor operating voltage	4~12V
Speed of reducer	7 rpm
Sensor Product number	5528
Solar cell operating Voltage	5V
Solar cell Working current	0~30mA
Solar cell Size	53*30mm

The control circuit is connected in parallel with a 5V to 12V battery so that the sunlight initially tracked using the battery power. When solar tracking is over, the control circuit uses the power of the outlet where the battery power and solar battery charging power connected in parallel. The reason for this is that the control circuit for following the sunlight should be in a constant operating state even after the tracking is over. If the battery continuously used as a power source for the circuit, the power consumption of the battery exists. To decrease the battery power consumption, the power of the solar panel used as the power for the circuit. Also, since the energy density of the sun is low, the circuit cannot be operated when the power from the solar panel is not high. In this case, the power switching relay installed at the circuit entrance operates to convert the power entering the circuit into the power of the battery. It is very significant in saving battery power and ensuring continuous solar tracking.

Also, the switch installed at the entrance of the DC stabilized supply circuit for the safety and protection of the motor and relay serves to block and control the abnormal operation process of the solar tracking system driving motor and relay.

4. Results and analysis

The results of experiments on the operation characteristics of the fabricated solar tracking system are as follows.

Table4. The results of experiments on the operation characteristics

Experiment parameters	Value	characteristics
Solar Tracking		Arbitrary location
Tracking time	0.5~0.8s	Good
Electric drive characteristics		Good
Solar cell Voltage	5V	Normal
Solar cell current	30mA	Normal
Solar energy utilization increase rate	20%	Good

As shown in the above experimental results, the manufactured solar tracking system is a solar tracking system based on two-axial tracking. Also, the tracking time was 0.5 to 0.8 seconds, which proved that the driving characteristics of the solar tracking system were quite good. It proved that the voltage coming out of the solar panel during the operation was 5V, and the current value was 30mA, guaranteeing the rated characteristics of the solar panel fully. As a result, it verified through the experimental results that the produced solar light tracking system improved energy efficiency by 20% or more compared to the fixed solar light system. It proved quantitatively that the solar panel can exhibit excellent ability. In this way, the thin-film solar panel can produce more power even under the same conditions, thereby improving the output efficiency of the solar panel.

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