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Effect of Sand, Ash and Soil on Photovoltaic Performance: An Experimental Study

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Abstract— *The outcome performance of Photovoltaic in hot and dusty regions is the primary question regarding the usage of PV. In this article, three types of PV panels (monocrystalline, polycrystalline, and amorphous) were tested. The investigation focused on the effect of variable sorts of dust and pollutants on the generated power. The degradation in the PV power due to subjected to solar radiation time was investigated. Different air pollutants were tested (red soil, ash, sand, brown sand), ant the effect of its accumulation on the generated power was analyzed. The obtained results show that a considerable reduction in PV power was measured. The reduction rate depends strongly on the pollutant type and accumulation quantity. Also, the power reduction was increased with time which reveals the effect of temperature on the panels' output. For comparison purposes, red soil has the highest reduction effect on mono and poly crystalline panels. The brown sand was the most effective pollutant on the amorphous panel outcome compared with other tested pollutants.*

Keywords— *Photovoltaic, dust deposition, red soil, sand, ash.*

I. INTRODUCTION

The earth is threatened by two main problems: the depletion of fossil fuels which is the main source of energy, and the air pollution resulted from the burning of fossil fuels [1]. Today, a great part of the world became confident that the use of the renewable and sustainable energies can reduce the damage happened by fossil fuels. The solar energy is one of the sustainable energies and most significant for use [2-4].

Solar energy proved its suitability for generated electricity and hot water for domestic purposes. Also, it can be used for concentrated power plants efficiently [5]. Using solar energy to produce power by photovoltaics became widely used all over the world. This technology proved its convenience and the produced electricity costs start to reduce and it will become in near future the first competitor to fossil fuels [6-8].

PV arrays are easy to be installed and used and does not contain moving parts; it is silent without noise; and the fuel used which is a solar radiation. However, the picture is not always shining; there are some obstacles that were the cause that delayed the use of solar cells to the day [9]. The PV arrays influenced by the environmental parameters as solar radiation, air temperature, humidity, wind speed, and dust and air pollution. These parameters cause degradation in the PV performance and efficiency [10]. Many valuable papers investigated the impact of each parameter alone or with another one [11-13]. However, the dust and pollution effect which was studied heavily still needs more investigation due to the wide range of dust types, kind, origins, and particle sizes [14]. In the same time, pollutants differ according to the locations, human activates, topography, and natural parameters as relative humidity and wind speed [15].

Accumulation of air pollution from environment on the photovoltaic panels reduces the performance of solar panels. The reduction in the peak power generated can be up to 18% [16]. The effect of air pollution slightly reduced under peak solar radiation conditions, but its effect is not negligible [17]. Anything that blocks sunlight from the panel is reducing the effectiveness of the photovoltaic system. Any reduction in the solar radiation which is reaching the solar cell whether by dust or other factors such as tree sap, bird droppings, or environmental pollutants will lead to a drop in the produced energy [18].

Some references indicated that a diffuse layer of dust can actually reduce solar absorption by more than 5% while opaque pollutants like sap, droppings, or fallen tree's leaves can reduce absorption by even more. It's easy to imagine how much when you realize that a cloudy, stormy sky can reduce solar uptake by 50%. Dirt that blocks all light in segments of the panel could have an even more significant effect [19-22].

Ref. [23] reviewed the effect of several parameters on dust and dust storms and the effect of this phenomenon on the PV performance for Iraq. Ref. [24] investigated the effect of pollutants and airborne dust on the performance of the solar cell in the nearby areas on highways where frequent air pollution from vehicle exhaust. The study results revealed that cleaning the PV panel every two to three weeks reduces the impact of pollutants and dust accumulation highly.

Ref. [25] studied the effect of dust on PV performance at north region of Oman. The study indicated good possibilities to use this technology in this part of Oman due to low dust formation because of this area topography. Ref. [26] investigated the effect of dust physical properties on the PV performance. The study manifested that the dust particle size and other physical properties have a very serious impact on the accumulation figure on the PV panel. Also, these properties control the relationship nature with air humidity and how much the dust grains will stick on the PV panel face.

The Objectives of this study is to evaluate the impact of four selected dust and air pollutants on the PV panels' performance. The study aims to compare this effect on the energy yield and conversion efficiency of two types of PV panels. This work is a part of continuous effort of Energy and Renewable Energies Technology Centre in University of

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Technology, Baghdad-Iraq to wide spread the renewables usage culture [27-68].

II. Experimental Setup

The study focused on determining the impact of four selected pollutants (which are exist normally in the air) on PV-panels' performance and compare the energy yield and conversion efficiency of two statistically checked identical pairs of PV-panels. The studied pollutants were ash, sand, red sand, and brown soil. The ash was gathered from fish cookers who are distributed profusely in Baghdad streets where a large part of it volatizes in air. The sand was gathered from distilled dust after a sand storm which is an ordinary event in Baghdad. The red soil was imported from the west part of Iraq and this sand has phosphorous in its compound. The brown soil came from the near river soil and this one has high water content. Figure 1 represents the used pollutants.

Fig. 1. the pollutants used in the tests

The experimental analysis and tests were conducted in the laboratory using solar simulator represented in figure 2. The solar simulator was used to define and fix the solar radiation intensity during the tests.

Fig. 2. Solar simulator used in the tests

Three types of PV panels (monocrystalline, polycrystalline, and amorphous) were used in the investigation to evaluate the dust deposition impact on each one of them. Table I lists the specification of each panel.

The following parts of the laboratory's equipment were used:

- Three types of PV-panels (polycrystalline, monocrystalline, and amorphous PV panels) were examined.
- A control panel.
- A lead-acid battery storage system.
- A DC/DC charge controller (1 kW rated power),
- An electrical loads (lighting and a water pump).
- The pollutants

TABLE I. Summary of the design and sizing parameters of the PV systems.

Parameters	units	Poly-c	Mono-c	Amorphous
Out peak power	Wp	10	10	10
Open circuit voltage	V	21.3	21.9	21.0
Short circuit current	A	0.66	0.63	0.64
No. of cells	-	36	36	36
Power tolerance	%	0/+3%	0/+3%	0/+3%
Max. power voltage	V	17.3	17.5	16.0
Max. power current	A	0.58	0.57	0.46
size of module	mm	440×282×28	475×282×28	615×310×18
Weight of module	kg	1.5	1.61	1.52

A. Experimental Procedure

The tested PV panel's current and voltage were measured in variable cases. First the panel current and voltage were measured when the panel was clean. Then, the panel was polluted with one of the selected pollutants with specific weight to evaluate the impact of the distilled pollutant on the panel's outcome. The pollutants were added in quantities of 3g each on the surface of the panels and the panels were covered after that by plastic cover. A blower was used to diffuse the pollutants particles on the whole PV cell surfaces. The PV current and voltage were measured after the settlement of the added pollutants and the effect of increasing the accumulated pollutants on the PV generation was measured. The steps were repeated for each pollutant three times to confirm the repeatability of the experiments.

III. Results and Discussion

The indoor tests were conducted to study the impact of dust and pollutants on three types of PV performance. Dust is related to the geographical topography and the local air pollution in the site where the PV is installed. The tests were conducted for each element separately. Fig. 3 represents the power variation with time for the three tested panels when they were clean. The figure reveals that the polycrystalline started with higher power and then the monocrystalline exceeded it while the amorphous power was less than the others. This figure gives an indication about the outcome of each panel.

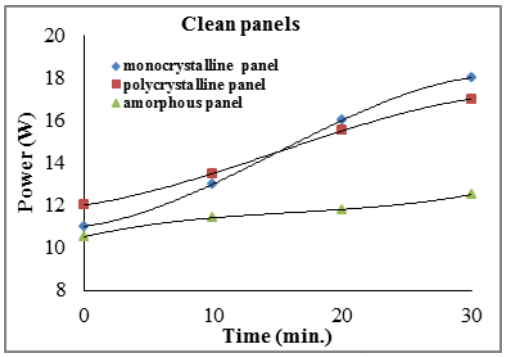

Fig. 3. The relation between time and output power for the tested clean panels.

Red soil comes from the west deserts of Iraq. Figure 4 shows the effect of this material accumulation on the tested PV Panels. Variable mass fractions of red soil were used and

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the accumulation was managed by adding 3 grams each time. The panels were polluted uniformly with sprayed pollution. For all PV panels used the power was reduced but the reduction was larger with monocrystalline panel. The reduction level for amorphous panel power was limited. Based on the recorded measurements, the exposure to solar radiation increases the panels' temperature which is an additional parameter aid in the power reduction.

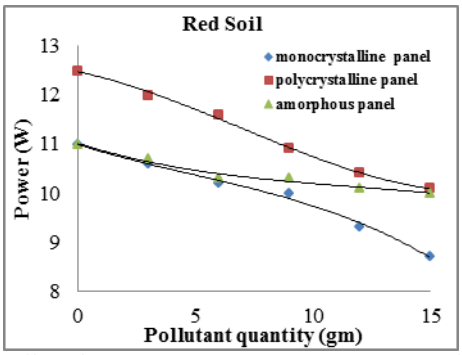

Fig. 4. The effect of red soil accumulation on the rated power of the tested panels.

The airborne carbonaceous fly-ash that is resulting from hydrocarbons fuels incomplete combustion which is emitted from vehicular exhausts and thermal power stations. This pollutant has a different effect on the tested panels as figure 5 reveals. The amorphous PV panel power was reduced more than the other panels. Fly ash has variable particle sizes which are sometimes in nano size. The accumulation of nano-particles on the panel face caused a tiny layer that sticks on the panel's faces and reduced the solar radiation effect resulting in power reduction. The effect of this pollutant was larger on amorphous panel.

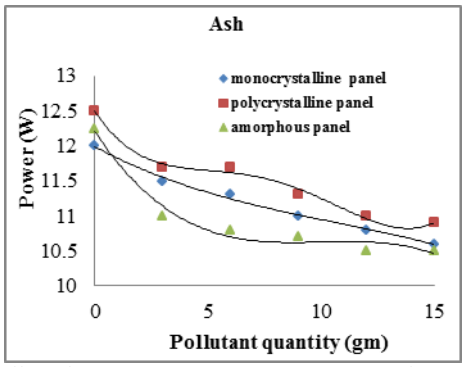

Fig. 5. The effect of ash accumulation on the rated power of the tested panels.

The brown sand composition is extremely different from the red sand; as it has more humidity in its compound due to its existence near revers shores. This sand is used as local rock sources which are used for construction applications. Figure 6 manifests that the brown soil effect is huge on the amorphous panel power compared with other tested panels. The brown sand has high water content, for this reason it sticks in the cracks and slits in the panel face and becomes hard to clean.

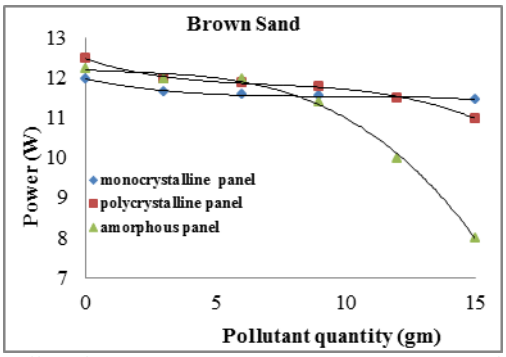

Fig. 6. The effect of brown sand accumulation on the rated power of the tested panels.

Silica is the main common constituent of sand in desert sands. This sand with low sizes volatilizes with air and wind and transfer for long distances. Figure 7 represents the impact of this common urban air pollutant, sand, on the tested PV panels. The mono and poly crystalline panels were highly affected with this pollutant accumulation compared to amorphous panel.

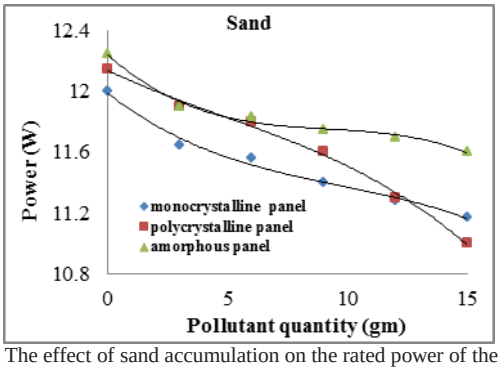

Fig. 7. The effect of sand accumulation on the rated power of the tested panels.

Figures 8, 9 and 10 indicate the effect of each studied pollutant on the tested PV panels. The results for the three panels clarify that res soil has the most defective effect as it reduced the power larger than the other pollutants with time except for the amorphous panel where the effect of brown soil was the dominant.

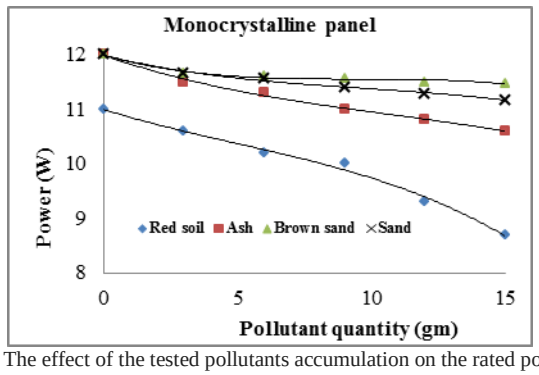

Fig. 8. The effect of the tested pollutants accumulation on the rated power of Monocrystalline panel.

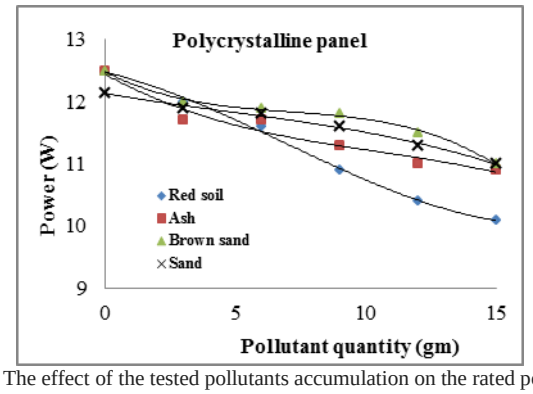

Fig. 9. The effect of the tested pollutants accumulation on the rated power of Polycrystalline panel.

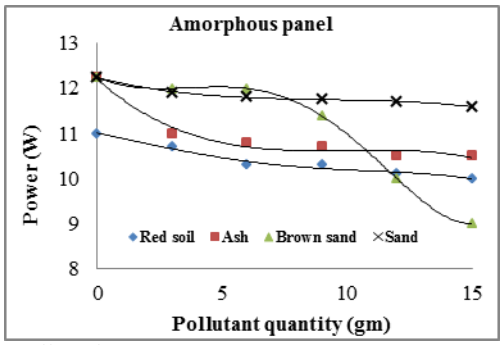

Fig. 10. The effect of the tested pollutants accumulation on the rated power of amorphous panel.

Preceding to the obtained results from the former three figures it is obvious that the clean panels have the highest outcomes. The highest recorded effect to the smallest was: red sand, ash, sand, and brown sand, respectively for mono and poly crystalline. For amorphous panel the order varied where the most effective pollutant was the brown soil, red and, ash and then sand. The results show a clear indication that the studied pollutants accumulation on the PV surface leads to high reduction in its power. In the same time, the studied pollutants caused quite different effects on PV's performance.

IV. Conclusion

The dust and pollutants effect on three types of PV was studied indoor. The effect of ash, red sand, brown sand and sand on the outcomes of PV were separately studied. Variable PV technologies (mono-c, multi-c, and amorphous) were tested with the former mentioned

The obtained results indicated a descent of PV outcomes power when dust and pollutants particles were accumulated on the tested PV panels. The power reduction depends on the accumulated mass and the pollutant type. More power reduction occurred with time which reveals the effect of the PV panels' temperature increase impact. For mono and poly crystalline panels the pollutants impact from maximum to minimum order was red sand, ash, sand, and brown sand, respectively. For amorphous panel the order was brown soil, red soil, ash, and sand, respectively.

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