Solar panel cleaning vehicle based on Konda effect

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Abstract. In order to solve the problem of parking difficulties in urban residential areas, a small auxiliary parking device is proposed. Starting from solving the social pain points such as unreasonable parking space planning, residents' random parking, and reducing parking difficulty, it achieves the effect of assisting parking space planning and reducing parking difficulty. The device mainly provides power through the motor, and drives the drum to realize binary control by controlling the steering wheel of the vehicle owner, that is, controlling the switching of the whole movement, and the switching of the front back and left right of the control device. By pressing the spring switch on the wheel, the front control motor drives the gear clutch device to complete the bidirectional switching from left and right movement to back and forth movement. Through the shear fork supporting mechanism and separate self-locking slide rail, the car is lifted and the parking device is driven away.

1. Introduction

With the rapid development of China’s solar photovoltaic industry, large-scale solar power stations are also developing. However, 1MW is about 4100 solar panels, covering an area of about 25 mu. If manual cleaning is used, it will consume a lot of manpower. At the same time, the hand-made rag or rubber strip will inevitably scratch the solar panel and scratch the glass surface, and the efficiency is low. For the cleaning of solar panels, high-pressure water gun is used for mechanical cleaning. Although the cleaning effect is good, it consumes a lot of water resources. China's solar energy industry is mainly distributed in Northwest China, which is relatively short of water. If it is not cleaned for a long time, with the accumulation of dust on the module surface, the heat transfer resistance of photovoltaic module will be increased, which will become the thermal insulation layer on the photovoltaic module and affect its heat dissipation. Dust adhering to the surface of the panel will block, absorb and reflect the light. The output power of the clean panel module is at least 5% higher than that of the dust accumulation module. At the same time, improper cleaning will produce hot spot effect, which will cause damage to the solar panel, and the surface of photovoltaic panel is mostly made of glass. When wet acid or alkaline dust adheres to the surface of glass cover plate, the glass surface will be slowly eroded.

However, solar panels cannot absorb a lot of energy due to dust barrier. According to the survey, due to the dust barrier, most of the solar panels that have not been cleaned for a long time have a power generation rate of only 76% or even lower than that of the clean solar panels. However, the traditional cleaning is difficult to achieve in the desert areas with extreme water shortage, and it takes a long time to wipe the solar panels one by one.
2. research meaning
At present, there are many cleaning methods for solar panels, but most of them cannot be separated from the restriction of water. At the same time, the power reduction rate of photovoltaic panels cannot be obtained according to the dust thickness on the surface of photovoltaic panels, and the cleaning effect is not satisfactory. In this design, no water cleaning is realized. The special dust sensor is used to collect the ratio of the initial light intensity and the end light intensity to obtain the dust thickness on the surface of the solar panel. According to the relationship curve between the output power of the photovoltaic panel and the dust thickness, as well as the range of the dust thickness that can be cleaned by the device, the cleaning threshold is determined to ensure the maximum income and the cleaning efficiency of the solar panel. At present, the method is more automatic and intelligent, and can be widely used in the cleaning of solar panels in water shortage desert areas, so as to ensure its work efficiency at a high level.

3. conceptual design

3.1. Overall design
The whole device is mainly composed of dust sensor module, electrode driving module, fixed guide wheel module, venturi injector module and control module.

![Figure 1. working diagram of the device](image)

The working process is that the device is directly powered by the solar panel, and the sand dust sensor module is used to monitor the dust thickness on the surface of the solar panel in real time. When the cleaning standard is reached, the coaxial centrifuge generates air flow, which flows through the venturi acceleration tube for acceleration, forming a high-speed air flow from the jet head. Due to the CONDA effect, the high-speed air flow is close to the surface of the solar panel, and the dust on the surface of the solar panel is cleaned up. The electrode driving module drives the cleaning car to move on the surface of the solar panel. The guide wheel is fixed to prevent the car from deviating from the track and connecting. The specific device is shown in the following figure:
3.1.1. Dust sensor module. The sand and dust sensor module is composed of sand and dust sensor and processing system. The dust sensor is close to the surface of solar panel to monitor the dust density in real time, and the detection data is fed back. When the measured data is higher than the set standard, it is fed back to the control module. The sand and dust sensor has several data processing systems, and uses the data system comparison to determine whether the ejector cleaning work is needed. The information feedback of measurement and data processing is concentrated on the control module. The function of dust sensor is to control the switch of ejector. The dust sensor can be used for real-time monitoring because of its sensitive response and high precision.

In order to ensure that the dust sensor has a stable light intensity, we need to use a high-power LED with a power of about 1W, which is powered by the stable current generated by the electronic circuit of the LED driver. LED driver consists of three pin DC regulator lm317t and linear regulator. Its input voltage range is 3-40v, and its current output is between 10mA and 1.4A.

Figure 3. Schematic diagram of dust sensor

Figure 5 shows the LED driver circuit that controls the current input in the LED lamp. It is composed of lm317t regulator, the resistance R is located between the two pins of the regulator, its value depends on the output current of driving LED lamp, the voltage between the two branches is always equal to 1.25V; the function of capacitor C1 and C2 is to ensure the stability of LM317 regulator, a protection diode (D1) is placed in front of the regulator, and a second anti backflow diode is placed between the pin and the vehicle identification numberTube D2. According to the calculation, the polarization resistance R of LED operating under the optimal conditions is calculated, where \( V_{LED} = 3.2V \), iled
must be equal to 0.350a. At the same time, in order to minimize the risk of damaging LEDs whose current is much higher than their nominal value.

![Drive Circuit Diagram](image)

**Figure 4.** Drive circuit

3.1.2. **Motor drive module.** The motor driving module uses the driving function of the stepping motor to drive the gear to rotate, thus driving the crawler to rotate. The stepping motor is directly powered by the solar panel. Through the fixation of two fixed plates, it is transmitted to the driven wheel through the rotating driving shaft, thus driving the whole cleaning vehicle to rotate. The electrode driving module is mainly divided into front baffle, rear baffle, driving motor, driving shaft, driven shaft and crawler. The front and rear baffles are mainly used to fix the position of the driving shaft and driven shaft of the device. The front and rear baffles are used to fix the position of the driving shaft and the driven rotation of the stepper motor to drive the crawler to drive the rotation of the driven wheel. The friction between the track and the solar panel drives the whole device. At the same time, the connection of the solar panels can be carried out, which plays a fixed role. The crawler drive moves on the device with the fixed action of the fixed guide wheel.

![Overall Drawing of Motor Drive Module](image)

**Figure 5.** Overall drawing of motor drive module

3.1.3. **Fixed guide wheel module.** The fixed guide wheel module is located on the front and rear baffles of the device, the fixed shaft is installed at the front and rear of the front and rear baffle plates, and a pressing sprocket is installed under the fixed shaft to prevent the device from moving laterally. When the device moves forward, the fixed guide wheels on both sides rub against the plane of the solar panel for synchronous rotation. When passing through the connecting part of the solar panel, the fixed guide wheel on the outer side compresses the surface of the solar panel, and the fixed guide wheel on the inner surface moves up, and the connecting plate at the fixed groove moves upward to reach the fixed guide wheel module at the inner side. After passing through the connecting part of the solar panel, the guide wheel slides back to its original position after passing through the connection point, and continues to
rotate synchronously, in which the movement between the solar panels is carried out through the fixed role of the fixed guide wheel.

The middle and lower clamping mechanism is used to fix the guide wheel.

Fig. 6. fixed guide wheel module

3.1.4. Venturi ejector module. The venturi ejector module is mainly composed of three parts: coaxial centrifuge, venturi accelerator and jet head. Coaxial centrifuges are mainly used for the generation of air flow. Through the rapid action of coaxial centrifuges, low velocity air flow is generated. Then the airflow flows through the large cross-section end of the venturi tube. With the gradual decrease of the cross-section, the speed of the air flow increases gradually. The whole inrush flow will experience the process of pipe shrinkage at the same time, ejected from the small section end of the venturi accelerator and compressed high speed air flow from the jet head.

Fig. 7. venturi injector

3.2. Main requirements of control system
(1) Data analysis: by comparing the ratio of the initial beam intensity and the end beam intensity collected by the dust sensor, the data obtained are compared with the standard light intensity ratio of solar panels.

(2) Control operation: through the comparison and analysis of the data obtained, the device can be cleaned up when the power decline rate of the solar panel is small.

(3) Data feedback: it can store the information, control the direction and ensure that the device moves in the direction of cleaning.
4. Calculation and verification

4.1. Size selection of venturi injector

Table 1. Structural dimensions of different outlets.

| Dimensional structure | Diameter of inlet section (mm) | Length of entrance section (mm) | Diameter of throat (mm) | Throat length (mm) | Outlet section diameter (mm) | Angle of entrance section $\alpha_1$ (°) | Exit section angle $\alpha_2$ (°) |
|------------------------|-------------------------------|---------------------------------|------------------------|---------------------|-------------------------------|----------------------------------|----------------------------------|
| 1                      | 20                            | 4                               | 4                      | 30                  | 70                            | 18                               | 15                               |
| 2                      | 20                            | 4                               | 6                      | 30                  | 70                            | 18                               | 15                               |
| 3                      | 20                            | 4                               | 8                      | 30                  | 70                            | 18                               | 15                               |
| 4                      | 20                            | 4                               | 12                     | 30                  | 70                            | 18                               | 15                               |

For different throat diameter, the acceleration efficiency of venturi device is greatly affected. The inlet and outlet sections of the device conform to the overall device size of the device.

![Figure 8](image1.png)

**Figure 8.** Flow field velocity diagram of numerical simulation venturi tube

According to the formula derivation, the following conclusions can be drawn theoretically: (1) the venturi throat pressure $P_3$ is linear with the pressure difference $\Delta P$, that is, it is linear with $H(q_2-q_1)$; (2) the venturi throat pressure $P_3$ is linear with the square of flow rate. Based on this design, the length ratio and angle of the fluid acceleration effect are the largest.

4.2. Driving and calculation of optimum dust thickness

The device adopts stepper motor to drive. The stepper motor has the advantages of stable stop, low heating, fast response and stable operation. The motor of 0.48N.m is selected to drive the device to run stably with low power consumption.
Table 2. Characteristic parameters of components with ash distribution on the surface

| parameter                      | 0g/m² | 1.13g/m² | 3.39g/m² | 5.65g/m² | Pouring water 1.13g/m² | Pouring water 3.39g/m² |
|-------------------------------|-------|----------|----------|----------|------------------------|------------------------|
| Open circuit voltage V₀/V     | 21.62 | 20.72    | 20.69    | 20.30    | 20.90                  | 19.99                  |
| Short circuit current I₀/A    | 8.34  | 8.23     | 8.03     | 7.84     | 8.11                   | 8.15                   |
| Maximum power P/W             | 128.8 | 118.3    | 113.7    | 109.2    | 119.5                  | 116.2                  |
| Maximum voltage Vₙ/V          | 16.90 | 15.78    | 15.63    | 15.24    | 15.89                  | 15.82                  |
| Maximum current Iₙ/A          | 7.62  | 7.49     | 7.28     | 7.17     | 7.52                   | 7.35                   |
| Filling factor F/%            | 71.4  | 69.3     | 68.5     | 68.6     | 70.5                   | 71.4                   |
| η/%                           | 13.9  | 12.7     | 12.2     | 11.8     | 12.9                   | 12.5                   |
| Power loss/%                  | 0     | 8.2      | 16.7     | 18.6     | 7.2                    | 9.8                    |

It can be seen from the table that if the solar panels are not treated, the power generation efficiency will continue to decline due to the gradual accumulation of sand and dust. In the cleaning experiment: on the first day after cleaning, the power generation per kilowatt module of the battery panel under the daily cumulative radiation of 22mj / m² is 5.73kwh. On the seventh day, the power generation per kilowatt of the module has decreased to 4.91kwh under the same radiation amount, and the power generation loss has reached 14.3% in 7 days.

For the cleaning car, the power of the trolley is 180 watts per hour, while for the coaxial centrifuge, the power is 50 watts per hour. The cleaning unit length per hour is 10.86 meters, which increases the power generation power by 20 percent. The cleaning car can generate 74.08 watts of additional energy generated by the solar panel after working for one hour. Therefore, selecting this motor to drive can ensure that the increase efficiency is higher than the power consumption rate.

5. Conclusion
The device that can clean up the dust on the surface of photovoltaic panels can solve the problem of current cleaning methods. Compared with the existing three methods, the device has higher efficiency. In the future, it can be widely used in desert areas where water resources are relatively scarce, and has great development potential. Due to the increasing heat of solar energy utilization in desert areas in recent years, the future market of the device is broad and the prospect is very considerable.

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