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Effect of Fouling on the Corrosion Properties of Solar Photovoltaic

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With the gradual development of applications on solar photovoltaic, the "PV power plant construction stage" has transited to the "PV power plant operation stage" in China. In the most process of the solar photovoltaic, it is frequent that the decrease of the photovoltaic system efficiency and economic benefits always occurs, which are caused by the fouling on the surface area of the photovoltaic modules. And it has attracted the attention of the experts and scholars in this area. In this paper, through investigating the application status in photovoltaic station and the research status in fouling problems, the power generation situation of the practical projects on the clean and fouling monolithic solar panels is comparatively analyzed. So as to quantitatively analyze the influence extent of the fouling on photovoltaic power generation efficiency. And a kind of mechanized, automated cleaning device is developed, and the improving method of this problem is put forward.

1. Introduction

Solar energy, an inexhaustible and renewable energy source for mankind, is characterized by full cleanliness, absolute safety, relative generality, real long life and maintenance-free, resource adequacy and potential economy and so on (Martinez, et al., 2016). It has an important position in the long-term energy strategy. The solar energy in China is rich, and there are great conditions to generate electricity in taking full advantage of solar energy. As a major application of solar photovoltaic power generation, large-scale photovoltaic power stations mainly concentrate in the northwest desert and dusty areas where the solar radiation is better (Saidan, et al., 2016). The surface of PV modules in these areas is prone to produce fouling and other debris, which significantly reduces the amount of solar radiation received and thus seriously affects the photovoltaic system power generation efficiency and economic benefits of related projects (Wolske, et al., 2017). The relevant data shows that the battery ash can make the solar panel power generation efficiency decrease by an average of 17%, and it may even reduce 40% when it is serious.

In this paper, through investigating the application status in photovoltaic station and the research status in fouling problems, the power generation situation of the practical projects on the clean and fouling monolithic solar panels is comparatively analyzed so that the influence extent of the fouling on photovoltaic power generation efficiency can be quantitatively analyzed. And a kind of mechanized, automated cleaning device is developed, and the improving method of this problem is put forward. There are many forms of the installation of solar panels, so different installation forms correspond to different cleaning devices.

In this paper, it mainly aims at the cleaning of dust on the surface of the solar panel that is arranged horizontally. The track car type solar panel cleaning device with automatic travel, waterless cleaning, fast dust and other functions is put forward, which achieves automatic clean by the usage of crawler chassis, high temperature wire roller brush and medium power suction fan.

2. Experiment

2.1 Corrosion principle of fouling to photovoltaic system

PV module was an important device that the solar energy can be directly converted into electrical energy, which was composed of multiple single solar cells, and its principle was the photovoltaic effect based on the

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semiconductor material PN junction (Adhya, et al., 2016). Its advantages were volt-ampere characteristics, short circuit characteristics, open circuit characteristics and output power characteristics. The power generation of photovoltaic power generation project was mainly determined by the efficiency of photovoltaic system (Hassabou, et al., 2013). There were three main factors influencing the power generation of PV system, including environmental, equipment and human (Gupta, 2017). Environmental factors mainly included solar energy exposure and temperature. Equipment factors were the main factors that affected the power generation efficiency of PV system, including PV module installation, PV module matching, inverter efficiency, AC and DC line loss, equipment failure and maintenance and other aspects. Human factors were mainly in the photovoltaic power generation project design, construction, operation stage, the decrease of photovoltaic power generation efficiency caused by the negligent management and other human factors, which led serious results, mainly including the insufficient design and belated clean and so on.

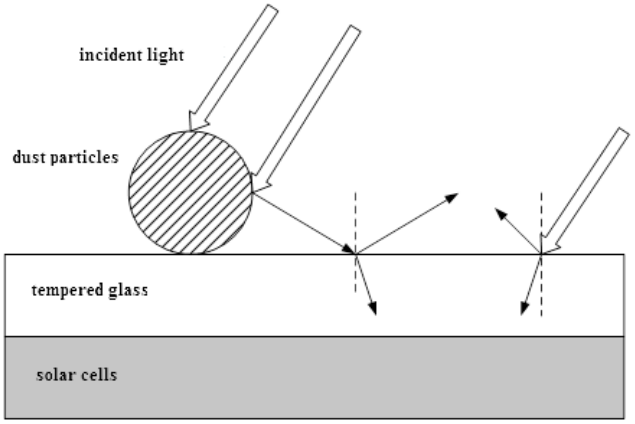

Figure 1: Fouling block diagram

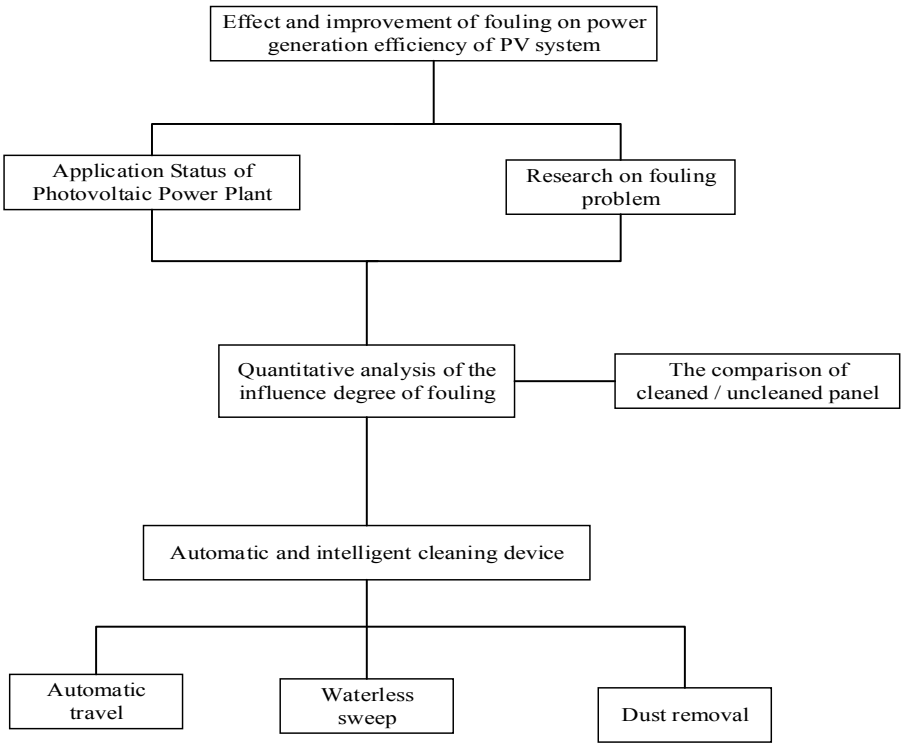

Figure 2: Technical roadmap

The effect of fouling on the efficiency of solar photovoltaic systems was mainly the corrosion of fouling (Qi et al., 2017; Verma, et al., 2016). The main sources of fouling on the surface of PV modules were natural and anthropogenic sources, which affected the efficiency of PV power by affecting the transmittance, temperature and corrosion of PV modules. When the fouling adheres to the surface of the PV module, the dust particles absorb and scatter the incident sunlight, resulting a decrease in the effective area of the panel irradiated to the PV module and in the light transmittance. Thereby the photovoltaic power generation efficiency reduced. And the deposition rate of the fouling was faster, the actual transmittance of the PV module was lower, and the output power was lower. The local shadow caused by the presence of fouling will cause the temperature of the blocked part to rise far greater than the unshielded part. Even because of the high temperature, the dark spots burned occurred, affecting the efficiency of photovoltaic power generation. After the combination of fouling and harmful substances in the air, there will be a certain degree of acid or alkaline. And it gradually corroded tempered glass on the surface of the PV module, forming diffuse reflection, which resulted in reduction of the energy that solar cells received the radio, the weakness of the photoelectric effect, the decrease of power generation efficiency and the reduction of the power generation (Alexander, 2016).

Fouling was also affected by a variety of factors, including wind speed, installation angle, air humidity, air pollution and so on. In general, the formation of fouling at higher wind speeds had a higher light transmittance. The fouling level increases as the wind blew to the surface of the PV module, and there was little fouling as the wind blows against the backplane of PV module. Based on the above theoretical basis, the research results of this paper were expected as the following. In addition, a kind of automated, intelligent cleaning device could be developed, which was characterized by low energy consumption, no water consumption, no pollution, good cleaning effect and other advantages. And it was important to declare a patent. The specific technical roadmap was shown in Figure 2.

2.2. Fouling on the photovoltaic system power generation efficiency of the field test

2.2.1 Experimental design

The first was the experimental Location, this article mainly relied on Dalian University of Technology teaching service center 100KW solar photovoltaic demonstration project, and the power generation of the clean/fouling monolithic solar panel was measured.

The second was the experimental object. According to the experimental situation, Dalian University of Technology photovoltaic demonstration project in the 3kW photovoltaic subsystem was selected as the experimental object because of taking into account the reliability and ease of operation. The 3KV photovoltaic subsystem consisted of 10 280WP polysilicon PV modules in series, and a 3KW photovoltaic inverter was grid-connected to make power generation.

The third was experimental tools. The main test tool for the test was single solar panel detector that Qingdao Sanas Co., Ltd. customized. It could be used to measure the solar string in any single solar panels voltage, current, power, backplane temperature and power generation, and its functions were anti attack and anti-security and others. The minimum acquisition frequency was 10s, and the detection software can display real-time monitoring data and curves. Environmental data (solar irradiance, wind speed, ambient temperature) was provided by the environmental monitoring instrument in the 100KV PV demonstration project of Dalian University of Technology.

2.2.2 Experimental process

Using the method of comparative experiment, two PV modules with similar output characteristics were selected, and the two were in the same series. One of them was cleaned every morning to be as a comparison standard. Another one did not always clean expect for the first day of the experiment to keep normal working outdoors, and it was as the object of comparison. Through the the comparative experiment of two clean/fouling solar panels generation capacity to study the impact of the fouling of photovoltaic power generation efficiency.

The first was the arrangement of detection point. 10 serials of 280W polycrystalline silicon PV modules for the 3kW PV subsystem were numbered from one to ten and a single solar panel detector was prepared for each PV module. By connecting the In + and In- of the single solar panel detector to the positive and negative output lines of the PV module, out + and Out- were connected to Out- and Out + of the two single solar panel detectors respectively, to make the test equipment connect in parallel 3kW photovoltaic subsystem under the premise of the normal operation of the PV string. Correspondingly, 10 single solar panel detectors were numbered from one to ten, and the on-line testing of the ten detectors were carrieed out to check the stability of the device and the output characteristics of 10 PV modules. Combining the detection software data record results with the comprehensive consideration. 9 and 10 group of two PV modules were selected to make contrast test, they were written as Panel A and Panel B that were cleaned on every morning, and Panel A and

Panel B were cleaned on the first day of the experiment. Later, it not cleaned any longer and remained in the outdoors.
Test time was the second part. A total of 10 days from May 15 to May 24, 2014 were selected for continuous testing (no rainy weather during this period). The daily detection period was from 8:00 am to 6:00 pm. And the relevant parameters of data acquisition were set as the data interface COM5 and acquisition frequency 100S. The data was analyzed on May 15, May 16, May 19, May 24, and the interval were 1 day, 3 days and 5 days. The weather conditions of four days were sunny, cloudy, cloudy and overcast. The environmental monitoring instrument recorded in the sunshine curve shown in Figure 3. It can be seen that the cumulative solar control volume gradually reduced during the four days.
The third was accumulated electricity generation.

Table 1: The accumulated electricity generation of Panel and Panel B during the four days.

Panel A	1721.8 W·h	1441.4 W·h	1107.6 W·h	471.8 W·h
Panel B	1781.6W·h	1490.2W·h	1150.3W·h	498.4W·h

For clear and easy analysis of the four days of cumulative power generation, the figure was as shown below.

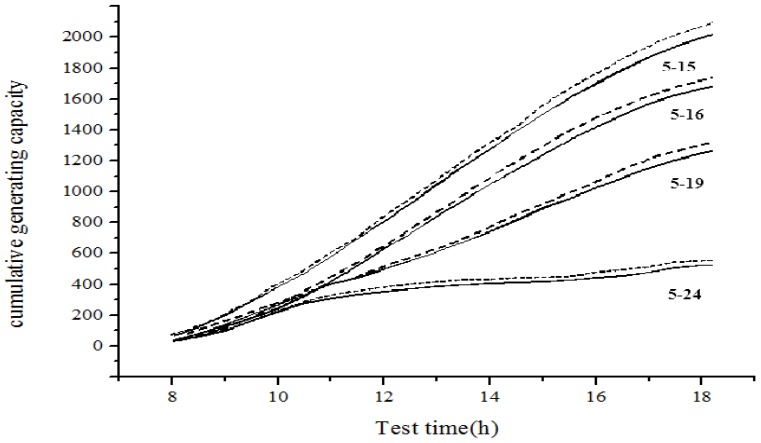

Figure 3 cumulative power generation

It could be seen from the figure. First, on May 15, Panel A and Panel B were cleaned in the same PV string and the same daylight. And Panel B was more expensive than Panel A, due to the different performance of PV modules. And Panel B was better than Panel A in original performance. Second, Panel A was cleaned every morning, and Panel B was not cleaned except for May 15. And the accumulated power generation curve of Panel B and Panel A was smaller and smaller as time passes, due to the the continuous reduction of its power generation of surface fouling of the Panel A and Panel B. Third, the cumulative daily generation of Panel A and Panel B decreased, which was consistent with the ever-decreasing solar radiation.

2.2.3 Experimental analysis
It can be seen from the Figure 4. First, with the passage of time, there were more and more accumulation of fouling, and the fouling on the photovoltaic components to reduce the generation of electricity grew. Second, as time goes on, the effect of fouling on the surface of PV modules in actual operation was not a simple linear relationship. Additionally, it was the reduction of fouling on power generation efficiency. The equation of the reduction of the fouling on photovoltaic power generation efficiency.

$$\eta = \frac{\Delta W}{W + \Delta W} \tag{1}$$

Among them, η was reduction rate of the photovoltaic power generation efficiency. ΔW was the amount of the reduction of the power generation caused by the fouling. W was the actual power generation.
The corresponding data was substituted into the formula. After 2 days of Panel B fouling, the photovoltaic system power generation efficiency reduced about 1.5%, after 5 days, the fouling of photovoltaic power generation efficiency reduced about 2.2%. And after 10 days, the fouling of photovoltaic power generation efficiency reduced about 6.4%.

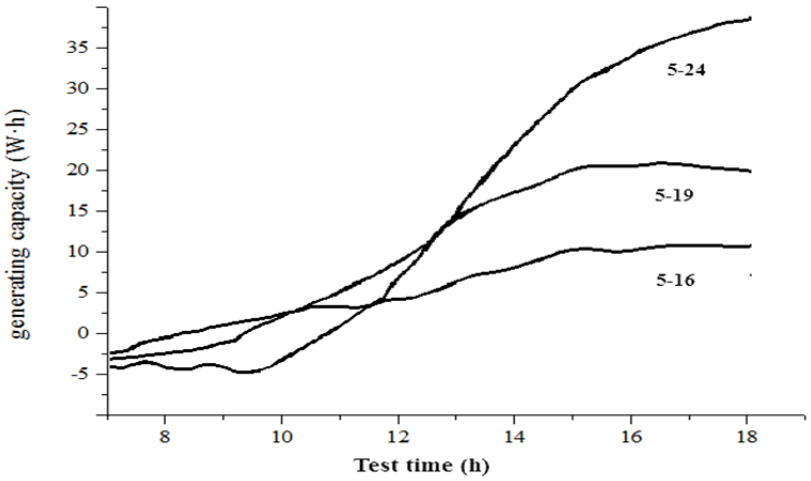

Figure 4 Reduced power generation caused by fouling

3. Results and discussions

In this experiment, the effects of fouling on the power generation efficiency of photovoltaic system were measured. The panel of Panel A and Panel B with the same meteorological conditions (solar irradiance, ambient temperature and wind direction) were selected for the same 3kW PV series. Panel A was cleaned every morning. Panel B was cleaned on the first day of the experiment, and then it was not cleaned any longer and remained in the outdoors. Through the comparison of the two clean / fouling PV modules, the influence of fouling on the power generation efficiency was studied. The main conclusions were as the following.

First of all, different PV modules had different factory performances, the actual work of the power generation was mainly related to solar radiation.

In addition, with the passage of time, there are more and more accumulation of fouling, and the fouling on the photovoltaic components to reduce the generation of electricity grew.

What's more, as time goes on, the effect of fouling on the surface of PV modules in actual operation was not a simple linear relationship.

At the end, in the Dalian area, the power generation efficiency of PV systems decreased about 1.5% after 2 days of fouling, and it decreased about 2.2% after 5 days of fouling. The power generation efficiency of PV systems decreased about 6.4% after 10 days of fouling.

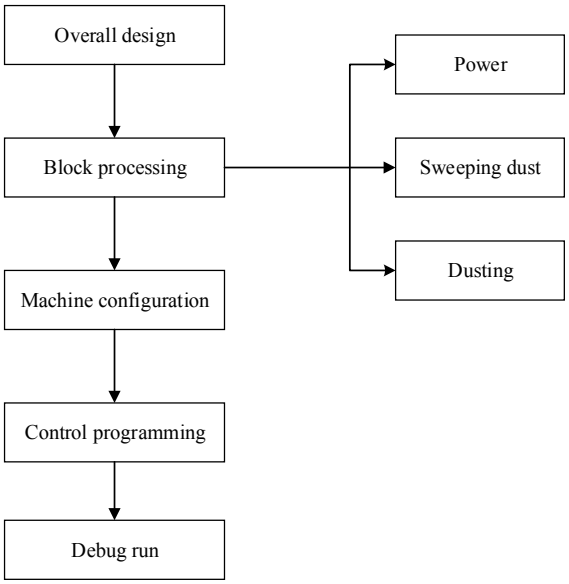

Figure 5: Technical flow chart

In order to solve the problem of fouling and cleaning of photovoltaic power generation project (mostly photoelectric building integrated project), a new type of crawler solar panel cleaning device was proposed in this paper, which adopted crawler chassis to carry clean roller brush and suction dust control device. It was through the control of dual drive motor to achieve the forward, backward and turn. The sweeping dust and dusting could be synchronized by controlling the roller brush motor and dust abatement fan. The machine was equipped with PLC control board, which could program for the motor speed and action route, and it can be adjusted at any time by Wifi parameters. The entire R & D work was carried out according the overall design, block processing, machine assembly, control programming and commissioning operation.
The specific technical flow chart was as shown in Figure 5.
First, the advantages were low energy consumption, no water consumption, no pollution, good cleaning effect.
Second, its functions were automatic travel, no water cleaning, fast dust, anti-high-altitude fall and others.
Third, perfect mechanical transmission, cleaning and automatic control device was to achieve a kind of automatic control of cleaning MW-level photovoltaic power plant cleaning device.

4. Conclusion

In this paper, the application status of photovoltaic power plants and the related research status of fouling were studied. Relying on the 100KW solar photovoltaic demonstration project of Dalian University of Technology Teaching Service Center, the comparative analysis of the clean/fouling monolithic solar panel power generation was made. So that the degree of influence of the actual operation of the PV module surface fouling on the photovoltaic power generation efficiency could be quantitatively analyzed. And a kind of mechanized, automated cleaning device was studied. It effectively reduces the problem of significant decline in power generation efficiency caused by the fouling on the surface of the PV system components, which restores a lot of economic losses for the actual production.

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