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Research on Four Quadrant Intelligent Tracking System Based on Solar Energy

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ABSTRACT

In order to reduce the power consumption of the system, the tracking mode is designed as discrete, and the system is powered off and standby when the system is idle. The disturbance observation method to realize maximum power point tracking is optimized and improved, and a differential disturbance mode is proposed to avoid disturbance observation. Observe the mis-operation of the method when vibration and light intensity change near the maximum power point. The experimental results show that the tracking resolution of the system can reach 0.344°, the system error is less than 2.5°, and the charging efficiency of the system is improved by more than 40%.

1. Introduction

With the rapid development of modern industry and agriculture and the increasing population[1], human demand for energy is increasing day by day, with an annual growth rate of 5% ~ 6%. While traditional fossil energy is non renewable energy[2], which is drying up day by day[3]. All countries are facing a huge energy crisis; On the other hand, conventional energy such as coal[4], oil and natural gas will seriously pollute the environment in the process of use[5]. Therefore, all countries are looking for renewable and pollution-free new energy[6,7,8], such as wind energy, solar energy, nuclear energy and so on. Among them, solar energy, as a new energy with rich reserves, no pollution, convenient application and no transportation, has great advantages in the development of new energy[9]. The use of solar energy is the most common in various countries[10].

How to improve the utilization efficiency of solar energy has also become the focus of research in various countries[11]. In recent years, there are many topics related to solar tracking system.[12] Although China's solar energy development technology started late, and there is still a big gap in technology and scale compared with developed countries, in recent years, with the research of more and more experts and scholars on solar power generation technology, China's solar energy application technology has made rapid development[13].

According to relevant research, when the tracking system is applied to the solar photovoltaic panel array, the power generation efficiency of this mode can be improved by 36% compared with the fixed mode. However, almost all system designs do not consider the problem of calibration. From the perspective of solar tracking and calibration, this paper not only realizes solar tracking, but also improves its tracking accuracy and further eliminates the cumulative error through continuous calibration.

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2. The Basic Coordinate System and Coordinate Transformation Method for Describing the Law of Solar Motion

2.1 Vector representation in equatorial coordinate system

Establish an equatorial coordinate system O-XYZ, Z axis pointing to the Arctic. X axis, Y axis in equatorial plane, X axis pointing. In the south, Y axis points to the east. In the equatorial coordinate system, the position of the sun is described by the latitude angle δ and the time angle ω. The sun passes through the local meridian w = 0 (solar noon), westward (afternoon) is ' + '. The equator angle δ is the angle between the solar-earth line and the equator plane. The sun is ' + ' in the north of the equator, '− ' in the south of the equator, and 0 in the equator. N is the N Day from January 1. The calculation formula of δ is: which is shown in formula (1).

$$\sin\delta = \sin 23.18^{\circ} \cos[\frac{360^{\circ}(N+10)}{365.25}] \tag{1}$$

In the equatorial coordinate system, the unit vector n_s from the earth center to the sun can be expressed as:

$$n_s = (\cos\delta\cos\omega, -\cos\delta\sin\omega, \sin\delta) \tag{2}$$

In the region with latitude λ, the unit vector n_c of the normal line on the surface of the flat plate receiver facing the south and the inclination angle β can be expressed as:

$$n_c = [\cos(\lambda - \beta), 0, -\sin(\lambda - \beta)] \quad (3)$$

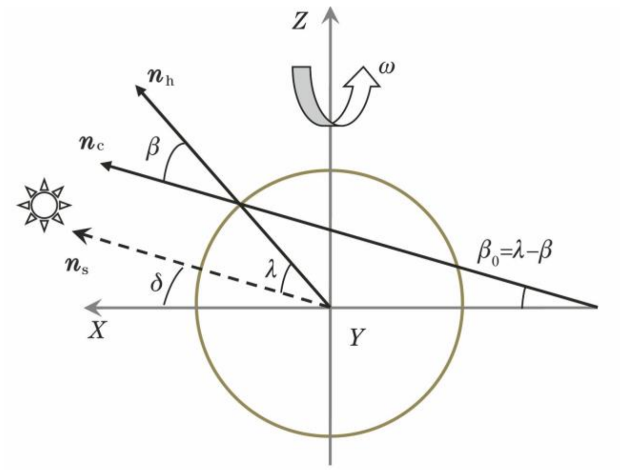

Fig. 1. Equatorial System of Coordinates.

In the region with latitude λ, the unit vector n_h of the horizontal normal can be expressed as:

$$n_h = (\cos\lambda, 0, \sin\lambda) \quad (4)$$

2.2 Vector representation of horizontal coordinate system

The ground coordinate system O'-X'Y'Z' is the result of rotating the equatorial coordinate system O-XYZ around the Y axis clockwise λ. The Y ' O ' Z ' coordinate plane is located at the horizontal plane. The X ' axis perpendicular to the ground points to the zenith, Y ' points to the east, and Z ' points to the north sky. The azimuth angle φ_s of the sun is the angle between the projection of the sun vector on the horizontal plane and the south direction.

The unit vectors of X' and Z' axes in the O-XYZ coordinate system are X' = (cosλ, 0, sinλ) and Z' = (− sinλ, 0, cosλ), respectively. Therefore, the coordinate component of the unit vector n's of the sun in the X'Y'Z' coordinate system is, which is shown in formula.(5)

$$\begin{cases} n_x' = n_s \cdot X' = n_\lambda \cdot \cos\lambda + n_z \sin\lambda \\ n_y' = n_9 \\ n_Z' = n_s \cdot Z' = -n_x \sin\lambda + n_z \cos\lambda \end{cases} \quad (5)$$

At this time, the system automatically tracks the sun through time control; in the rainy weather, the solar radiation is weak, the photoelectric conversion efficiency is not high, and the automatic conversion mode of the system enters the sleep state. In this state, it can not only ensure the accuracy of tracking control, but also effectively reduce the loss of power resources.

Single axis tracking method only tracks in one direction dual axis tracking is simultaneous tracking from the position of solar height and horizontal angle. In addition, according to the different tracking mechanism, there are two methods to track the solar energy, which are photoelectric tracking mechanism and solar trajectory tracking mechanism[18].

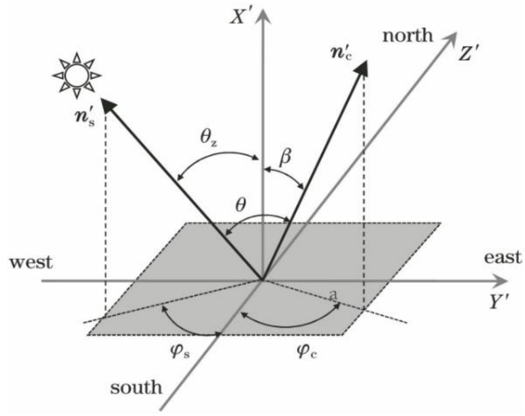

Fig. 2. Unit vector of the sun and solar panels in the ground plane coordinate system.

It can be seen that the coordinate transformation using vector algebra is simpler and more direct. The traditional coordinate transformation is to project n_x and n_z onto X ' and Z ' axes respectively, and then calculate n ' x and n ' z. In the ground coordinate system, for the receiving plane with inclination angle β (the angle between the battery plate plane and the horizontal plane) and azimuth angle φc (the angle between the ground projection line of the surface normal of the battery plate and the south), the unit vector of the surface normal is expressed as:

$$n_c' = (\cos\beta, -\sin\beta\sin\phi_c, -\sin\beta\cos\phi_c) \quad (6)$$

2.3 Incidence Angle and Sunrise and Sunset Angle of Sunlight on Fixed Surface

When analyzing the incident angle of the sun on the fixed plane, a suitable coordinate system is selected to facilitate the determination of the normal vector of the fixed plane, and then the calculation expression of the incident angle θ is derived by using the dot product of the normal vector of the sun and the solar panel $\cos\theta = n_s \cdot n_c = n_s' \cdot n_c'$. In order to solve the sun ' s rise and sunset time angles on the solar panel, it is necessary to calculate the time angle corresponding to the incident angle equal to 90°, and then determine the sun ' s rise and sunset time angles on the ground.

For example, in a horizontal coordinate system, the vector of the ground normal is n_h' = (1,0,0), so the incident angle of the sun on the ground (also known as the zenith angle) is:

$$\cos\theta_Z = \left(n_x', n_y', n_z'\right).(1,0,0) \quad (7)$$

$$n_\lambda' = \cos\lambda\cos\delta\cos w + \sin\lambda\sin\delta \quad (8)$$

Assuming θz = 90°, the sun ' s rising and sunset angles on the ground can be obtained as：

$$\cos w_0 = -\tan\delta\tan\lambda \quad (9)$$

The normal vector of the south facade of the building is (0,0, -1), and the incident angle of the sun on the south facade is:

$$cos_{sw}(n_x', n_y', n_z') \bullet (1,0,0) \quad (10)$$

$$-n_z = -\sin\lambda\cos\delta\cos w + \cos\lambda\sin\delta \quad (11)$$

Let θsw = 90°, combined with the ground sunset angle w0, the sun rise and sunset angle of the south facade can be obtained as:

$$\begin{cases} \omega_{sw,ss} = -\min(\omega_{sw,}\omega_0) \\ \omega_{sw,sr} = \min(\omega_{sw,}\omega_0) \end{cases} \tag{12}$$

$$\cos w_{sw} = -\frac{\tan\delta}{\tan\lambda} \tag{13}$$

When choosing coordinate system, the criterion is to determine the normal vector of fixed plane conveniently. For example, the equatorial plane coordinate should be used to calculate the incident angle of the sun on the Arctic surface, because the Arctic surface (horizontal plane) is parallel to the equatorial plane.

The vector of the Arctic surface in the equatorial plane coordinate is (0, 0, 1), and the incident angle is cosθz = (0, 0, 1) ·ns = sinδ. In the summer half year, sinδ > 0, the sun does not fall all day, wc = 180° ; in the winter half year, $sin\,\delta$< 0, the sun cannot shine to the Arctic, wc = 0). For example, for the collector facing the south, the normal line in the equatorial plane coordinate system is (1,0,0), and the solar incidence angle is $cos\,\theta_c = n_x = cos\,\delta\, cos\, w$。

3. Design of Solar Tracking System

3.1 Control strategy and implementation

According to whether the output responds, the solar tracking system can be divided into four modes: open loop control, anti-closed loop control, closed loop control and hybrid control. The open loop control method mainly tracks the time and the solar trajectory[14]. The anti-closed loop control method is mainly read by the photoelectric encoder. The rotation angle of the electric energy device is compared with the solar positioning angle read by the photoelectric sensor, and the tracking of solar light is realized through the gap between the two[15].

According to the different number of system axes, solar tracking methods can usually be divided into single-axis tracking and dual-axis tracking[16]. Single axis tracking method only tracks in one direction dual axis tracking is simultaneous tracking from the position of solar height and horizontal angle. In addition, according to the different tracking mechanism, there are two methods to track the solar energy, which are photoelectric tracking mechanism and solar trajectory tracking mechanism[18]. In reality, the commonly used solar tracking methods are mainly the following time-space control method, uniform control method and light intensity control method[19,20].

3.1.1 Time control method

The sun rises and falls repeatedly every day, and observers on the planet will be in different places at different times in a year because of their location. In addition, the solar trajectory is related to the complex factors of time, season and local latitude and longitude[21]. The rotation of the sun has certain regularity. The position of the sun should be confirmed from two different perspectives, namely the orientation angle and the height angle[22]. Therefore, the above related data can be input into the microprocessor in advance, and the time and space synchronization can be realized by checking the table and calculating the solar azimuth angle and altitude angle, and finally the actual angle can be obtained to achieve accurate control.

The method has high precision, good adaptability and is not suitable for implementation.

3.1.2 Light intensity control method

Due to the diversity of atmospheric environmental conditions, not sufficient lighting can be guaranteed every day. The light energy tracking mechanism can make up for some defects of the time control mechanism. The light environment is usually divided into four categories: sunny weather, cloudy weather, rainy weather and bad weather. In various meteorological conditions, in order to automatically track the sun and reduce energy consumption, it is necessary to select the tracking mode according to the actual situation.

Under sunny weather conditions with sufficient sunlight, the solar radiation is the strongest, and the tracking accuracy is the highest. The improvement of solar power generation efficiency is more and more obvious. The system first uses time control mode for rough tracking, and then uses light energy control mechanism for fine tracking. In the cloudy meteorological environment, the solar light is easily disturbed by the cloud [28], which is not suitable for ray tracing. At this time, the system automatically tracks the sun through time control; in the rainy weather, the solar radiation is weak, the photoelectric conversion efficiency is not high, and the automatic conversion mode of the system enters the sleep state. In this state, it can not only ensure the accuracy of tracking control, but also effectively reduce the loss of power resources. Under severe weather conditions such as heavy rain and snowstorm, the system is transformed into an automatic protection mode to prevent the damage that cannot be restored due to the harsh natural environment.

The characteristics of this method are high measurement accuracy, simple circuit, easy to implement, but in cloudy and cloudy weather conditions will appear can not track the state.

3.1.3 Uniform speed control method

Since the earth ' s rotation speed is fixed, it can be assumed that the sun rises from the east in the morning and goes southward, moving westward and falling. The sun moves at a constant speed of 15° / h in azimuth, and moves for a week in 24 h. Height angle is equal to the local latitude as a polar axis. The tracking process is to rotate the solar panel fixed on the polar axis at the speed of 15° / h of the earth' s rotation angle, so as to track the sun and keep the solar panel plane perpendicular to the solar light.

The control method is simple, but it is difficult to install and adjust. The initial angle is very difficult to determine and adjust. It is greatly affected by seasonal factors and the control accuracy is poor.

3.2 System structure and working principle

The high-precision all-weather solar automatic tracking system designed in this paper consists of a tracking control unit with STM32 microcontroller as the core, a photoelectric detection module, a signal processing circuit, a GPS module, a wind speed sensor, a clock circuit, a touch screen, a stepper motor. Structure diagram of solar automatic tracking system, which is shown in Fig. 3.

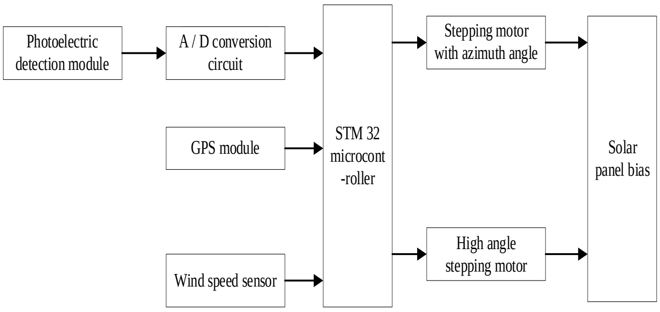

Fig. 3. Structure Diagram of Solar Automatic Tracking System.

After the system works, the photoelectric detection module collects and processes the sunlight, and outputs a weak current signal. The current-to-voltage and voltage amplification are realized through the signal processing circuit, and then the analog signal is transformed into a digital signal through the analog-to-digital conversion circuit, which is transmitted to the tracking control unit. The collected signals are processed by the tracking control unit, and the azimuth stepper motor and the altitude stepper motor are driven by the stepper motor driver to track the real-time change of the sun position. At the same time, the human-computer interaction interface based on touch screen is designed to display the current date, time, latitude and longitude, and the corresponding elevation angle and azimuth angle information.

3.3 Hardware design of day-of-sight trajectory tracking method

Day-of-sight trajectory tracking requires accurate local time, so the clock circuit is indispensable. Although the single chip microcomputer also has the function of timing, but the long time will cause large error. The serial clock chip DS1302 is a real-time clock chip with high precision, low power consumption and high performance-to-price ratio produced in the United States, and it can still continue to time when power is off. Therefore, this paper selects the serial clock chip DS1302 as the core of the external clock circuit. Although DS1302 does not adopt photoelectric isolation, it has good anti-interference effect due to the timing control of reading and writing and the writing protection. At the same time, it is small in size and has few connections. There is only one crystal oscillator (32.768 kHz) in the periphery, so it is flexible to use. which is shown in Fig. 4

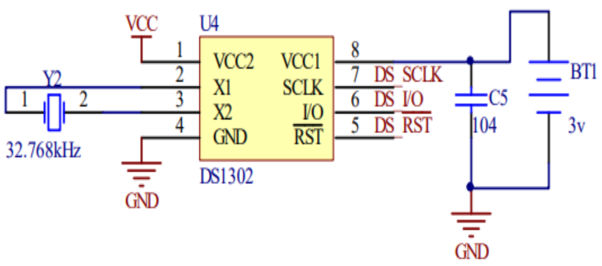

Fig. 4. Clock circuit

When debugging the clock circuit, the keyboard and display circuit must be added, because for the clock circuit, when the first power debugging, the display time must be inaccurate, which needs to be adjusted by the keyboard circuit. The keyboard circuit can realize the functions of bit selection, addition and subtraction, and it is also convenient to adjust the time in the future. which is shown in Fig. 5.

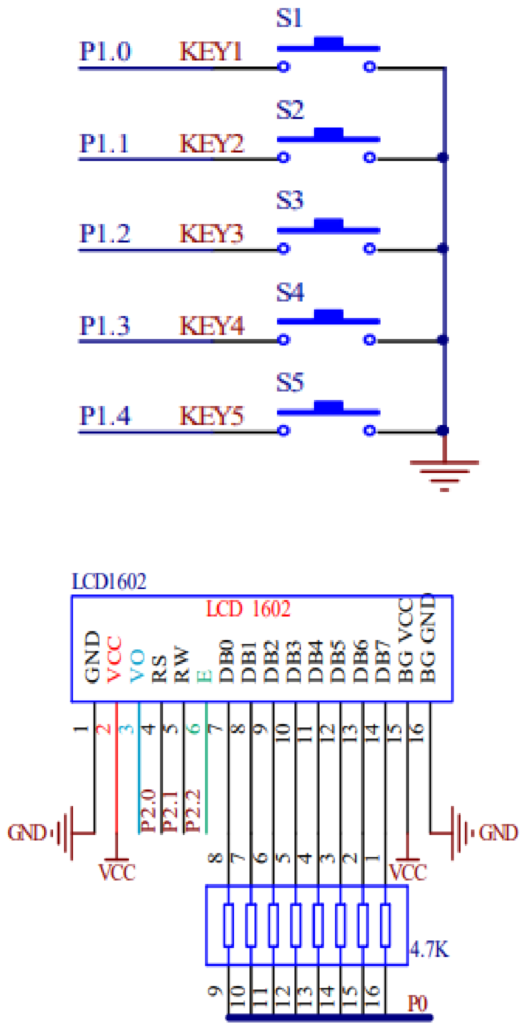

Fig. 5. Key and display circuit

3.4 Design of Solar Position Detection Circuit

The solar position detection circuit is the core circuit in the photoelectric tracking mode. The system selects the photosensitive resistance as the front-end sensor of the photoelectric tracking mode. According to the characteristics of the photosensitive resistance, we can know that the photosensitive resistance can change the corresponding resistance value according to the intensity of the incident light, so as to output different electrical signals.

When the light intensity is stronger, the resistance value is smaller. In addition, within a certain range of light intensity or luminous flux, the photosensitive resistance does not change with the change of external voltage, but only depends on the input luminous flux or light intensity.

Generally, the photosensitive resistor will be made into a thin sheet structure, and the advantage is that it can absorb more light energy. In order to obtain high sensitivity, the electrodes of photoresistors are often made of comb structure, which is made of gold or indium and other metals by evaporation on the photoconductive film under a certain mask coating cover.

The parameters of the photosensitive resistance are not only related to its own material, but also to the wavelength of the light, so different light corresponds to different types of photosensitive resistance. Solar light, except ultraviolet light and infrared light, belongs to the category of visible light. In most cases, cadmium sulfide photoresistor corresponds to the wavelength range of visible light. Therefore, cadmium sulfide photoresistor is selected as the photoelectric detection device of solar position in this paper. Common models are GL5528, GL5516, GL5506, GL5537, GL5539, GL5549, etc.

Four peripheral photosensitive resistors and ordinary resistors constitute a simple divider circuit, circuit diagram. When the solar light is vertically irradiated on the solar panel, the light intensity of the four photosensitive resistors is almost the same. With the passage of time, the solar light will gradually deviate from the central position, resulting in changes in the light intensity on each photosensitive resistor, the resistance value and the voltage value at both ends of the photosensitive resistor.

The single chip microcomputer reads the voltage values at both ends of the four photosensitive resistors and processes data. When the voltage difference between the upper and lower, the left and right photosensitive resistors exceeds the preset voltage value, the microcontroller will drive the stepper motor to rotate for adjustment until the voltage difference between the upper and lower, the left and right photosensitive resistors is within the preset voltage value. which is shown in Fig. 6.

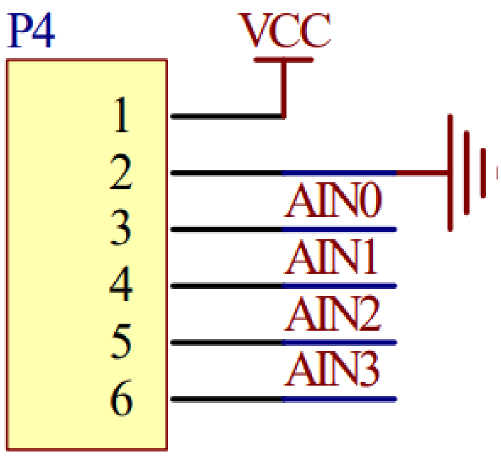

Fig. 6. Solar position detecting circuit

3.5 Hardware design of day-of-sight trajectory tracking method

The core processor of the system is the single chip microcomputer module. Its main function is: Under the photoelectric tracking mode, the light intensity information of the photoelectric detection module is received. The single chip microcomputer uses the light intensity deviation to control the stepper motor to realize the photoelectric tracking. The single chip microcomputer uses the time information collected by the clock module to calculate the height angle and azimuth angle. The stepper motor is driven by instructions to realize the tracking of the day-of-sight trajectory.

(1) According to the hardware resources required by the system, the selected microcontroller can integrate the hardware resources as much as possible within the microcontroller, such as ADC, DAC, SPI bus, etc. The advantage of doing this is that it can facilitate the software management of the whole system, at the same time, it can reduce the investment of external hardware, and also reduce the area of the circuit board, which is conducive to the drawing of our circuit diagram, and board making.

(2)In the selection of single chip microcomputer, try to select the mainstream single chip microcomputer on the market, so as to ensure that the relevant information, literature and external hardware resources of the selected single chip microcomputer are sufficient.

(3)In the case of single chip microcomputer resources to meet the needs of the system, in order to reduce power consumption, should choose low voltage, low power consumption of single chip microcomputer.

(4)Under the condition of resources and funds permitted, in order to facilitate future system upgrade, we should choose to have stronger performance.

According to the above points, combined with the solar panel automatic tracking system hardware resource requirements, this paper chooses,STC89C52RC microcontroller. which is shown in Fig. 7.

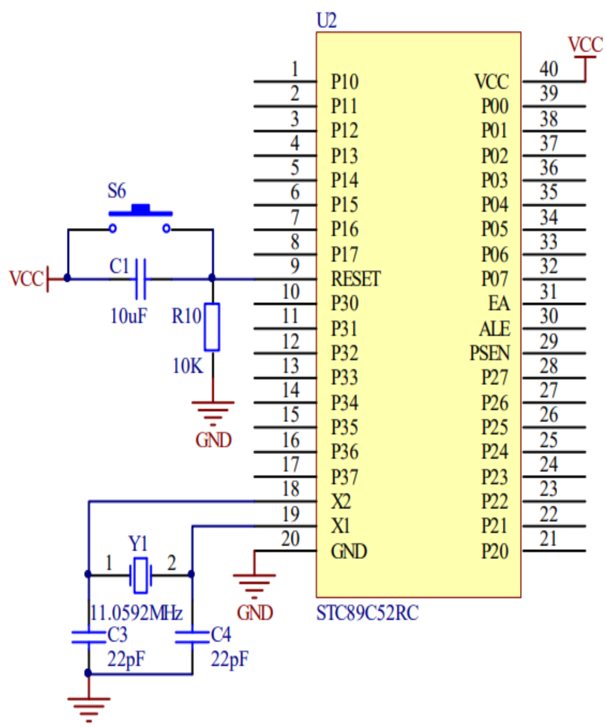

Fig. 7. Minimum system of STC89C52RC

3.6 Design of photoelectric detection module

The solar energy automatic tracking system designed in this paper is mainly based on photoelectric tracking mode. In order to improve the tracking accuracy of the system, a two-stage tracking photoelectric sensor with coarse and fine combination is designed. Its outstanding advantage is to overcome the shortcomings of the traditional baffle-based sensor which is vulnerable to stray light and the small tracking range of the cylindrical shading sensor. The structure diagram is shown in Figure 2. Mainly includes transparent cover, optical system, baffle, photocell, four quadrant photoelectric detector. The optical system is installed at the top of the baffle, and the four-quadrant photodetector is placed at the bottom of the baffle. One photocell is placed upward from the outside of the baffle to the east, west, south and north, respectively. The performance parameters of the four-photo cell are consistent. Design of photoelectric sensor, which is shown in Fig. 8.

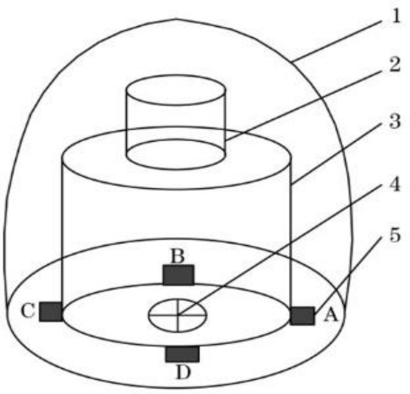

Fig. 8. Structure diagram of two - stage tracking photoelectric sensor. Number 1 represents the light shield; number 2 represents the optical system; number 3 represents the shader; number 4 represents the four-quadrant photodetector; number 5 represents photovoltaic cells.

The precise positioning sensor uses a four-quadrant photoelectric detector to accurately locate the azimuth information of the sun. Solar light through the optical system will form a spot on the surface of the four-quadrant photodetector at the bottom of the baffle.

When the solar light obliquely irradiates the photodetector, the deviation of the spot in the transverse X-axis and longitudinal Y-axis direction of the four-quadrant photodetector is ΔX and ΔY, respectively. At this time, the light receiving areas of the four quadrant photosensitive surfaces are not equal, and the photocurrents I_1, I_2, I_3 and I_4 with different output sizes are not equal. Due to detection. The output of the device is a weak current signal. In order to facilitate the recognition and processing of single chip microcomputer, it is necessary to convert it into larger voltage signals U_1, U_2, U_3, U_4.

Voltage U_X and U_Y are used to represent the offsets ΔX and ΔY of the spot center on X and Y axes, which is shown in formula (12).

$$\begin{cases} U_x = U_1 + U_4 - U_2 - U_3 \\ U_y = U_1 + U_2 - U_3 - U_4 \end{cases} \tag{12}$$

In view of the output photocurrent of the detector will change with the change of light intensity, in order to eliminate the influence of spot intensity on the offset as much as possible, E_X and E_Y are obtained by normalizing U_X and U_Y,which is shown in formula (14).

$$\begin{cases} E_X = \dfrac{U_1 + U_4 - U_2 - U_3}{U_1 + U_2 + U_3 + U_4} \\ E_Y = \dfrac{U_1 + U_2 - U_4 - U_3}{U_1 + U_2 + U_3 + U_4} \end{cases} \tag{14}$$

The tracking control unit can track the change of solar position by judging the amplitude, positive and negative of E_X and E_Y. When $E_X > 0$, it means that the sun moves eastward in azimuth, and vice versa ; when $E_Y > 0$, it means that the sun moves southward at the elevation angle, and vice versa ; the tracking control unit drives the solar panel to adjust the solar azimuth angle and altitude angle by controlling the stepper motor, so that when E_X and E_Y are 0, the solar light irradiates the detector vertically.

The photoelectric cell is selected for the coarse positioning sensor. When the sun is perpendicular to the sensor, the four photoelectric cells suffer the same illumination, the same output voltage, and the tracking device does not operate.

When the solar tilt irradiates the sensor, the shadow of the baffle will block the photovoltaic cells, resulting in unequal light intensity of four photovoltaic cells, and thus unequal output voltage. The controller can track the change of solar azimuth angle by using the voltage difference of A and C photocell output. Using the output voltage difference B, D of 2 photocell to track the change of solar altitude angle.

In addition to the preliminary detection of the azimuth and elevation angles tracking the sun, the coarse positioning sensor also has the function of judging the weather conditions. By reading the voltage values of A, B, C and D four photovoltaic cells and comparing with the set threshold, when the threshold is greater than the set threshold, it is sunny day with good lighting conditions, and vice versa.

3.7 Design of photoelectric detection module

Day-of-sight trajectory tracking is an open-loop active tracking based on astronomical parameters. The tracking control unit uses GPS module to obtain the information of longitude, latitude and time. According to the corresponding calculation formulas and parameters, the theoretical values of the solar altitude angle and azimuth angle at the current moment are calculated. According to the error of the position and theoretical value of the current tracking device, the control unit calculates the number of pulses that the high angle stepper motor and the azimuth stepper motor should rotate, and sends the corresponding signal to the stepper motor driver to drive the stepper motor to rotate and complete the real-time tracking of the sun.

3.8 System software design

The function of the solar automatic tracking system control system is mainly reflected in the acquisition of data information of different detection modules, and the corresponding operation processing, and then the actuator issued instructions to make the corresponding action, and finally complete the goal set by the system. The functions required for the design of the system software are as follows :

When the system starts, the wind speed sensor starts to work. When the wind speed is greater than the set value, the controller considers that the current wind speed may damage the platform, and the control device is leveled to minimize the damage of the wind to the tracking device.

When the wind speed is in the working range, read the system time, then the system time in the set night time period, tracking system does not start. When the system time is in the daytime (8 : 00-18 : 00), the light intensity is judged. The controller reads the output voltage of the coarse positioning sensor and compares it with the voltage threshold set, so as to judge whether the sunny day with better light intensity or the cloudy day with poor light intensity. The photoelectric tracking method is used in sunny days with good light intensity.

After entering the photoelectric tracking method, the coarse positioning sensor is used for coarse adjustment, and the fine positioning sensor is used for fine adjustment, so as to realize high precision tracking of real-time changes in solar position. Day-of-day trajectory tracking is used in rainy weather with poor light intensity. By GPS module to obtain local latitude and longitude and time information, so as to calculate the solar azimuth and elevation angle. After the system started, every 30 minutes cycle detection to determine the current weather conditions, in order to select the appropriate tracking mode, until the night system closed.

Main program flow chart of tracking control system, which is shown in Fig. 9.

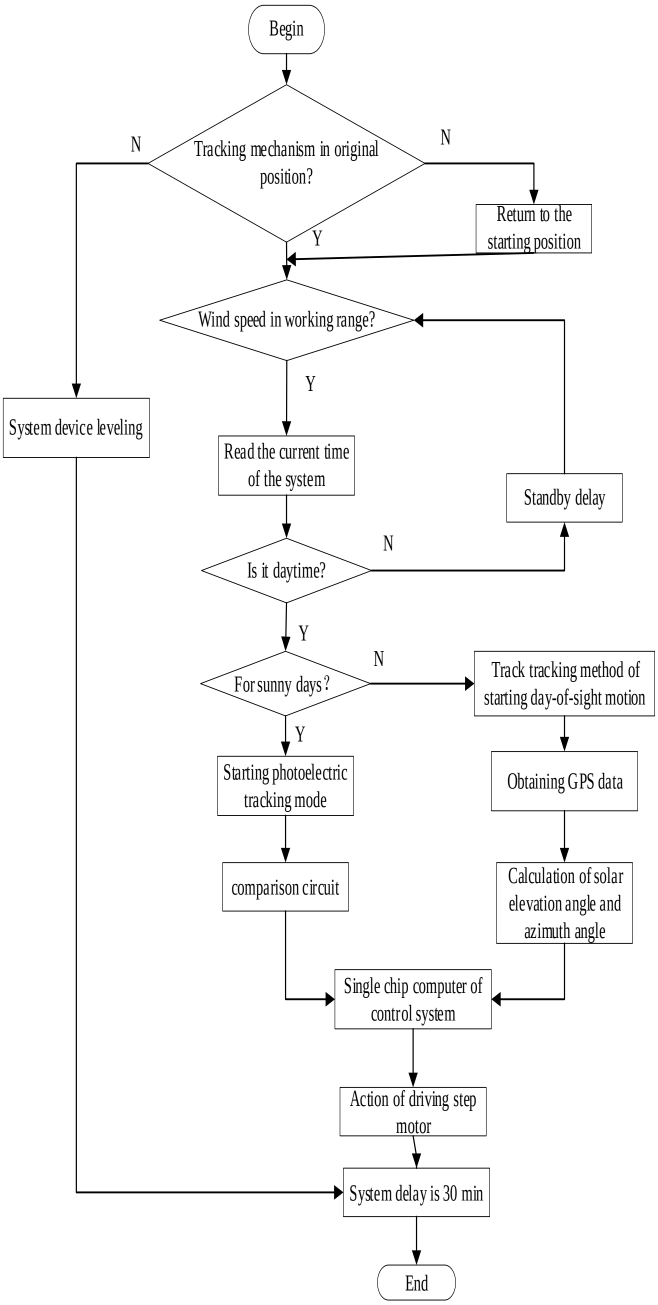

Fig. 9. Main program flow chart of tracking control system

4. Experimental Results and Analysis

4.1 Solar panel parameters

The system adopts the 5 V polycrystalline solar cell plate of Risym brand. The relevant parameters are as follows, which is shown in Tab. 1.

Parameter	Numerical value
Maximum power /mW	150
Working voltage / V	5
Working current / mA	0 ~ 40
Size / mm	53×30
Test condition	AM1.5，$25^{o}c$

Tab. 1. The relevant parameters.

4.2 Experimental results and analysis

The power of the solar panel is calculated by testing the open circuit voltage and short circuit current of the solar panel. At the same time, the energy collection is realized by using the fixed mode and the tracking mode, and the power comparison diagram of the two modes can be obtained by comparing the power generation. which is shown in Fig. 10. and Fig. 11.

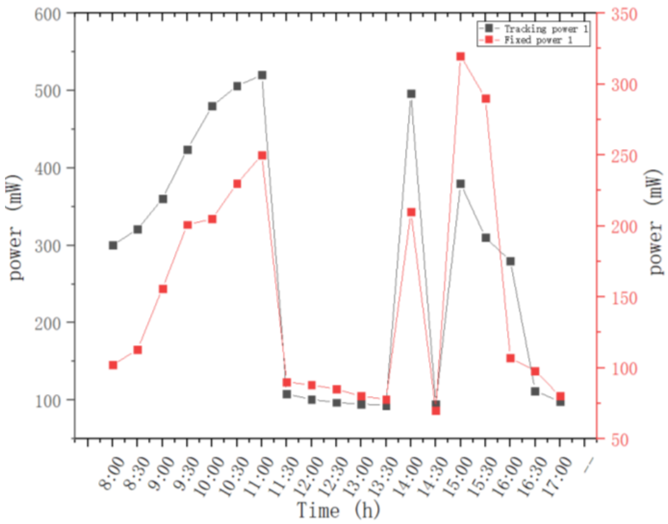

Fig. 10. Comparison of tracking mode and fixed mode in Test 1

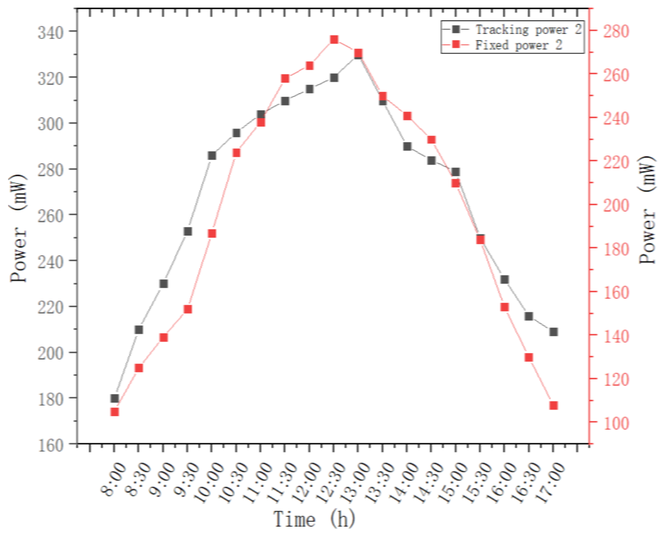

Fig. 11. Comparison of Tracking Mode and Fixed Mode in Test 2

Weather condition of Test 1: clear and cloudy in the morning; midday; cloudy afternoon. Data is collected every half hour. As can be seen from Figure 8 (1), the weather is clear between 8 :30 and 11 : 30 a.m. and the power of the tracking system is significantly higher than that of the fixed tracking system. The power changes after 11 :00 are mainly due to the cloud covering the sun. At this time, the power obtained by the daily tracking method or the adjustable partial pressure resistance method is not significantly improved compared with the fixed method. Through the analysis of the solar energy monitoring system based on LabView, the average power of the system is 160.3mW from 8 :30 to 16 :30, the average power of the fixed solar panel is 118.5mW, and the power gain is 31 %. The power gain is 36.3 % excluding the power calculation from 11 :00 to 13 :30.

Test 2 Weather conditions: sunny morning; the clouds appeared at about 11 : 30 ; cloudy after 14 : 00, light intensity decreased. It can be seen from Fig. 8 (b) that before 11:00, the output power ratio of tracking mode to non-tracking mode is 1.54 ; between 11 : 00 and 13 : 00, the angle between the solar panels of the two modes and the sun is basically the same, and the output power ratio is 1.12 ; after 14 : 00, the light intensity decreased and the output power ratio was 1.28. The average power gain is 27.5 %. The results show that the tracking without illumination can only increase the power consumption of the system, and can not effectively improve the utilization of solar energy.

5. Summary

This paper designs a calibrated solar tracking control system. By analyzing the advantages and disadvantages of solar angle tracking and photoelectric tracking, a scheme combining the two modes is proposed, and the parameter design of photoelectric mode is analyzed; At the same time, the added calibration module can calibrate the system once a day, so that the system can meet the accuracy requirements and further improve the utilization efficiency of solar energy.

The whole system has simple mechanical structure design and easy programming. It can realize all-weather tracking of the sun. It can be applied to solar power generation and other occasions, which is conducive to promoting the development and utilization of solar energy. The results show that tracking without light can only increase the power consumption of the system, but can not effectively improve the utilization of solar energy. The system has low cost and high practicability.

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