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Conference paper

Analysis of the efficiency of a Solar Photovoltaic Power Plant linked to the electrical grid

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ABSTRACT

The growing need for energy in emerging nations gives rise to apprehensions over energy security, so underscoring the criticality of harnessing the potential of renewable resources. Empirical evidence has demonstrated that photovoltaic systems integrated into the network are the optimal options for large-scale renewable energy. The analysis of the performance of these network-connected centrals can enhance the design, operation, and maintenance of new systems. The commissioning of a 12 MW photovoltaic solar power plant in Sidi Bel Abbès, located in the Dhaya region, has established it as one of the largest solar power plants in Algeria. The site yields a mean solar radiation of 5.21 kilowatt-hours per square metre per day and an average yearly temperature of 18.9 degrees Celsius. The present work provides an analysis of the yearly performance and conceptual aspects of the photovoltaic central unit. We compare the performance outcomes of the power plant with the simulated values generated by the SolarGis PvPlanner program. Analysis of real-world performance in relation to simulations allows for the detection of inconsistencies and the enhancement of future initiatives. SolarGis PvPlanner is an essential modelling program for accurately forecasting performance and effectively strategising solar projects, therefore guaranteeing sustainable and dependable energy for the future.

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1. INTRODUCTION

Researchers Scientists are doing research on alternative energy sources in order to address the worldwide energy demand, mitigate climate change, and reduce reliance on fossil fuels (Majeed, 2023). Solar energy is considered to be a highly promising and environmentally friendly solution (Mason & Kumetat, 2011). Algeria's advantageous geographical position and abundant solar resources position it as a leading producer of solar energy. Algeria possesses a substantial solar power capacity, boasting an annual sunshine duration over 2,000 hours and reaching up to 3,900 hours in certain areas (Rahmane et al. 2019). Algeria has the potential to leverage its abundant solar irradiation in order to capture renewable energy sources, so contributing to the global shift towards sustainability (Stambouli, 2011). Algeria constructed a 12 MW solar photovoltaic power plant that is connected to the grid, in order to meet its increasing energy demands with environmentally friendly and sustainable power. The practicality and effectiveness of solar photovoltaic systems in Algeria's energy landscape are demonstrated by the successful operation of a power station (Saiah & Stambouli, 2017). An exhaustive assessment of performance is essential to attain maximum utilisation and efficiency of solar power plants. This study assesses the energy generation, power dissipation, temperature effects, and system efficiency across various climatic conditions (Sharma & Chandel, 2013). Gaining insight into the operational efficiency of the 12 MW solar photovoltaic power plant can contribute to the development, management, and upkeep of grid-connected systems in Algeria and other regions (Saleheen et al. 2021). Assessing this solar photovoltaic power plant that is connected to the grid improves renewable energy technologies and positions Algeria as a trailblazer in sustainable energy generation. It promotes an environmentally conscious and enduring future (Bouraiou et al. 2020). The objective of this study is to conduct a comparative analysis of the actual data obtained from a 12 MWp solar photovoltaic power plant coupled to the grid, and the simulated data generated by SolarGis planner.

2. REVIEW OF THE SOLAR PHOTOVIDEIC-GRID SYSTEM

2.1 Geographical location of the site

With a 12 MW capacity, the Dhaya Photovoltaic Power Plant is situated near Sidi bel Abbes, Algeria (Fig 1). Its coordinates are -0.6″ N, 34.69″ E, and 1329 m (Bouzid et al. 2015).

Fig 1. Dhaya solar photovoltaic power plant

2.2 Architectural arrangement of plants

The power station spans an area of 33.59 hectares and generates a total power output of 12 MW. This component of the facility is divided into six skids. The total combined output capacity of all six skids is 12 MW, with each skid capable of producing around 2 MW per cycle. Each skid is equipped with approximately 7,868 solar panels. This vast array of solar panels is further divided into 329 parallel threads, with each thread consisting of 24 panels linked in series. These strings are configured to connect the two Sunny Central 800-900 CP XT inverters.

2.3 Plant specification

Usually, the applied methodology, data, and tools are presented in section 2. If numerical investigations are performed, the applied approach should be validated.

The solar power facility in Dhaya utilises HSL60-PB-1-250 polycrystalline silicon solar panels, which are characterised by a stationary arrangement and a 15% efficiency rating. The panels, which are capable of functioning within a temperature range spanning from -40°C to +80°C, produce a short-circuit current (I_sc) of 8.79 A and an open-circuit voltage (V_co) of 37.7 V. Consistent bi-monthly cleaning is essential for achieving optimal performance. Moreover, the power conditioning units are furnished with an 880 kW inverter, which enables the transformation of direct current (DC) into alternating current (AC) (Jbilou et al. 2018). This conversion is crucial for a range of applications, including solar panels. The inverter produces an alternating voltage of 360 V and an output current of 1411 A, using a DC input current of 1270.9 A and a PV voltage of 1000 V. The panels exhibit a 35-degree inclination and a southward azimuth angle of -6 degrees. A nearby weather station allows for the continuous monitoring of real-time data, encompassing information on wind, temperature, and solar radiation. Within the control room, a specialised server, outfitted with SCADA software, meticulously records comprehensive data on voltage, current, and inverter power production on a minute-by-minute basis. This technology enhances operational efficiency by streamlining data retrieval and analysis, hence optimising plant performance (Kumar & Sudhakar, 2015).

2.4 System parameters

The performance of a PV solar farm is assessed using the metrics listed below, in accordance with IEC 61724 and additional literature (Marion et al. 2005; Ayompte et al. 2011):

Array Efficiency: $\eta_A = E_{DC}/H_T$ (1)

Inverter Efficiency: $\eta_{inv} = P_{AC}/P_{DC}$ (2)

System Efficiency: $\eta_{sys}T = \eta P_{VT}/\eta_{int}T$ (3)

Array Yield: $Y_A = E_{DC}/P_0$ (4)

Reference Yield: $Y_R = H_T/G_0$ (5)

Final Yield: $Y_F = E_{AC}/P_0$ (6)

Performance Ratio: $P_R = Y_F/Y_R$ (7)

Capacity Factor: $C_F = E_{AC}/(P_0 \times 24 \times 365)$ (8)

3. RESULTS AND DISCUSION

Solar panels harness solar radiation to generate practical energy, with power production influenced by both ambient temperature and solar irradiative intensity. The impact of irradiance on the electrical generation of the Dhaya power plant is depicted in Figure 2(a), which displays the average output during the peak and nadir days of the year. The data shown in Figure 2(b) Shows that the sun irradiation indicates that the electricity generation in June surpasses that of December.

Remote Control and Data Acquisition (SCADA) software is used to manually collect energy generation data. The month of August exhibited the largest energy output, with 2181.5 MWh, while December had the lowest production, measuring 1605 MWh. An aggregate energy production of 22339 MWh was documented for the year, as shown in Table I.

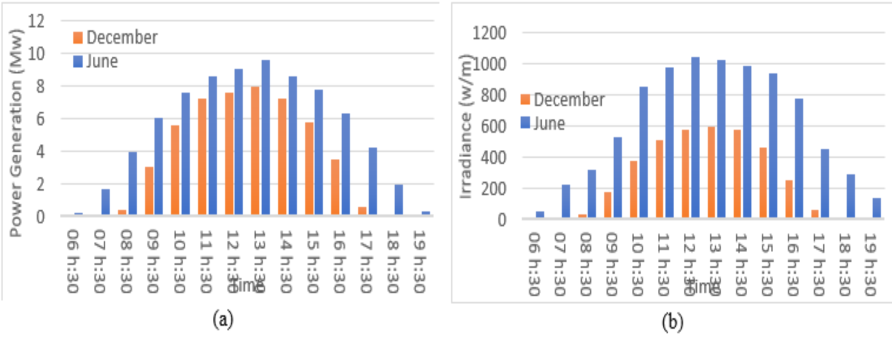

Fig 2. (a) Power generation difference between July and December (2023), (b) Irradiance difference between July and December 2023.

Table 1. Energy generation

M O NTH S	Mean Daily Energy Generation (Milowatt-Hours)	Monthly Energy (Milliwatt-Hours)
June	70.626	2118.8
July	67.203	2083.3
August	70.626	2181.5
December	38.492	1193.27
January	38.980	1208.4

3.1 Simulation USING SolarGis planner

3.1.1 SolarGis planner

The Solar GIS is a specialised geographic information system designed to meet the specific requirements of the solar energy industry (Tarigan et al. 2014). Through the integration of meteorological and solar resource data into a web-based application system, this platform provides extensive support for the design, development, and management of solar energy systems.

3.1.2 Monthly statistics

Table 2 provides the theoretical estimates of the average monthly and yearly PV electricity production, without considering long-term degradation and performance losses of the system. The monthly specific PV production (per installed kWc) ranges from 117.3 kWh/kWc in December to 163.1 kWh/kWc in July, with a yearly average of 1,737.0 kWh/kWc. The monthly total PV production (for the 12,000 kWc installed capacity) fluctuates between 1.408 GWh in December and 1.957 GWh in July, for an average annual production of 20.844 GWh. The monthly performance ratio (PV system efficiency) goes from 75.8% in July to 85.9% in January, with a yearly average of 80.7%. This table thus allows estimating the theoretical monthly and yearly PV generation potential of the project, with the summer months (June to August) being the most productive.

Table 2. Monthly statistics

Months	Energie specific monthly sum kWh/kWp	Energie spcific daily sum Wh/kWp	Energie total Monthly sum MWh	Energie total share	PR
Januray	123.9	3992.1	1487	7.12	86.1
February	128.0	4558.2	1533	7.38	85.0
March	154.1	4957.8	1846	8.87	83.0
April	153.3	5116.3	1845	8.81	81.3
May	160.5	5157.4	1920	9.22	79.5
June	158.9	5288.1	1906	9.16	77.6
July	163.7	5262.5	1960	9.41	75.9
August	159.9	5152.3	1918	9.21	76.4
September	152.3	5061.7	1823	8.76	79.1
October	147.8	4750.2	1769	8.50	81.7
November	121.6	4043.9	1457	7.00	84.7
December	117.6	3786.7	1410	6.77	85.6
Total	1737	4760.6	21873.96	100	80.7

3.1.3 Loss diagram

Fig.3 shows in a diagram form the different theoretical energy losses in the considered photovoltaic system. It starts from the theoretical global horizontal irradiation of 1,883.1 kWh/m2 which, after taking all the losses into account, leads to a total system performance of 1,737.0 kWh/kWp. The main losses come from soiling and dust (3.5%), angular reflectivity (2.3%), radiation to DC conversion (6.1%), DC mismatches (2.3%), DC/AC conversion (2.9%) and transformers/AC cabling (1.4%). The technical availability also induces 0.5% loss. This diagram allows simply visualizing the distribution of the different losses in the photovoltaic system and identifying the weak points to optimize the overall efficiency, here very good with 80.7%.

3.2 Performance comparison

Table 3 provides a summary of the comparison between the outcomes of the monitored SCADA data system and SolarGis planner. It is clear that throughout the course of the year, the real performance closely matches the simulated performance of SolarGis planner.

Table 3. Performance comparison

M O NTH S	SolarGis planner	Monitored result (MWH) 2023
June	1903	2118.8
July	1957	2083.3
August	1915	2181.5
December	1408	1193.27
January	1485	1208.4

Table 3 illustrates a strong correlation between the real energy output and the predictions made by Solar GIS simulations. However, there is a tiny decrease in energy production during winter and a slight increase during summer. The observed periodical variation can be attributed to the correlation between energy production and the presence of sunlight, which is more abundant in the summer, as well as the decline in temperature during the winter season. Notwithstanding, the display's performance ratio exceeds that of the simulations. The findings of this study suggest that simulations may reveal a modest inclination to overestimate the generation of photovoltaic energy, maybe due to the existence of somewhat inaccurate climatic data.

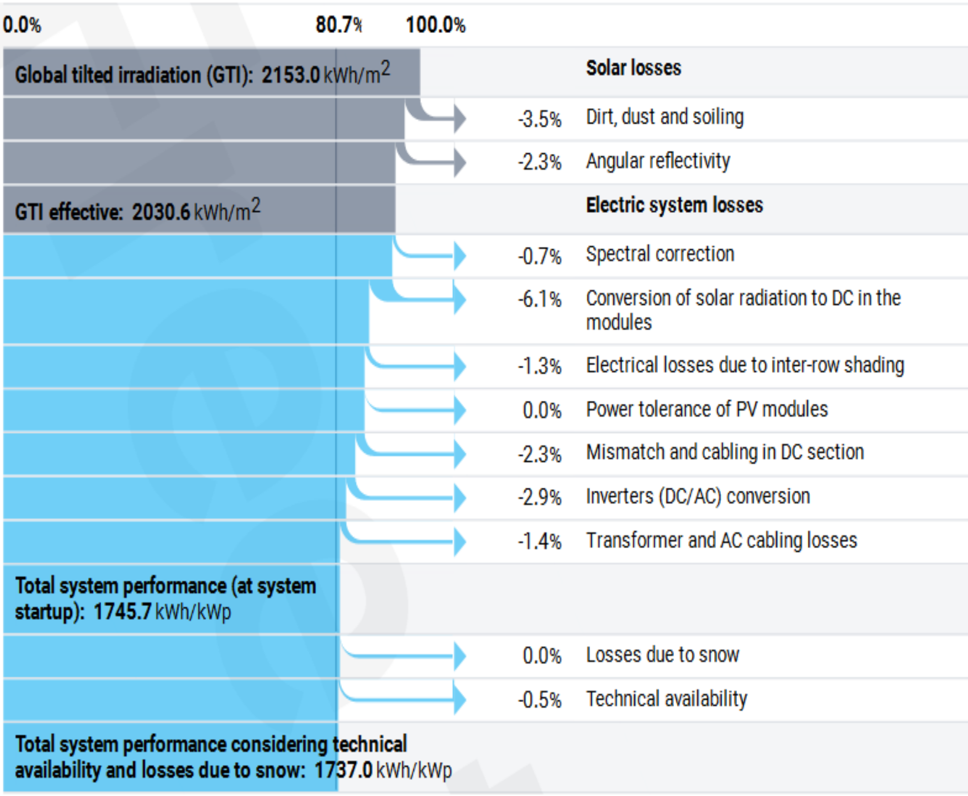

Fig.3. Loss diagram

4. CONCLUSION

This paper presents a yearly performance analysis of a grid-connected 12 MW peak power solar photovoltaic plant situated in Sidi Bel Abbess, Dhaya region. The study yielded the subsequent findings:

- A high peak power of 11.66 MW and a minimum power of 54 kW were recorded throughout the operational year (2023).
- When comparing the monitored data with the simulation results from the SolarGis planner, the plant's actual energy generation is close to the values predicted by the modeling software.
- The plant's maximum total energy generation of 2181.5 MWh was observed in August, while the minimum total energy generation of 1193.27 MWh was observed in December.

NOMENCLATURE

P_0	Peak Power (kWp)	E_{DC}	Direct Current Energy
H_T	daily irradiation (kWh/m2)	E_{AC}	Alternating Current Energy

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