INFLUENCE OF ATMOSPHERIC POLLUTION ON THE PARAMETRES OF PHOTOVOLTAIC MODULES IN THE SOUTHERN REGIONS OF UZBEKISTAN

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Abstract. *During the study, the degree of surface contamination of a silicon photovoltaic module (PV) was studied for one month. In the conditions of the city of Termez, the change in short-circuit currents of two identical PVs under the influence of day and night dusting of their surfaces was analyzed. During the presence of the Afghan wind, the degree of pollution of the PV surface was determined and relevant scientific and important practical conclusions were drawn.*

Keywords: *photovoltaic module, short circuit current, atmospheric air, pollution degree, Afghan wind.*

Introduction

The southern regions of Uzbekistan, including the Surkhandarya region, have different climatic conditions than other places: very dry air, hot climatic conditions, periodic Afghan wind and dust. In winter, the temperature rises from February and begins to drop in autumn in November. A certain part of the territory is surrounded by desert and mountains. In such arid climatic conditions, the wind causes an increase in the amount of dust in the atmosphere [1]. The short circuit current of semiconductor solar cells depends on the amount of sunlight absorbed by the crystal lattice of the cell. Therefore, dust collecting on the surface reduces the efficiency of the PV.

Fig. 1 shows an experimental setup for determining the degree of dusting of the PV surface.

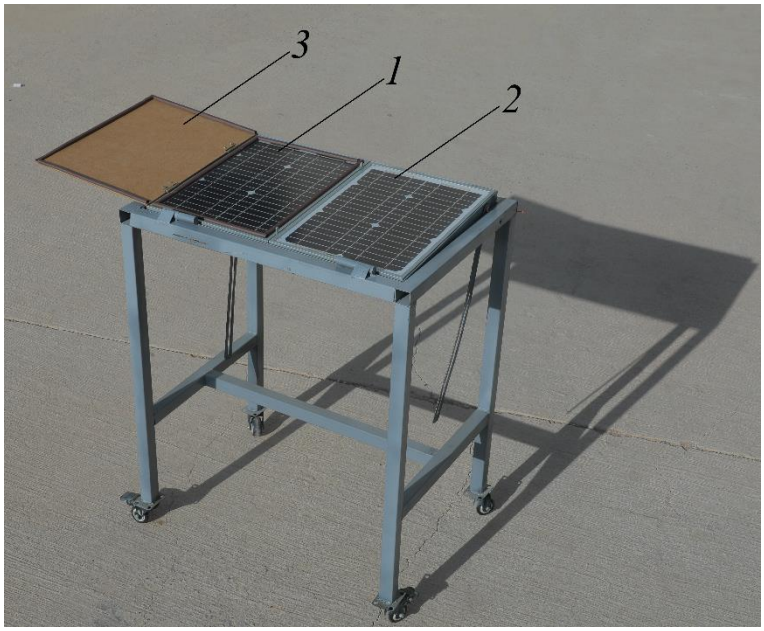

Fig. 1. An image of the PVs installation for the experiment.
1 – PV whose surface opens only at night, 2 – PV whose surface is always open, 3 – cover.

To ensure maximum contamination of PVs, they are placed horizontally. The first PV surface is closed during the day and open at night (from 7:00 p.m. to sunrise until 7:00 a.m.). Unlike the first, the second PV surface is always open day and night.

PV parameters were measured each day when the sun reached the zenith. In this case, the amount of solar radiation falling on the PV surface is almost the same, and measurement errors are minimal. The measurements were taken on sunny days with minimal changes in wind speed (Afghan wind did not blow) and air humidity.

The degree of pollution of the PV surface was determined according to the following formula:

$$\gamma = \frac{I_0 - I_n}{I_0} \cdot 100\% \qquad (1)$$

here, γ is the degree of pollution, I_0 is the initial value of PV short-circuit current, i.e. before pollution, I_n is the value of PV short-circuit current after n days [2].

Fig. 2 shows the results of the study conducted in June 2021, i.e., the time dependence of the two PV pollution degrees.

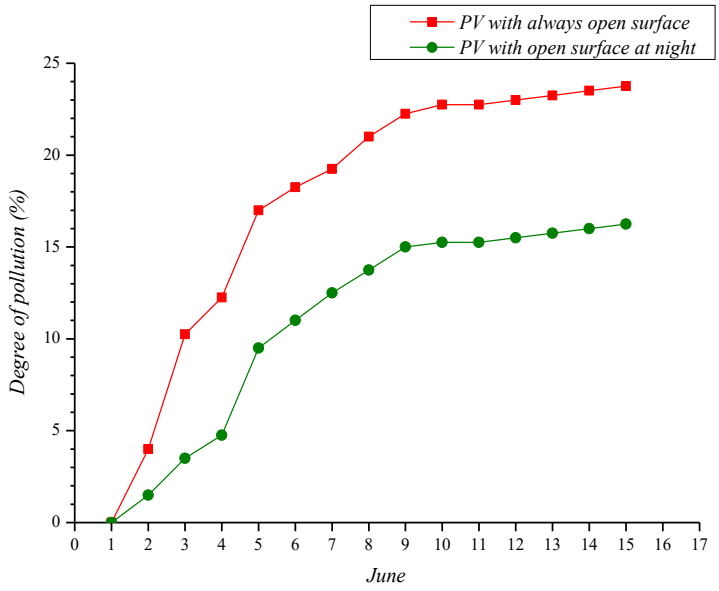

Fig. 2. Time dependence of PV surface contamination degree

During the experiments, the degree of contamination was ~23% for the FEB whose surface was always open, and ~16% for the FEB whose surface was exposed only at night. The reason for this is that when the temperature is high, dust particles, like gas molecules, are in thermal motion. The mean square speed of gas particles at high temperature is proportional to temperature [3].

A high mean square speed causes a large kinetic energy of the particle. As a result, they are less likely to be attracted to the earth. When the temperature decreases, the decrease in kinetic energy causes an increase in the potential energy of the particles. In this case, dust particles combine with water vapor. Therefore, at night due to the heaviness of dust particles, it is pulled down - to the PV surface.

Methods and materials

During the analysis of the above experimental results, the influence of PV surface dusting on PV short-circuit current on normal days and days with Afghan wind was studied. For this, the total short-circuit current of PVs was taken as the total of the short-circuit currents of both PVs open during the day and open at night.

$$I_{total} = I_{day} + I_{night} \quad (2)$$

After a certain period of time, the amount of dust on the surface of PVs, that is, due to the increase in the degree of contamination, the short-circuit currents decrease from the initial value. The table below shows the changes in PV pollution degrees and short-circuit currents in one month.

Table 1

Variations in pollution degrees and short-circuit currents of PVs

Days	PV whose surface opens during the day		PV whose surface opens only at night		Change in total short-circuit current
	Pollution degree	Change in short circuit current	Pollution degree	Change in short circuit current	
1	0	2,990	0	2,99	5,98
2	1,003344	2,960	1,672241	2,94	5,9
3	2,006689	2,930	3,344482	2,89	5,82
4	3,010033	2,900	5,016722	2,84	5,74
5	4,013378	2,870	6,688963	2,79	5,66
6	5,016722	2,840	8,026756	2,75	5,59
7	6,020067	2,810	9,364548	2,71	5,52
8	6,688963	2,790	10,70234	2,67	5,46
9		*Afghan*	*wind*	*blew*	
10	8,026756	2,750	13,37793	2,59	5,34
11	8,695652	2,730	14,71572	2,55	5,28
12	9,364548	2,710	15,71906	2,52	5,23
13	10,03344	2,690	17,05686	2,48	5,17
14	10,70234	2,670	18,39465	2,44	5,11
15	11,37124	2,650	19,39799	2,41	5,06
16	12,04013	2,630	20,40134	2,38	5,01
17	12,70903	2,610	21,40468	2,35	4,96
18	13,37793	2,590	22,40803	2,32	4,91
19	14,04682	2,570	23,41137	2,29	4,86
20	14,71572	2,550	24,41472	2,26	4,81
21	15,05017	2,540	25,41806	2,23	4,77
22		*Afghan*	*wind*	*blew*	
23	15,55184	2,525	27,0903	2,18	4,705
24	15,71906	2,520	27,7592	2,16	4,68
25	15,88629	2,515	28,42809	2,14	4,655
26	16,05351	2,510	29,09699	2,12	4,63
27	16,22074	2,505	29,76589	2,10	4,605
28	16,38796	2,500	30,43478	2,08	4,58
29	16,55518	2,495	32,44147	2,02	4,515
30	16,72241	2,490	33,11037	2,00	4,49

Results and Discussion. From Table 1, it can be seen that the short-circuit current of the PV open during the day decreases by 1.2 times and that of the PV open at night by 1.5 times as a

result of the increase in the degree of pollution of PVs during one month. Therefore, the change in the short-circuit current of PVs under the influence of pollination in one month can be written as follows.

$$I_{total} = 1,2\Delta I_{day} + 1,5\Delta I_{night} \quad (3)$$

(3) the coefficients in terms of equality are slightly different for days with Afghan wind.

The Afghan wind is a hot, dry, and dusty southwesterly wind that invades the southern regions of Uzbekistan, especially the city of Termez. The local people called it the "Afghan wind" because the wind blows in the south-west direction from Afghanistan. With the approach of the Afghan wind, eddies and vortices are formed, then a dust storm with a speed of 20 m/s and more is formed [4].

Fig. 3 shows the average wind speed in June 2023, according to the information provided by the hydrometeorological center of Surkhandarya region.

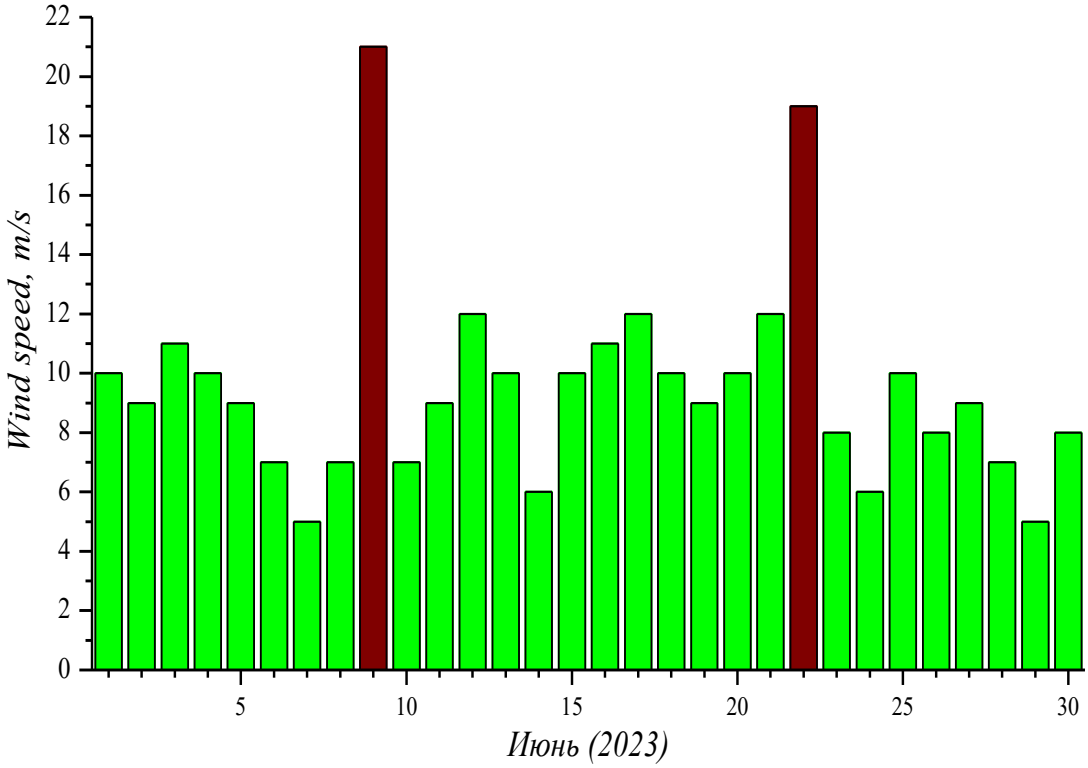

Fig. 3. Average daily wind speed in Termez city in June 2023

One month's data shows that the average wind speed in Termez for June is 10 m/s. However, on June 9 and June 22, the wind speed was 21 m/s and 19 m/s respectively. These numbers indicate that the Afghan wind was blowing on these dates. In particular, the data presented in Fig. 4 confirm that the degree of atmospheric air pollution was high on these dates.

Fig. 5 shows hourly indicators of atmospheric air pollution in June. It can be seen from the graph that the average value of air pollution on June 9 and 22 was higher than usual and was 4196 μg/m^3 and 2489 μg/m^3, respectively [5].

Information on the degree of atmospheric pollution was obtained from the automatic monitoring station of atmospheric air pollution installed in the city of Termez within the framework of the project implemented in cooperation with the international public fund "Zamin" and the Hydrometeorological Service Agency (Fig. 6).

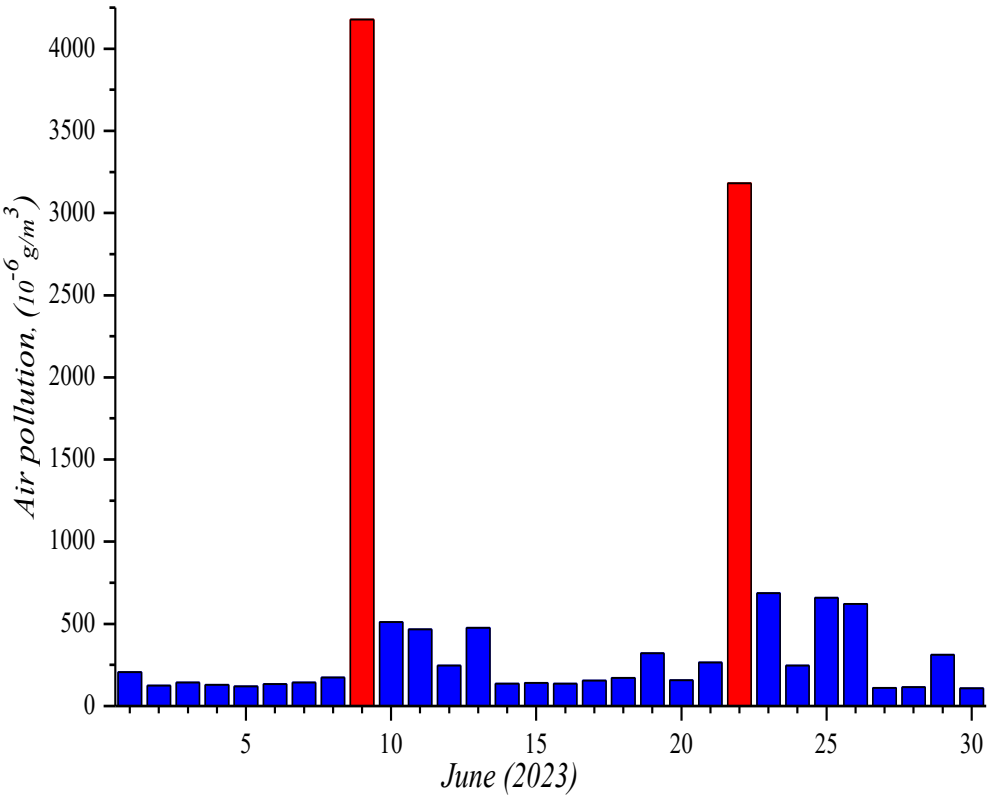

Fig. 4. Average daily values of atmospheric pollution

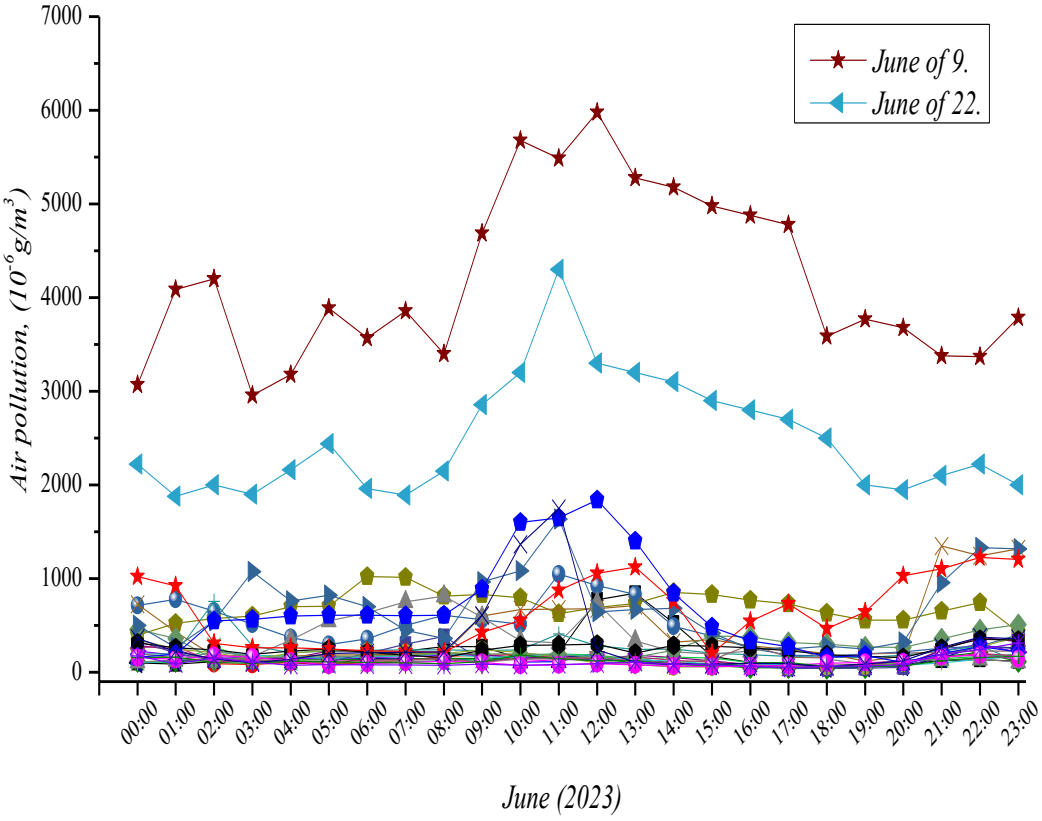

Fig. 5. Hourly average values of air pollution degree

Fig. 6. Automatic air pollution monitoring station installed in the city of Termez

The automatic air pollution monitoring station is equipped with air particle analyzers APMA 370 and APDA-372, these devices record the mass of polluting particles in 1 cubic meter of air in units of μg/m^3. Atmospheric air pollution and PV surface pollution degree are related to each other. Because the degree of atmospheric air pollution is high, the amount of dust settling on the PV surface is also high. In order to determine how equation (3) changes for the days when the Afghan wind blows, it is necessary to tabulate the numerical values of the diagram in Fig. 4.

Table 2

Variations in pollution degrees and short-circuit currents of PVs

June	Atmospheric air pollution degree, μg/m^3		June	Atmospheric air pollution degree, μg/m3	
	On normal days	On the days when the Afghan wind blows		On normal days	On the days when the Afghan wind blows
1	207		16	136	
2	125		17	154	
3	143		18	172	
4	129		19	320	
5	119		20	158	
6	134		21	265	
7	144		22		3182
8	174		23	688	
9		4178	24	245	
10	512		25	659	
11	467		26	622	
12	246		27	110	
13	475		28	114	
14	136		29	312	

15	140		30	108	
Total	3151	4178		4063	3182
Degree of atmospheric air pollution on normal days, μg/m^3					7214
Degree of atmospheric air pollution on days when the Afghan wind blows, μg/m^3					7360

It can be seen from Table 2 that the total of the degree of atmospheric air pollution on normal days is approximately equal to the degree of atmospheric air pollution on days when the Afghan wind blows.

Taking into account that the Afghan wind usually lasts for one night, and assuming that the daytime and nighttime pollination degrees of PVs are equal, equation (3) takes the following form:

$$I_{total} = 1{,}33\Delta I_{Afg.w.day} + 1{,}33\Delta I_{Afg.w.night} \qquad (4)$$

That is, equation (4) represents the formation of dust on the surface of the PV on the days when the Afghan wind blows, which is equal to its degree of pollination for one month.

Conclusion

Based on the results obtained in the experiment and the information provided by the hydrometeorological center, it was concluded that it is necessary to cover the surface of PVs on days when the Afghan wind blows.

In order to effectively use PVs in the southern regions, it is advisable to provide additional protection of their external surfaces from dust and periodically (quick) cleaning measures.

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