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Effect of Cleaning, Cooling and Shading on Current and Electrical Power of Photovoltaic Panels

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Abstract— **The purpose of this paper is to determine the effect of cleaning, cooling and shading on the current and electrical power produced by photovoltaic panels. A practical experiment at the solar site of the Renewable Energy Laboratory of Shahid Beheshti University was arranged on a part of the panels installed at the pilot plant of the laboratory. The results are presented and discussed in this paper. For this purpose, an overview of previous work and articles published in this field is first provided, and then the results of this field experiment are presented. The analysis of the data obtained from this experiment shows that the removal of dust from the surface of the photovoltaic panels and the cooling of the panels, increases the electrical power generated by these panels by approximately 10%. Also, the result of this test shows, the half shadowing may cause to completely cut-off the electrical current output of photovoltaic panels. Due to the fact that Iran is located in the desert belt of the planet, most cities of Iran in most seasons of the year witness winds with dust, which reduces the electrical power production and efficiency of the installed photovoltaic panels. Therefore, the results of this experiment can be used to improve the performance of photovoltaic systems.**

Keywords— renewable energy; photovoltaic panel; shadow; cooling; electrical power

I. INTRODUCTION

The electrical power produced by the photovoltaic (PV) panels, in addition to the amount, direction and intensity of sunlight, depends on the other parameters such as air temperature, panel surface temperature, air pollution, wind speed, transparency and cleanliness of the panels. As far as the photovoltaic panels are cleaner and free of foreign materials such as dust, grease, ash and likewise the efficiency and, consequently, the amount of electrical power generated by the panels, increases.

The importance of dirty panels issue becomes apparent when it comes to the installation in outdoor conditions since these panels are always exposed to airborne particles. Especially in Iran, which is located on the desert belt of the planet, and most of its cities are always exposed to winds and storms with dust, these effects are more evident. Also, given that a large part of photovoltaic panels, such as traffic lights and road lightings are installed in urban areas with high air pollution levels, the settled layers of soot and suspended air particles greatly reduces their efficiency. Photovoltaic plants, on the other hand, are also being constructed in the desert areas around the cities, due to the large area of the land occupation. These areas, in spite of winds that are dusty, have the potential to reduce the efficiency and electrical power produced by panels. What is presented in this study is the results of a field experiment in real-world weather conditions in the north-eastern part of Tehran. Moreover, the purpose of this study is to estimate the effect of cleaning and dust removal of these photovoltaic panels on the performance and the electrical output power from the panels. In this field research test, water has been used to clean the panels surface, thereby the temperature of the panels reduces as well and their efficiency increases. This experiment was conducted in the first weeks of February and continued from 14:00 to 15:00.

Al-Nazahi and et al. [1] conducted a study on two groups of photovoltaic panels installed on the roof of a building in a region with very hot climate. The first group of photovoltaic panels was equipped with a cooling system that was cleaned at certain intervals. The second group of photovoltaic panels lacked a cooling and cleaning system. The results of this study showed that in the same environmental conditions, the efficiency of the first group was 11.7% and the efficiency of the second group was 9%. The maximum output power of the cooled and cleaned panels was 89.4 watts versus 68.4 watts for the non-cooled and uncleaned panels.

Dorobanţu and Popescu [2] presented a study on the effect of water films on increasing the efficiency of photovoltaic panels. In this study, a comparison was made between two groups of photovoltaic panels. The first group was cooled and cleaned by a water film and the second group lacked such a water film. Both groups of photovoltaic panels are shown in Fig. 1. During the experiment, the temperature of the panels was controlled continuously by a thermal camera in two modes, i.e. with and without the water film. The results of this study indicated that the efficiency of the photovoltaic panels was improved by the cooling and cleaning of the water film. The study found that an increase of 9.5% in electricity produced by photovoltaic panels equipped with water film,

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could also provide the electrical energy required for the water filtration pumps.

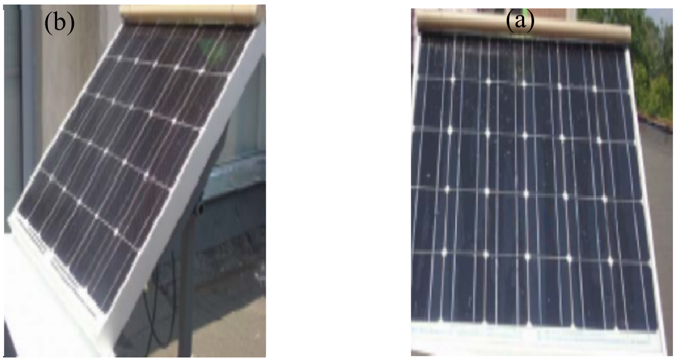

Fig. 1. Photovoltaic panels in cooling effect test by [2].

(a) Photovoltaic panel without water film
(b) Photovoltaic panel with water film

Dorobanțu et al. carried out another study on the experimental performance evaluation of the photovoltaic panels with water film. In view of the fact that the operation of photovoltaic panels is strongly influenced by the surface temperature of the panels, in this study, the performance of flat photovoltaic panels with a layer of water films was evaluated experimentally. The panels were installed in a power plant located on the roof of the Bucharest Polytechnic University building (see Fig. 2). The water flowed from a water-cooled water reservoir through a perforated tube that was placed above the active surface in front of the panels as a thin film on the panels. This water film, in addition to cooling the active surface of the panel, cleaned it as well.

Fig. 2. An overview of the photovoltaic power plant of Bucharest Polytechnic University [3].

As a result of this study, it became clear that the active surface cooling of the photovoltaic panels causes the panels efficiency and their reliability to be increased. Due to lower operating temperatures, the life of the panels increases too. Meanwhile, the stains created by airborne pollutants that can degrade photovoltaic panels, are eliminated by the water film.
Kazem et al. [4] undertook a study on the effect of dust deposition on the performance of multicrystalline (multiband) photovoltaic modules based on experimental measurements. In this study, the effect of precipitation and accumulation of various types of air pollutants including red earth, ash, sand, calcium carbonate and silica on the amount of electrical energy produced by photovoltaic panels has been investigated. The results of this study indicate that the decrease in the voltage and power of photovoltaic panels depends largely on the type of pollutant and its thickness on the surface of the panel. The results show also that ash has the most impact on reducing the voltage of photovoltaic panels in comparison to the other pollutants, and that the maximum voltage drop (25%) has been recorded on the surface of the photovoltaic panels. These experiments were carried out in the conditions of the Omani Desert.

Kaldellis and Kapsali [5] accomplished a study on the effect of dust on the performance of photovoltaic power plants based on experimental measurements. The results of this study showed that one of the side effects of urban air pollution is the reduction of the efficiency of photovoltaic panels. The reason was found to be due to the sedimentation and accumulation of various air pollutants such as red soil, lime and ash. This study showed that reducing the efficiency of photovoltaic panels strongly depends on the type and source of the pollutant particles as shown in Fig. 3. In this research, a theoretical model was presented that can describe laboratory findings with acceptable accuracy. This theoretical model could be used in designing solar systems such as industrial and home photovoltaic plants, solar street lighting, and likewise, in the event of development and long-term predictability enhancement.

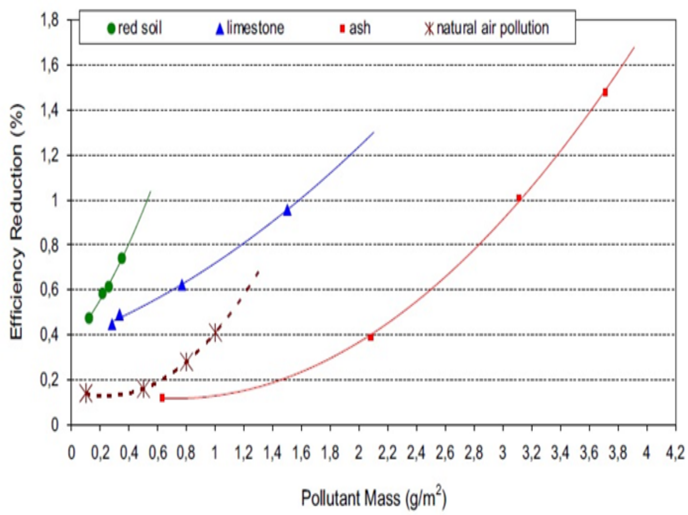

Fig. 3. Reduction of the efficiency of the photovoltaic panel by the effect of different pollutants sedimentation [5].

II. Research Methodology

The current experiment was performed on a series of photovoltaic pilot plant arrays mounted on the roof of the Renewable Energy Laboratory building at Shahid Beheshti University located in Tehran, Iran. To handle the experiment appropriately, a team of students were divided into two groups. The first group was on the roof of the building and used wet and damp cloths as observed in Fig. 4. The active surface of the photovoltaic panels was cleaned and cooled by the group. Then the shadows on the photovoltaic panels were created using fitting covers. The second group inside the laboratory managed the reading and recording of the values and parameters of the photovoltaic power plant output before and after the cleaning, cooling and shadowing operations (see Fig. 5). This experiment was conducted on a sunny day in February 2017. The data was recorded and then evaluated and analyzed.

Fig. 4. The first group of students for cleaning and cooling the photovoltaic panels.

Fig. 5. The second group of students for reading and recording the output parameters of photovoltaic panels.

III. Results and Discussion

Output parameters from the array under the test of photovoltaic panels, including current (*I*), voltage (*V*) and power (*P*), as well as environmental conditions including solar radiation intensity (*G*), ambient temperature (T_1) and module surface temperature (T_2) were read and recorded by the second group of students in four cases as following:

A) Warm and dusty photovoltaic panels before shading.

B) Warm photovoltaic panels with dust after shading.

C) Cool and clean photovoltaic panels before shading.

D) Cool and clean photovoltaic panels after shading.

The readings and recordings for cases A to D are tabulated in Table 1.

TABLE I. The Data Recorded for Different Operating Cases

T_2 [°C]	T_1 [°C]	G [W/m^2]	P [kW]	V_{AC} [V]	V_{DC} [V]	I [A]	
32.00	13.00	479.00	2.30	227.00	548.38	8.10	A
32.00	12.00	473.00	1.00	228.00	208.15	4.30	B
23.00	14.00	455.00	2.52	230.00	543.00	11.00	C
23.00	14.00	455.00	1.40	228.00	448.00	6.50	D

As it is clear from the data given in Table 1, by cleaning and cooling the surface of the photovoltaic panels in the test array, in relatively uniform ambient conditions, the surface temperature of the panels decreased by 9°C. This is due to the fact that as far as the removal of pollutants from the photovoltaic panel surface goes on, the power output of this array is increased 9.5% in the non-shadowing mode and 40% in the shadowing conditions.

In the above experiment, shading is done on half of the photoelectric panel, and the figures in the table above show that the electrical current (ampere) in the shadowing mode is almost halved. However, it should be noted that zeroing the electrical current does not necessarily need covering of the entire area of the photovoltaic panel. Moreover, owing to the internal interconnection of the electrical circuits of the photovoltaic cells together, if these circuits are cut off by shadowing a part of the photovoltaic panel, the output current may be disconnected completely.

The values recorded in Table 1 show that during the test, which lasted one hour, the intensity of sunlight dropped by 24 watts per square meter, and the ambient temperature increased by 1°C, with a slight effect on the current of photovoltaic panels. This effect has been ignored.

Below are the charts for describing the relationship between the shading, cleaning and cooling of the photovoltaic panels and the current and production capacity based on the findings during the test. Fig. 6 and Fig. 7 illustrate the dependency of the current and output on different operating conditions of PV panels.

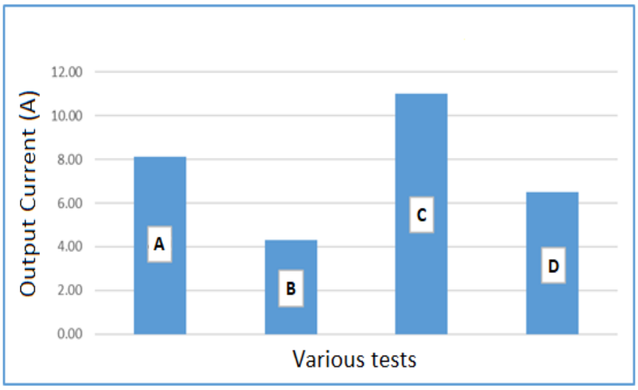

Fig. 6. The effect of shading, cleaning and cooling on the current of photovoltaic panels.

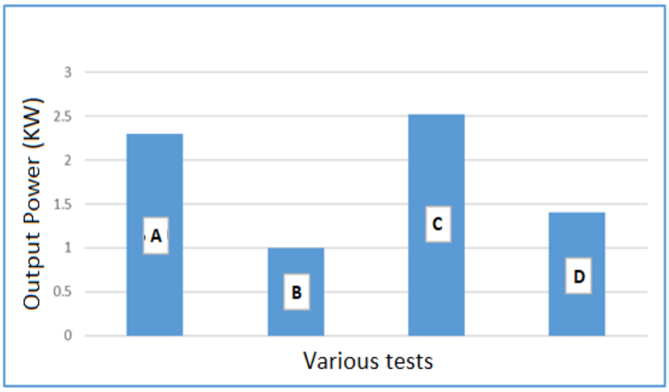

Fig. 7. The effect of shading, cleaning and cooling on the output power of photovoltaic panels.

IV. Summary and Conclusion

Based on the results achieved from present investigation, the cleaning and cooling of the photovoltaic panel increases the output current of the panels by 27% in non-shadowing mode and 34% in shading mode of operation. Also, by performing cleaning and cooling operations on photovoltaic panels, the power output of these panels increased by 9.5% in non-shadowing mode and 40% in shadowing mode.

Even though by shading, the output current and photovoltaic panel output power have been reduced by almost fifty percent, the increase in both parameters in shadowing mode has been more than non-shadowing condition, which indicates the high impact of cleaning and cooling process on the efficiency of photovoltaic panels.

By analyzing the data obtained from this experiment it can be concluded that the effect of cleaning and cooling operations on photovoltaic panels are of great importance. It is revealed that both effects increase the efficiency and power produced by the photovoltaic panels, either household type or industrial power plants as well as the PV panels for installation in public places such as traffic lights and urban lighting systems. It is strongly recommended to schedule a maintenance cleaning program to achieve the highest possible performance. It should be noted that for some applications the design and installation of a permanent cooling system may seem to have no such economic justification. These applications could be traffic lights; urban lighting systems or power supply systems; and equipment installed in areas lacking a national grid, such as a gas station for connection of the oil and gas pipelines that are designed and installed in a desiccant and vacant area. However, the preparation and implementation of a regular cleaning program for these panels can have a significant impact on their proper operation.

On the other hand, in large units such as photovoltaic power plants, where a large number of panels are installed in a confined area, in addition to the establishment of a regular cleaning plan for photovoltaic panels, the design and installation of a permanent cooling system, for example, a cooling system with the flow of water, can considerably increase the efficiency and power generated by these power plants.

References

[1] Ahmed Elnozahy, Ali K. Abdel Rahmana, Ahmed Hamza H. Ali, Mazen Abdel-Salam and S. Ookawarad, “Performance of a PV module integrated with standalone building in hot arid areas as enhanced by surface cooling and cleaning,” Energy and Buildings, vol. 88, pp. 100–109, (2015).

[2] Loredana DOROBANŢU and Mihai Octavian POPESCU, “Increasing the efficiency of photovoltaic panels through cooling water film,” U.P.B. Sci. Bull., Series C, vol. 75, iss. 4, (2013).

[3] L. Dorobanțu, M. O. Popescu, C. L. Popescu, and A. Crăciunescu, “Experimental assessment of PV panels front water cooling strategy,” International Conference on Renewable Energies and Power Quality (ICREPQ’13), Bilbao (Spain), 20th to 22th, ISSN 2172-038 X, No.11, (2013).

[4] Hussein A Kazem, Tamer Khatib, K. Sopian, Frank Buttinger, Wilfried Elmenreich, and Ahmed Said Albusaidi. “Efect of dust deposition on the performance of multi-crystalline photovoltaic modules based on

experimental measurements," International Journal of Renewable Energy Research., vol. 3, no.4, (2013).

[5] J.K. Kaldellis and M. Kapsali, "Simulating the dust effect on the energy performance of photovoltaic generatorsbased on experimental measurements," Energy, vol. 36, pp. 5154- 5161, (2011).