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CLOUD-POWERED SOLAR OPTIMIZATION: THE FUTURE OF DOUBLE-AXIS LIGHT TRACING DEVICES

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Abstract: In the 21st century, as human society continues to evolve and urbanization progresses worldwide, the mounting demand for urban energy solutions has become a pressing concern. However, the current landscape of power generation remains heavily reliant on traditional, non-renewable energy sources. The extensive exploitation of fossil fuels has given rise to severe environmental pollution, a concerning climate crisis, energy shortages, and other complex challenges. This predicament not only demands immediate global attention but also poses a significant long-term threat to future generations. Against the backdrop of an inevitable shift in energy structures, green energy has emerged as a focal point of global interest. Within the realm of sustainable energy alternatives, water and wind power are contingent on specific natural conditions and geographical factors, which may not always align with the needs of urban development. In this context, solar energy stands out as a prime candidate for urban development, as it merely requires available rooftops and access to sunlight. Solar energy, characterized by its inexhaustible potential and zero emissions, remains a compelling choice for sustainable energy generation. However, it grapples with the challenge of energy dispersion, meaning that energy cannot always be concentrated effectively at a single point. The directional nature of sunlight further complicates this issue, as a significant portion of solar energy remains inaccessible in a fixed direction for prolonged periods. In conventional photovoltaic power generation, the total energy output is contingent on the amount of incident solar radiation. Many residential solar panels are statically positioned on rooftops, effectively harnessing sunlight but with some limitations. Fixed panels restrict the absorption of solar radiation and, consequently, diminish the overall power generation output, thereby reducing the efficiency of solar rooftops. This paper presents a solar tracking turntable designed to address this limitation. The turntable integrates solar tracking technology with rooftop solar panels, enabling automatic adjustments in the panel's orientation throughout the day to align with the sun's position. This dynamic approach enhances the power generation efficiency of the entire system by optimizing the incidence of solar radiation.

Keywords: Solar Energy, Renewable Energy, Solar Tracking, Photovoltaic Technology, Urban Development

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1. Introduction

Since the 21st century, with the development of human society and the continuous urbanization of the world, the increasing demand for urban energy also needs to be addressed urgently. However, at present, power generation mainly relies on traditional nonrenewable energy. With the large-scale exploitation of fossil energy, it has caused serious natural environment pollution, dramatic climate change, energy crisis and other thorny problems. This is not only a dilemma that the world needs to solve, but also a huge hidden danger for future generations in the long run. Under the inevitable trend of energy structure reform, green energy has focused the attention of the world. Among them, water energy, wind energy, etc. are very dependent on natural conditions and site factors, which is not conducive to urban development. Solar energy, which only requires roofs and sunlight, is undoubtedly the best answer in urban development.

Compared with other energy sources, the solar energy that can achieve zero emission is inexhaustible, but it has the characteristics of energy dispersion, which makes the energy that can be concentrated at a certain point less. Due to the inherent directionality of the sun, it means that a large amount of solar energy will not be available in a fixed direction for a long time. In traditional photovoltaic power generation, the final power generation is determined by the amount of solar radiation incident at the source. [1]According to relevant data, the energy of sunlight on the earth's surface per minute is as high as 4.8 million kilowatts. As long as 0.2% of it is converted, the conversion rate of 10% will be 22.4 × 1012kW. h. We can see the potential of solar energy. Although the current scientific and technological level cannot effectively improve the conversion rate of the photocell itself within the cost range, it can change its thinking and increase the total amount of radiation that can finally enter the photocell. At present, many solar panels installed on domestic roofs are fixed. Although effective, they also limit the absorption of solar radiation to some extent, greatly reducing the achievable power generation output and reducing the working efficiency of solar roofs. The solar tracking turntable designed in this paper applies the solar tracking technology to the solar panel on the roof, enabling it to automatically adjust the receiving angle with the change of the sun's position all day, so as to improve the power generation efficiency of the entire device by increasing the incidence rate of solar radiation.[2]

2. Overall idea and scheme

2.1. Design idea

Most factories and power stations use array photovoltaic power generation systems. Although there are many designs for photovoltaic tracking devices, they have not entered the homes of ordinary people. Most of the light tracking devices on the market are designed based on the single-chip microcomputer, which is not only difficult to make, but also difficult to develop. The solar light tracking system assembled by industrial equipment is controlled by the upper computer software, which not only reduces the cost but also is easy to maintain. In industrial application, most of the tracking devices based on photoelectric tracking are adopted. Although they have achieved high tracking accuracy, they sacrifice the practicability of the device and the anti-interference ability to deal with complex weather. This project is designed to use the sun tracking mode, the upper computer control technology and the upper computer software to build the tracking system.

2.2. Design scheme

This design scheme mainly considers the realization of dual axis operation and the feedback of the external environment of the device. RS-485 communication is carried out with each module through the upper computer software, the DC motor drive device changes the pitch angle, and the rotary table on the base of the stepping motor drive device completes the horizontal rotation. The system structure diagram is shown in Figure 1.

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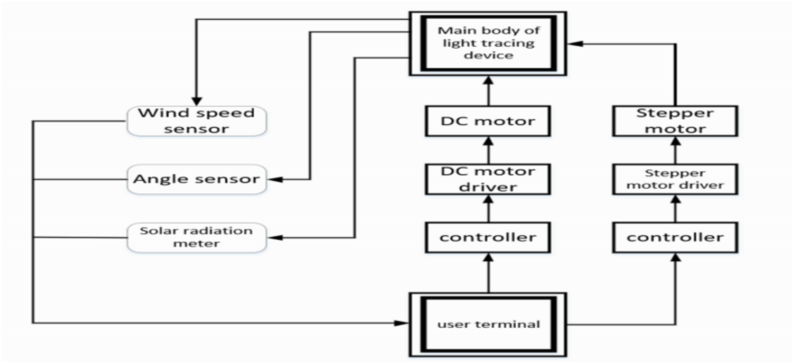

Figure 1: System Structure

3. Introduction to Device Structure

The dual axis solar tracking system of the IoT cloud platform is divided into three parts, including the main structure of the device, the upper computer (control end software), and the electric energy storage system.

The main body of the device, as shown in Figure 2, comprises a solar panel, a base turntable and a support frame assembly. The base turntable is provided with a round table, a base balance foot stand, a middle gear connector and a stepping motor that drives the gear to rotate horizontally; The support frame in the middle part includes a fixed platform, a steel frame structure, a support rod (DC motor), and a solar support. The fixed platform connects the rotary table of the base and the support rod. The fixed support rod is connected to the solar support through the steel frame structure. The support rod is composed of a DC motor and a hydraulic rod, so that the solar panel can complete the angle change in the vertical direction; Angle sensor module, wind speed detection module and light detection module are set on the appearance of the device. The box body is shown in Figure 3, with control module, power module and wireless communication module. The invention can track the solar angle by rotating the solar panel, collect more solar energy, and improve the solar energy utilization efficiency. Predict strong wind and rainy days by feeding back wind speed and light value, and reset the device shape to avoid damage to the device caused by bad weather. At the same time, the detected data can be transmitted to the data terminal to realize remote data visualization and data controllability.

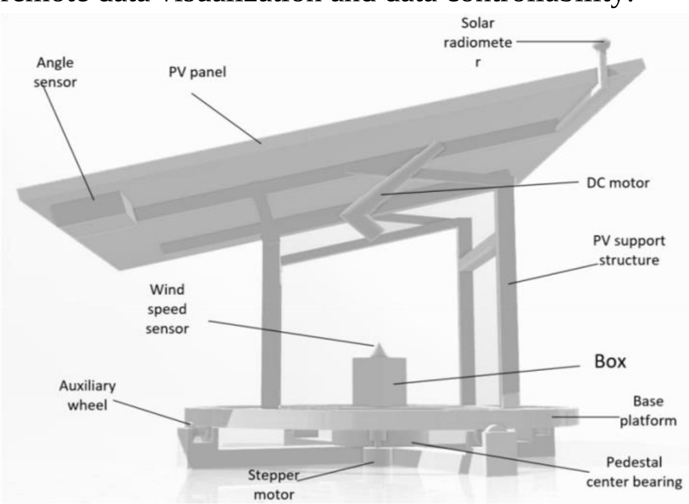

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Figure 2: Three dimensional view of device body

The upper computer system mainly includes the software of the PC end. It establishes communication with each module of the device body through RS485 communication module. It mainly uses communication to read the light intensity value, wind speed value and various electrical parameters of the photovoltaic panel, control the step motor rotating in the horizontal direction and the DC motor pitching in the vertical direction, and calculate the solar angle to ensure that the device is always facing the sun, so as to maximize the power generation efficiency.[3]

The electric energy storage system is composed of photovoltaic panels, inverters, controllers, batteries and DC meters. It is used to store the electric energy collected by the photovoltaic panel, among which, the DC meter is used to record the cumulative power generation of the photovoltaic panel and compare it with the fixed device.

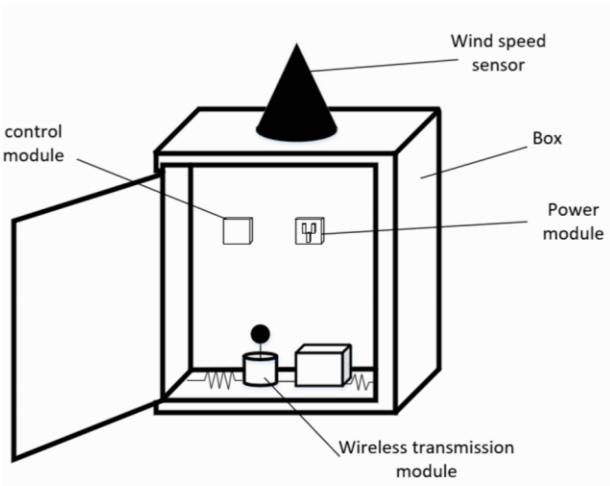

Figure 3: Internal Composition of Box

4. Hardware design

4.1. Power module

The power module is mainly divided into two parts, device power supply and photovoltaic power storage.

The power supply design of the device adopts two power supply modes, namely general power and individual power. In order to supply power to the device conveniently, most devices and peripheral circuits support 24V power supply voltage. Individual power consumption mainly provides 5V power supply voltage for the light sensor to ensure the collection of light intensity value. The general power is supplied by 24V /5A external power supply. For individual power supply, a MP1584EN voltage stabilizing module is assembled on the basis of 24V external power supply to obtain 5-10V continuous regulated voltage.

In photovoltaic power storage, Taiyi 500W photovoltaic panels produced by Taiyi Company are used as photovoltaic panels. This design is in the experimental stage, so it is characterized as 1kW off grid photovoltaic power generation device. Two 500W photovoltaic panels are installed on the top of the device; The controller adopts ML2430 solar charging and discharging controller produced by RoHSISO. The controller supports RS485 communication and has built-in maximum power tracking algorithm. It can significantly improve the energy utilization efficiency of the photovoltaic system, which is about 15% higher than the traditional PWM charging

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efficiency. It supports different types of battery charging programs, and can generate charts visible to users for analysis, which is convenient for monitoring electrical parameters and analyzing power generation. In addition, the controller is also equipped with waterproof protection, charge and discharge protection functions, and temperature sensor to enable users to obtain alarm signals through 485 communication.[4]

4.2. Control module

The control module is mainly divided into DC motor control and stepping motor control. The two groups of control power supply are powered by 24V external power supply, and communication with the upper computer is established through RS485.

4.2.1. DC motor control module

57BL75S10-230TF9 brushless DC motor is selected as the DC motor. The rated power is 100W, the rated torque is 0.32N · m, and the rated speed is 3000rpm. The DC motor drives the hydraulic rod to do work. The main body of the hydraulic rod is fixed with the K-shaped movable support. The k-shaped movable support is welded with the solar fixed support. The pitching angle is adjusted by relying on the hinge structure of the k-shaped movable support. For the adjustment of PV panel pitch angle, it is required to meet the requirements of large adjustable speed range and high upper limit of motor bearing. DC motor driver supporting RS485 communication is adopted, and the upper computer sends commands to change PWM duty cycle and motor speed to meet the tracking situation of solar angle change.

4.2.2. Stepper motor control module

Stepping motor is widely used in digital control system. Compared with servo motor, its advantages are as follows: ① cost advantage, lower price than servo motor system; ② Good tracking performance, that is, the response of stepping motor to pulse signal is better than that of servo motor. The speed and rotation angle of the stepping motor are determined by the frequency and number of pulses of the pulse control signal.[4] It is an open-loop control mode. When the rotation angle is wrong, it cannot be corrected automatically. In order to ensure the control accuracy of the stepping motor, it is necessary to deal with the process of speed increase and speed decrease in the pulse design.

The stepping motor is 60CM30X hybrid stepping motor produced by Shenzhen Rexay Intelligent Company, with a torque of 3.0N · m, a rated current of 5A, and a rotor inertia of 690g · cm2. It supports Modbus protocol. This stepping motor has the characteristics of small volume and large torque, which is convenient for assembly and stable and safe. Photoelectric isolation of input signal can be controlled by computer, PLC and industrial touch screen to realize remote operation; Multiple round-trip modes can be provided according to application requirements, including eight output current options and 15 subdivision modes,. In the low subdivision state, high-precision positioning can be achieved. The builtin software can realize operations: ① query step angle, subdivision value, pitch, speed (r /min), distance and direction; ② The motor returns to zero, positive and negative point rotation; ③ Stop mode, data saving, and engineering parameter reset. The change of sun position is slow. In order to meet the slow horizontal rotation speed, a reducer is added to the original stepping motor. The reducer is PLF120 planetary reducer produced by Bupermann Company. This product has simple structure, high cost performance, high precision and high output torque. The DM556S stepping motor driver of Rexay intelligent brand is selected as the stepping motor driver. Considering the long running time of the dual axis light tracking

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device, the driver has the advantages of reducing motor heating, and has overvoltage, overcurrent and other protection functions to meet the needs of the device.

The stepper motor control module receives the rotation command sent by the upper computer through the 485 communication serial port, drives the reducer shaft to rotate by rotating the stepper motor shaft. The reducer shaft is equipped with 2.5 mold gear to link with the center shaft gear key of the base rotary

table, so that the center shaft gear can rotate to drive the base platform to rotate. To ensure the stability of the base platform, four auxiliary rotating wheels are installed on the extension of the platform to reduce the rotation friction and improve the stability of the base platform.

4.3. Angle sensor module

The angle sensor module adopts a 9-axis MEMS attitude sensor produced by Witte Intelligence Company, which can collect the X, Y, Z three-axis angles. The sensor contains an accelerometer, gyroscope, and magnetometer, which can obtain the absolute azimuth of the installation position. The three-axis acceleration information is obtained through accelerometer measurement, and the unit is gravity acceleration g. It should be noted that the information measured by the accelerometer includes motion acceleration and gravity acceleration. When the object is stationary, the data measured by the accelerometer is gravity acceleration. The three-axis angular velocity information is measured by the gyroscope in ° /s. The three-axis magnetic field strength is obtained through a magnetometer. The sensor has a waterproof and rust proof shell, which is suitable for outdoor construction environment.

4.4. Wind speed detection module

The wind speed sensor corresponding to the wind speed detection module adopts the PR-3000-FSJTN01 polycarbonate wind speed sensor produced by Prisson. The sensor supports 485 communication and is installed with flange. The sensor is connected with a threaded flange and fixed on the flange plate. It adopts a three air cup wind collection structure, which has the characteristics of high strength and good startup.

Set the wind speed threshold through the upper computer software. If the threshold value is exceeded, the device will automatically reset to the safe state. In this design, the wind speed threshold is set as level 10 wind, and the wind speed is 24.5-28.4m /s. When the wind speed is higher than the threshold value of 24.5m /s for 1min, the upper computer software will disconnect the tracking program and send the reverse reset command to the DC motor to return the photovoltaic panel to the initial angle. When the wind speed is lower than the threshold value of 24.5m /s, the upper computer software will restart the tracking program, and the software will send the command to the motor according to the altitude angle and azimuth angle of the database sun at this time, The feedback angle from the mobile device to the angle sensor corresponds to the sun angle. Flow chart of automatic wind protection program is shown in Figure 4.

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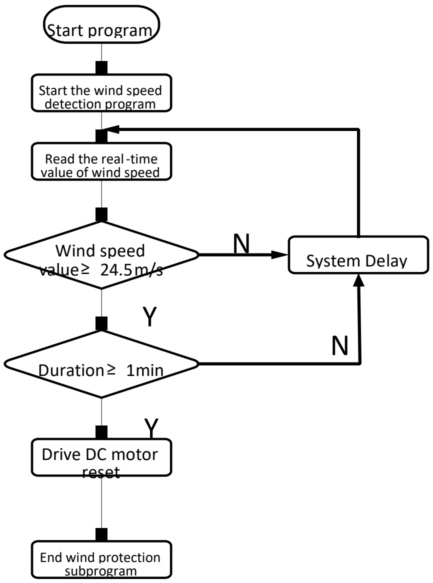

Figure 4: Flow chart of wind protection subprogram

4.5. Light detection module

The solar radiation measuring instrument provides solar intensity measurement data for photovoltaic energy storage in this device. Through calibration and measurement of energy conversion process, the impact of solar radiation on power generation can be obtained.

The module adopts RS-TRA-N01-AL solar radiation measuring instrument, which adopts thermoelectric principle and can measure the spectral range of 0.3~3 μ M solar radiation. The product adopts standard Modbus RTU485 communication protocol, which can directly read the current total solar radiation value. Its built-in software can realize: ① Send the command to read the current solar radiation value and the current solar deviation value; ② Modify and query the communication address and baud rate.

4.6. Wireless communication module

The wireless communication module adopts the DTD433M industrial wireless data terminal sold by Xi'an Datai Electronics Co., Ltd., which provides two communication ports (RS232 /RS485 interface). The reliable wireless transmission distance is more than 3 kilometers. The DTD433M can be diffracted through the wall. As a remote wireless PLC communication product, it can not only realize point-to-point communication, but also be suitable for point-to-point communication, It provides a low-cost solution for medium and short distance wireless communication in the field of industrial measurement and control design.

Considering the labor cost applied to the construction site, the user is required to receive and control the device remotely. This module is selected to effectively solve the problems of cumbersome construction and high equipment maintenance cost in the later period of the wired scheme. It can be directly configured and connected with configuration software, PLC, touch screen and intelligent instrument without programming and trenching wiring.

5. Cloud Platform Management Software Design

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In order to allow the actual situation of the device to be monitored remotely, a user interface combining 3D graphics with curve graph is developed, which can show the user 3D device orientation graph, as well as the curve graph generated by lighting, wind speed, solar angle, etc. In addition, the visual block diagram data is generated by each module through the command fed back by 485 to facilitate the user to observe the specific situation of the biaxial device.

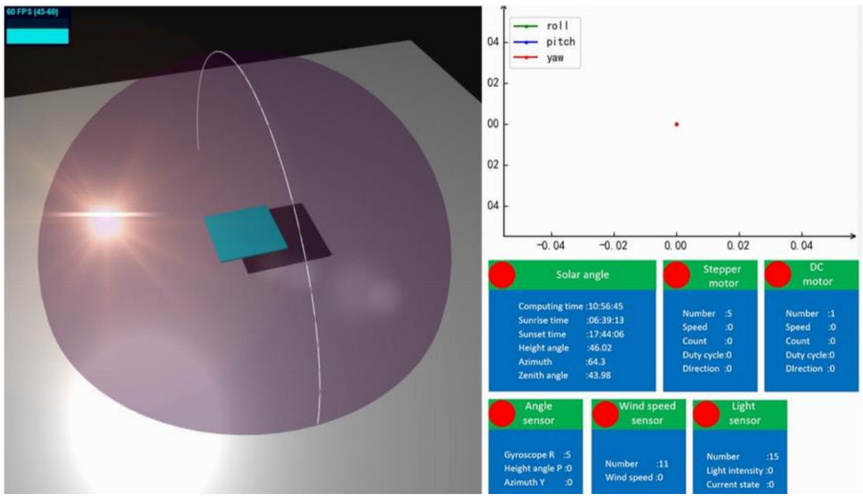

Figure 5: Main interface of cloud platform dual axis tracing software

The software uses Python as the development language. As the most popular development language at present, Python is not only easy to use and easy to get started, but also can build many functions with a small amount of code, and has a rich package resource library. The Tkinter library function is used to make the software body, and the module library in the library function can be called to make buttons, secondary menus, labels, curve drawing and other components.

The biaxial device management interface is divided into device status 3D interface, module parameter interface and status record interface, as shown in figure 5. The upper computer software uses Python programming, using sublime as the software development environment, and the upper computer continuously sends signals to modules to update the status of each module in real time. The mature solar angle calculator is used to provide the software with the track parameters of local sunrise and sunset at specific longitude and latitude, send the parameters to the upper computer, and the upper computer software will process them, control the motor operation, make the angle sensor consistent with the theoretical angle, and complete the tracking process.

6. Conclusion

The dual axis daily tracking system of photovoltaic power generation described in this design adopts a hybrid control strategy combining automatic control and manual remote control mode. The solar angle calculation software is used to calculate the real-time height angle and azimuth angle of the sun, to ensure the tracking accuracy of the system, so that the solar panel can always maintain the optimal inclination state perpendicular to the solar ray, improve the photoelectric conversion rate, and fully absorb the solar energy. Under the automatic mode, the system is subject to less interference from cloudy and sunny weather conditions by adopting the daily

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motion tracking mode. In manual mode, the wireless communication module is used for remote detection and control of daily photovoltaic power generation system.[5]

This design will be applied to clean energy power supply in the production process of the factory in the future. The feasibility of the application of this method in the dual axis solar tracking system is illustrated by combining theory with experiment. However, in the process, there is a problem that has not been taken into account, that is, the relationship between the increased power generation and the increased load bearing capacity of the device for multiple photovoltaic panels. Simply put, it is to study whether more photovoltaic panels can meet the power consumption of factory production, that is, the energy optimization of the whole system. Therefore, the energy optimization of the whole system is worthy of further study.

From the perspective of improving the power generation efficiency, this paper studies the ways to improve the power generation efficiency of the DC side of the photovoltaic power generation system. In fact, the power generation efficiency of the photovoltaic system refers to the overall power generation efficiency. Therefore, the research on the power generation efficiency of other equipment in the photovoltaic system, especially the research on the efficiency improvement of photovoltaic inverter, is also a direction worthy of in-depth research.

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