Matarneh, Ghayda' A.; Al-Rawajfeh, Mohammad A.; Gomaa, Mohamed R.

Article

Comparison review between monofacial and bifacial solar modules

Technology audit and production reserves

UDC 621.311.243
DOI: 10.15587/2706-5448.2022.268955

Ghayda' A. Matarneh,
Mohammad A. Al-Rawajfeh,
Mohamed R. Gomaa

COMPARISON REVIEW BETWEEN MONOFACIAL AND BIFACIAL SOLAR MODULES

The objects of the study are solar modules. The world has witnessed a change in all aspects of life, especially in the last period, when the world witnessed an increase in the demand for energy and all regions. Here the imperfection appeared in meeting the energy needs, just as the traditional sources (oil, coal, and natural gas), for example, are no longer hope as they are non-renewable sources. In addition to these sources, to exploit the energy in them, we must burn, which pollutes the environment, in addition to the cost of transportation. Not long ago, solar energy began to produce electricity through photovoltaic modules, and competition began to make photovoltaic modules with higher efficiency. The main aim of this study is to clarify the concept of bifacial photovoltaic modules and show some differences between them and monofacial photovoltaic modules. The current report consists of the definition of bifacial photovoltaic modules and their most important specifications, comparing them with monofacial photovoltaic modules, which are the best, the factors affecting their energy production, and the type of radiation used in each type. In fact, the utilization of albedo radiation for monofacial photovoltaic modules does not exceed 2 %, while this percentage is exceeded in bifacial photovoltaic modules. So, it can be recommended here that the trend to use bifacial photovoltaic modules can be economical and space-saving space because it produces more amount of electricity for the same unit area, which in turn this spaces it available for other applications, and also, increase the amount of electricity due to the increase in the effective side size (two sides: one upwards and the other is downward) of the solar modules.

Keywords: *monofacial photovoltaic modules, bifacial photovoltaic modules, photovoltaic efficiency, photovoltaic technology, albedo radiation.*

Received date: 07.11.2022
Accepted date: 12.12.2022
Published date: 14.12.2022

How to cite
Matarneh, G. A., Al-Rawajfeh, M. A., Gomaa, M. R. (2022). Comparison review between monofacial and bifacial solar modules. Technology Audit and Production Reserves, 6 (1 (68)), 24–29. doi: https://doi.org/10.15587/2706-5448.2022.268955

1. Introduction

A photovoltaic module is a device that converts solar energy directly into electrical energy by the Photovoltaic effect. It provides its current, voltage, and resistance, as well as a physical and chemical phenomenon [1–3]. The radiation from the sun to the earth is divided into direct radiation that reaches directly to the earth's surface, called direct normal irradiance (DNI) [4–6]. Scattered radiation usually happens due to two reasons Clouds and Negative Ozone Anomalies (NOA) [7–9]. Albedo radiation definition is the ratio between the radiation coming from the sun and the radiation incident to the surface of the earth [9–11]. The patent for a bifacial solar module was registered in 1979. This module is effective on both sides, meaning that both sides convert the radiation falling on it into direct electricity [12, 13]. The manufacture of a bifacial solar module is more expensive than the monofacial solar module due to the presence of additional materials such as (cells and glass) due to the presence of two effective sides in the cells and what requires glass and cells from both sides [14]. It's important to study and differentiate between different technology of Photovoltaic cells to optimize and investigate their performance and the effect of weather conditions on power production in an actual system [15, 16].

In Fig. 1, the upper left represents the structure of a monofaical solar cell and one layer of anti-reflection coating (ARC). The upper right represents the module of the same solar cell, the authors also see that there is one glass layer from the top of the cell, which is the part that is upward towards the sun. The bottom of all the cells is a back sheet layer to put the cells on top of, and there is an EVA layer for more protection. In Fig. 1, We also see in the lower left bifacial solar cells with two layers of (ARC), In the lower right, we see the module for bifacial solar cell, and we also see that there are two glass layers at the top and bottom of the cell.

It became known that albedo is the amount of solar radiation reflected from the earth's surface by water, trees, land, snow, etc., directly upwards or repeatedly bumping and reversing.

In monofacial solar cell systems, the utilization of albedo cells ranges from (1 to 2) percent [18]. Recent studies have shown that bifacial solar cells' power gain ranges between 13–35 % in sunny weather and 40–70 % in cloudy conditions [19]. We know that albedo is part of the sunlight falling on the earth's surface. And this radiation varies based on the spectral distribution and the sun's angle of incidence. These differences are based on the change in the sun's position in the day, location (latitude), and clouds in the sky [18].

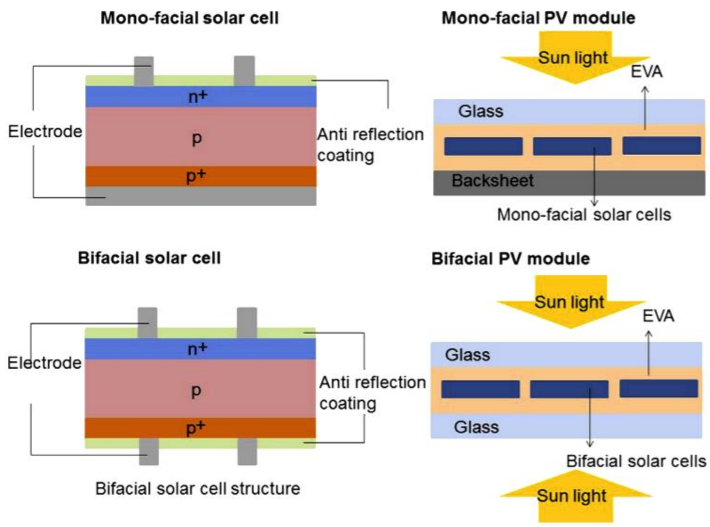


Fig. 1. Structure for Monofacial and Bifacial cell and module [17]

Table 1 provides the albedo value for the various surfaces, and the given albedo value is the annual mean. The author notes from the values given in the table and chart that there is a discrepancy in the albedo value based on the surface on which it fell. Hence, we can say that the amount of albedo will not be equal in all places, Since the most benefit from albedo is over pasture grass, and less albedo is over Semidesert grassland.

Fig. 2 explains and shows the difference between albedo values by location (surfaces).

After we learned that the bifacial solar module benefits from direct sunlight and albedo; this is one of the most important advantages.

Also, the sensitivity of the module for orientation to the south is lower, meaning that there is flexibility in choosing the orientation. When there are obstacles that do not allow the direction to the right south, it can be placed as close to the south as possible [20].

The power generated per unit area of the bifacial solar module is greater than that of the monofacial solar module.

This means we can save more space to generate the same amount of power [20].

Also, the bifacial solar cells are characterized by the effect of warping due to the small difference in thermal expansion between silicon and aluminum. It also reduces electrical losses due to aluminum absorption of spectral light [21].

The biggest disadvantages of a bifacial solar cell are the high cost compared to monofacial solar cells due to the presence of additional materials, such as cells on both sides of the module [16].

Table 1

Albedo reflected from some surfaces

Station ID	Location	Data Source	Data Years	Ground Surface	Overall Albedo
BondvilleIL	Bondville, IL, USA	SURFRAD	24	Native grasses	0.247
BouldinCA	Bouldin Island, CA, USA	AmeriFlux	3	Alfalfa	0.221
SonoranDesertCA	Sonoran Desert, CA, USA	AmeriFlux	7	Desert	0.245
SmileyburgKS	Smileyburg, KS, USA	AmeriFlux	3	Tall grass prairie	0.210
SantaRitaAZ	Santa Rita, AZ, USA	AmeriFlux	11	Semidesert grassland	0.204
BrookingsSD	Brookings, SD, USA	AmeriFlux	7	Pasture grass	0.262

Note: the table is based on data from [18]

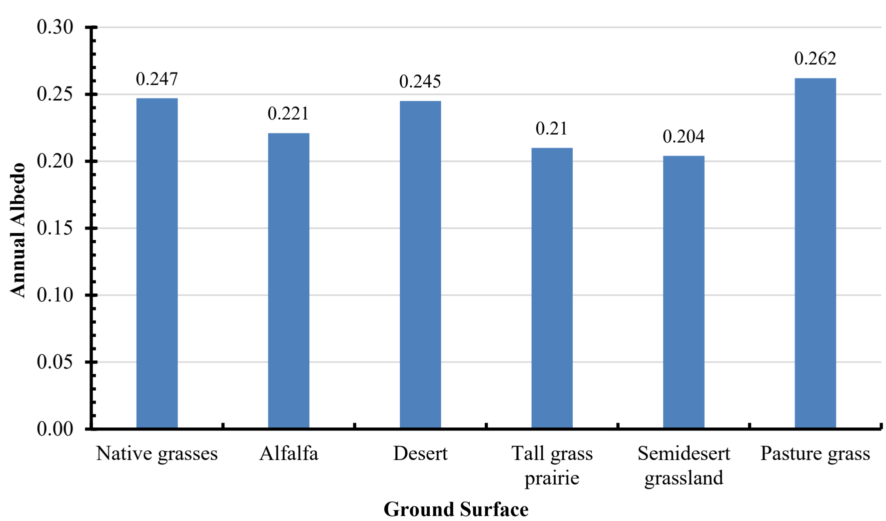


Fig. 2. The difference value of albedo for some surfaces

2. Materials and Methods

The subtitles will be discussed here, is the performance in energy production, temperature effect in both types, and bifacial solar cell datasheet.

2.1. Performance in energy production. The performance of solar cells in terms of electricity production varies according to the intensity of the radiation falling on them, and this is what we will discuss in this section.

As shown in Fig. 3, *a*, the electricity production in both types increases at sunrise and reaches its peak at approximately noon since there are no clouds in the sky. That is, there does not impede the arrival of sunlight to the surface of the solar cell and the surface of the earth, meaning that albedo is present and can be exploited.

In Fig. 3, *b* as for here, in the presence of clouds in the sky, the production of electricity is greatly affected by the decrease in value.

2.2. Temperature effect in both types. The performance of solar cells varies depending on temperature (ambient air temperature) as well as solar radiation and wind cooling processes [23], the increase in the temperature of the solar cell reduces the voltage that given [24].

Fig. 4 shows the effect of a monofacial solar cell on radiation and temperature. As shown in Fig. 4 IV curve for the same solar cell at different radiation intensity and operating temperatures, the radiation intensity ranged from 0–100 mw/cm^2, and the operating temperature ranged 20–50 °C. We note well that the higher the temperature, the lower the voltage, which leads to a decrease in the power coming out of the solar cell. We also note that the increase in the radiation value increases the current coming out of the solar cell.

Fig. 5 shows the IV curve for the bifacial solar cell under different temperatures for the front and rear sides. Also, it shows the voltage and current at two ranges of temperatures 25 °C and 50 °C for two modules (B and D) at the same power density of 1000 W/m^2. As the case in the polycrystalline solar cell, the increase in the temperature of the solar cell leads to a decrease in the value of the voltage. Here the voltage output from the front and rear sides are both affected by temperature.

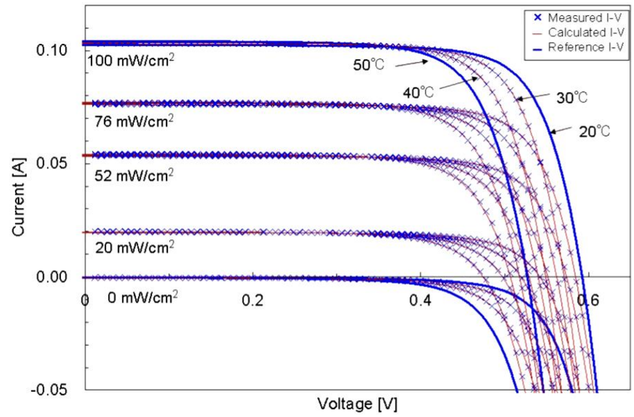


Fig. 4. IV curve for polycrystalline solar cell [23]

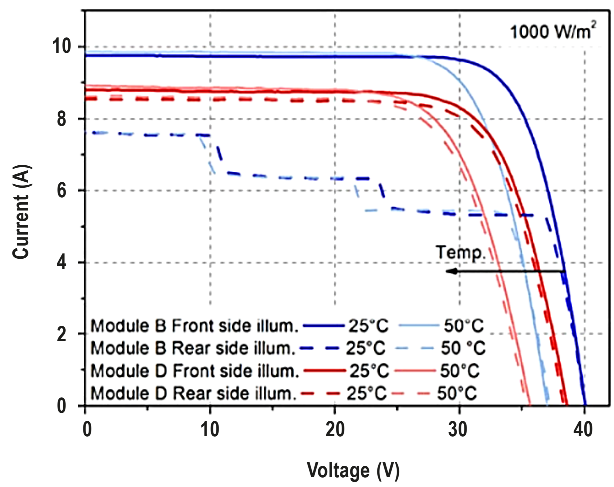


Fig. 5. IV curve for bifacial solar cell [25]

2.3. Bifacial solar cell datasheet. From the literature review, the bifacial cells are producing more power. When looking at Table 2 and Fig. 6, we see the characteristic (thermal and electrical), and can compare them with any data sheet for monofaial module.

The result can be that the bifacial module gives more power value if the cell in module is in the same characteristic.

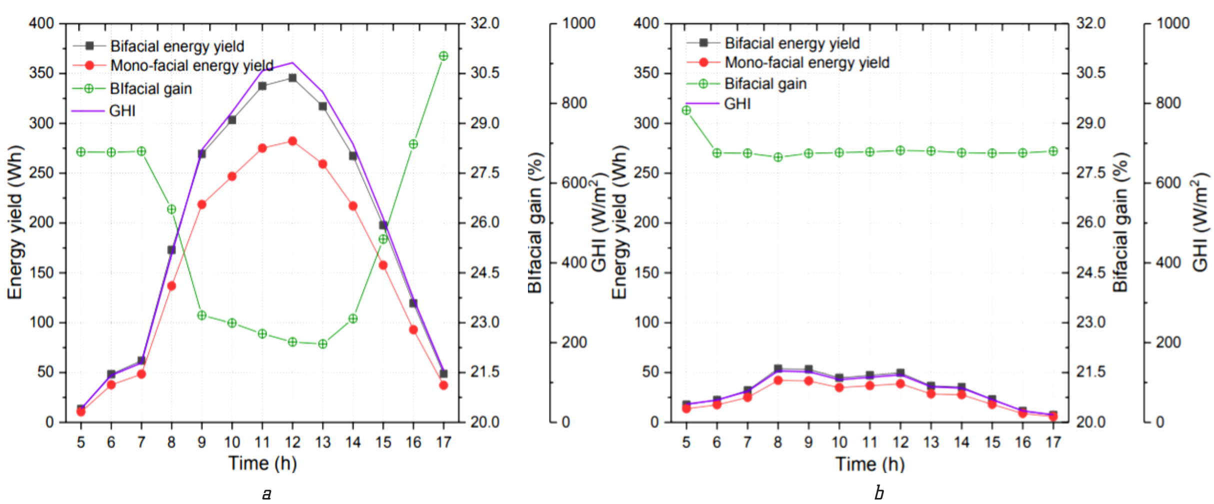


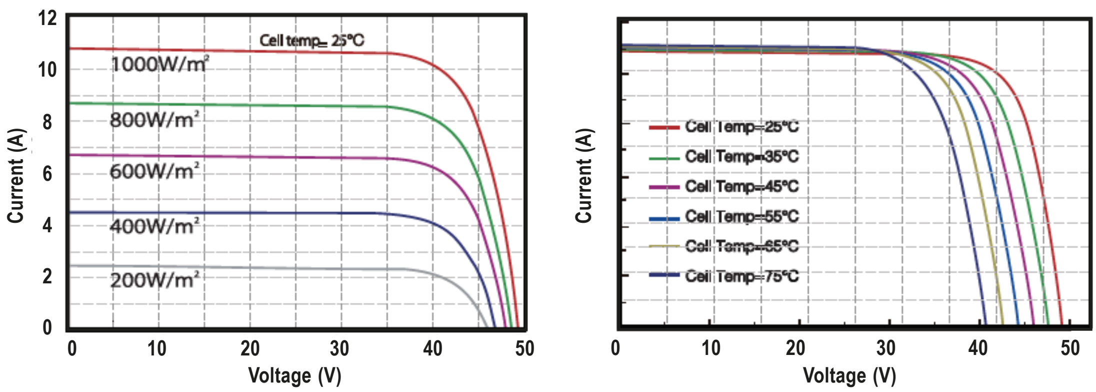
Fig. 3. The performance of solar cells [22]: *a* – sunny; *b* – cloudy

Table 2

Electrical and Thermal characteristics of bifacial solar module

Electrical Characteristics (STC)*		435 W	440 W	445 W	450 W	455 W
Short Circuit Current	I_{sc} (A)	11.21	11.26	11.30	11.35	11.39
Maximum Power Current	I_{mpp} (A)	10.67	10.72	10.76	10.81	10.86
Open Circuit Voltage	V_{oc} (V)	48.93	49.20	49.49	49.75	50.00
Maximum Power Voltage	V_{mpp} (V)	40.78	41.08	41.36	41.69	41.94
Module Efficiency	η′ (%)	20.0	20.2	20.5	20.7	21.0
Short Circuit Current	I_{sc} (A)	11.21	11.26	11.30	11.35	11.39
Maximum Power Current	I_{mpp} (A)	10.67	10.72	10.76	10.81	10.86
Thermal Characteristics				Operating Conditions		
Characteristics			*Value*	*Characteristics*		*Value*
Open Voltage Temperature Coefficient VOC (%/°C)			−0.26	Maximum system Voltage – V_{max} (V)		1500
Short Circut Current Temperature Coefficient I_{SC} (%/°C)			+0.04			
Power Temperature Coefficient PMP (%/°C)			−0.30	Maximum Series Fuse (A)		20
NOCT (°C)			45±2	Operating Temperature Range (°C)		IEC: −40 to +85 UL: −40 to +90

Notes: the table is based on data from [26]; *STC: means Air Mass AM 1.5, Irradiance 1000 W/m^2, Cell Temperature 25 °C



a *b*

Fig. 6. IV curve for bifacial solar module [26]: *a* – under variation of solar irradiation; *b* – under variation of cell temperature

3. Results and Discussion

The comparison between monofacial and bifacial solar cell are shown in Table 3 and Fig. 7. It became clear from Table 1 that solar cells depend on their production for power, effective surface area, radiation intensity, and operating temperatures, the use of bifacial solar cells is better in terms of the value of the output of electricity. Still, it is more expensive. On the other hand, the electrical losses are more in monofacial solar cells, the utilization of albedo in bifacial solar cells is better, and the power generated per unit area is better in bifacial. The ability of warping is large in monofacial compared to bifacial. The need for the right orientation is more significant in monofacial than bifacial, the performance of bifacial in cloudy time is better than the monofacial, increasing in temperature effect in both types as reducing the output voltage.

Fig. 7 below explain the difference between monofacial and bifacial solar cell in different parameter.

Table 3

Some points of comparison between monofacial and bifacial solar cell

Type of solar cell	Monofacial	Bifacial
Cost	Less	Larger
Exploit albedo radiation	Very little, not more than 2 %	Larger
Power generated by unit area	Less because only one effective side	Larger because tow effective side
Needs the right orientation	More sensitive due to right orientation	Less sensitive due to right orientation
Possibility of warping	Larger	Less
Electrical loses	Larger	Less
Electricity production with cloudy time	Less	Larger
Temperature effect	Decreasing output voltage and overall power	Decreasing output voltage and overall power
Weak Irradiation utilization	Less because only one effective side	Larger because two effective side

Note: the table is based on data from [14, 20–22, 24, 25]

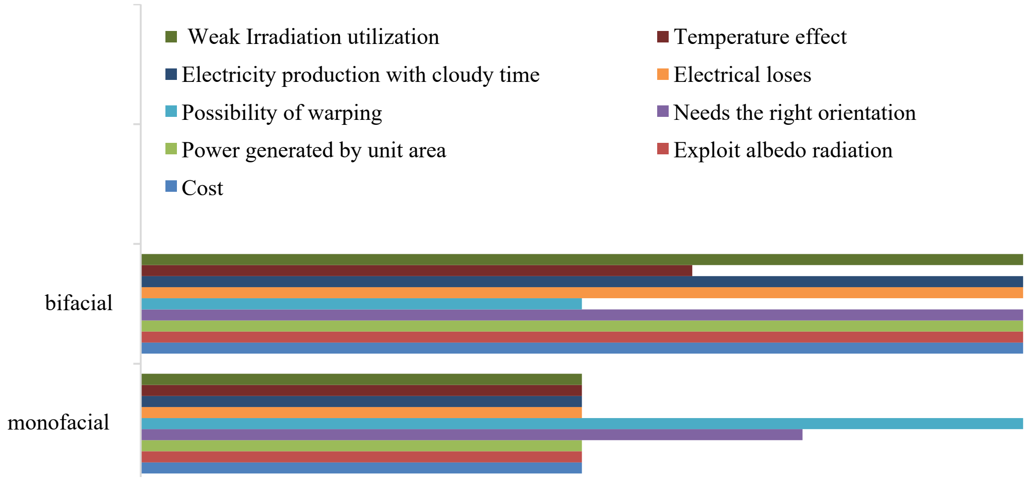


Fig. 7. Comparison between monofacial and bifacial solar cell

The use of bifacial photovoltaic modules is available for work in all areas, and the quality of this work lies in areas where the reflection of solar radiation increases, as well as it is suitable to work in areas where the concentration of solar radiation is low.

For example areas with a floor of Semidesert grassland (20.4 % of reflection for incident radiation), it is considered the least suitable land for the use of this application of solar modules because there is the area with the least reflection of the sun's rays, compared with the Pasture grass areas (26.2 % of reflection for incident radiation), it is considered the best suitable land for the use of this application of solar modules because there is the area with the most reflection of the sun's rays. Can be understood from this research that the use of bifacial modules may be the future of electricity production from solar modules. As well as saving space, installation, and transportation costs. This is due to the need for fewer modules from bifacial to produce the same amount of electricity in comparison with monofacial modules. In addition, it concluded from the current research that the use of bifacial cells in the best case is in Pasture grass areas, with the highest maximum power of modules to obtain the highest possible cell efficiency.

It should be taken into account that the cleaning of bifacial modules, it is harder than monofacial modules because the upper and lower sides must be cleaned to obtain the maximum power, likewise cleaning the lower part added cost, effort and time. On the other hand, the cleaning of bifacial modules need special technique. As well as the cooling technics for bifacial module is difficult than the monofacial modules to reduce the temperature of solar cell to enhance the PV module performance.

4. Conclusions

This study concludes from the previous research that changing to the use of bifacial solar cells can produce a greater amount of electrical energy, if we take into account that the price of bifacial solar cells is higher than the monofacial solar cell, what motivates people to use bifacial cells is their greater production of electricity, and these cells are exploited for that albedo radiation, which varies from place to place and from one surface to another. It may not be feasible on some surfaces, such as Tallgrass prairie. The best design for bifacial cells is to have pasture grass underneath because it reflects 26.2 % of the radiation falling on it. If cleaning is a defect of solar cells in general, the use of bifacial may constitute an additional burden for cleaning matters. The presence of glass on both sides requires more consideration in transportation and installation. To reduce the areas used in producing electricity with solar energy, the use of bifacial may be feasible, and the purchase of land may be expensive; this is also a saving.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

Presentation of research in the form of publication through financial support in the form of a grant from SUES (Support to Ukrainian Editorial Staff).

Data availability

Manuscript has no associated data.

References

1. Bagher, A. M., Vahid, M. M. A., Mohsen, M. (2015). Types of Solar Cells and Application. *American Journal of Optics and Photonics, 3 (5),* 94–113. doi: https://doi.org/10.11648/j.ajop.20150305.17
2. Al-Rawashdeh, H., Hasan, A. O., Al-Shakhanbeh, H. A., Al-Dhaifallah, M., Gomaa, M. R., Rezk, H. (2021). Investigation of the Effect of Solar Ventilation on the Cabin Temperature of Vehicles Parked under the Sun. *Sustainability, 13 (24),* 13963. doi: https://doi.org/10.3390/su132413963
3. Gomaa, M. R., Ahmed, M., Rezk, H. (2022). Temperature distribution modeling of PV and cooling water PV/T collectors through thin and thick cooling cross-fined channel box. *Energy Reports, 8,* 1144–1153. doi: https://doi.org/10.1016/j.egyr.2021.11.061
4. Gomaa, M. R., Murtadha, T. K., Abu-jrai, A., Rezk, H., Altarawneh, M. A., Marashli, A. (2022). Experimental Investigation on Waste Heat Recovery from a Cement Factory to Enhance Thermoelectric Generation. *Sustainability, 14 (16),* 10146. doi: https://doi.org/10.3390/su141610146

5. AlJuhani, M., Gomaa, M. R., Mandourah, T. S., Oreijah, M. M. A. (2021). The Environmental Effects on the Photovoltaic Panel Power: Jeddah Case Study. *Journal of Mechanical Engineering Research and Developments, 44 (6),* 251–262. doi: https://doi.org/10.21608/erjm.2021.57077.1069
6. Blanc, P., Espinar, B., Geuder, N., Gueymard, C., Meyer, R., Pitz-Paal, R. et al. (2014). Direct normal irradiance related definitions and applications: The circumsolar issue. *Solar Energy, 110,* 561–577. doi: https://doi.org/10.1016/j.solener.2014.10.001
7. Feister, U., Cabrol, N., Häder, D. (2015). UV Irradiance Enhancements by Scattering of Solar Radiation from Clouds. *Atmosphere, 6 (8),* 1211–1228. doi: https://doi.org/10.3390/atmos6081211
8. Ineichen, P., Guisan, O., Perez, R. (1990). Ground-reflected radiation and albedo. *Solar Energy, 44 (4),* 207–214. doi: https://doi.org/10.1016/0038-092x(90)90149-7
9. Rezk, H., Arfaoui, J., Gomaa, M. R. (2021). Optimal Parameter Estimation of Solar PV Panel Based on Hybrid Particle Swarm and Grey Wolf Optimization Algorithms. *International Journal of Interactive Multimedia and Artificial Intelligence, 6 (6),* 145. doi: https://doi.org/10.9781/ijimai.2020.12.001
10. Gomaa, M. R., Hammad, W., Al-Dhaifallah, M., Rezk, H. (2020). Performance enhancement of grid-tied PV system through proposed design cooling techniques: An experimental study and comparative analysis. *Solar Energy, 211,* 1110–1127. doi: https://doi.org/10.1016/j.solener.2020.10.062
11. Kanagaraj, N., Rezk, H., Gomaa, M. R. (2020). A Variable Fractional Order Fuzzy Logic Control Based MPPT Technique for Improving Energy Conversion Efficiency of Thermoelectric Power Generator. *Energies, 13 (17),* 4531. doi: https://doi.org/10.3390/en13174531
12. Gomaa, M. R., Al-Dhaifallah, M., Alahmer, A., Rezk, H. (2020). Design, Modeling, and Experimental Investigation of Active Water Cooling Concentrating Photovoltaic System. *Sustainability, 12 (13),* 5392. doi: https://doi.org/10.3390/su12135392
13. Salloom, A. H., Abdulrazzaq, O. A., Ismail, B. H. (2018). Assessment of the Performance of Bifacial Solar Panels. *International Journal of Engineering and Technical Research, 8 (7),* 13–17. Available at: https://www.researchgate.net/publication/326994994
14. Sun, X., Khan, M. R., Deline, C., Alam, M. A. (2018). Optimization and performance of bifacial solar modules: A global perspective. *Applied Energy, 212,* 1601–1610. doi: https://doi.org/10.1016/j.apenergy.2017.12.041
15. Gomaa, M. R., Mohamed, M. A., Rezk, H., Al-Dhaifallah. M., Al Shammri, M. J. (2019). Energy Performance Analysis of On-Grid Solar Photovoltaic System- a Practical Case Study. *International Journal of Renewable Energy Research, 9 (3),* 1292–1301. doi: https://doi.org/10.20508/ijrer.v9i3.9629.g7706
16. Rezk, H., Ali, Z. M., Abdalla, O., Younis, O., Gomaa, M. R., Hashim, M. (2019). Hybrid moth-flame optimization algorithm and incremental conductance for tracking maximum power of solar PV/thermoelectric system under different conditions. *Mathematics, 7,* 875. doi: https://doi.org/10.3390/math7100875
17. Guo, S., Walsh, T. M., Peters, M. (2013). Vertically mounted bifacial photovoltaic modules: A global analysis. *Energy, 61,* 447–454. doi: https://doi.org/10.1016/j.energy.2013.08.040
18. Marion, B. (2020). Albedo Data Sets for Bifacial PV Systems. *2020 47th IEEE Photovoltaic Specialists Conference (PVSC).* doi: https://doi.org/10.1109/pvsc45281.2020.9300470
19. Russell, T. C. R., Saive, R., Augusto, A., Bowden, S. G., Atwater, H. A. (2017). The Influence of Spectral Albedo on Bifacial Solar Cells: A Theoretical and Experimental Study. *IEEE Journal of Photovoltaics, 7 (6),* 1611–1618. doi: https://doi.org/10.1109/jphotov.2017.2756068
20. Uematsu, T., Tsutsui, K., Yazawa, Y., Warabisako, T., Araki, I., Eguchi, Y., Joge, T. (2003). Development of bifacial PV cells for new applications of flat-plate modules. *Solar Energy Materials and Solar Cells, 75 (3-4),* 557–566. doi: https://doi.org/10.1016/s0927-0248(02)00197-6
21. Liang, T. S., Pravettoni, M., Deline, C., Stein, J. S., Kopecek, R., Singh, J. P. et al. (2019). A review of crystalline silicon bifacial photovoltaic performance characterisation and simulation. *Energy & Environmental Science, 12 (1),* 116–148. doi: https://doi.org/10.1039/c8ee02184h
22. Gu, W., Ma, T., Li, M., Shen, L., Zhang, Y. (2020). A coupled optical-electrical-thermal model of the bifacial photovoltaic module. *Applied Energy, 258,* 114075. doi: https://doi.org/10.1016/j.apenergy.2019.114075
23. Huld, T., Gottschalg, R., Beyer, H. G., Topič, M. (2010). Mapping the performance of PV modules, effects of module type and data averaging. *Solar Energy, 84 (2),* 324–338. doi: https://doi.org/10.1016/j.solener.2009.12.002
24. Tsuno, Y., Hishikawa, Y., Kurokawa, K. (2006). Translation Equations for Temperature and Irradiance of the I-V Curves of Various PV Cells and Modules. *2006 IEEE 4th World Conference on Photovoltaic Energy Conference.* doi: https://doi.org/10.1109/wcpec.2006.279619
25. Lopez-Garcia, J., Pavanello, D., Sample, T. (2018). Analysis of Temperature Coefficients of Bifacial Crystalline Silicon PV Modules. *IEEE Journal of Photovoltaics, 8 (4),* 960–968. doi: https://doi.org/10.1109/jphotov.2018.2834625
26. *PS-M144(HC)-xxxW Half-Cell MBB Mono Module.* Available at: https://philadelphia-solar.com/wp-content/uploads/2022/09/PS-m144HC450W.pdf

✉***Mohamed R. Gomaa,*** *Associate Professor, Department of Mechanical Engineering, Al-Hussein Bin Talal University, Ma'an, Jordan, e-mail: Behiri@bhit.bu.edu.eg, ORCID: https://orcid.org/0000-0003-4799-6119*

Ghayda' A. Matarneh, *Lecturer, Department of Mechanical Engineering, Al-Hussein Bin Talal University, Ma'an, Jordan, ORCID: https://orcid.org/0000-0003-2304-3102*

Mohammad A. Al-Rawajfeh, *Postgraduate Student, Department of Mechanical Engineering, Al-Hussein Bin Talal University, Ma'an, Jordan, ORCID: https://orcid.org/0000-0002-3740-5007*

✉*Corresponding author*