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ORIGINAL ARTICLE
Electrica 2024; 24(2): 525-531

Comparative Performance Analysis of PV Systems in Summer and Winter Seasons: A Case Study in İstanbul

Ertuğrul Adıgüzel

Department of Electrical and Electronics Engineering, İstanbul University—Cerrahpaşa, Faculty of Engineering, İstanbul, Türkiye

Cite this article as: E. Adıgüzel, "Comparative performance analysis of PV systems in summer and winter seasons: A case study in İstanbul," *Electrica*, 24(2), 525-531, 2024.

ABSTRACT

Photovoltaic (PV) panels are energy production elements that are directly and catastrophically affected by climatic conditions. In this study, the performances of monocrystalline and polycrystalline photovoltaic panels, which are most commonly used in photovoltaic systems, were experimentally examined in summer and winter seasons. A comparison was made of the factors affecting the electrical performance of PV panels in summer and winter seasons under geographical climatic conditions at Istanbul University—Cerrahpaşa Avcılar center. In this experimental study, monocrystalline and polycrystalline PV panels with a power of 100 W were used. By drawing the characteristic curves of the current–voltage–power parameters, which are the electrical output parameters of the PV panels, seasonal performance comparisons were made comparatively with different weather conditions following the instantaneous effect in Avcilar, Istanbul.

***Index Terms*—**Efficiency, environmental factors, PV panel, seasonal effect

I. INTRODUCTION

Energy is the most important factor that has become the basic need of all humanity in the last 100 years. The increase in global energy demand, limited resources of fossil fuels, and global warming have led to a shift toward clean and environmentally friendly renewable energy sources. On the basis of this transformation, solar energy, which is a renewable energy source, stands out as the primary energy source. According to the report published by International Energy, in Fig. 1, solar energy will be the first with 22.2% power capacity, leaving behind other energy sources in 2027 [1]. Photovoltaic (PV) systems have become the cornerstone of renewable energy, providing a sustainable and environmentally friendly method of electricity generation. The efficiency and output parameters of PV systems can vary significantly depending on seasonal changes, especially between summer and winter. Understanding these differences is crucial to optimizing performance, predicting energy yield, and improving the operation of PV systems [2]. The efficiency and output of PV systems are affected by various environmental conditions such as temperature, solar radiation, wind, and pollution. For this reason, many studies have been conducted on seasonal environmental factors for PV systems analysis.

Researchers have shown that PV systems can operate marginally better in winter compared to summer [3]. This is because they found that higher solar radiation levels in the summer months lead to increased dust accumulation on PV panels, which negatively affects performance, and they found that the loss in the summer months is 8.7% more than in the winter months [4]. Additionally, Tamoor et al. found that dust pollutants and suspended particulate matter affect the performance of PV systems with a greater impact in summer than in winter. They found that there were more than 100 quarries in the geographical location where they studied, and as a result of the measurements, they found that energy production decreased by 10.68% in June and 8.03% in January [5]. In their study, Abdallah et al. made comparisons with 6-month periods as January–June and July–December. They extracted the lost power difference of 8.98% and 9.23%, respectively. As a result, they noted that rain had a positive effect on the performance of PV systems, with higher average values in the spring/summer season [6].

Khan and Memon studied the effect of temperature on PV performance and revealed that in hot and arid climates such as Pakistan, surface temperatures significantly affect the performance of

Corresponding author:
Ertuğrul Adıgüzel

E-mail:
eadiguzel@iuc.edu.tr

Received: March 27, 2023

Revision Requested: April 3, 2024

Last Revision Received: April 6, 2024

Accepted: April 24, 2024

Publication Date: May 31, 2024

DOI: 10.5152/electrica.2024.24043

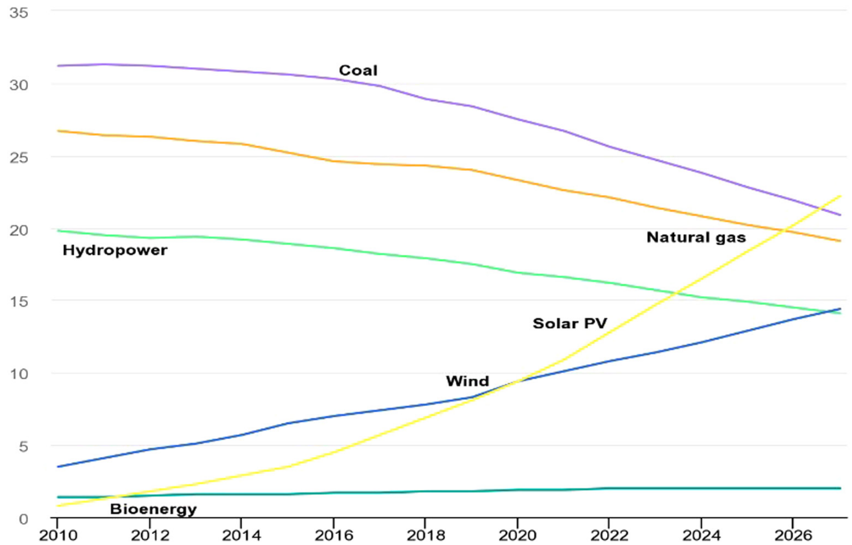

Fig. 1. Share of cumulative power capacity by technology, 2010–2027 [1].

PV modules in both summer and winter [7]. Additionally, Saadoon et al. have conducted research to reduce temperature-related performance degradation by using nanofluids for thermal management in PV systems in Iraq during summer. By using 1g and 1.5g nanofluids to reduce the PV panel temperature, they achieved an overall efficiency of 15% and 18%, respectively [8].

In their study on the operating conditions of PV systems in Malaysia, Mohammad and his colleagues found that the output power decreased by 0.22% when the cell temperature increased by 1°C [9]. In Fig. 2, Katkar and colleagues presented the efficiency change according to the PV panel surface temperature value. While it operates at maximum efficiency at 36°C, efficiency decreases at higher and lower temperatures. They found that the efficiency at high temperature was significantly less than the efficiency at low temperatures. They measured efficiency to 4% when the module temperature increased from 36°C to 40°C [10]. Similarly, Malik and colleagues found that the module temperature efficiency at 64°C decreased by 69% compared to standard test conditions (STC) [11].

Seasonal changes also play a role in the performance of PV systems. Gopi and colleagues emphasized the importance of taking seasonal changes in weather parameters into account when modeling energy production in tropical regions. They found that wind is not very effective in PV energy production depending on the region, and the efficiency is high when atmospheric pressure is low. They have presented that the energy production and performance of PV systems are almost the same in winter and summer seasons, especially in geographically tropical regions [12]. By testing PV panels with an inclination angle of 13° in summer and 30° in winter, Sharma et al. found that the incoming solar radiation increased by 2.41% and the annual efficiency increased by 0.26% [13]. As a result, the performance of PV systems in summer and winter depends on temperature, solar radiation, dust accumulation, pressure, rain, etc. It is affected by a combination of factors such as seasonal changes. Understanding these factors and their interactions is crucial to optimizing the performance of PV systems under different climatic conditions.

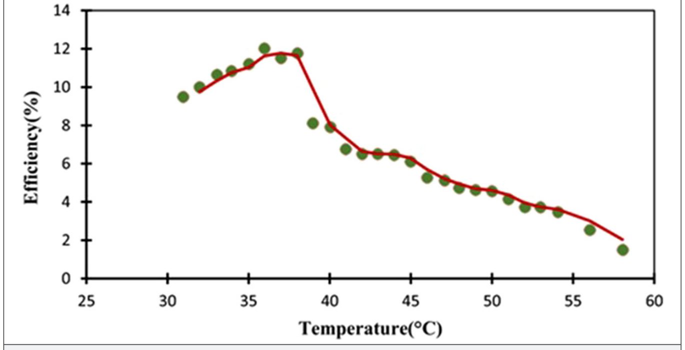

Fig. 2. Effect of PV panel temperature on efficiency [10].

The amount of humidity in the atmosphere has various effects on the efficiency of PV panels. Katkar et al. found that when the relative humidity increased from 48% to 60%, the module efficiency decreased from 12.04% to 9.7% [10]. In another study, Ramli et al. found a more than 40% decrease in PV power output at 76.32% humidity in rainy weather conditions [14].

This study was designed experimentally in an outdoor environment at Istanbul University—Cerrahpaşa Avcılar center. Measurements of all environmental factors in summer and winter for the Avcılar region of the system in the field were recorded according to the IEC 61724-1:2021 standard [15]. In addition, while the environmental parameters were measured, the electrical output values of the PV panels were constantly recorded. By making seasonal analysis of the geographical conditions of PV systems, it can provide a resource in terms of the efficiency of the systems and investments.

II. MATERIALS AND METHODS

The PV system for the experimental study shown in Fig. 2 was designed to include a monocrystalline and a polycrystalline PV panel of 100 watts each. While electrical measurements were made automatically with this PV system electronic load, data measurements and records were made in the system according to IEC 61724-1:2021 standards.

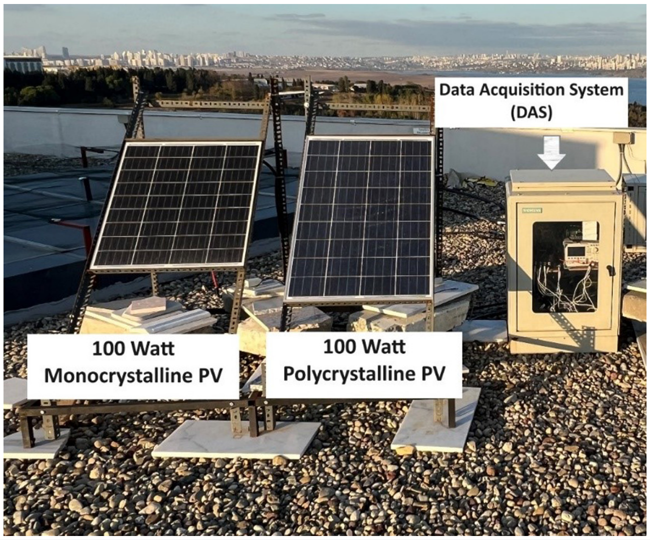

Fig. 3. Data acquisition system outdoor test bench [15].

With the complex data collection system given in Fig. 3 of the experimental study, the electrical output parameters of PV panels and the environmental parameters affecting them, such as solar radiation, temperature, and humidity values, are recorded.

While the electrical parameters and characteristic curves are obtained by automatically measuring the electronic load PV panels with the control box, the weather station measurement values are obtained wirelessly via the data console in Fig. 4. All collected data are transferred to a computer, visualized and analyzed.

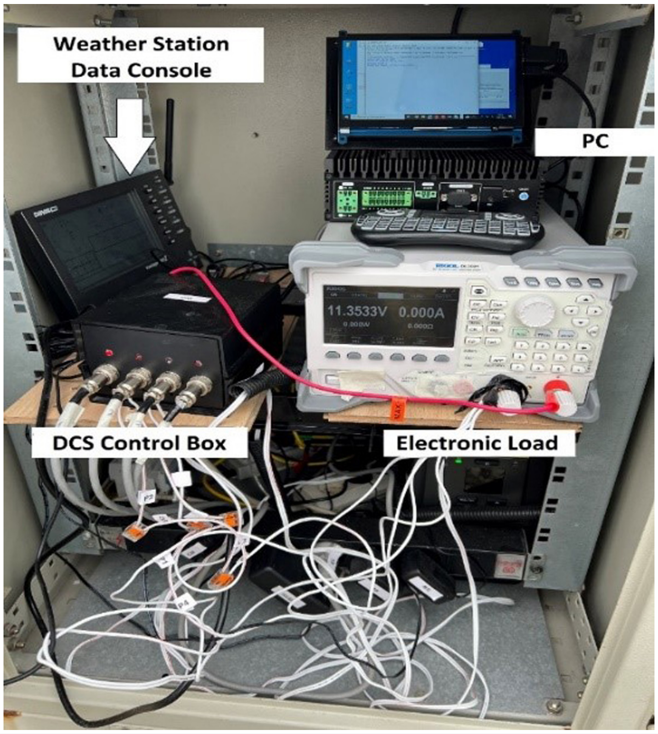

Fig. 4. Data acquisition system [15].

TABLE I. ELECTRICAL CHARACTERISTICS OF PHOTOVOLTAIC MODULES AT STC

Module Name	**TT100-36PM**	**TT100-36P**
Cell type	Monocrystalline	Polycrystalline
Maximum power (Pmax)	100 W	100 W
Maximum power voltage (Vmp)	20.60 V	19.4 V
Maximum power current (Imp)	4.86 A	5.16 A
Open circuit voltage (Voc)	24.0 5V	22.9 V
Short circuit current (Isc)	5.13 A	5.52 A
Number of cells	36	36
Dimensions	680 × 790 × 20 mm	674 × 944 × 20 mm

In terms of comparison and accuracy of the study, experiments were carried out using PV panels whose electrical properties under standard test conditions are given in Table 1, one monocrystalline panel and one polycrystalline panel of the same brand with equivalent power.

III. RESULTS

With the experimental study, the data obtained from the measurements made with PV panels during the summer (June–July–August) and winter (December–January–February) months in Avcılar district are presented graphically.

Fig. 5 shows the solar radiation value affecting PV panels in summer and winter. According to the analysis made here, the highest solar radiation value was measured as 1200 W/m^2 on average in June and July, while the lowest value was measured as 50 W/m^2 in December. It has been determined that the average solar radiation value decreases the most in January and February.

The temperature measurement value, which is another environmental condition affecting PV panels, is presented in Fig. 6. The highest temperature was measured in July and August, and the lowest temperature was determined in January. It has been determined that the summer–winter outdoor temperature difference affecting PV panels is 35°C.

The humidity amount for summer and winter seasons is given in Fig. 7. Although the amount of humidity is generally similar in summer and winter, it has been determined that the average humidity value in winter is higher. In the winter months, the humidity level is more like 90%, and in the summer months, especially in July, a serious humidity level of 30% has been detected.

Characteristic curves of monocrystalline (Fig. 8) and polycrystalline (Fig. 9) PV panels, whose measurements were made automatically by the data acquisition system, were obtained. Fig. 8 shows the current-voltage (I-V) and power-voltage (P-V) values of the six-month maximum value of the monocrystalline PV panel. In Fig. 9, the I-V and P-V values of the six-month maximum value of the polycrystalline PV panel are given.

Current, voltage, and power data of the 6-month characteristic curve graphs of the PV panels shown in Figs. 8 and 9 are given in Table 2. When the data were examined, it was determined that December was, on average, more productive than July.

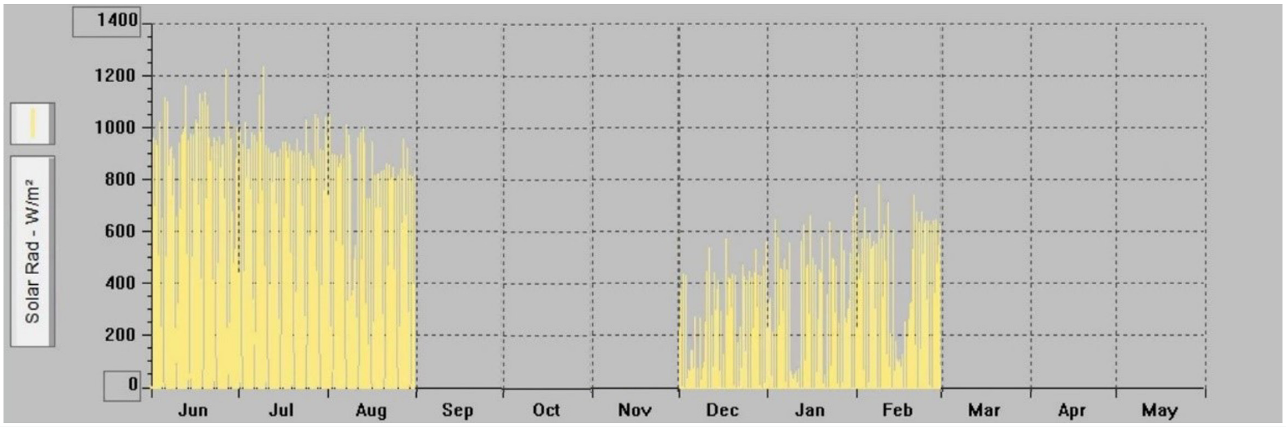

Fig. 5. Solar radiation value in 2023 summer and 2024 winter seasons.

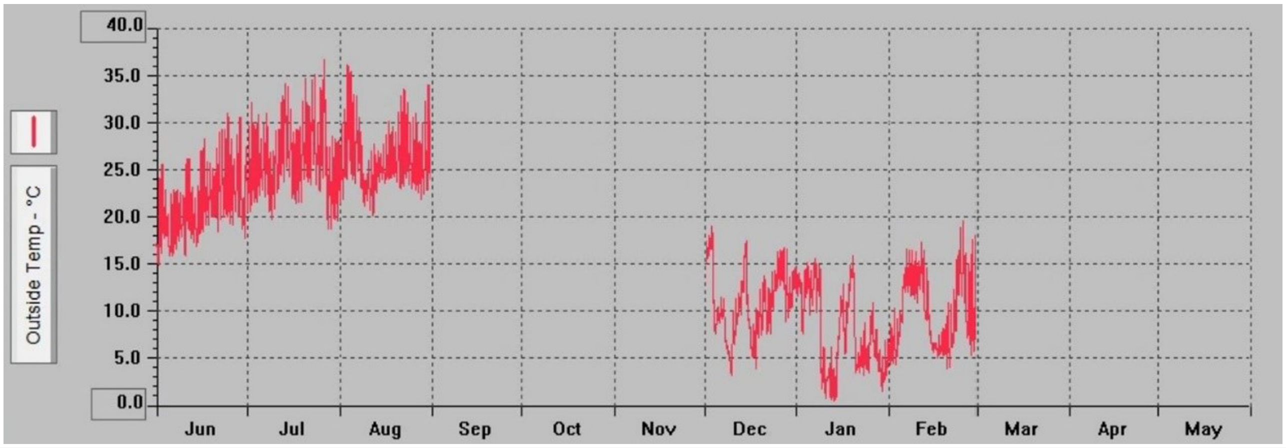

Fig. 6. Temperature value in 2023 summer and 2024 winter seasons.

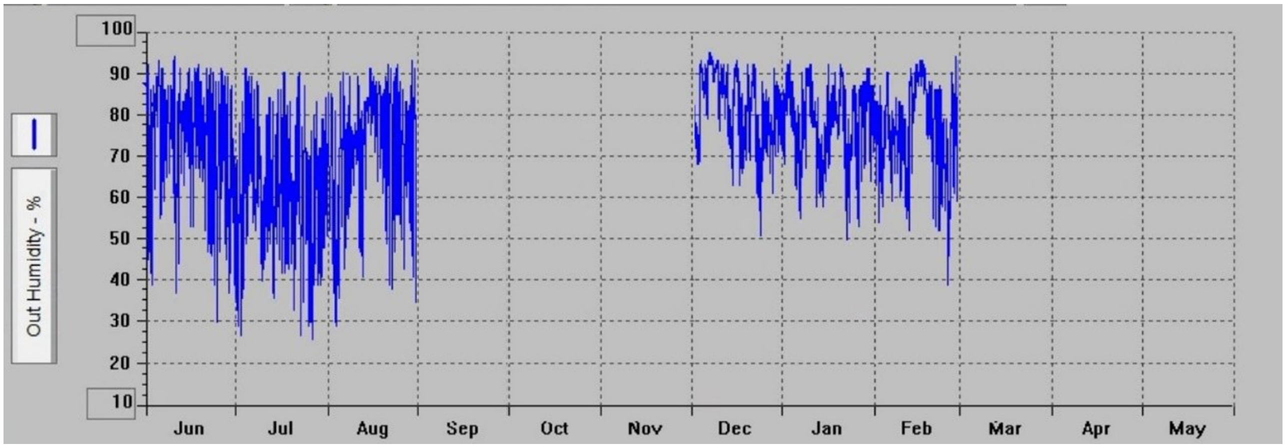

Fig. 7. Humidity value in summer 2023 and winter 2024.

IV. CONCLUSION

The use of solar energy is rapidly increasing in the field of renewable energy. Although there are international standards for the application and use of solar energy, environmental factors and the geographical location used provide different operating performance on the efficiency of PV panels. For this reason, extensive PV panel efficiency studies are carried out in the literature on different climates and geographical locations. In this study, the effects of environmental parameters radiation, temperature, and humidity affecting the operating performance of PV panels in the Istanbul-Avcılar region of Türkiye were investigated. Experimental studies carried out outdoors

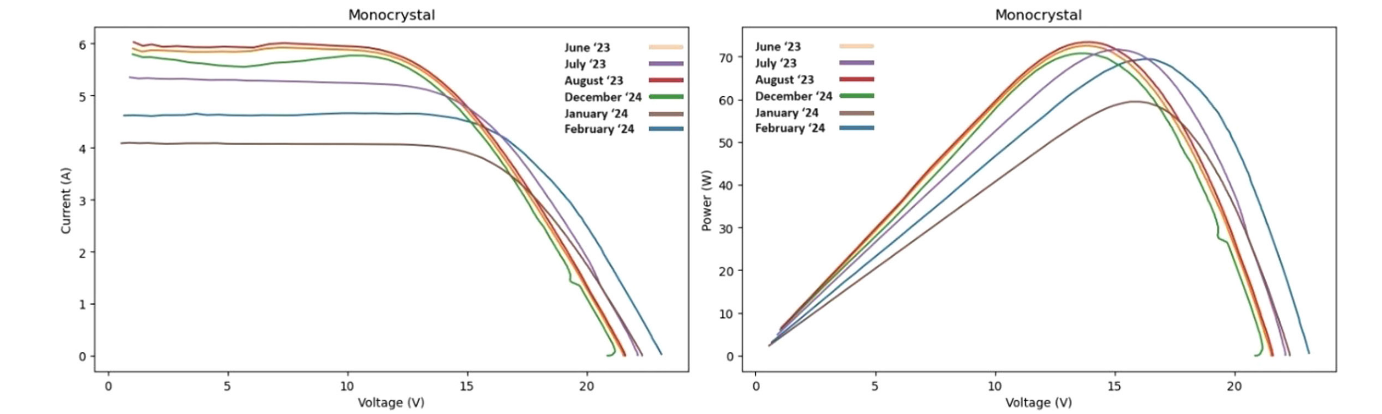

Fig. 8. Monocrystalline PV panel I-V and P-V characteristic curves for 2023 summer and 2024 winter seasons.

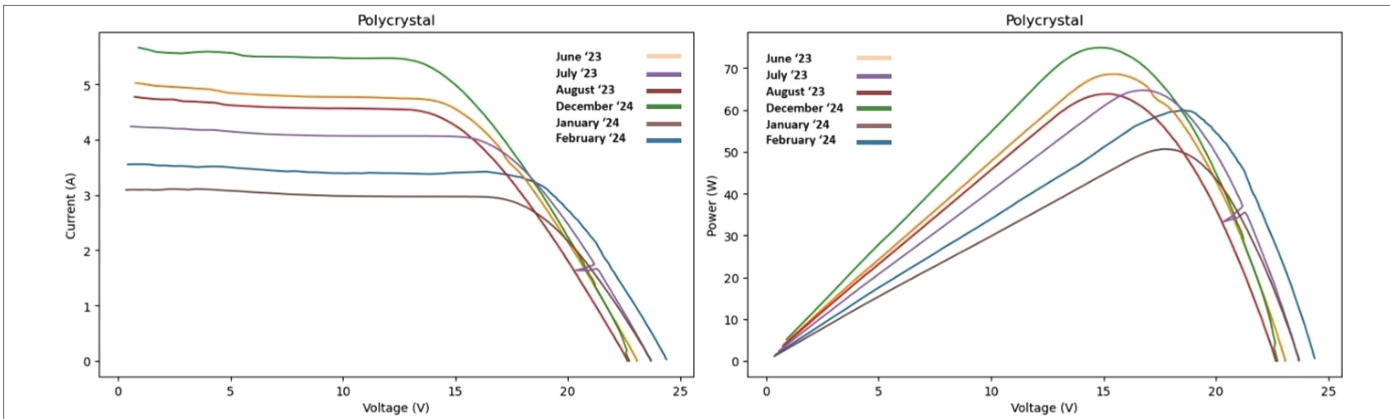

Fig. 9. Polycrystalline PV panel I-V and P-V characteristic curves for 2023 summer and 2024 winter seasons.

TABLE II. PHOTOVOLTAIC PANEL MONTHLY MAXIMUM ELECTRICAL OUTPUT PARAMETERS

Monocrystalline PV panel					Polycrystalline PV panel				
		I	V	P			I	V	P
1	June 2023	5.24	13.84	72.54	1	June ‘23	4.45	15.4	68.53
2	July 2023	5.23	13.51	70.76	2	July ‘23	4.21	15.15	63.81
3	August 2023	5.25	13.97	73.38	3	August ‘23	5.04	14.85	74.88
4	December 2024	4.72	15.17	71.66	4	December ‘24	3.87	16.72	64.70
5	January 2024	3.75	15.85	59.45	5	January ‘24	2.84	17.78	50.63
6	February 2024	4.22	16.44	69.40	6	February ‘24	3.24	18.48	59.89

PV, photovoltaic.

and data measurements were made according to IEC 61724-1:2021 standards.

As a result of these experiments;

1. Monocrystalline PV panel power output has been found to be generally higher than the polycrystalline PV panel power parameter.
2. According to the summer and winter seasons of monocrystalline and polycrystalline PV panels, the maximum power output was measured to be in August and the least maximum power output to be in January. Although the highest radiation value is in July, the reason for obtaining the maximum power in August is the temperature. The temperature in August is lower than in July. This increases the PV panel's operating efficiency.
3. Although the high radiation value and lower humidity value in July compared to the winter months are among the factors that increase PV panel efficiency, it has been observed that PV panels

work more efficiently compared to July due to the lower temperature value in December.

4. Between summer and winter seasons, the power difference between monocrystalline PV panels were determined to be 19%, and the power difference for polycrystalline PV panels were determined to be 32%.
5. It has been observed that the efficiency of PV panels decreases depending on the increase in humidity. It has been observed that suspended water particles in the air block the solar radiation reaching the PV panel surface and reduce the efficiency even if the solar radiation value is high. It also reduces the performance of the PV panel by causing corrosion.

Peer-review: Externally peer-reviewed.

Declaration of Interests: The author has no conflict of interest to declare.

Funding: The author declared that this study has received no financial support.

REFERENCES

1. "Share of cumulative power capacity by technology, 2010–2027 – Charts – Data & Statistics - IEA." Available: https://www.iea.org/data-and-statistics/charts/share-of-cumulative-power-capacity-by-technology-2010-2027. [Accessed: March 07, 2024].
2. H. A. Kazem, "Impact of long-term dust accumulation on photovoltaic module performance — A comprehensive review," *Environ. Sci. Pollut. Res. Int.*, vol. 30, no. 57, pp. 119568–119593, 2023. [CrossRef]
3. R. Srimathi, J. Meenakshi, R. Vijayabhasker, and S. S. Belay, "Performance evaluation and estimation of energy measures of grid-connected PV module," *Int. J. Photoenergy*, vol. 2022, 1–13, 2022. [CrossRef]
4. K. M. Alawasa, R. S. Alabri, A. S. Al-Hinai, M. H. Albadi, and A. H. Al-Badi, "Experimental study on the effect of dust deposition on a car park photovoltaic system with different cleaning cycles," *Sustainability*, vol. 13, no. 14, p. 7636, 2021. [CrossRef]
5. M. Tamoor *et al.*, "Investigation of dust pollutants and the impact of suspended particulate matter on the performance of photovoltaic systems," *Front. Energy Res.*, vol. 10, p. 1017293, 2022. [CrossRef]
6. R. Abdallah *et al.*, "The effects of soiling and frequency of optimal cleaning of PV panels in Palestine," *Energies*, vol. 15, no. 12, p. 4232, 2022. [CrossRef]
7. A. Khan, and S. Memon, "Effect of hot-arid climatic solar energy on monocrystalline photovoltaic performance in Pakistan," *Int. J. Sol. Therm. Vac. Eng.*, vol. 2, no. 1, pp. 19–39, 2020. [CrossRef]
8. M. Saadoon, I. A. Hasan, and M. J. Mohammed, "Preparing nanofluids (Al2O3) for enhancement performance of photovoltaic," *Eng. Technol. J.*, vol. 39, no. 9, pp. 1445–1453, 2021. [CrossRef]
9. M. M. Rahman, M. Hasanuzzaman, and N. A. Rahim, "Effects of operational conditions on the energy efficiency of photovoltaic modules operating in Malaysia," *J. Clean. Prod.*, vol. 143, pp. 912–924, 2017. [CrossRef]
10. K. A. Ashok, N. N. Shinde, and P. Patil, "Performance & evaluation of industrial solar cell wrt temperature and humidity," *Int. J. Res. Mech. Eng. Technol.*, pp. 69–73, 2011.
11. A. Q. Malik, and S. J. B. H. Damit, "Outdoor testing of single crystal silicon solar cells," *Renew. Energy*, vol. 28, no. 9, pp. 1433–1445, 2003. [CrossRef]
12. A. Gopi, K. Sudhakar, N. W. Keng, A. R. Krishnan, and S. S. Priya, "Performance modeling of the weather impact on a utility-scale PV power plant in a tropical region," *Int. J. Photoenergy*, vol. 2021, 1–10, 2021. [CrossRef]
13. G. S. Sharma *et al.*, "Performance evaluation of a MW-size grid-connected solar photovoltaic plant considering the impact of tilt angle," *Sustainability*, vol. 14, no. 3, p. 1444, 2022. [CrossRef]
14. M. A. M. Ramli, E. Prasetyono, R. W. Wicaksana, N. A. Windarko, K. Sedraoui, and Y. A. Al-Turki, "On the investigation of photovoltaic output power reduction due to dust accumulation and weather conditions," *Renew. Energy*, vol. 99, pp. 836–844, 2016. [CrossRef]
15. E. Adıgüzel, K. Gürkan, and A. Ersoy, "Design and development of data acquisition system (DAS) for panel characterization in PV energy systems," *Measurement*, vol. 221, p. 113425, 2023. [CrossRef]

Ertuğrul Adıgüzel was born in Kars. He received his MSc degree in electrical and electronics engineering from İstanbul University in 2018. He received his PhD degree in electrical and electronics engineering from İstanbul University-Cerrahpaşa, in 2023. Currently, he is working as a PhD research assistant in the Electrical–Electronics Engineering Department of İstanbul University-Cerrahpaşa. His research interests are high voltage techniques and renewable energy.