New bracket and motion control system for distributed photovoltaic power stations

Yida An*, Longkun Yu and Minxi Lu
Wuhan University of Technology, Wuhan, China

*Corresponding author: baishanyi .whut.edu.cn

Abstract. In view of the existing solar panel blackout, affecting the ecological environment, unreasonable spatial distribution, low power generation efficiency, high failure rate, difficult to operate and other issues, design a mechanical uniform solar power bracket: weather conditions, temperature, light strength and other multi-factor evaluation of the way to monitor the state of photovoltaic panels to adjust. According to the latitude and longitude and terrain of photovoltaic plate installation, the periodic movement trajectory is automatically planned, the operation is monitored centrally, and the failure point is located quickly and the operational efficiency is improved by comparing with big data speculation.

1. The background and significance of the development
At present, a series of problems such as the depletion of fossil fuels at home and abroad and the pollution caused by the use of fossil fuels to the environment are becoming more and more serious, and the development of clean, efficient and environment-friendly new energy has attracted wide attention. Solar energy is the ideal renewable resources and green energy, so the current state strongly supports the development of solar energy resources in the 13th Five-Year Plan, the demand for renewable energy will increase significantly, and the market prospects are broad.

In order to respond positively to the country's vigorous development of environmental protection new energy policy to make full use of solar energy, fishing and light complement each other, agriculture and light complement each other, light agriculture and so on a series of photovoltaic power generation and other industries combined with the new industry shows the development of blowout. This is shown in Figure Group 1. Existing solar support a wide variety but single function, there is no universality, in the face of changing complex terrain and climate problems, equipment maintenance difficulties. And the existing device is difficult to balance the power generation with environmental protection, which has caused some harm to the local ecology and affected the biological diversity.
Based on the above background, this project designs a new type of mechanical smooth solar panel support, which can be applied to many scenes such as fishing and light integration, photovoltaic sand control, etc. in complex areas of the environment. Improve the generality of the device, reduce operating costs, extend the time period of deep maintenance, improve the fault tolerance of the device, can protect the local environment under the premise of maximum power generation.

2. Design

By combining mechanical structure with big data electronic control, the device designs a new type of solar panel, which uses different latitude and longitude of the installation area and the change law of the local solar height angle, and realizes the light-chasing effect through the stable mechanical structure, and solves the problem of low reliability and easy damage of the current optical recovery system. At the same time, the device adopts the double-layer solar panel structure, through the combination of electric putter and raspberry pie, realizes the switching of single-double-layer solar panel, so that the device can be applied to distributed scenes without affecting the local ecological environment, and adapts to the needs of a variety of distributed installation scenarios.

2.1. Mechanical design

The mechanical structure of the design of this device mainly consists of photovoltaic plate angle adjustment mechanism, double plate telescopic mechanism and column telescopic mechanism. The overall unit is shown in Figure Group 2. The two-plate telescopic mechanism enables the contraction and stretching of two solar panels. The photovoltaic panel angle adjustment mechanism controls the solar panel to rotate at a certain angle and improves the luminous efficiency of the solar panel.

2.1.1. Photovoltaic plate angle adjustment module

The photovoltaic board angle adjustment module is shown in Figure Group 3, which considers the cost and stability of the adjustment scheme in the angle adjustment module.
The device is designed with the horizontal distance between the housing and the center of the lower hole of the pushrod at $l=465mm$, the height at $h=80mm$, and the center distance between the bearing and the lower hole of the pushrod as $L = \sqrt{l^2 + h^2} = \sqrt{465^2 + 80^2} = 472mm$ (1)

The angle between the bearing and the lower hole of the pushrod and the horizontal surface is $\alpha$

$$\alpha = \tan^{-1} \frac{h}{l} = \tan^{-1} \frac{80}{465} = 9.9^\circ$$ (2)

The center distance of the upper and lower holes of the putter is 255mm, the stroke $s=150mm$, the total length $S$ length range of the putter is 255-405, and the distance of the slider from the housing is $b$

$$b = \sqrt{L^2 - S^2}$$ (3)

2.1.2. Dual board telescopic mechanism design

The two-plate telescopic module is shown in Figure 4 and the telescopic lever is controlled by the Raspberry Pi. The telescopic lever here is a PXTL putter with a speed of 12mm/s, a dynamic load of 1KN, motor parameters of 30W, voltage 24 V, weight 5.1 kg, and protection class IP54.
This device does not require much movement speed of the photovoltaic plate. The thruster can be pushed at a speed that meets the requirements for use. The photovoltaic panels are 820mm × 670mm × 30 mm, and a photovoltaic power generation unit requires 8 photovoltaic panels, which are divided into 8 layers. The photovoltaic panel has a maximum force of 400N on the lower putter, and the two putters operate at low power to meet the power requirements of the unit.

2.2. Monitoring control module
The monitoring control module obtains the series values of the solar height angle day change of the year through the data library, the raspberry pie determines the sun's altitude angle value by date, specifically, the raspberry pie sends a signal to the double H bridge electric pusher drive module by controlling the GPIO pass or out, and the electric putter adjusts the base angle of the solar panel. The detailed process is shown in Figure 5.

\[ H = \text{asin}(\sin W \sin \phi + \cos W \cos \phi \cos \varphi) \]  

(4)

\( H \) is the height angle of the sun, \( W \) is the latitude, \( \phi \) is the red latitude angle, and \( \varphi \) is the time angle. Formula for the time angle:

\[ \varphi = 15 \times (T_d + \frac{T_c}{60} - 12) \]  

(5)

\[ T_d = h + \frac{m-(120-f) \times 4}{60} \]  

(6)

\[ T_c = 0.0028 - 1.9857 \sin \theta + 9.9059 \sin 2\theta - 7.0924 \cos \theta - 0.6882 \cos 2\theta \]  

(7)

\( \theta \) is the angle of the sun; \( h \) is the hour of Beijing time; \( m \) is the minute of Beijing time; \( T_d \) is the local time; \( T_c \) is the time difference; \( J \) is longitude. Among them, Beijing time at 12 noon, that is, with the height angle of noon instead of the angle of the day.

After obtaining the series values of the solar height angle change of the year, the computer can read the day value by date and adjust the angle of the photovoltaic plate with an electric putter.

2.2.2. Multi-mode control. The device adopts multi-mode operation mode to adapt to a variety of terrain environment: in the face of fish ponds, agricultural land and other ecological environment affected by...
lighting conditions, the device uses ecological energy-saving methods to work, while in the face of severe weather conditions, the use of protection mode to work.

1. Eco-energy saving mode

When the device is installed in an environment affected by lighting conditions, the fish pond, for example, will be the best living temperature of the fry in the current season as the standard. The monitoring and control module collects real-time data through temperature and light strength sensors to complete daily monitoring. When a change in the temperature of the pool water is monitored, the sensor takes the data collected here as an excitation signal, and the excitation device adjusts the angle change of the photovoltaic plate. Three adjustment levels are designed according to the magnitude of the temperature change. The adjustment level corresponds to the following table:

| grade | The temperature difference range is / degrees C | How to adjust |
|-------|-----------------------------------------------|---------------|
| 1     | 0~1                                           | Remains the same |
| 2     | 1~1.5                                         | The photovoltaic plate shrinks |
| 3     | 1.5 or more                                   | The angle of the photovoltaic plate is adjusted |

When the water temperature picks up, the photovoltaic panels will return to their optimum working posture in order of class 3, 2, and 1.

2. Protection mode

- In rainy weather conditions: In rainy weather, the networking program receives real-time weather forecasts and sends data to the Raspberry Pi, which sends instructions to control the thruster movement of the solar panels horizontally. Horizontal photovoltaic plate can receive a larger area of rainwater wash, to achieve the initial cleaning effect of photovoltaic plate. The overall height of the horizontal state photovoltaic plate is raised, which can effectively prevent the photovoltaic module from being soaked by rain.

- In windy weather conditions: When accompanied by high winds, horizontal solar panels can reduce the overall wind area of solar panels, to prevent excessive wind damage to photovoltaic modules.

- In snowy weather conditions: Snow can cause extensive damage to photovoltaic modules, affecting the output of electrical energy, and low temperatures caused by melting snow can cause damage to photovoltaic panels. When the amount of snow on the photovoltaic plate reaches a certain level, the Raspberry Pi controls the putter to make the photovoltaic board stand upright and clear the snow.

2.3. Smart Operations

The Big Data Prediction feature can obtain predicted theoretical power generation power by uploading instantly measured light strength and temperature values. This part uses Baidu EasyDL development platform, the theoretical training data upload and use regression algorithm training model, the theoretical data set for accurate actual experimental data, including light strength, temperature, etc. and the corresponding power generation power value, the trained model in Baidu public cloud deployment online, can use the http protocol call api interface upload sensor measurement The temperature and light strength and other data and forecast, will get the predicted power generation power and the actual power generation power comparison, if the gap between the two data is too large, then after a period of time to make a second prediction, if the forecast power generation power and the actual power generation power gap is still too large, that is to say, the work of the device has a problem, need manual repair or commissioning.

3. Energy saving and emission reduction benefit analysis

The energy saving and emission reduction benefits of this device are mainly reflected in the larger power generation under the condition of iso-pillar, and promote the development of fisheries and light agriculture.
3.1. Greater power generation under equal column conditions

The device adopts a two-layer rotary telescopic solar panel, which extends and shrinks it according to the actual situation, and maximizes the power generation under the same column conditions. The current conventional solar panels support one solar panel for two columns, according to the formula:

\[
P_0 = \frac{P}{2n} \tag{8}
\]

In the form: \(P\) is solar power station power; \(P_0\) is power generation power per unit column solar panel; \(n\) is number of columns.

It can be calculated that the unit column power generation capacity of the traditional solar field can be calculated.

According to the formula

\[
P = P_0 \times 2 \times n \times \mu + P_1 \times 2 \times n \times (1-\mu) \tag{9}
\]

Type: \(P\) is solar power station power; \(n\) is number of columns; \(\mu\) is the time occupied by shrinking state; \(P_1\) is power generation power per unit of column solar panels in expanded state.

Conservatively, assuming that the unit shrinks 20% of the time of day, the unit generates 1.5 times as much power as under the same column conditions.

3.2. Promote the development of fishing and light agriculture

In addition to increasing power generation, the emergence of this device in the eastern region, mixed with fishing and light agriculture, but also to achieve inhibition of bacterial growth, reduce the use of raw lime, promote fish growth.

3.2.1. Inhibits bacterial growth. By increasing the light flux, the device inhibits the reproduction of water bacteria, prolongs the disinfection cycle and reduces the use of raw lime. The existing "fish light pond" needs to put raw lime 80-120g/m² month to ensure that the pool water is weak alkaline, oxygen-soluble sufficient, promote the growth of fish and shrimp. Based on a 1 hm² fish pond, 100g of raw lime per square meters of water is used, and 1000kg of raw lime is spilled each month.

With the use of this device, it is estimated that the use of raw lime will be reduced by 50%. In Hubei Province, for example, the lake area of the province is 2656.6km², and the use of this device can reduce the use of raw lime by 4847×10⁶ kg per year, with an estimated cost reduction of 1.45 × 10⁷ yuan.

3.2.2. Improving the ecological environment. The use of this device can also improve the ecological environment of fish ponds and reduce the bait coefficient.

Plankton algae are an integral part of the current fish pond culture ecosystem. There are four common plankton algae: cyanobacteria, hidden algae, green algae, diatoms. Among them, the largest number of cyanobacteria and green algae, with small spherical algae as aquatic phytoplankton algae representative plants.

The effect of light strength on chlorophyll content is shown below:

| algae     | Light intensity (lx) | Chlorophyll content per unit of water body (μg/L) |      |      |      |
|-----------|----------------------|--------------------------------------------------|------|------|------|
|           |                      | chlorophyll a                                    | chlorophyll b | Total | a/b  |
| Chlorella | 1000                 | 233.45±14.89*                                   | 199.37±9.01*  | 432±13.93 | 1.17 |
|          | 3000                 | 496.60±80.08*                                   | 178.25±21.58* | 674.85±58.57 | 2.79 |
|          | 5000                 | 553.35±79.88*                                   | 388.93±20.41* | 942.28±67.87 | 1.42 |
|          | 7000                 | 337.18±17.91*                                   | 178.91±9.68*  | 516.09±18.56 | 1.88 |
According to the data in the table, it can be seen that chlorella can obtain the maximum chlorophyll content, the photosynthesis rate reaches the highest value under the condition of light intensity of 5000 lx.

Studies show that on a clear day, the light intensity outside is $1 \times 10^5$ lx, the shadow part of the light intensity is $3 \times 10^4$ lx, so it can be considered that the device refracted light can meet the optimal photosynthesis needs of aquatic algae.

After the use of this device, the oxygen dissolved at the shadow is expected to reach 2.2 mg/L. The results show that when the dissolved oxygen content in water reaches more than 2 mg/L, the fish grow normally, the digestion and absorption of feed is better, and the feed coefficient is lower. It is easy to know that the use of this device can greatly improve the "fishing light pond" ecological benefits.

### 4. Feasibility analysis

The device uses multi-point parallel drive to scale and rotate, which increases the wind resistance, so that the device can maintain a low failure rate in the windy weather common in the western region.

According to the China Meteorological Administration's "Wind Rating", the corresponding wind speed of 8 strong winds is 18 m/s, according to the formula:

$$m \cdot v = F \cdot t$$  \hspace{1cm} (10)

$$m = \rho \cdot V$$  \hspace{1cm} (11)

$$V = S \cdot v \cdot t$$  \hspace{1cm} (12)

Medium: $m$ is air quality; $v$ is wind speed; $F$ is wind size; $t$ is time; $\rho$ is air density; $V$ is air volume; $S$ is solar panel area.

Available from the top finishing, force size formula:

$$F = \rho \cdot S \cdot v^2$$  \hspace{1cm} (13)

Type: $F$ is wind size; $\rho$ is air density; $S$ is solar panel area; $v$ is wind speed.

Available from above, in the case of vertical solar panels blown by eight strong winds, the force size per square meter is 418.9N, in Jingzhou City, for example, the latitude of the region is 30 degrees N, in the southeastern monsoon prevailing in mid-July, the region's midday solar height angle can be based on the formula:

$$h = 90° - (\alpha - \beta)$$  \hspace{1cm} (14)

Medium: $h$ is noon sun height angle; $\alpha$ is local latitude; $\beta$ is direct solar radiation latitude.

It can be calculated that the angle of the sun's height at noon is 77.28 degrees, at which point the angle of the solar panel of the unit is 12.72 degrees. According to the formula:

$$F_1 = F \times \sin(90° - h)$$  \hspace{1cm} (15)

Type: $h$ is noon sun height angle; $F$ is wind size; $F_1$ is solar panel force size.

The available solar panel force size is 92.23N.

According to the following formula, the force of the electric putter can be calculated:

$$F_2 = \frac{(F_1 + m'g \times \cos \theta)}{\sin \delta}$$  \hspace{1cm} (16)
Type: $F_2$ is the force of the electric putter; $F_1$ is the size of the wind to which the solar panel is subjected; $m$ is the quality of the solar panel; $\theta$ is the angle between the solar panel and the horizontal surface; $\delta$ is the angle between the solar panel and the electric putter;

According to the formula, when the electric putter is perpendicular to the solar panel, the putter is the least forced, when the electric putter and the solar panel angle is the smallest, the putter is the most powerful, the minimum angle between the solar panel and the putter is 20 degrees, the replacement formula can calculate $F_2=400N$, less than the maximum tolerance of the electric putter. Since the electric putter is a two-force rod and the direction of the force is along the axis direction of the rod, the support column shaft force is also $F_2$, which is less than its maximum carrying capacity. In summary, the device is structurally feasible.

5. **Innovation points:**
   1) Ecological aspects: the angle of photovoltaic plate, telescopic state of adjustment, to achieve light compensation, seeking power generation and ecological optimal solution. 2) Construction: two-plate design, optimize spatial distribution, apply different terrains, strengthen universality, reduce the number of columns, and reduce construction costs. 3) Operational aspects: set up a variety of operating modes, to achieve adaptive to the environment, reduce the failure rate, the use of cooling mechanism, to solve the problem of single board overheating leading to reduced efficiency, big data forecast power generation trends, easy operation and maintenance.

6. **Conclusions**
   In this paper, a mechanically smooth solar energy bracket is designed. Based on different factors such as weather and wind, the state of solar panels is adjusted. According to different geographical and geological conditions, the periodic change trajectory design of solar panels is carried out. According to big data calculation, quickly locate fault points and improve operational efficiency. This work has good adaptability and popularization, and it is in line with the national sustainable development strategy to maximize the exploitation of natural resources without destroying the ecological environment.

References
---
[1] Zhai, Wu Zongwen, Xie Wei, etc." Effects of the "Fishing Light One" on plankton in stingray ponds. Aquaculture, 2015, 36 (7): 6-9. DOI:10.3969/j.issn.1004-2091.2015.07.002.
[2] Wu Xu, Yan Meixuan. Growth Response of Microcystic Algae to Light Changes , 2008, 25 (11): 45-46.
[3] Yan Meixuan, Wang Yindong, Hu Xianjiang. Effect of light on the growth rate and chlorophyll content of chlorella, oblique grid algae, anhui Agricultural Bulletin, 2007, 13 (23): 27-29,59. DOI:10.3969/j.issn.1007-7731.2007.23.012.
[4] Wei Zonghui. The structural design of the tracking part of a solar street lamp with solar tracking function DOI:10.3969/j.issn.1672-3791.2013.18.040.