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The Effect of Photovoltaic Panel Cooling & Cleaning System on Power

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ABSTRACT

Environment-friendly renewable energy has been drawing attention recently because of the concern on limited resources. Photovoltaic market among various renewable energies has been increasingly growing for its simple structure and less risk than any other renewable energy technologies. Photovoltaic system is influenced by photovoltaic panel temperature, dust on panel surface and snow or other pollutants. In this study, a system for automatic operation of cooling and cleaning at a time was developed and power rate before & after applying the system was compared. Consequently, power efficiency of the panel after applying the system was increased by 3.3% in maximum. If this C&C system is applied continuously, the efficiency is expected to increase by more than 3%. This system would be required for photovoltaic system in the future as well.

Keywords: *Photovoltaic power system, panel, cooling and cleaning system, renewable energy*

1. INTRODUCTION

Because of limited resources including mineral, petroleum and gas, environment-friendly and renewable energy has been drawing more attention than ever.

Photovoltaic system (PV) among renewable energy converts the light energy to electrical energy. Because of no mechanical or chemical action in energy conversion process and simple system structure, it requires a very few maintenance [1]. Besides, extended service life, noise-free, no radioactivity and explosion risk are the advantages as well. As technology develops, the performance has been improved and the cost is on the decline that will promote the distribution of PV system domestically and internationally.

PV system comprises PV module that generates the electricity from the light, battery that stores the electricity and inverter that connects the electricity to power system. To receive the light energy from the sun, panel which is mechanically assembled by modules is used and then this panel is influenced by temperature and pollutants in generating the power. If the temperature rises to the certain level or the pollutants such as dust, snow or mute are piled up on panel, the area to absorb the light is reduced and the power efficiency is reduced accordingly.

Hence, panel cooling & cleaning technology is indispensable. But in fact, the study mostly focuses on power efficiency and the study on panel cooling & cleaning system stays far behind.

This study is intended to identify the effect of panel cooling & cleaning technology on power efficiency of PV system. In Section 2, review of preceding study and technologies was performed and in Section 3, the study on development of PV panel cooling & cleaning system was conducted and in Section 4, visual comparison and power efficiency with and without panel C&C system was made and in Section 5, conclusion was suggested.

2. RELATED WORK

2.1 Study on PV Panel Cooling Technology

Nordmann and Clavadetscher [3] classified the installation method into 4 kinds to compare the heat loss due to rising temperature of PV panel and used 18 system data for each installation. Based on system operation hours, an hourly unit data for a year or longer was used.

Panel installation types used were Façade, Sloped roof, Freestanding and Flat roof type. As a result of analysis, annual heat loss was 1.7~11.3% and temperature rising was lower with Freestanding and Flat roof type and the heat loss was lower accordingly. PV system in Sloped roof type required the wind for cooling the air between the roof and panel and Façade type required cooling system when the temperature was high.

Vick and Clark [4] studied on power efficiency depending on seasonal PV panel temperature after collecting a minute-unit average data. Silicon (Si) panel was used and the efficiency at 25 ℃ was about 7~10% and based on this, seasonal power efficiency was compared.

Analysis showed that the efficiency was increased by 1% when average panel temperature was 22 ℃ in December and January and the efficiency was decreased by 6.5% at average panel temperature was at 47 ℃ in July and August.

Omubo-Pepple et al. [8] conducted study on effect of panel temperature, intensity of the sunlight, Relative Humidity (RH) and ambient temperature and the equation to calculate the efficiency is as follows.

$$\text{Power} = \text{Voltage} * \text{Current (watts)} \quad (1)$$

Power efficiency (%) = (PV panel Power * 100%) / area of PV panel * 100 W/m^2 (2)

As a result of analysis, the efficiency tended to fall when the PV panel temperature rose to a certain level. Intensity of sunlight was proportional to the current and efficiency. RH had little effect both on efficiency and current and ambient temperature had no direct effect on PV panel temperature. The environment for optimal efficiency was provided when the solar cell temperature was 43℃ and RH 70%, 76%, sunlight 78.85Klux and the power was 18.42*10-1A and the efficiency was increased by 82.28% in maximum.

2.2 Study on PV Panel Cleaning Technology

Sulaiman et al. [9] conducted the study on effect of the dust piled up on panel on power efficiency. The experiment was conducted at lab and a light source was used to generate the light energy. The dried clay and talcum powder was used instead of real dust. Conditions of the experiment were no plastic, clean plastic, dusts on panel. The effect on power generation was compared while changing the amount of dust, intensity of the light (255 W/m^2, 301 W/m^2, and 340 W/m^2) and the distance between panels. As a result, the panel without plastic generated the highest power except 340W/m^2.

When dried clay was piled up on panel, the power was decreased by 18.1% and when talcum powder was piled up on panel, it's decreased by up to 16.5%. And when the dust was piled up on a panel, the lower the intensity of the light, the greater the effect on panel. As a result of calculating the power efficiency by applying maximum power, voltage and light intensity, it's 4.82% for the panel without plastic and the panel without dust and 3.95% for the panel with clay and 4.03% for the panel with talcum powder.

Denver et al. [7] conducted the study on how to remove the dust on PV panel and the effect on power efficiency. Dust containing iron and mute may cause the semi-permanent damage to PV panel which is not removed by rain-water and the efficiency is reduced accordingly.

Kimber [5] asserted power efficiency is reduced by 5% annually due to dust. Harberlin et al. [2] conducted the analysis of power efficiency of PV system near the railroad and revealed that the efficiency was reduced by 8~10% due to dust containing iron and pollen. Hammond et al. [1] studied on effect of mute on power efficiency comparing to other dust and consequently, further decrease in power efficiency comparing to others was 8% and the mute was not completely removed by rain-water.

As a result of reviewing the preceding studies, management of temperature of PV panel and cleaning the pollutant were indispensable to enhance the system efficiency. Thus this study is aimed at developing the PV panel C&C system as well as comparing the power efficiency.

3. DEVELOPMENT OF PV PANEL COOLING & CLEANING SYSTEM

3.1 Development Summary

Previous PV panel cooling system mostly uses a simple water spray system which causes the waste of water and inconvenience due to manual operation.

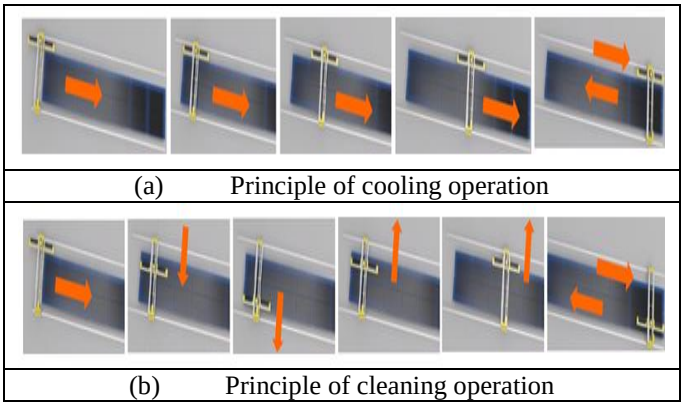
Cleaning system uses the brush or wiper which is inefficient in cleaning. In this study, instead of manual water spraying using nozzle, automatic water spraying uniformly over entire area of PV panel was used to maximize the power efficiency, and motorized brush was developed to remove the massive objects such as snow.

Cooling and Cleaning(C&C) were designed to operate either simultaneously or individually and both dry and wet cleaning could be performed.

3.2 Development of PV Panel Cooling & Cleaning System

PV panel C&C system comprises of cleaning head, driving cart, rail, water & power supply line and control. Cleaning head has water spray and the brush to remove the pollutants and driving cart functions to move cleaning head laterally. Rail provides the route for movement of PV panel cooling & cleaning system as designed and the control equipped with temperature and humidity weather sensor to collect the weather data at the installation site while controlling the power supply to other parts.

This system has three different functions including wet cleaning, dry cleaning and cooling. Figure 1shows the system operation principle. Wet cleaning is designed to clean the panel surface using a certain water pressure and brush while cleaning head moves vertically. After finishing the cleaning of certain zone, it moves laterally using driving cart to repeat the same process. Dry cleaning has same cleaning process as wet cleaning but without water. Cooling function is performed to the surface of the panel while moving on rail with cleaning head fixed on top of driving cart.



(a) Principle of cooling operation

(b) Principle of cleaning operation

Figure 1: Cooling & cleaning operation principle of PV panel

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Two PV systems having same scale were installed at Korea Institute of Civil engineering and building Technology in order to compare power efficiency before & after applying PV panel C&C system. Figure 2 shows the PV panel C&C system installed at the site.

Figure 2: PV panel C&C system installed at the site

4. APPLICATION OF PV PANEL COOLING & CLEANING SYSTEM AND RESULT

In this study, visual inspection of the result before & after applying PV panel C&C system was conducted and power was compared with existing panel.

As the test was conducted in Jan 2016 and cleaning system was only used because the panel temperature was not high.

Wet cleaning using water is usually adopted in summer, while dry cleaning system using brush without water is used to remove the snow on panel in winter. Visual inspection result is as Figure 3. As a result of visual inspection, dust on panel was removed.

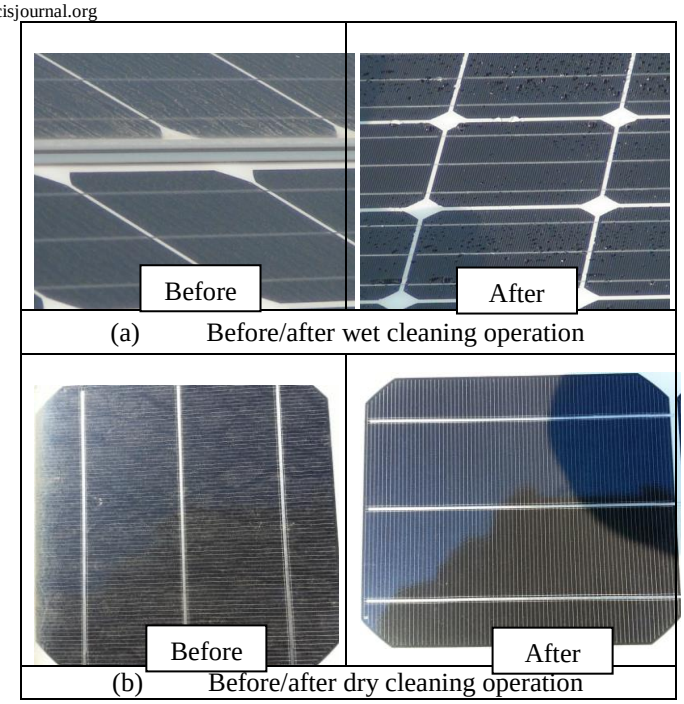

Figure 3: Result of operation of PV panel cleaning system

To compare the power efficiency, data comparison and analysis after snow in Jan 2016 were made. Fig 4 shows the panel with snow on surface.

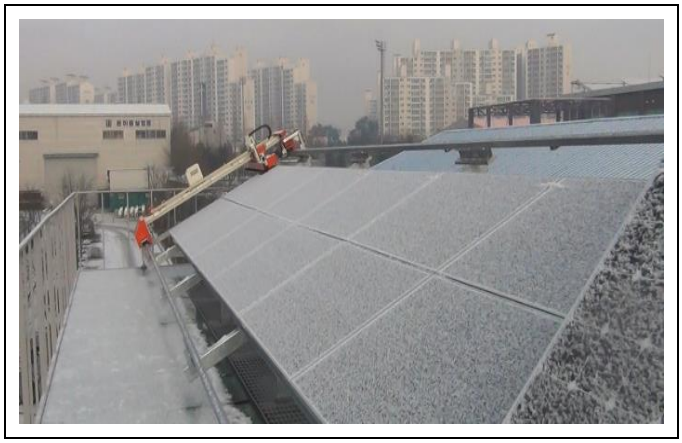

Figure 4: PV panel after snow

PV panel C&C system was applied at 10:30 am and power before & after applying PV panel C&C system was analyzed for an hour at 1 minute and 5 minutes interval. As a result, panel temperature was at 0~4℃, irrespective of applying C&C system. Figure 5 shows the power at 1 minute interval. Viewing the graph, power for 15 minutes with PV panel C&C system was higher than without the system. According to comparison of average value for an hour, power after applying C&C system was higher by 1% than before application.

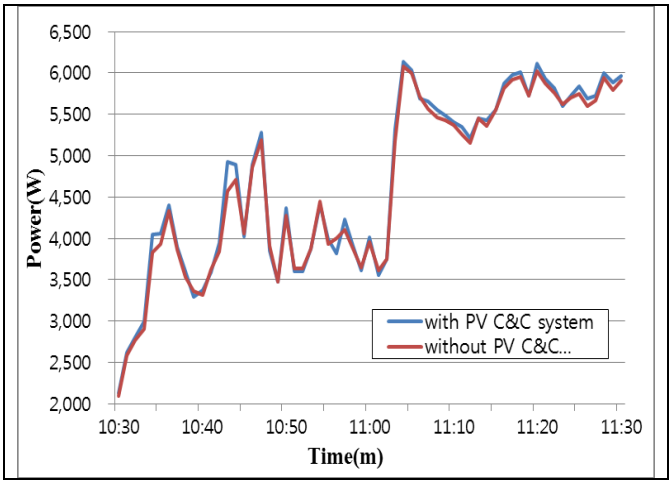

Figure 5: Comparison of power with and with C&C system

Average power at 5minutes interval is as Table 1. As seen in graph, power for 15 minutes after applying to the panel appeared to be higher. But the most of power after 15 minutes was under 1% because it was attributable to small amount of snowfall during the test.

Table 1: PV panel C&C system operation result

System / Time	Power(W)		
	With C&C	Without C&C	Rate (%)
10:30	2,917	2,835	2.78
10:35	3,851	3,806	1.16
10:40	4,145	4,010	3.25
10:45	4,303	4,296	0.16
10:50	3,972	3,972	0.00
10:55	3,912	3,912	-0.02
11:00	4,557	4,516	0.91
11:05	5,685	5,636	0.86
11:10	5,369	5,320	0.91
11:15	5,828	5,791	0.63
11:20	5,838	5,796	0.72
11:25	5,829	5,751	1.34
11:30	5,731	5,682	0.85

5. CONCLUSION

In this study, it was conducted to review the advanced studies in order to improve the power efficiency of PV system. Result of the review was that the efficiency was found to have been decreased due to rising panel temperature and pollutants. Thus PV panel C&C system was developed in an effort to supplement such problem and power efficiency depending on the system was analyzed so as to identify the effect of the system.

The system with wet cleaning, dry cleaning and cooling function was developed and the PV panel C&C system was applied after snow in this study. As a result of comparing and analyzing the power efficiency at 1 and 5 minutes interval, the efficiency for 15 minutes after application was highest. Efficiency was increased by 3.3% in maximum at 5 minutes interval, but the efficiency was not significant because of small amount of snowfall and application of cleaning system alone. Thus when applying the system at high temperature in summer or after a large amount of snowfall in winter, the efficiency would obviously increase further.

PV power is expected to increase depending on outcome of this study which would be indispensable in PV power generation market in the coming days.

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