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Performance assessment of PVSyst-based grid-connected solar systems in Gharraf City, Iraq

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A B S T R A C T

Renewable energy is in high demand in many countries around the world because of the increased demand of energy and environmental issues associated with greenhouse gas emissions. Fossil fuels are still predominant in the USA but their sustainability in the long run cannot be truly guaranteed, which is why the transition to clean energy is necessary. The paper assesses the output of a 6 kW grid-tied photovoltaic (PV) system mounted in Iraq at Al-Gharraf City. The PVsyst software was used to perform the simulation to determine the annual energy generation, the system efficiency, and design optimization. The PV system proposed produces an annual energy of 9,192kWh with a yield of 1532 kWh/kWp/year. The average performance ratio of the calculated was 74.68% which means that the system can be operated reliably under the local climatic conditions. The essential novelty of the work is that it gives the indicators of real regional performances of small-scale grid-connected PV installations in southern Iraq, where not many evaluations have been documented so far. It is believed that the findings will be helpful in implementing solar energy in the future as well as assist in better technical planning of renewable energy projects in Iraq.

Keywords: Solar Power Systems, Fossil Fuels, Energy Management in Photovoltaic Systems, Performance, Solar Energy

1. Introduction

Electricity shortage has been experienced in Iraq which is largely because of its reliance on imported natural gas with Iran. Blackouts disrupt day-to-day activities particularly in seasons of high

temperatures which cause the closure of cooling systems, water supply unit and other essential services. These deficiencies have an adverse impact on community productivity, economic stability, and the general quality of life in the country [1, 2].

With the growing international interest in environmental pollution as well as the emission of greenhouse gases, most countries are currently abandoning the use of fossil fuels in power generation and instead turning to renewable forms of power generation. The solar photovoltaic (PV) systems have received much interest as far as the renewable capabilities are concerned due to their clean nature, reasonably straightforward maintenance and lasting sustainability [3]. PV systems directly transform solar radiation into electricity by employing semiconductor materials and it is one of the most rapidly expanding clean energy technologies in the world [4-6].

Regardless of the progress in the globe, there is variation in the use of solar energy. The southern provinces of Iraq have a great potential of solar radiation, but there is a lack of large-scale PV application. It is believed that the Rooftop photovoltaic systems can be a good solution to lessen reliance on the national grid supply and limit the impacts of power outages [7, 8]. Nevertheless, no practical studies of grid-connected PV system performance have been carried out under the local climatic conditions in Iraq.

This research aims to evaluate the performance of a 6 kW grid-tied PV system located in Al-Gharraf City, Iraq, using PVsyst simulation software. The study analyzes total annual energy generation, specific yield, performance ratio, and seasonal variation. The purpose is to provide technical insights that help support future PV system design and promote wider use of solar power in similar environments. [9,10].

2. Potential solar irradiation in Iraq

Iraq is famous for its lengthy hours of sunlight. According to studies, Baghdad alone in Iraq gets more than 3,000 hours of sunlight annually. The potential for solar radiation in Iraq is 2000 kWh/m2/year [11]. PV solar technology is suitable for the generation of power across Iraq due to the country's semi-uniform dispersion of sun radiation. The annual-daily average of global solar radiation in Iraq varies spatially from 4266 to 4700 Wh/m² in the northern region, from 4750 to 5000 Wh/m² in the middle and southern (flat plains) regions, and from 5378 to 5596 Wh/m² in the desert region and western plateau. Over 3000 hours of sun radiation are received by Baghdad annually [12].

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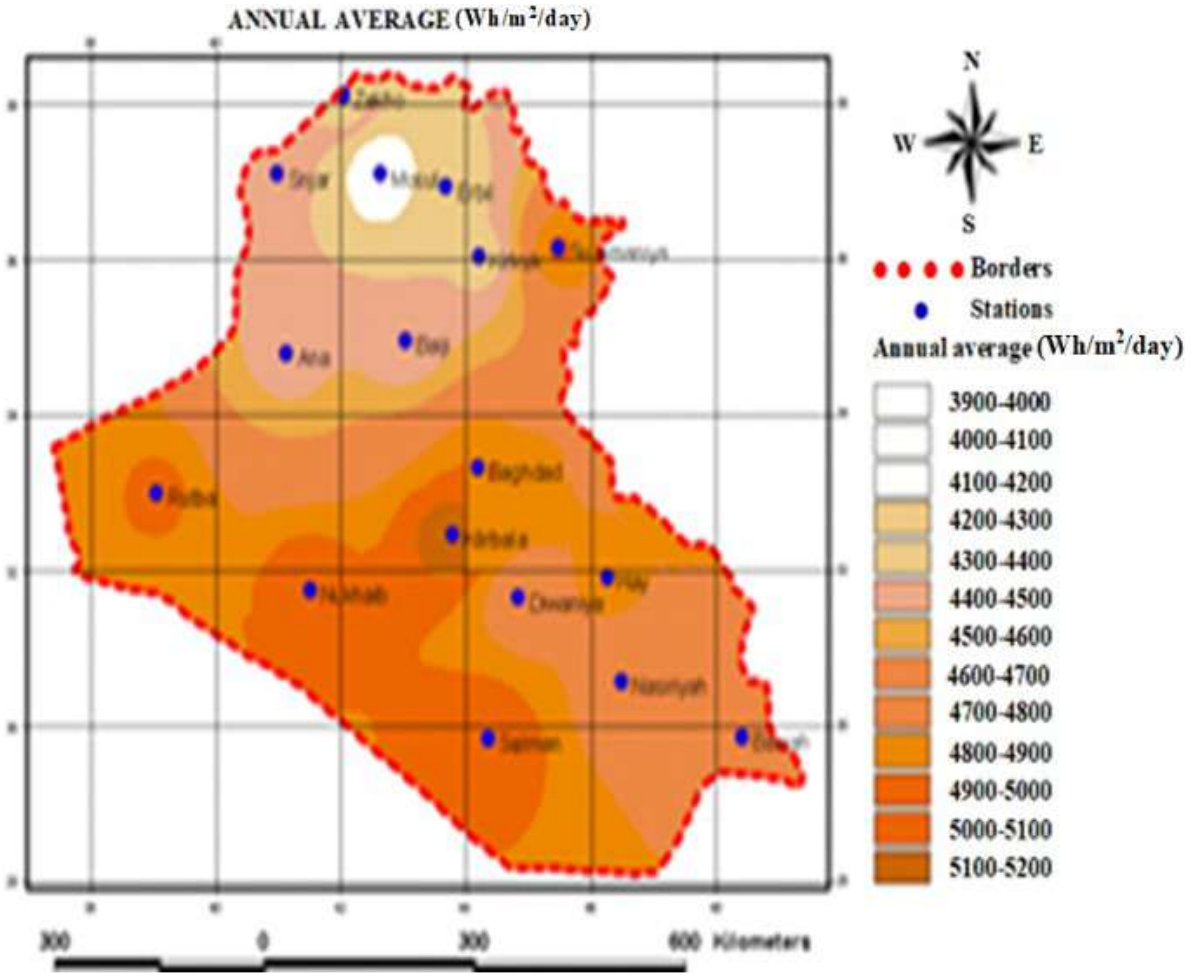

Figure 1. Variations in the total solar radiation falling on the horizontal surface of Iraq by year,[12].

3. Performance Parameters of PV-Systems

Performance evaluations are acknowledged by PV system experts as a standard for a successful PV system deployment [13] .Performance models are mathematical representations of the electrical output of PV systems in relation to the design, the components of the system, and the climate at the installation site. The many performance parameter types are covered in the next section, including the performance yields (array YA, reference Yr, and final Yf) and performance ratio (PR). [14-19]. Recent comprehensive reviews and advanced simulations [19-21]

Table 1. Designing an array using PV modules and inverters in Gharraf City.

PV module		**Inverter**	
Manufacturer	Aleo Solar	Manufacturer	Huawei Technologies
Model	Aleo-Elegante / 200	Model	SUN2000-5KTL-M1-400V
(Original PVsyst database)		**(Original PVsyst database)**	
Unit Nom. Power	200 Wp	Unit Nom. Power	5.00 kWac
Number of PV modules	30 units	Inverters number	1 unit
Nominal (STC)	6.00 kWp	Total power	5.0 kWac
Modules	1 Strings x 30 In series	Operating voltage	140-980 V
At operating cond. (50 °C)		Max. power (=>50 °C)	5.50 kWac
P mpp	5.40 kWp	Pnom ratio (DC:AC)	1.20
U mpp	588 V		
I mpp	9.2 A	**Total inverter power**	
		Total power	5 kWac
Total PV power		Number of inverters	1 unit
Nominal (STC)	6 kWp		
Total	30 modules		
Module area	45.6 m²	Pnom ratio	1.20

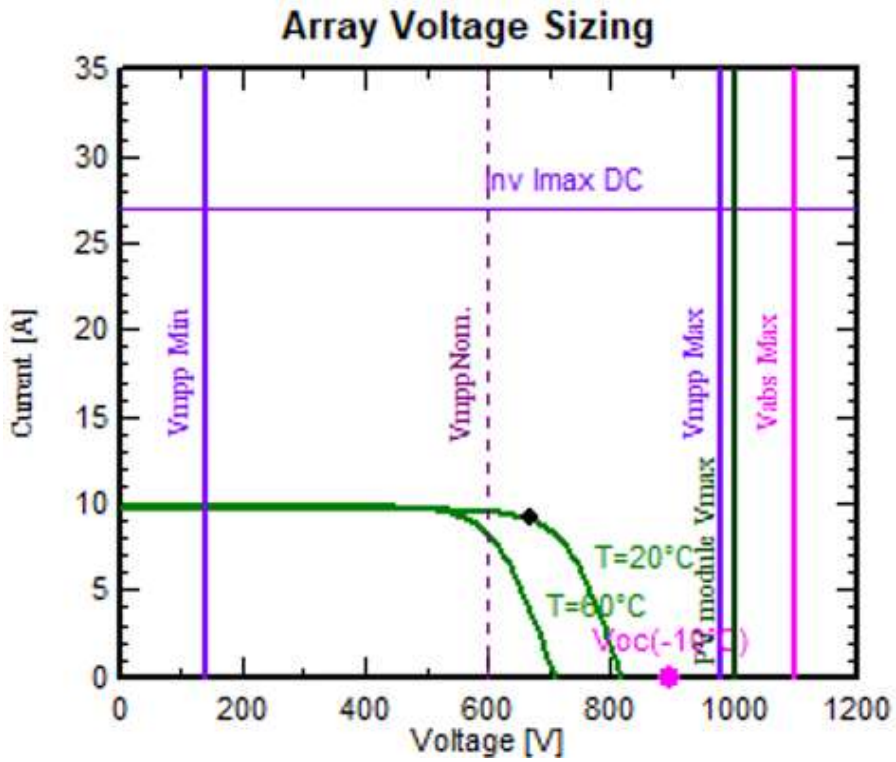

Figure 2. Photovoltaic Module Characteristics

Figure 3 illustrates the sun's daily trip across Gharraf city, which forms a golden arc in the sky. This tool can help engineers and researchers enhance how solar panels interact with the sun.

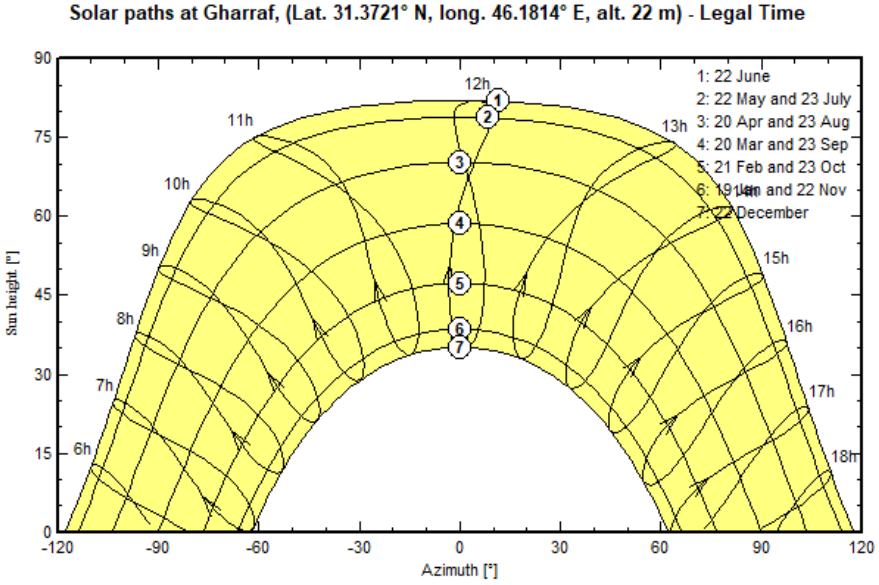

Figure 3. Sun route traveling direction.

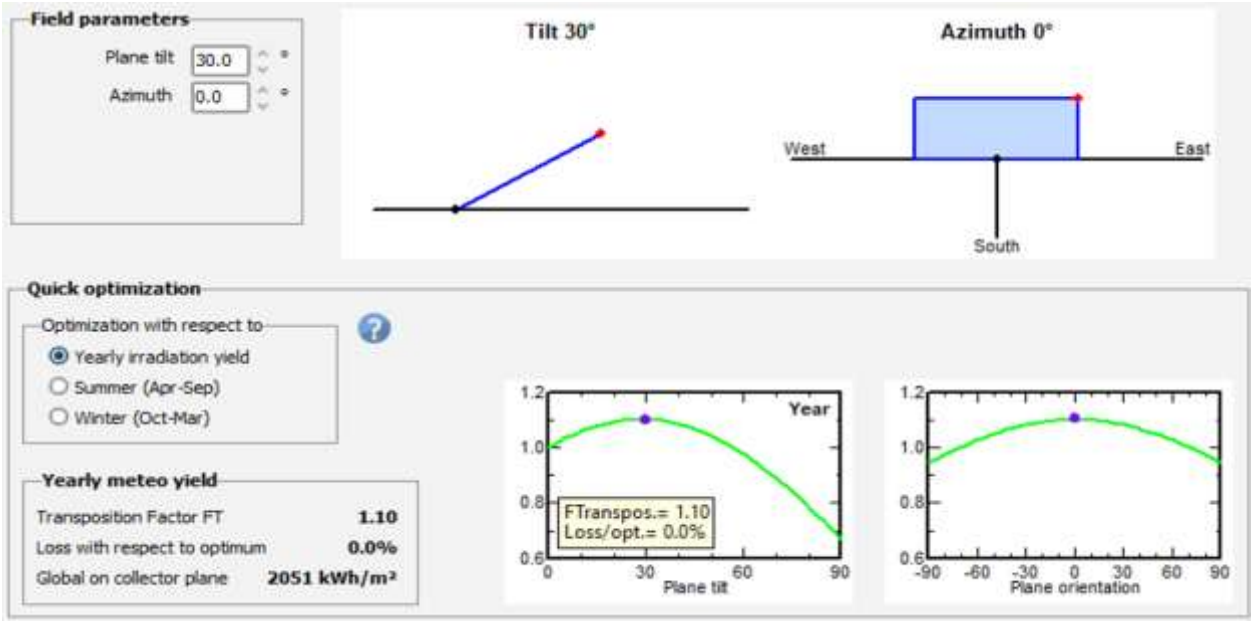

Figure 4. Choosing a 30° tilt angle and a 0° azimuth angle for Dhi Qar (Iraq) in ideal conditions with PVSyst

Research Gap:

Although previous research has investigated PV performance in Iraq, there is still a lack of applied performance evaluation for medium-scale rooftop grid-connected PV systems in Al-Gharraf and similar southern regions. Most existing works are either theoretical, focus on off-grid systems, or lack seasonal output analysis.

Novelty of This Study:
This study contributes by providing:

- A **complete performance assessment** of a 6 kW grid-tied PV system in Al-Gharraf City.
- **Simulation-based evaluation using PVsyst**, including energy yield, losses, and performance ratio.
- **Seasonal and environmental impact interpretation** under real local climate conditions.

4. Results and discussion

When evaluating energy generation, experts rely heavily on solar data. Analyses are conducted using meteorological records, particularly those pertaining to temperature and humidity. The normalised energy and performance ratios are shown in Figure 5. System loss and collection loss are the two categories of losses. Losses that only happen within the solar PV array are referred to as collection losses. Conversely, system loss describes losses that affect every part of the system, including cables and the inverter. The overall collection loss is estimated to be 1.24 kWh/kWp/day, whereas the expected system loss is 0.19 kWh/kWp/day. In addition, the system's performance ratio is 74.68%. demonstrating that it is functioning in advantageous circumstances.

This is written down in percentage terms as the ratio between actual energy produced and theoretical maximum. The annual PR dance in a particular place in AL Garraf City is demonstrated in figure 5(a).

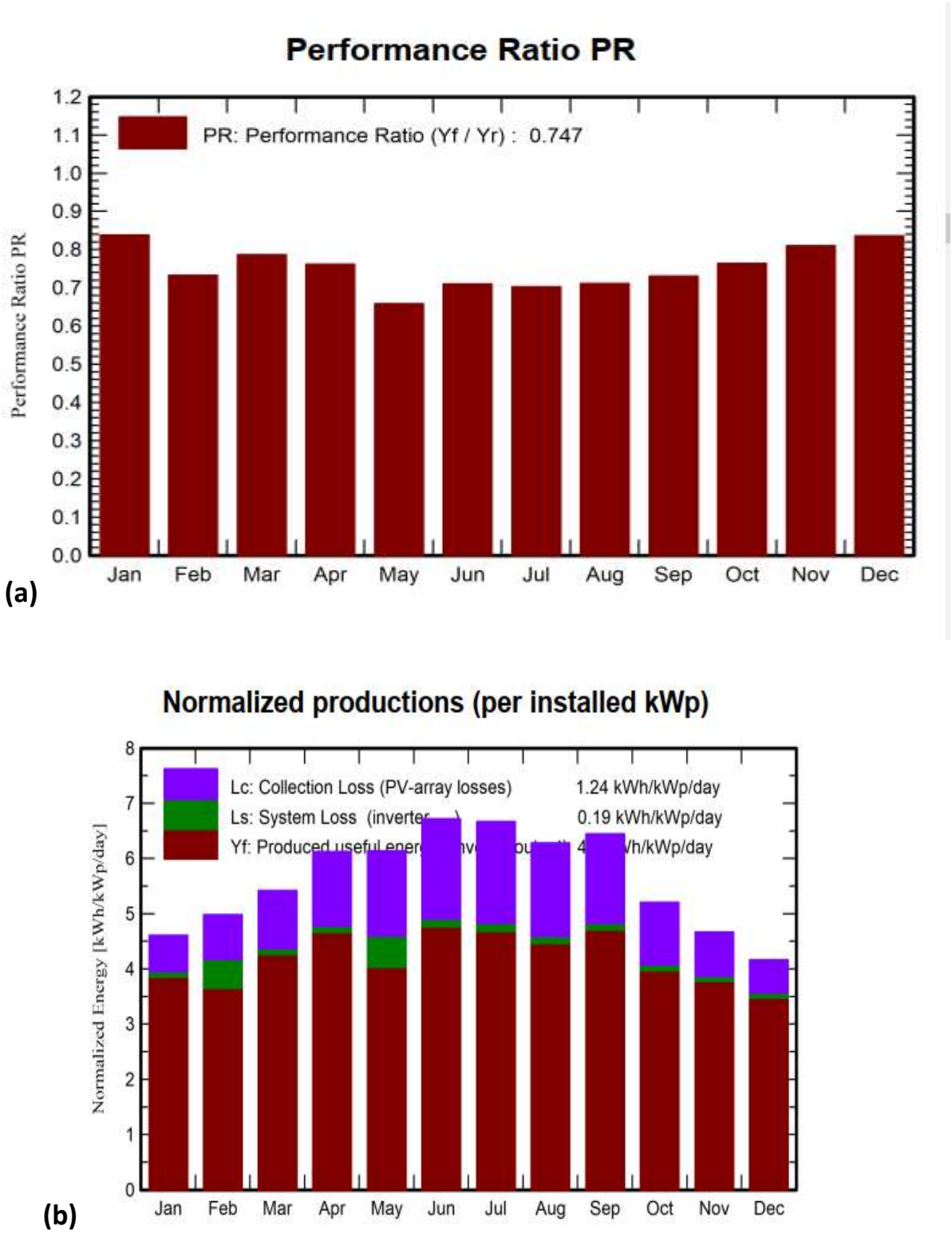

Figure 5. PV system performance evaluation results.(a) displays the Performance Ratio (PR) of the system, and (b) Normalized Monthly Production (NMP).

Table 2 shows a pretty unusual connection between grid-injected energy, PR, and climatic conditions of the proposed PV system. July has the highest energy intake at 872.2 kWh, while February has the lowest injection at 614.1 kWh. The system is capable of creating clean energy for households and businesses, as it generates 9192.4 kWh annually. An analysis of the Performance Ratio (PR) reveals a link between module temperature and relative humidity.

Table 2: Energy injected in the grid, as well as its PR ratio.

Month	E-Grid KWh	PR ratio
January	718.1	0.838
February	614.1	0.733
March	793.7	0.787
April	839.7	0.762
May	750.9	0.658
June	858.9	0.710
July	872.2	0.703
August	830.9	0.711
September	847.4	0.730
October	739.2	0.763
November	679.9	0.810
December	647.3	0.836

Table 3 shows meteorological data obtained for the Gharraf City location from the Meteonorm 8.1 database, which includes the most recent and up-to-date climatic periods. The database was incorporated into PVsyst software, guaranteeing that simulations for this location match current climatic conditions.

Table 3: The mean of the monthly climatic data of Gharraf

Month	**GlobHor** KWh/m^2	**DiffHor** KWh/m^2	**T-Amb** C^o	**Wind Velocity m**/s
January	98.4	44.9	12.07	1.89
February	109.4	56.2	14.81	2.31
March	148.2	79.3	20.41	2.40
April	177.3	91.3	25.88	2.59
May	199.5	103.2	33.48	2.69
June	.2194	101.0	37.15	3.60
July	221.1	97.1	39.31	3.30
August	194.7	97.0	38.66	2.79
September	172.5	69.5	33.67	2.29
October	132.1	66.9	27.80	1.80
November	101.5	48.4	18.78	1.70
December	88.5	43.7	13.39	1.80
Year	1862.7	898.5	26.35	2.4

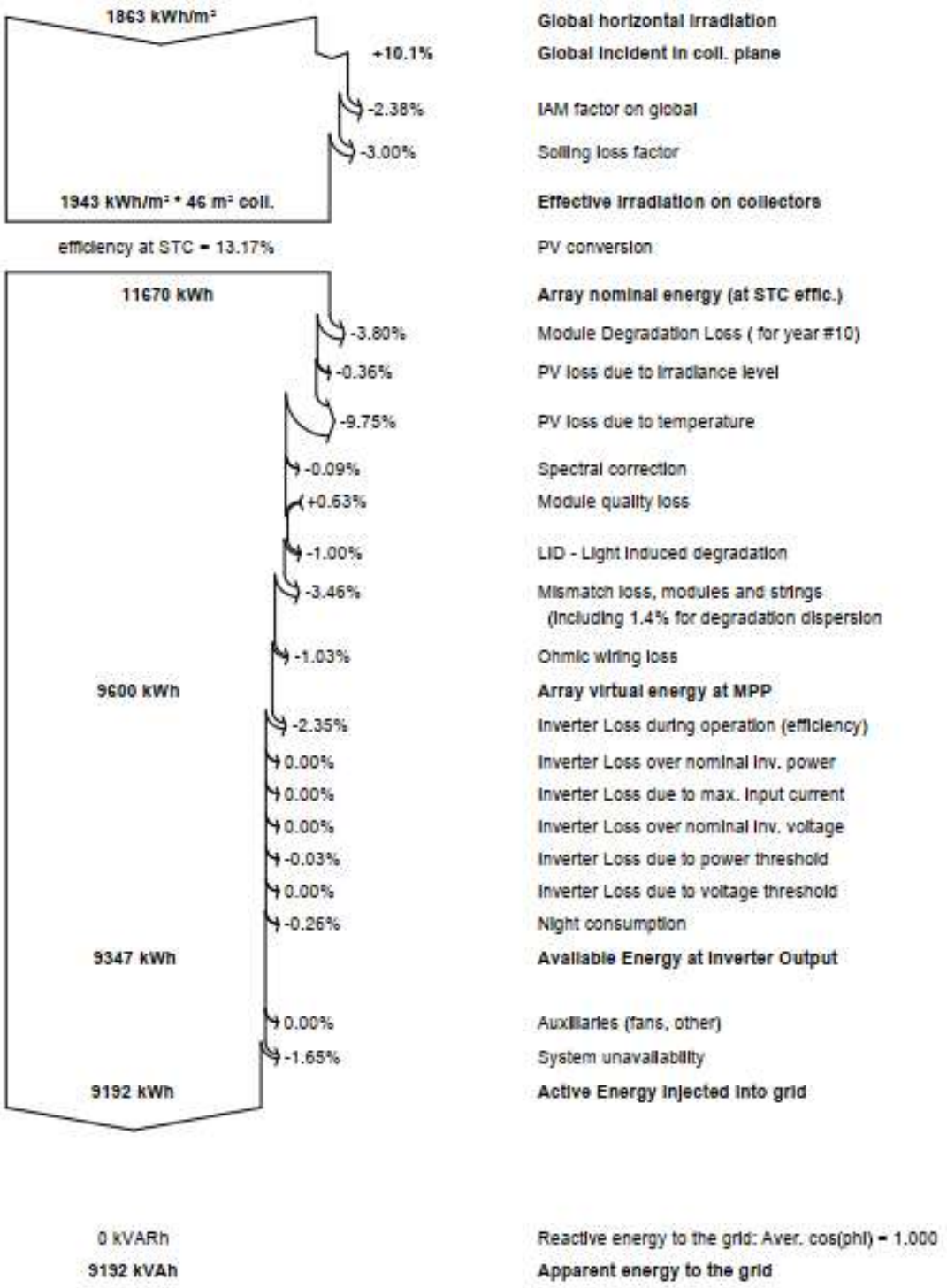

Figure 6. Diagram depicting the system's annual losses

an overall energy production of 898.5 kWh, with around 872.2 kWh of energy still being added to the system. A crucial indicator of PV systems' dependability and efficiency is PR. The present system's average yearly PR is 74.68 percent.

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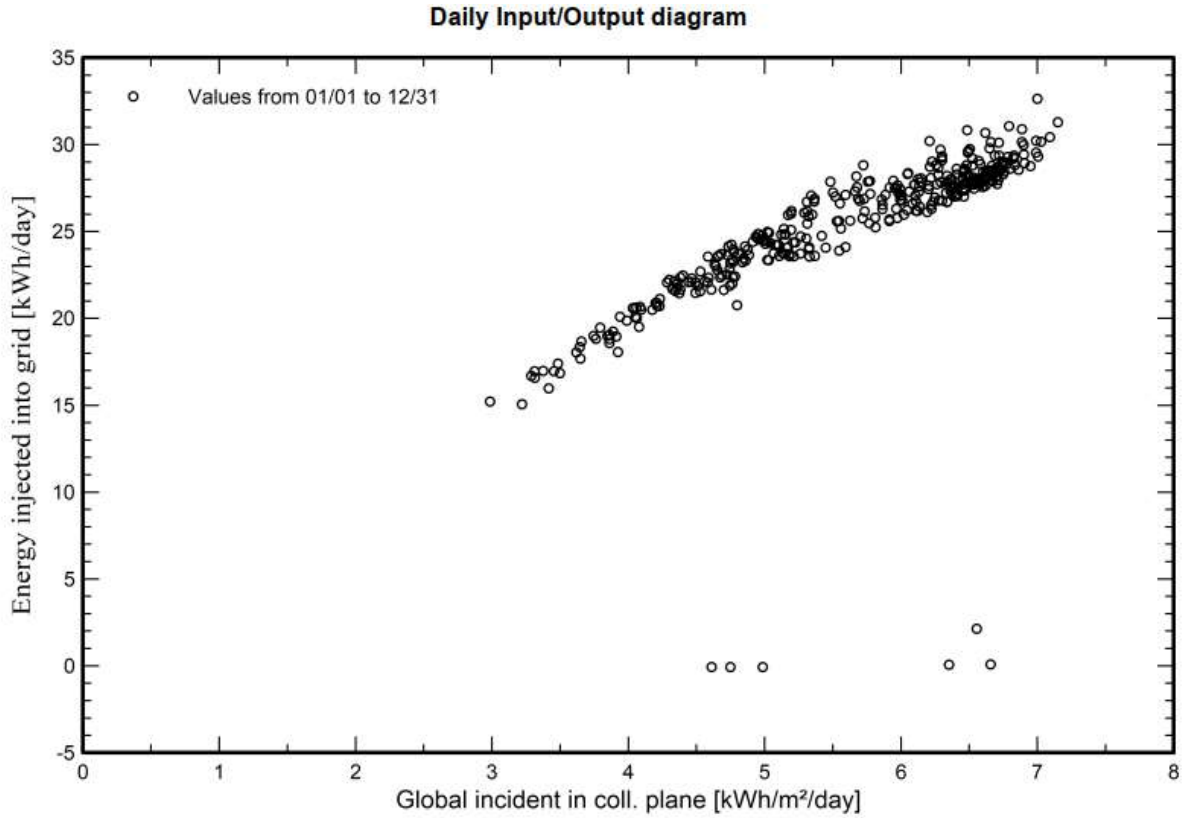

Figure 7. It displays a daily graphic of the projected PV system's incoming and outgoing energy.

5. Conclusions

The Dhi Qar governorate has a sufficient amount of solar fuel, according to the present research, underscoring the need for solar PV projects as a practical way to offer electricity to residences that are off the grid. According to the statistics, the yearly performance ratio was around 74.68 percent, and the total losses were 1.24 kWh/kWp/day. Based on the conclusions of the present research, it can be stated that, despite the greater ambient temperatures during the summer season.

The environmental or anthropogenic factors, including the favorable global irradiation of the city, which is 1862.7 kWh m -1 yr -1, with minimal photovoltaic loss due to ambient temperature of 26.35 C being an added key factor in determining the maximum efficiency of the Dhi Qar solar system. Following the results of the current research, it will be possible to create a solar power station with the least number of losses, the best performance ratio, and the choice of the best photovoltaic cells and inverters in the place of high location.

References

[1] Istepanian, Harry. (2014). Iraq's Electricity Crisis. The Electricity Journal. 27. 10.1016/j.tej.2014.04.006.

[2] Salman, H. M., Pasupuleti, J., & Sabry, A. H. (2023). Review on causes of power outages and their occurrence: Mitigation strategies. *Sustainability*, *15*(20), 15001.

[3] Nawar, M. F., & Türler, A. (2022). New strategies for a sustainable 99mTc supply to meet increasing medical demands: Promising solutions for current problems. *Frontiers in chemistry*, *10*, 926258.

[4] Belaïd, F., Al-Sarihi, A., & Al-Mestneer, R. (2023). Balancing climate mitigation and energy security goals amid converging global energy crises: The role of green investments. *Renewable Energy*, *205*, 534-542.

[5] Bogdanov, D., Ram, M., Aghahosseini, A., Gulagi, A., Oyewo, A. S., Child, M., ... & Breyer, C. (2021). Low-cost renewable electricity as the key driver of the global energy transition towards sustainability. *Energy*, *227*, 120467.

[6] International Energy Agency, Renewables 2022-Analysis and Forecast to 2027, 2022.

[7] Solar Power Europe, Global Market Outlook for Solar Power 2023-2027, 2023.

[8] Ates, A. M., & Singh, H. (2021). Rooftop solar Photovoltaic (PV) plant–One year measured performance and simulations. *Journal of King Saud University-Science*, *33*(3), 101361. https://doi.org/10.1016/j.jksus.2021.101361.

[9] Ali, W. A. R. (2024). Solar energy in Iraq: potential and new technologies. *Samarra Journal of Engineering Science and Research*, *2*(2), 43-53.

[10] Tahri, F., Tahri, A., & Oozeki, T. (2018). Performance evaluation of grid-connected photovoltaic systems based on two photovoltaic module technologies under tropical climate conditions. *Energy Conversion and Management*, *165*, 244-252. https://doi.org/10.1016/j.enconman.2018.03.065

[11] Hersch, P., & Zweibel, K. (1982). *Basic photovoltaic principles and methods* (No. SERI/SP-290-1448). Solar Energy Research Inst.(SERI), Golden, CO (United States).

[12] Muneer, Solar Radiation and Daylight Models, 2nd edition., Elsevier Ltd; 2004.

[13] Li, C. (2018). Comparative Performance Analysis of Grid-Connected PV Power Systems with Different PV Technologies in the Hot Summer and Cold Winter Zone. *International Journal of Photoenergy*, *2018*(1), 8307563.

[14] Mašić, F., Džemić, Z., & Šarić, M. (2024, June). Effect of Measurement Uncertainty on PV Output Power Estimation. In *International Symposium on Innovative and Interdisciplinary Applications of Advanced Technologies* (pp. 749-765). Cham: Springer Nature Switzerland.

[15] Hashemian, N. and A. Noorpoor. (2023). Thermo-eco-environmental investigation of a newly developed solar/wind powered multi-generation plant with hydrogen and ammonia production options. Journal of Solar Energy Research, 8(4), 1728–1737.https://doi.org/10.22059/jser.2024.374028.1388.

[16] Bouzida, Y., Chehhat, A., Si-Ameur, M., & Arrif, T. (2025). Computational Analysis of Radial Turbine Design and Performance for Renewable Power Generation in Solar Chimney. *Journal of Solar Energy Research*,

[17] WAHILE, G. S., Londhe, S. D., MALWE, P. D., & Shaik, F. (2025). A review on cooling techniques for performance improvement of solar photovoltaic systems. *Journal of Solar Energy Research*.

[18] Jyani, L., Chaudhary, K., Purohit, K., & Sharma, S. (2025). Sustainable Cooling Technique for Maximizing Performance of Photovoltaic Panel in The Hot Climate of Rajasthan. *Journal of Solar Energy Research*, *10*(Emerging Trends in Photothermal Conversion for Solar Energy Harvesting), 56-71.

[19] Znaki, F. Z., Said, K., Znaki, J., Adadi, M., Moustabchir, H., Chtita, S., ... & El Khattabi, S. (2025). Enhancing the Photovoltaic Performance of lead-free CH3NH3SnBr3 Solar Cells via Compressive Strain Engineering: A Numerical Investigation. *Journal of Solar Energy Research*, *10*(3), 2475-2490.

[20] Abdul Rahiman, B., Jayaraj, J., & Rajasekaran, M. (2025). Performance Enhancement of Photovoltaic System Using Nature Inspired Optimization Algorithms. *Journal of Solar Energy Research*, *10*(2), 2415-2436.

[21] Chiteka, K., & Enweremadu, C. (2025). A Review on Modeling and Prediction of Soiling on Solar Photovoltaics and Thermal Collectors. *Journal of Solar Energy Research*.