Design of An Integrated Solar Panel Monitoring and Cleaning System Based on Pixy Cmucam5

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Abstract. In recent years solar power has become the main source of clean energy in China. At the same time, the country has also introduced relevant policies to support it, and against this background, the solar photovoltaic industry has also flourished. However, solar photovoltaic power generation still has many problems, such as the huge amount of light energy and water loss caused by contamination of the solar panel surface and the high labour costs of dealing with the contamination, so it is necessary to carry out research on solar panel crack detection and cleaning.

Keywords: Clean energy, battery testing, clean.

1. Design background
According to a research group's tests, the dust accumulated on solar panels in China's plain areas over an average of three months can block 3%-5% of sunlight, while dust in places with serious environmental pollution can reduce the power generation efficiency of solar panels by 17%-40%, and the transmission of sunlight becomes worse and worse with the accumulation of dirt. In addition, cracks in the solar panels can lead to a serious reduction in power generation efficiency and even create problems such as the risk of leakage and equipment damage. Initially, it is estimated that if PV plants do not adopt effective cleaning and crack identification measures, up to 400,000 kWh/year of power could be lost from megawatt-scale PV systems, resulting in significant financial losses. In order to ensure that the solar panels are as efficient as they should be, the panels are often cleaned manually and checked for cracks, and replaced in a timely manner. According to statistics, on average, a cleaner can clean solar panels about 0.1Mw per day (the panel area is about 830m2) and consumes about 5 tonnes of water per person per time. In the face of the huge loss of light energy and water due to contamination of the solar panel surface and the high labour costs associated with dealing with the contamination, research into crack detection and cleaning of solar panels is therefore necessary.

With the rapid development of the solar industry, more and more photovoltaic power plants are being built. The future of the energy sector is set to be brighter with solar energy. According to numerous studies, dust, bird droppings and chunks of dirt produce a hot spot effect that can lead to a drop in the overall power generation of a power station, and cracks in the solar panels can also lead to reduced power generation efficiency, equipment damage and the risk of leakage. The Pixy Cmucam5 solar panel dust cleaning, crack and bird droppings and other stubborn stains simultaneous detection and cleaning solution is designed. The system uses the STM32F407ZGT6 as the main controller, using the camera and RFID to scan the solar panels to identify stubborn stains such as cracks and bird...
droppings, locate the position of the solar panels and count the number of clean panels. Once the conditions for cleaning have been met, the device is reset to read the position at the specified place, while the cleaning head starts working. A camera mounted on the running track moves with it, scanning the solar panel to determine whether cracks or bird droppings are present. Data from the work is transmitted wirelessly back to a mobile phone app, which allows the operation of the device to be controlled remotely and the status of the device to be monitored. The device is suitable for all types of solar photovoltaic power generation industry, can greatly reduce labour costs, improve power generation efficiency, market application prospects.

2. Overall design
At present, there are two main categories of maintenance methods available on the market. The first is manual maintenance, which includes manual cleaning of PV panels and high-pressure water jets; the second is automated maintenance, which includes construction vehicle cleaning equipment and intelligent PV panel cleaning robots. None of the technologies have been studied in terms of crack detection or communication.

Table 1 gives a brief comparison of these technologies and the individual indicators of the device.

Table. 1 Summary comparison of current clean technologies for solar panels (example of a 10 MW PV plant)

| Methodology                     | Manual cleaning of photovoltaic panels | High-pressure water jet cleaning | Construction vehicle cleaning equipment | Intelligent photovoltaic panel sweeping robot | This device |
|---------------------------------|----------------------------------------|----------------------------------|-----------------------------------------|---------------------------------------------|-------------|
| Prices                          | At an estimated cost of RMB 100 per person per day, the labour cost for a single cleaning of a 1MW module is RMB 6,000. | 120,000; water costs extra | approx. 350,000 RMB/unit; water costs extra | 6000/unit* array; water costs vary depending on location | Installation cost approx. 2000 RMB, plus rails |
| Effects                         | So-so cleaning results                 | Good cleaning effect             | Less effective and more efficient than manual labour | Good cleaning effect                          | Good cleaning effect |
| Advantages                      | Low water consumption, approx. 1 tonne of water per 1MW cleaning; low cost | Less labour cost and cleaner cleaning | The cleaning equipment is powerful, efficient and has a good consistency of pressure on the photovoltaic panels, making it difficult to cause hidden cracks in the panels. | Self-powered; intelligent control and unattended, saving labour costs. Waterless cleaning, energy saving and environmental protection | Low labour costs, suitable for all terrains, can identify cracks and control them remotely |
| Disadvantages                   | Prone to approx. 65                    | Excessive                       | Poorly mounted                          | High cost of                                |             |
causing hidden cracks in the cells; prone to leaving partial marks on the surface of the panels, causing large areas to be obscured by shadows

tri/trip; excessive water pressure can cause hidden cracks in the cells. Slow speed

water pressure can cause hidden cracks in the cells. After washing and drying, the panels dry by themselves, forming water stains that can cause a spot effect over time.

robots can get stuck in the frame and the robot cannot be positioned properly; it is difficult to find a place to stay. Position of the robot

guide rails; slow cleaning speed (3 minutes/block); difficult installation of devices

Compared to current mainstream cleaning techniques for solar panels, the device can replace labour, thus saving significant labour costs; the device does not require the use of water, thus avoiding the problem of water pollution caused by cleaning; the device can identify stubborn stains such as cracks and bird droppings, thus enabling targeted cleaning; the device can communicate with APP, thus realising automated operation and facilitating automated management of the PV station.

The overall hardware block diagram of the system is shown in Figure 2.

**Figure. 1** General hardware block diagram of the system

### 3. Operating principle and performance analysis

When the cleaning conditions are met, the camera starts working and the cleaning device leaves the protective box. When the device locates a panel, it is mechanically zeroed and the current position of the solar panel is read via RFID for storage. An X and Y axis stepper motor is then driven to drive the cleaning head over the entire solar panel to clean it, while the camera collects and analyses the images frame by frame. After cleaning one panel, the cleaning head fan is switched off and the data and pictures are sent to the APP via the wireless module, which moves to the next solar panel and repeats the above operation.
When dust adheres to the surface of a solar panel, it alters the uniformity of the incident sunlight transmission in the tempered glass, reducing the amount of effective sunlight hitting the panels and reducing light transmission. Cracks in the solar panels can also lead to problems such as reduced power generation efficiency, equipment damage and risk of leakage.

Solar panels are usually encapsulated in 3.2mm super-white calendered glass and are known to transmit around 91.5% of light. A very small amount of dust can reduce the efficiency of a solar panel by 17-40%, which has been calculated to be around 120-140W for 1 square metre of crystalline solar panels. Calculated at approximately 120-140W for a 1-square metre crystalline solar panel, the amount of electricity $Q_1$ lost to dust in one day (8 hours) would be at least:

$$Q_1 = (120/1000) \times 8 \times 17\% = 0.1621kWh$$

(1)

If the area of the solar panels in a solar PV plant is 100,000 m², the amount of electricity lost due to dust is $Q_2$ (one day) up to:

$$Q_2 = Q_1 \times 100000 = 16320kWh$$

(2)

With a utility price of RMB 0.573/kWh in the plain area (Wuhan for example), the amount lost from a solar PV plant is $W$ (one day) For.

$$W = Q_2 \times 0.573 = 9351.36\text{元}$$

(3)

The finished price of the unit is around 2,200 RMB (plus rails) and for a solar PV plant with a panel area of around 100,000 m², the amount lost to dust (per day) is sufficient to purchase several cleaning units.
The advantages of the device are:

1. The cleaning device uses a powerful fan and a waterless dust removal system to avoid wastage of water and secondary pollution; the cleaning head has a built-in dust collection bin to prevent dust from spreading and to ensure cleaning effectiveness.

2. The cleaning unit has a protective box with a detection system that prevents damage to the unit outdoors due to environmental variability and allows for selective cleaning by adjusting the working cycle to the monitored environment.

3. An image processing system is installed on the frame of the device to check the amount of dust cover on each panel before cleaning it, to determine whether it needs to be cleaned and to check whether the panels are damaged, so that the staff can be notified to repair the panels, thus improving the overall cleaning efficiency of the panels in the PV power station.

4. The device cleans the solar panels and identifies stubborn stains such as cracks and bird droppings, communicates with the mobile phone app and facilitates the automated management of the PV plant.

The PV industry is booming today, in line with the national policy of vigorously developing new green energy sources, while corresponding clean and crack detection products are few and far between, and few combine wireless communication technology with APP for data history recording and analysis, which makes remote control impossible. Compared with existing products, this project has the advantages of saving water resources, labour costs and a high degree of automation, and it has good economic and social benefits; the device can automatically adapt to a variety of harsh environments and is suitable for the automatic management of solar power stations.

4. Summary and outlook

The following summary and outlook for the system is presented in this paper.

1. The system structure has been upgraded with new materials to make the unit lighter and reduce costs, further expanding its application areas.

2. The system goes into standby mode when it is not working. The base station is connected to the network using GPRS, receives recent weather data, processes the data for big data and determines whether cleaning is to be carried out.

3. The crack identification technology is used in a wider range of applications, with the cleaning module and the crack identification communication module being encapsulated to increase availability.

4. The cleaning device has been improved so that it cleans all types of dust and dirt, further enhancing the cleaning effect.

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