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Research Article

Evaluating Photovoltaic Panel Efficiency During the Cooling Season in Mersin: Insights from Alternative Performance Models

Fatih Ünal*, Merve Şentürk Acar[2] and Bünyamin Demir[3]

[1]*Engineering Faculty, Mersin University, Turkey*
[2]*Engineering Faculty, Bilecik Şeyh Edebali University, Turkey*
[3] *Engineering Faculty, Mersin University, Turkey*

(fatihunal@mersin.edu.tr)

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***Abstract* –** This study analyzes the performance of photovoltaic (PV) panels in Mersin during the cooling season using different performance models. Accurate performance assessments are crucial for enhancing the efficiency of PV panels and maximizing the benefits of solar radiation. In this context, the use of various modeling techniques is necessary, taking into account the solar radiation intensity during the summer months. The study combines local meteorological data from Mersin with EnergyPlus software to evaluate the energy production capacity of PV panels using different performance models. Each model offers a distinct approach to calculating energy production, considering Mersin's unique geographical and climatic conditions. The research systematically compares the efficiency outcomes of these models and highlights their respective strengths and weaknesses. The results show that the accuracy levels of each model in evaluating PV panel performance during the summer season vary. The study emphasizes that selecting the appropriate performance model is critical for accurately reflecting PV panel efficiency and optimizing energy production. This research highlights the contributions of various models in assessing PV panel performance during the cooling season and underscores their potential to improve regional energy efficiency.

Keywords – Photovoltaic Panel Efficiency, Performance Models, Cooling Season, Mersin, Solar Radiation.

I. INTRODUCTION

In today's world, there is a growing shift towards renewable energy sources to meet energy needs sustainably. In this context, photovoltaic (PV) systems stand out due to their environmental benefits and their potential to ensure sustainability in energy production. Thanks to its geographical location, Mersin has a high potential for solar energy. This region, characterized by a Mediterranean climate, receives abundant sunlight throughout the year. However, during the summer months, increased temperatures and high humidity levels can negatively impact the energy production capacity of PV panels. These environmental factors can lead to fluctuations in energy production during the cooling season and make it challenging for PV panels to operate optimally. In this regard, selecting the appropriate performance models to evaluate PV panel efficiency and optimize energy production is very important. Effective performance analysis requires not only the optimization of panel placement and tilt angles but also a comprehensive assessment of environmental factors. Accurate performance models can help minimize efficiency losses during the summer months and enhance overall energy production efficiency.

This study aims to evaluate the performance of PV panels in the Mersin region during the cooling season using various models and to compare their effectiveness. By analyzing the results of different performance models, the research seeks to identify the necessary strategies to ensure PV panels operate at maximum efficiency. The findings from this evaluation will contribute to the development of strategies that help PV systems perform more efficiently during the cooling season and reduce seasonal fluctuations in energy production.

Numerous studies have examined the performance of PV systems from different perspectives, such as system design, the impact of environmental factors, and optimization of energy production through software simulations. For instance, Altınkok (2021) assessed Turkey's solar energy potential and performed simulations for a PV system planned to be installed on the roof of the Engineering Faculty at Giresun University using PVSol software. The simulation revealed that the system could meet 52% of the annual energy demand. This study demonstrates the effectiveness of PVSol software in designing realistic and efficient PV systems [1]. Similarly, Rout and Kulkarni (2020) optimized the design of a 2 kW rooftop PV system in Odisha and analyzed its energy production capacity in detail. Their work showcased the potential of software simulations to enhance the energy output of PV systems [2]. Kazem and Chaichan (2015) highlighted the significant impact of relative humidity on PV system performance, noting that relative humidity is inversely related to parameters such as solar radiation, wind speed, and ambient temperature [3]. Park et al. (2013) identified a linear relationship between temperature and relative humidity, while Mekhilef et al. (2012) explored the interconnected effects of dust, humidity, and wind speed on PV efficiency [4-5]. Chaichan and Kazem (2016) found that while wind has a minimal effect on module temperature, high relative humidity adversely affects solar radiation and panel performance [6]. These studies collectively emphasize the need for a holistic approach to understanding the role of environmental factors in optimizing PV system efficiency. This research aims to contribute to the existing literature by evaluating the efficiency of PV panels during the cooling season in Mersin using various performance models and comparing their effectiveness.

II. MATERIALS AND METHOD

This study was conducted at the Faculty of Engineering in Mersin, Turkey. The region's climatic conditions and varying solar radiation data during the cooling season were used to analyze the performance of photovoltaic (PV) panels. Hourly meteorological data, including air temperature, wind speed, and solar radiation, were collected and utilized in the analysis. In this research, multicrystal photovoltaic module panels were selected.

To evaluate the performance of PV panels during the cooling season, three distinct performance models were employed. These models include the Simple Model, the Sandia Model, and the One-Diode Model. Each model was chosen for its strengths in simulating PV performance under different environmental and operational conditions. Simulations were conducted using EnergyPlus software, a powerful tool for modeling energy usage in buildings and renewable energy systems.

The Simple Model predicts the efficiency of PV panels based on fundamental physical principles. It depends on key parameters such as solar radiation and temperature. While this model has the advantage of faster computation, it is limited in terms of sensitivity to environmental variables. The Sandia Model, on the other hand, focuses on analyzing the electrical and thermal behaviors of PV panels in greater detail. This model accounts more accurately for environmental factors such as module temperature and irradiance intensity. The One-Diode Model simulates the electrical behavior of PV cells using a diode equivalent circuit, considering technical details such as internal panel losses and temperature, providing high-accuracy predictions.

For each month included in the cooling season, hourly meteorological data were input into EnergyPlus software. The efficiency of PV panels was assessed using the Simple, Sandia, and One-Diode models in the simulations. The results from these analyses provided a comprehensive dataset to understand the performance of PV panels.

The collected data were compared across the three models to analyze the relative efficiency of each. This comparison provided a basis for evaluating model performance under the specific conditions encountered in the Mersin region during the cooling season. The results enabled the identification of the most effective model for optimizing PV panel energy production.

This methodological approach aims to provide a comprehensive analysis of PV panel efficiency, considering the climatic challenges faced in Mersin during the summer months. The use of different models offers valuable insights into strategies for enhancing the energy production capacity of PV systems under conditions of reduced solar radiation.

III. RESULTS

In this study, the efficiency of PV panels was analysed using different performance models for the period designated as the cooling season in Mersin. The changes in meteorological data during the cooling season, which were used for the analysis, are presented in Table 1.

Table 1. The monthly averages of meteorological values during the cooling season

Month	**Outdoor Air Temperature [°C](Monthly)**	**Wind Speed [m/s](Monthly)**	**Solar Radiation Rate per Area [W/m^2](Monthly)**
May	21.941	2.299	254.734
June	25.778	2.393	266.711
July	28.760	2.391	262.988
August	29.045	2.288	287.869
September	25.593	2.203	252.118

The provided data show the monthly average values of air temperature, wind speed, and solar radiation levels during the cooling season in the Mersin region. In May, the average air temperature was 21.94°C, which increased to 28.76°C in July and 29.05°C in August. This indicates that July and August were the hottest months, with high temperatures potentially negatively affecting the efficiency of photovoltaic (PV) panels. However, these values are monthly averages, and it is important to note that there may be moments during specific days and hours when temperatures could be significantly higher or lower. Wind speed remained relatively constant throughout the season but decreased from 2.299 m/s in May to 2.203 m/s in September. As with air temperature, the variations in wind speed are also monthly averages, and specific days may experience higher or lower wind speeds. Wind can help cool PV panels, potentially allowing them to operate more efficiently in high temperatures. The decrease in wind speed during the summer months could lead to higher panel temperatures. Solar radiation levels averaged 254.734 W/m^2 in May, rising to 287.869 W/m^2 in August. June and July also experienced high solar radiation levels, with values of 266.711 W/m^2 and 262.988 W/m^2, respectively. However, solar radiation decreased to 252.118 W/m^2 in September. This demonstrates that while solar radiation is high during the summer, allowing PV panels to produce maximum energy, the radiation decreases in September. It is important to remember that these values represent monthly averages, and solar radiation can vary significantly at different times of the day. These data reveal the factors influencing the efficiency of PV panels during the cooling season in the Mersin region. It is evident that PV systems generate more energy during the summer months when solar radiation is higher, but excessive temperatures can reduce panel efficiency. Additionally, changes in wind speed are an important factor affecting panel performance. While monthly averages provide a general overview, variations in these values during specific days and hours should be considered, as they may impact the performance of PV systems. The results for PV panels during the cooling season, based on different performance models, are presented in Table 2.

Table 2. Results of PV panel performance during cooling season months

Month	Model	Produced DC Electric Power [W](Monthly)	PV Cell Temperature [°C](Monthly)	PV Efficiency (%)
May	SANDIA	17.520	29.022	6.330
	SIMPLE	22.467	24.284	8.050
	ONE-DIODE	19.650	25.284	7.560
June	SANDIA	17.745	33.306	6.310
	SIMPLE	23.523	27.164	8.730
	ONE-DIODE	20.180	29.164	7.470
July	SANDIA	17.312	36.069	6.210
	SIMPLE	23.195	31.060	8.170
	ONE-DIODE	19.712	32.060	7.290
August	SANDIA	18.690	37.177	5.850
	SIMPLE	25.390	31.202	7.870
	ONE-DIODE	21.608	32.202	6.730
September	SANDIA	16.960	32.784	5.530
	SIMPLE	22.236	27.590	7.270
	ONE-DIODE	19.027	28.590	6.280

The data presented in the table show how the three different performance models used for photovoltaic (PV) panels during the cooling season (May - September) in the Mersin region resulted in varying outcomes for DC electricity generation, panel temperatures, and efficiency rates. According to the SANDIA model, the DC electricity produced by the PV panels and their efficiency were generally lower compared to the other models. For instance, in May, the SANDIA model produced 17.520 W of electricity with an efficiency of 6.33%. In July, the electricity generation decreased to 17.312 W, and the efficiency dropped to 6.21%. PV cell temperatures in the SANDIA model were generally higher than those in the other models. In July, the temperature reached 36.069°C, which could potentially lead to a decrease in panel efficiency. High temperatures typically have a negative effect on the efficiency of PV panels, causing power losses. In the SIMPLE model, PV panels generally produced higher electricity compared to the other models. In May, the model generated 22.467 W of electricity, with an efficiency of 8.05%. In July, the electricity production increased to 23.195 W, achieving an efficiency of 8.17%. Panel temperatures in the SIMPLE model were lower than in the SANDIA model. In May, the temperature was 24.284°C, and in July, it was 31.060°C. This suggests that lower temperatures may enhance panel efficiency. A similar trend was observed in the ONE-DIODE model. While electricity generation and efficiency were similar to those of the SIMPLE model, they were generally slightly lower. In May, 19.650 W of electricity was generated with an efficiency of 7.56%, and in July, 19.712 W of electricity was produced, with an efficiency of 7.29%. PV cell temperatures in the ONE-DIODE model were generally similar to those in the SIMPLE model but were still slightly higher. In all models, panel temperatures increased, and efficiency decreased during the summer months (June, July, August). This indicates that PV panels are temperature-sensitive, and as the temperature rises, their efficiency declines. The SIMPLE model achieved the highest electricity production and efficiency, particularly in May and July. It can be concluded that this model operates more efficiently at lower temperatures compared to the other models. The SANDIA model exhibited the lowest efficiency, as it appeared to experience more significant losses at higher temperatures, with efficiency declining markedly as the temperature increased. The ONE-DIODE model, although not as efficient as the SIMPLE model, still performed as the second best in terms of energy production. In conclusion, different performance models reflect how environmental factors such as temperature, wind speed, and solar radiation affect the efficiency of PV panels in various ways. Therefore, selecting the most suitable model for specific climatic conditions is crucial for optimizing energy efficiency and production.

IV. DISCUSSION

In this study, the comparison of different performance models for evaluating PV panel efficiency in Mersin's cooling season reveals the significant influence of environmental factors, such as temperature, wind speed, and solar radiation, on the efficiency of solar systems. The SIMPLE model demonstrated superior performance, particularly under lower temperature conditions, highlighting its suitability for hot climates. However, the SANDIA model showed a marked decrease in efficiency, primarily due to power losses at higher temperatures. These findings suggest that selecting the most appropriate model is crucial for optimizing PV system performance, particularly in regions with extreme climatic conditions. Future research could focus on refining these models to account for a broader range of environmental factors, improving the accuracy of energy production predictions.

V. CONCLUSION

This study compares three different models used to evaluate the performance of photovoltaic (PV) panels during the cooling season in the Mersin region. The SANDIA, SIMPLE, and ONE-DIODE models were examined to determine how environmental factors affect the results. The findings indicate that the impact of each model on PV panel efficiency varies depending on environmental conditions and temperature fluctuations. The SIMPLE model consistently provided higher electricity production and efficiency across all months compared to the other models. In particular, during May and July, efficiency was higher due to the lower panel temperatures. This model, which operates more efficiently at lower temperatures, stands out as a viable option for enhancing PV panel efficiency during the summer months. The ONE-DIODE model yielded results similar to the SIMPLE model but generally produced slightly lower electricity generation and efficiency. In contrast, the SANDIA model demonstrated the lowest efficiency, especially under high-temperature conditions where greater power loss occurred. In conclusion, this research emphasizes the importance of selecting the correct model to optimize PV panel efficiency. The performance of PV systems is influenced by environmental factors such as temperature, wind speed, and solar radiation, and each of these factors can affect the accuracy of the chosen model. In this context, the SIMPLE model, due to its superior performance at lower temperatures, is deemed more suitable for hot climates such as Mersin. Future studies could further explore the performance of PV panels under different climatic conditions and develop more effective strategies to improve regional energy efficiency. This study contributes to enhancing the accuracy of models used to evaluate and optimize the performance of photovoltaic energy systems.

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