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وزارة التعليم العالي والبحث العلمي
جامعة الموصل/ كلية الآداب
مجلة آداب الرافدين

مَجَلَّةُ

آدَابِ الرَّافِدَيْنِ

مجلة فصليَّة علميَّة مُحكَّمة

تصدر عن كلية الآداب – جامعة الموصل

ملحق

العدد التاسع والثمانين/ السنة الثانية والخمسون

مُحَرَّم – ١٤٤٤هـ / آب ١٨/٨/٢٠٢٢م

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٢- بعد التسجيل ستُرسل المنصة إلى بريد الباحث الذي سجل فيه رسالة مفادها أنَّه سجَّل فيها، وسيجد كلمة المرور الخاصة به ليستعملها في الدخول إلى المجلة بكتابة البريد الإلكتروني الذي استعمله مع كلمة المرور التي وصلت إليه على الرابط الآتي:
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٣- ستمنح المنصة (الموقع) صفة الباحث لمن قام بالتسجيل؛ ليستطيع بهذه الصفة إدخال بحثه بمجموعة من الخطوات تبدأ بملء بيانات تتعلَّق به وببحثه ويمكنه الاطِّلاع عليها عند تحميل بحثه .

٤- يجب صياغة البحث على وفق تعليمات الطباعة للنشر في المجلة، وعلى النحو الآتي :

- تكون الطباعة القياسية على وفق المنظومة الآتية: (العنوان: بحرف ١٦/ المتن: بحرف ١٤/ الهوامش: بحرف ١١)، ويكون عدد السطور في الصفحة الواحدة: (٢٧) سطرًا، وحين تزيد عدد الصفحات في الطبعة الأخيرة عند النشر داخل المجلة على (٢٥) صفحة للبحوث الخالية من المصورات والخرائط والجداول وأعمال الترجمة، وتحقيق النصوص، و (٣٠) صفحة للبحوث المتضمنة للأَشياء المشار إليها يدفع الباحث أجور الصفحات الزائدة فوق حدّ ما ذُكر آنفًا .
- تُرتَّب الهوامش أرقامًا لكل صفحة، ويُعرَّف بالمصدر والمرجع في مسرد الهوامش لدى وورد ذكره أول مرة، ويلغى ثبت (المصادر والمراجع) اكتفاءً بالتعريف في موضع الذكر الأول ، في حالة تكرار اقتباس المصدر يذكر (مصدر سابق).
- يُحال البحث إلى خبيرين يرشِّحانه للنشر بعد تدقيق رصانته العلمية، وتأكيد سلامته من النقل غير المشروع، ويُحال – إن اختلف الخبيران – إلى (مُحكِّم) للفحص الأَخير، وترجيح جهة القبول أو الرفض، فضلًا عن إحالة البحث إلى خبير الاستلال العلمي ليحدد نسبة الاستلال من المصادر الإلكترونيَّة ويُقبل البحث إذا لم تتجاوز نسبة استلاله ٢٠% .

٥- يجب أن يلتزم الباحث (المؤلِّف) بتوفير المعلومات الآتية عن البحث، وهي :

- يجب أن لا يضمّ البحث المرسل للتقييم إلى المجلة اسم الباحث، أَي: يرسل بدون اسم .
- يجب تثبيت عنوان واضح وكامل للباحث (القسم/ الكلية او المعهد/ الجامعة) والبحث باللغتين: العربية والإنكليزية على متن البحث مهما كانت لغة البحث المكتوب بها مع إعطاء عنوان مختصر للبحث باللغتين أيضًا: العربية والإنكليزية يضمّ أَبرز ما في العنوان من مرتكزات علمية .
- يجب على الباحث صياغة مستخلصين علميين للبحث باللغتين: العربية والإنكليزية، لا يقلَّان عن (١٥٠) كلمة ولا يزيدان عن (350)، وتثبيت كلمات مفتاحية باللغتين: العربية والإنكليزية لاتقل عن (٣) كلمات، ولا تزيد عن (٥) يغلب عليهنَّ التمايز في البحث.

٦- يجب على الباحث أن يراعي الشروط العلمية الآتية في كتابة بحثه، فهي الأَساس في التقييم، وبخلاف ذلك سيُردّ بحثه ؛ لإكمال الفوات، أمَّا الشروط العلميَّة فكما هو مبيّن على النحو الآتي :

- يجب أَن يكون هناك تحديد واضح لمشكلة البحث في فقرة خاصة عنوانها: (مشكلة البحث) أَو (إِشكاليَّة البحث) .
- يجب أَن يراعي الباحث صياغة أَسئلة بحثيَّة أَو فرضيَّات تعبِّر عن مشكلة البحث ويعمل على تحقيقها وحلِّها أَو دحضها علميًّا في متن البحث .
- يعمل الباحث على تحديد أَهمية بحثه وأَهدافه التي يسعى إِلى تحقيقها، وأَن يحدِّد الغرض من تطبيقها.
- يجب أَن يكون هناك تحديد واضح لحدود البحث ومجتمعه الذي يعمل على دراسته الباحث في بحثه .
- يجب أَن يراعي الباحث اختيار المنهج الصحيح الذي يتناسب مع موضوع بحثه، كما يجب أَن يراعي أَدوات جمع البيانات التي تتناسب مع بحثه ومع المنهج المتَّبع فيه .
- يجب مراعاة تصميم البحث وأُسلوب إِخراجه النهائي والتسلسل المنطقي لأَفكاره وفقراته.
- يجب على الباحث أَن يراعي اختيار مصادر المعلومات التي يعتمد عليها البحث، واختيار ما يتناسب مع بحثه مراعيًا الحداثة فيها، والدقة في تسجيل الاقتباسات والبيانات الببليوغرافية الخاصة بهذه المصادر.
- يجب على الباحث أَن يراعي تدوين النتائج التي توصل إليها ، والتأكُّد من موضوعاتها ونسبة ترابطها مع الأَسئلة البحثية أَو الفرضيات التي وضعها الباحث له في متن بحثه .

٧- يجب على الباحث أَن يدرك أَنَّ الحُكْمَ على البحث سيكون على وفق استمارة تحكيم تضمّ التفاصيل الواردة آنفًا، ثم تُرسل إِلى المُحكِّم وعلى أَساسها يُحكَّم البحث ويُعطى أَوزانًا لفقراته وعلى وفق ما تقرره تلك الأَوزان يُقبل البحث أَو يرفض، فيجب على الباحث مراعاة ذلك في إِعداد بحثه والعناية به .

تنويه:

تعبِّر جميع الأَفكار والآراء الواردة في متون البحوث المنشورة في مجلتنا عن آراء أَصحابها بشكل مباشر وتوجهاتهم الفكريَّة ولا تعبِّر بالضرورة عن آراء هيأة التحرير فاقتضى التنويه

رئيس هيئة التحرير

المحتـــويـــات

The Effect of Dust and Shadows on the Efficiency of Polycrystalline Solar Panel in Dohuk city
-A study in applied climate –

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Faten Abdel-Baqi Khaled **

تاريخ التقديم: 2021/5/3 **تاريخ القبول: 2021/6/19**

Abstract:

This research aims to show the effect of both dust accumulation and shadows (as factors that affect the performance of the Photovoltaic (PV) systems) on the experimented 36 cells of polycrystalline solar panel, which investigate the effect in terms of voltage (V), current (I) and power (P). The results showed that the relation between dust and the power of the solar panel is a strong inverse relation, as the power of the panel decreases at a rate of (-0.4575) per gram of dust. The study also showed that the relation between (dust) and each of the current and voltage is a strong inverse relation, where (I) and (V) decrease at a rate of (-0.0268) and (-0.026) per gram of dust respectively. The study found that, in the case of shading only one cell of the solar panel, the solar panel recorded a decrease in (P) by a rate ranging between (51.97% - 55.46%), while when shading an entire column or an entire row of solar panel, the power of the panel found to be decrease by (99.30%) and (97.55%) respectively.

Keywords: solar panel, dust effect, shadow effect, power (p).

1. **Introduction**:

Photovoltaic (PV) cells are known as devices made of semiconductors such as (silicon, gallium arsenide, cadmium

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telluride ... etc.) that convert sunlight into electrical energy directly within a mechanism known as PV conversion, which is based on the use of electronic properties of semiconductors [(1)]. When connecting a group of cells with each other it is called (a solar panel unit or module) and when connecting a group of solar panels together it is called (Solar Array) [(2)]. There are many factors affecting the productivity of the solar panel, the most important of which are: (shadows and dust) which will investigate their effect in this paper.

Generally, the term "dust" refers to fine solid particles that its diameter is less than (500 μm). It found within the atmosphere from various sources such as wind-laden dust, pedestrian and vehicle traffic, volcanic eruptions, and pollution. Such particles are found ubiquitous and easily dispersed in the atmosphere that settle in the form of dust [(3)]. It is a fact that the accumulation of dust particles on the surface of the solar panel greatly affects its production capacity, since this process reduces the amount of sunlight that reaches the PV cells [(4)]. Furthermore, Hussain et al. concluded through their experiment that the dust accumulation on the on PV panels affect its performance and reduces the power up to 60% as compared to a clean PV panel [(5)]. Even so, Sayigh registered a power drop of approximately 11.5 % in uncovered PV module for only 72 hours [(6)].

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(1) Abdullah, A. M. 2018. "Renewable Energy: Thermal Energy, Wind Energy, Solar Energy." *Arab Press Agency* 41–42.

(2) Muhammad, C. Y. 2016. *Photovoltaic Energy*. Ministry of Electricity and Renewable Energy, Republic of Egypt.

(3) Mani, M. and R. Pillai. 2010. "Impact of Dust on Solar Photovoltaic (PV) Performance: Research Status, Challenges and Recommendations." *Renewable and Sustainable Energy Reviews* 14(9):3124–31.

(4) Al-Hasan A.Y. 1998. "A New Correlation for Direct Beam Solar Radiation Received by Photovoltaic Panel with Sand Dust Accumulated on Its Surface." *Solar Energy* 63(5):323–33.

(5) Hussain, Athar, Ankit Batra, and Rupendra Pachauri. 2017. "An Experimental Study on Effect of Dust on Power Loss in Solar Photovoltaic Module." *Renewables: Wind, Water, and Solar* 4(1):9.

(6) Sayigh, A. 2009. "Worldwide Progress in Renewable Energy." *Renewable Energy* 1–5.

The shading, on the other side, is considered as one of the many factors that have a great impact on the performance of solar panels. In the natural environment there are two potential sources of shading; first is plants like trees, while the other source of shading is a solid body like buildings (1).

Series-connected solar cells adversely affect the performance of the solar panel if not all of their cells are evenly lit (partially shaded). All the PV cells carry the same amount of current even though there are a number of cells in the shade that produce less current. However, these cells are obliged to carry the same current as other fully lit cells and thus, these shaded cells will act as loads, absorbing energy from the lit cells (2). Therefore, even if a small part of the PV panel is in the shade, its performance will be greatly reduced.

Deline observed that for a singular grid-tied Photovoltaic module, the reflection of a shadow can reduces the power of more than 30 times its physical dimensions (3). Furthermore, Khalaf et al. claimed that photovoltaic cells with small unit measurements (dimensions) are less impacted by the shading than models with larger sizes(4) . Additionally, Sera and Baghzouz conclude that the decline in the maximum power generation from a shaded PV system directly relies on the shaded area and on the structure of the modules (5).

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(1) DiPiazza, M. C. and G. Vitale. 2010. “Photovoltaic Field Emulation Including Dynamic and Partial Shadow Conditions.” *Appl. Energy* 87:814–23.

(2) Quaschning, V. and R. Hanitsch. 1996. “Numerical Simulation of Current-Voltage Characteristics of Photo Voltaic System with Shaded Solar Cells.” *Solar Energy* 56:513–20.

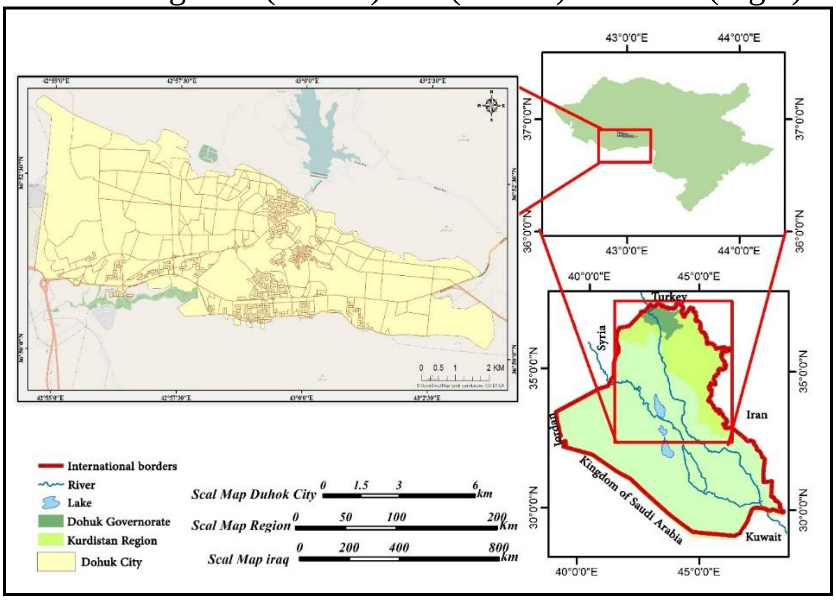
(3) Deline, Chris. 2009. “Partially Shaded Operation of a Grid-Tied PV System.” *The 34thIEEE Photovoltaic Specialists Conference Philadelphia, Pennsylvania* 8.

(4) Khalaf, Younis, Osama Ibraheem, Mustafa Adil, Salih Mohammed, Mohammed Qasim, and Khaled Waleed. 2014. “Maximum Power Point Evaluation of Photovoltaic Modules Under Shading Effect.” *European Scientific Journal* 10(9):281–94.

(5) Sera, Dezso and Yahia Baghzouz. 2008. “On the Impact of Partial Shading on PV Output Power.” P. 7 in *International Conference on Renewable Energy Sources*.

Spatial boundaries of the study:

Spatial boundaries of the study is Dohuk city which is the center of Dohuk Governorate, which is located in the far north of Iraq and northwest of the Kurdistan region, bordered to the north by the State of Turkey and Syria to the west. Erbil comes on its eastern and southeastern sides, while on the west and south it is bordered by Nineveh Governorate. As for the astrological point of view, the city is located between the latitude (36º 50') and (36º 52') to the north, and between longitude (42º55 ') and (43º 04') eastward (Fig.1).



Source: Depending on the Kurdistan Regional Government, Ministry of Planning, Urban Planning Directorate in Dohuk Governorate, 2020, and ArcMap10.8.

Fig. (1) the astronomical and geographical location of the study area in relation to Dohuk governorates and Iraq.

The Problem of study:

The problem of study is represented by the following question: "What is the effect of dust and shadows on the performance of the Polycrystalline Solar Panel in Dohuk city?"

Hypothesis of study:

The hypothesis of the study is the following:

"Dust and shadows have a significant impact on the performance of the Polycrystalline Solar Panel in Dohuk city"

The aim of study:

The aim of This Study is to determine the effect of dust and shadows on the performance of the Polycrystalline Solar Panel in Dohuk city.

2. Materials and Methods:

The solar panel (its characteristics are shown in Table (1), and installed horizontally - with inclined angle 0 degrees), was used to study the effect of dust and partial shading on the efficiency of the PV panel in practice by placing different weights of dust, as presented in figures 1, and applying different cases of shading on the solar panel, as shown in figure 2. Additionally, recording the values of voltage (V) and current (I) before and after performing the experiment was done by using a multimeter device (figure 4). The values of voltage (V), current (I) and power (P) before dusting were (17.25 volts, 5.50 amps and 94.88 watts) respectively. While these values were (17.75V, 5.17A and 91.77W) respectively before partial shading of the PV panel.

Table (1) qualifications of the solar panel used in the experiment

Description	The amount
The manufacture company	SOLAREX
Type	SXM-100W Polycrystalline
Efficiency	%14.5
Number of cells	36
Peak Power (Pmax)	100W
Open Circuit Current (Voc)	21.7 V
Short Circuit Current (Isc)	6.57 A
Max. Power Voltage (Vmp)	18 V
Max. Power Current (Imp)	5.56 A
Dimension (mm)	1030*670*30

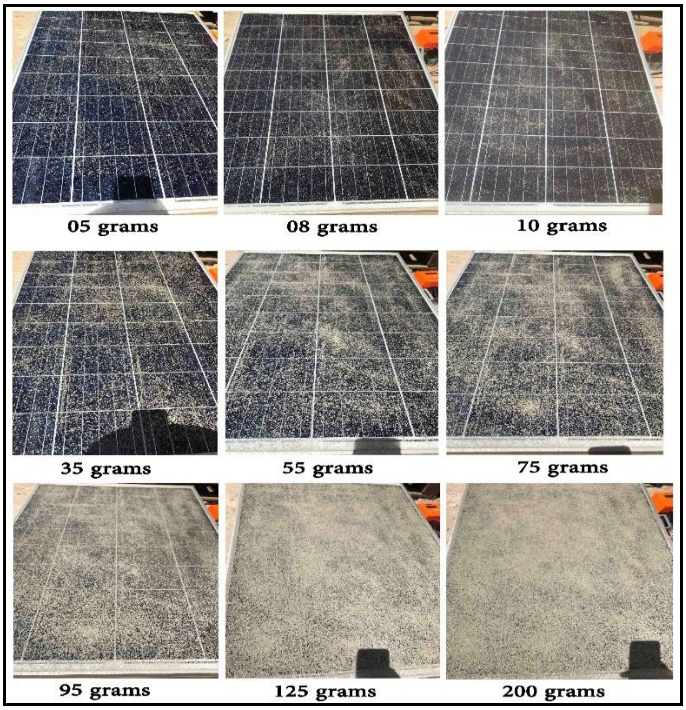


Fig. (2) Some cases of dust scattering with specific weights on the Photovoltaic panel.

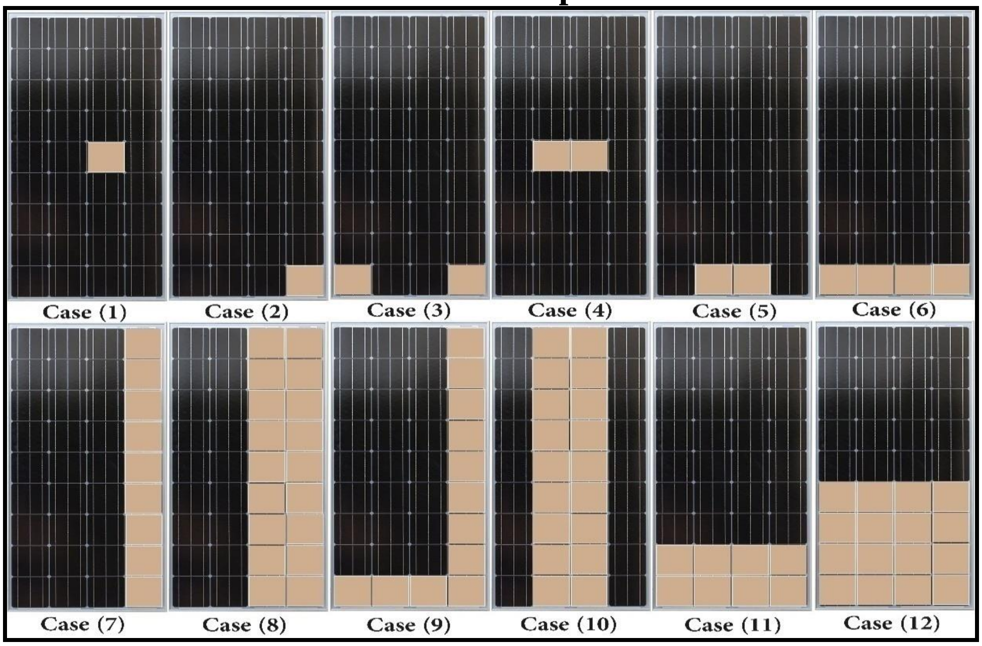


Fig. (3) Cases of partial shading of the PV panel

Fig. (4) The tools used to measure the effect of partial shading on the efficiency of the PV panel

3. Results and discussion:

3. 1. The solar panel tilting angle (β):

It is known that the greater the tilting angle of the solar panel (β), the less amount of dust that will be deposited on it. The solar panel tilt angle (β) is the angle formed between the solar panel and the horizontal level. This angle is directed towards the south in the northern hemisphere and the north in the southern hemisphere, the tilt angle of the solar panel ranges between ($0^\circ \leq \beta \leq 180^\circ$). When the panel is moving on the east-west axis of the horizontal, and the angle of inclination of the panel is to be adjusted daily, the equation (1) is used (Kaldellis and Zafirakis 2012):

$$\beta = |\varphi - \delta| \qquad (1)$$

Whereas:

β: Solar panel tilt angle. It ranges from *($0^\circ \leq \varphi \leq 180^\circ$).*

φ: Latitude, It ranges from ($-90^\circ \leq \varphi \leq 90^\circ$).

δ: Solar declination angle, ranges between ($-23.45^\circ \leq \delta \leq 23.45^\circ$) and it can be obtained using the equation (2), when (n) is the number of the day of the year whose value ranges between (1 and 365).

$$\delta = 23.45 * sin\left(360 * \frac{284 + n}{365}\right) \qquad (2)$$

When applying equation no. (1), to the research site, which is located at a latitude (φ) of (36.86°) for each day of the year (n), the following results are obtained and shown in figure (5) below.

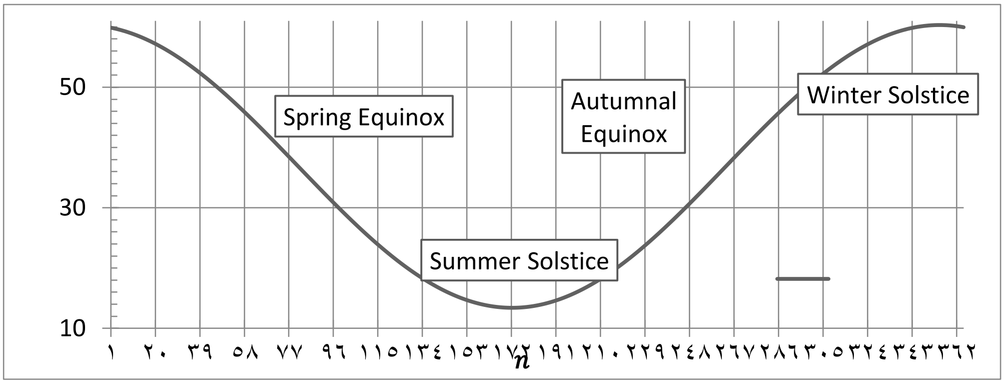


Fig. (5) The variation of the solar panel Tilt angle (β) throughout the year at latitude (36.86º)

Figure (5) shows that the solar panel tilt angle (β) varies throughout the year, as its value ranges between (13°) and (60°) for the sites located at the same latitude as the research area. As for the monthly optimum tilting angle, it was obtaining according to figure (5) and as shown in Table (2) and figure (6).

Table (2) the monthly solar panel tilt angle (β) at latitude (36.86º)

January	February	March	April	May	June
57.71°	50.19°	39.25°	27.37°	18.05°	13.78°
July	August	September	October	November	December
15.76°	23.56°	34.87°	46.71°	55.91°	59.96°

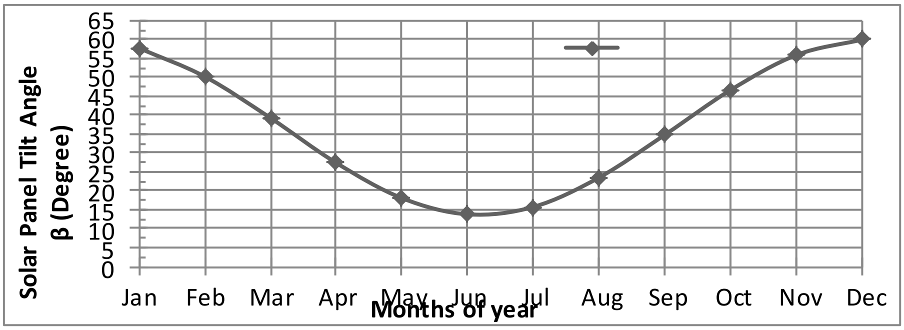


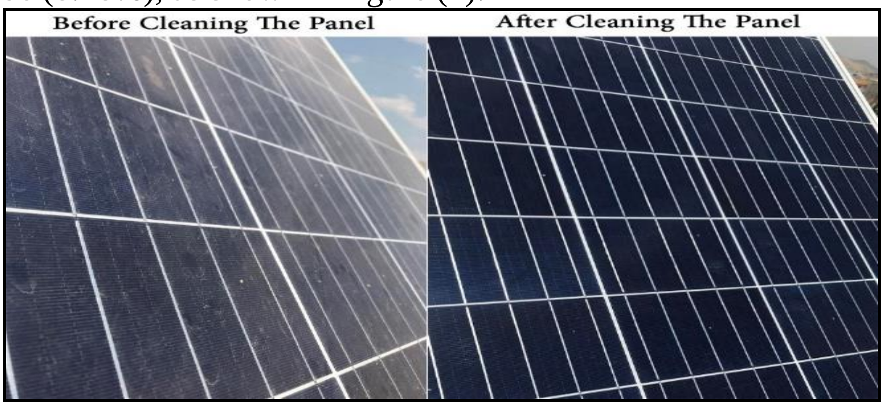
Fig. (6) The monthly solar panel tilt angle of the (β) at latitude (36.86º)

It was found from Table (2) that the monthly (β) ranges between (13.78°) in June and (59.96°) in December. Furthermore, the seasonal angles of solar panel tilt angles found to be (55.95°, 28.22°, 17.70°, 45.83°) for the seasons (winter, spring, summer and autumn) respectively. This means (β = φ + 9) for autumn and winter seasons and (β = φ-9) for spring and summer seasons.

On the other hand, if the solar panel tilt angle is to be adjusted twice a year, it will be set to (50.89°) for the seasons (autumn and winter) and (22.96°) for the seasons (spring and summer). While if this angle is required to be installed throughout the year, it will be installed at an angle of (36.93°), which is approximately equal to the latitude of the site. Thus, the optimum tilt angle of solar panel is (β = φ + 14°) for winter and (β = φ - 14°) for summer. Consequently, the former mentioned angle (36.93°) is used to tilt the solar panels in this research experiment.

3. 2. Effect of dust on solar panel power:

Directly, dust affects the amount of electricity produced from PV systems. Therefore, it is necessary to ensure the cleanliness of the PV panels periodically, as dust affects the output of the PV panel. When leaving the solar panel tilted at an angle of 36.93° for a period of (30) days without cleaning, the voltage (V) drops from (17.25 volts) to (16.80 volts). As for the current (I), it falls to (3.5 Amps) after it was (3.9 Amps), so the power (P) produced by the panel amounted to (58.5 Watt) after it was (67.28 Watt). Consequently, the percentage of loss in panel power (P) is estimate to be (8.48%), as shown in figure (7).



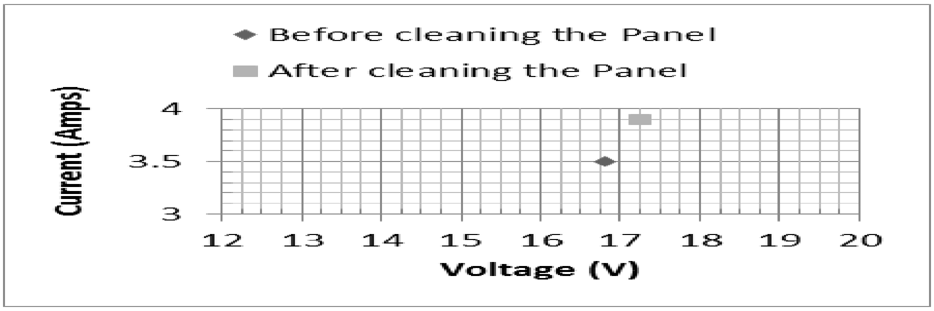


Fig. (7) Effect of dust on voltage (V) and current (I) of the PV panel after a month of non-cleaning

Moreover, Samples of different types of dust (such as soil, cement and soot) were taken and milled for minutes to a volume of less than 10 microns and sprayed with specific weights and distributed uniformly as possible on the PV panel (as shown in figure 2), in order to demonstrate the effect of dust and dirt on the performance of the PV panel. After that, readings of voltage (V), current (I) and power (P) were recorded by a multimeter, noticing that the solar panel voltage (V), current (I) and power (P) were (17.25 volts, 5.50 amps and 94.88 Watts) before the dusting process. See table (3) that shows the results of this experiment.

Table (3) Effect of dust and dirt on each of the voltage (V), current (I) and power (P) of the PV panel

Dust weight grams (g)	Voltage Volts (V)	Current (Amps)	Power (Watts)	Losses in panel power (%)
5	17.00	5.10	86.70	8.62
8	16.65	4.90	81.59	14.01
10	16.19	4.76	77.06	18.78
25	16.00	4.35	69.60	26.64
35	15.50	3.84	59.52	37.27
45	15.20	3.47	52.74	44.41
55	14.50	2.99	43.36	54.31
65	13.74	2.45	33.66	64.52
75	13.28	2.14	28.42	70.05
85	13.25	1.8	23.85	74.86
95	12.90	1.55	20.00	78.93

100	12.90	1.45	18.71	80.29
125	12.68	1.08	13.69	85.57
150	12.60	0.77	9.70	89.77
200	12.44	0.41	5.10	94.62

The results of the dusting experiment show that the effect of dust and dirt appears clearly on both the voltage (V) and the current (I) of the panel, and that its effect on the current is clearer than the voltage. Also, It is found that the power of the PV panel (P) decreases gradually as the amount of dust on the PV panel increases. It is observed that when adding (5 grams) of dust on the PV panel, the power of the solar panel (P) decreases by (8.62%). However, when adding (25 grams) of dust, the power (P) decreases by (26.64%). While a reduction in the panel power reached (94.62%) when adding (200 grams) of dust to the PV panel, the remaining results of the experiment are as shown in the mentioned (table 3).

Additionally, it was found through the linear regression models, shown in figure (8), that the relationship between dust and the rate of loss in the efficiency of the PV panel is a very strong direct relationship, which amounted to (0.93)(*), as well as the relation between dust and the power of the panel is a very strong inverse relationship reached (-0.93). It was also observed that the percentage of losses in the power of the panel increases at a rate of (0.4821%) per gram of dust, and the power decreases by (-0.4575) watts per gram of dust. Also, the value of (R^2) reached to (0.86). This high value enables to estimate the power of the solar panel at a certain value of dust weight according to the equations shown in figure (8).

(*)According to the Pearson correlation coefficient, which shows the direction and strength of the relationship between two variables (X, Y), which can be easily calculated using (Excel) program via the "Correl" function according to the following equation:

$$Correl\ (x,y) = \frac{\Sigma(\chi-\bar{\chi})(y-\bar{y})}{\sqrt{\Sigma(\chi-\bar{\chi})^2\,\Sigma(y-\bar{y})^2}}$$

Whereas:

$\bar{\chi}$: is the mean of (χ) values.

$\bar{y}$: is the mean of (y) values.

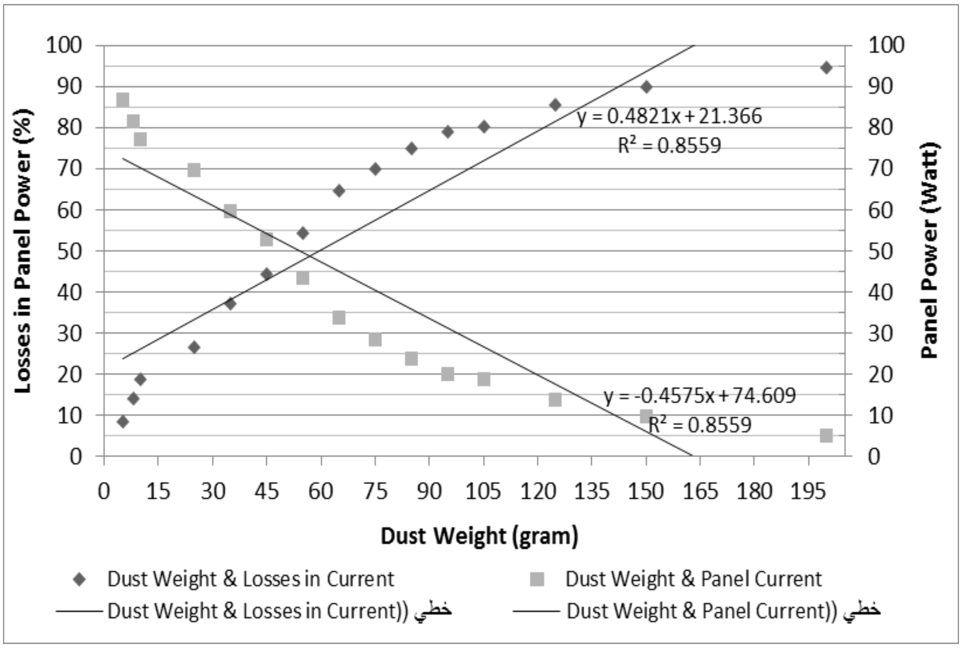


Fig. (8) The relationship between Dust and the Power (P) of the PV panel

As for the relationship of dust with voltage (V) and current (I) of the PV panel, and through figure (9) it was found that the inverse relationship between them is very strong, as the strength of the relationship between dust and voltage (V) reaches to (-0.90), while the strength of the relationship between dust and current (I) reaches to (-0.95). Moreover, the linear regression models show that the current (I) and the voltage (V) decreased at a rate of (-0.0268) and (-0.026) per gram of dust, respectively.

The value of (R^2) was (0.9021) and (0.8092) for the linear regression models of (dust and current) and (dust and voltage) respectively. These two high values enable the estimation of the current and voltage emanating from the PV panel at a certain value of dust weight according to the equations shown in figure (9).

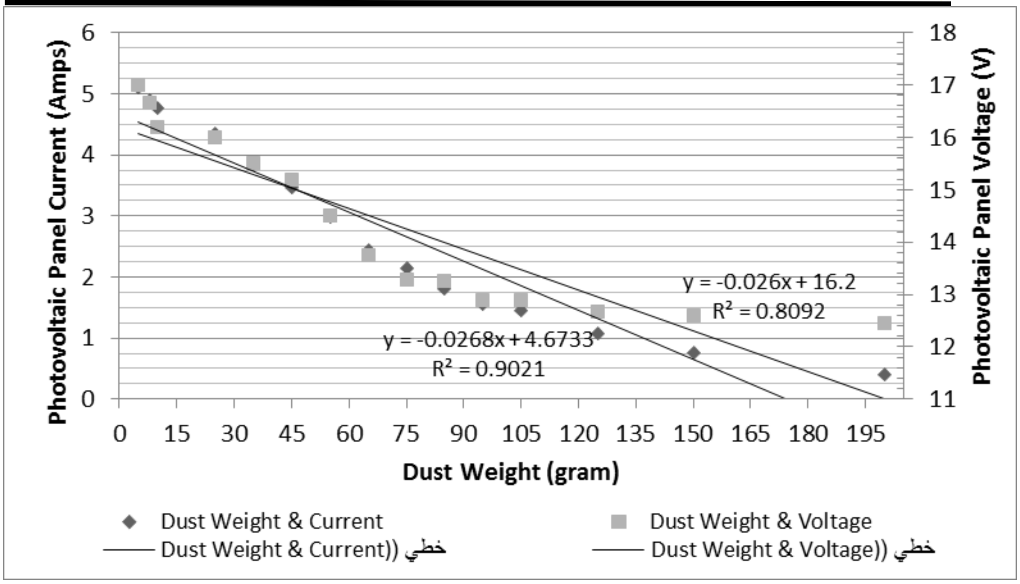


Fig. (9) The relationship between Dust, voltage (V) and current (I) of PV panel

In order to maintain the cleanliness and sustainability of the solar panel, some modern technologies such as Solar Piezoclean technology must be used. This technique is one of the most important technologies recently used to clean the solar panels from dust that impedes their work. It consists of a chip made of a compressed material in the form of a thin plastic sheet and equipped with wires that transfer the electric current generated from solar radiation to this plastic chip to move in a vibratory manner [1]. Therefore, this chip forms a barrier between the panel and the dust, so that it can be activated to start vibrating and remove the dust layer from the panel surface and fall off. Hence, contributes to raising the solar panels efficiency throughout the day.

3. 3. The effect of shading on the PV panel:

Shadows have great effect on the amount of electricity produced by PV panels systems. As the partial shading of PV panels affects the output and efficiency of the panel, therefore, it is necessary to ensure that the shadows do not fall on panels along the year, taking into considerations the future environmental changes that may occur

(1) Kobrin, Boris. 2018. "Self-Cleaning Technologies for Solar Panels." *N-Tech Research* 1–15.

after the installation of PV systems such as the growth of trees and the height of buildings, as the life span of the solar panels is more than 25 years.

The experiment considers applying different cases of partial shading (as shown in figure 2) to the type of PV panel used. The readings of voltage (V), current (I) and power (P) were recorded before and after shading. Note that the panel voltage (V), current (I) and power (P) were (17.75 volts, 5.17 amps and 91.77 watts) respectively before partial shading of the PV panel, and Table (4) shows the results of the shading proces

Table (4) Results of partial shading on voltage (V), current (I) and power (P) for the PV panel

Partial shading cases	Voltage Volt (v)	Current (Amps)	Power (Watts)	Decreases in panel power %
1	17.62	2.32	40.88	55.46
2	17.63	2.50	44.08	51.97
3	17.34	0.38	6.59	92.82
4	17.46	0.33	5.76	93.72
5	17.12	0.32	5.48	94.03
6	16.07	0.14	2.25	97.55
7	12.78	0.05	0.64	99.30
8	12.44	0.01	0.12	99.86
9	13.80	0.01	0.14	99.85
10	16.58	0.02	0.33	99.64
11	13.58	0.06	0.81	99.11
12	13.58	0.01	0.14	99.85

The results presented in both table (4) and figure (10) show that the PV panel works best when there is no shadow on it. As for shading only one cell of the PV panel (figure 3, cases 1 and 2) reduces the power of the panel significantly by a percentage ranging between (51.97% - 55.46%). While shading two cells of the PV panel (figure 3, cases 3, 4 and 5), decreases the power produced from the panel by a percentage ranging between (92.82% -94.03%).

Moreover, when an entire row of PV panel is shaded (figure 3, case 6), the productivity of the panel decreases by (97.55%). Whereas by shading two or four rows of solar panel cells (figure 3, cases 11 and 12), the productivity of the panel decreases to (99.11%) and (99.30%), respectively.

However, it was found that shading an entire column of the PV panel cells (figure 3, case 7) leads to a decrease in the power by (99.30%), while shading two columns of the panel cells that are connected in series (figure 3, case 8) leads to a decrease in the productivity of the PV panel by (99.86%). In the case of shading two columns of panel cells connected in parallel (figure 3, case 10), the production of the panel decreases by up to (99.64%). The productivity of the PV panel decreases by (99.85%) when a column and a row of the PV panel cells are shaded (figure 3, case 9).

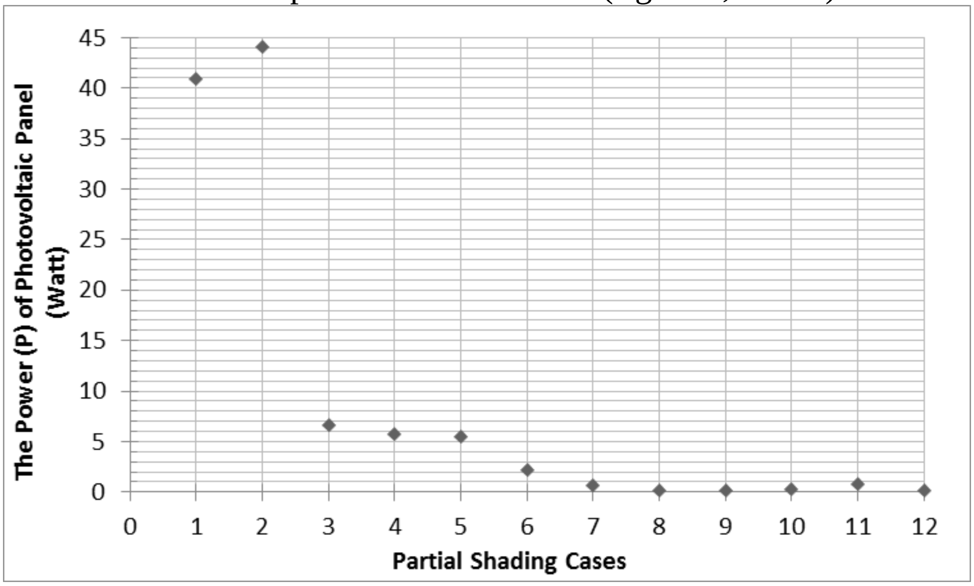


Fig. (10) The effect of partial shading on the power (P) of the PV panel

As for the effect of partial shading on current (I) and voltage (V), it had been observed from the experiment's results shown in figure (11) that the voltage (V) is not highly affected compared to the current (I). As the voltage (V) drops from (17.75 volts) to (17.62 volts) in the case of shading one cell, and it drops to between (17.46-17.12 volts) when two cells are shaded.

In case of one, two or four rows of PV panel cells are shaded, the voltage (V) values are dropped to (16.07, 13.58 and 13.58 volts) respectively. Moreover, shading one column reduces the panel voltage (V) to (12.78 volts), while shading two columns of panel cells connected in series, dropped the panel voltage (V) to about (12.44 volts). Either if two columns of PV panel cells connected in parallel are shaded, the panel voltage (V) will reach (16.58 V), but if one row and one column of PV panel cells are shaded together (as shown in figure 3, case 9), the value of the voltage will reach down to (13.80 volts).

Furthermore, for the PV panel current (I), as mentioned, it is more affected by the partial shading than the panel voltage (V). As the shading of one cell of the PV panel (as shown in figure 3, cases 1 and 2) leads to a decrease in current (I) from (5.17 Amps) to (2.32 Amps). While when two cells are shaded, the current (I) decreases to (0.32 Amps). Additionally, in the case of an entire row of PV panel cells is shaded then the current (I) drops to (0.14 Amps). Whereas by shading two or four rows of cells, the current (I) reaches (0.06 Amps) and (0.01 Amps) respectively.

As well as, in the case of columns shading, it is found that if one column of cells is shaded, the current (I) drops to (0.05 Amps), and if two columns of cells connected in series are shaded, the current (I) records (0.01 Amps). Furthermore, In the case of shading two columns of PV panel cells connected in parallel, the current (I) reaches (0.02 Amps), and when one row and one column of cells are shaded together, it was found that the current value (I) drops to about (0.01 amps).

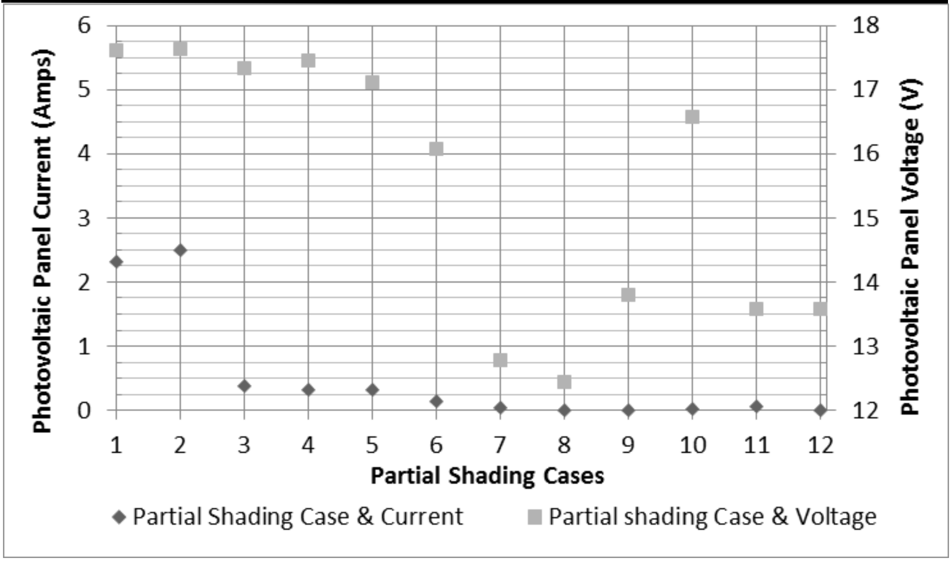


Fig. (11) The effect of partial shading cases on voltage (V) and current (I) of the PV panel

4. Conclusions:

The study has come up with many conclusions, the most important of which are:

- When leaving the solar panel (with a tilted angle of 36.93°) for a period of (30) days without cleaning, the percentage of loss in panel power (P) is estimate to be about (8.48%).
- The relationship between dust and the percentage of losses in the efficiency of the PV panel which installed horizontally is a very strong direct relationship, and the strength of this relationship reached to (0.93), as well as the relationship between dust and the power (P) of the panel, is a very strong inverse relationship and its strength reached to (-0.93).
- The percentage of losses in the power (P) of the solar panel increases at a rate of (0.4821%) per gram of dust, and the power decreases by (-0.4575) watts per gram of dust.
- Shading affects greatly on the PV panel power production that it may reduces by (51.97% - 55.46%) when shading only one cell of the panel, up to (99.30%) and (97.55%) when shading an entire column or row of the panel respectively.

5. Recommendations:

Out of the research results and conclusions, the following recommendations have been put forward:

- The importance of reducing the number of trees that are existed or planned to be planted near to the solar panel system and planted them at a distance of 1 km away from the area of the project.
- Preventing the old vehicles from passing through the city streets in order to reduce the exhaust and aerosol from spreading into the air and minimize the percentages of dust in the city atmosphere.
- Keeping construction projects and high-raised residential buildings away from the areas where solar systems are installed to avoid the shadows of tall buildings on the solar panel cells.
- The possibility of raising the angle of inclination of the solar panel from 36.93^{o} by 0.7^{o} to be 37^{o} for the purpose of removing dust from the surface of the solar panel and maintaining the largest amount of solar radiation received.
- The possibility of adding the solar piezoclean technology to the solar panel system to get rid of sediments and dust particles deposited on the surface of the panels and to maintain their efficiency and sustainability.

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تأثير الغبار والظلال على قدرة اللوح الكهروشمسي متعدد البلورة في مدينة دهوك

-دراسة في المناخ التطبيقي-

خضر رشيد عبدالرحمن * و فاتن عبدالباقي خالد**

المستخلص:

يُعدُّ الغبار والظلال من العوامل المؤثرة على أداء المنظومات الكهروشمسية، ويقدم هذا البحث تأثير هذين العاملين على قدرة (Power) اللوح الكهروشمسي (Solar Panel)متعدد البلورة (Polycrystalline) مكونة من (36) خلية، وتم التحقق عملياً من تأثير كل من الغبار (Dust) والظلال (Shadow) على مخرجات اللوح الكهروشمسي السليكوني متعدد البلورة من جهد (V) وتيار (I) وقدرة(P) ، وبيَّنت نتائج الدراسة العملية أَنَّ العلاقة بين الغبار وقدرة اللوح علاقة عكسية قوية؛ إذ بلغت قوة هذه العلاقة (-0.93)، وقدرة اللوح (P) ينخفض بمعدل (-0.4575) لكل غرام من الغبار، كما بيَّنت الدراسة أَنَّ العلاقة بين الغبار، وكل من التيار (I) والجهد (V)علاقة عكسية قوية؛ إذ بلغت قوتها (-0.95) و (-0.95) على التوالي، والتيار (I) والجهد (V) ينخفضان بمعدل (-0.0268) و (-0.026) لكل غرام من الغبار على التوالي. وتوصلت الدراسة إلى أَنَّ اللوح الكهروشمسي سجل هبوطاً في القدرة (P) بنسبة تتراوح بين (51.97% - 55.46%) في حالة تظليل خلية واحدة فقط من اللوح، أَمَّا في حالة تظليل خليتين من اللوح فإِنَّ القدرة المنتجة(P) تنخفض بنسبة تتراوح ما بين (92.82%-94.03%)، في حين إنَّ تظليل عمود كامل أَو صف كامل من خلايا

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اللوح الكهروضوئي فإنَّ قدرة اللوح (P) تنخفض بنسبة (99.30%) و (97.55%) على التوالي.

الكلمات المفتاحية: اللوح الكهروشمسي، تأثير الظلال، تأثير الغبار، القدرة (p).