A Comparative Experimental Study between a Fixed, One, and Two-Axis Tracker Solar Panels in the Sidikhouiled Region (Southern Algeria)

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Abstract

Photovoltaic modules or panels are made up of semiconductors that allow sunlight to be directly transformed into electricity. These modules can prove to be a source of energy that is safe, reliable, maintenance-free, and non-polluting for a very long time.

The majority of modules on the market today come with warranties longer than 20 years, and they will perform well beyond that time. In this paper, an experimental study of different solar trackers and their impact on the performances of a photovoltaic module was investigated in SidiKhouiled region, South-East of Algeria,

The results showed that the marginal temperature difference between the one- and two-axis trackers suggests a potential preference for the cost-effective monopolar option. During the period from 12:00 to 13:00, the presence of light, high-type clouds is observed.

Notably, the curves for the one- and two-axis trackers closely align, suggesting the potential exclusion of the more expensive bipolar tracker in favor of the cost-effective monopolar tracker. This decision is based on an economic assessment (LCOE) using SAM software.

Keywords: Solar panels, Photovoltaic, Economic assessment, LCOE, Solar tracking

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1-Introduction:

The ever-increasing consumption of fossil fuels poses a grave threat to our planet due to the resulting environmental pollution and climate change, including the ominous specter of global warming. In 2021, global oil consumption surged to approximately 94.1 million barrels per day, reaching 99.98 million barrels, highlighting the finite nature of these exhaustible energy sources. Consequently, substantial efforts are being made to transition towards renewable and inexhaustible energy options, such as solar, wind, and water energy. Among these alternatives, solar energy stands out as a key renewable resource. The sun, emitting energy with a flux density of around 63 m2/kW, showers the Earth with an astonishing 1014 x 1.7 kW, equivalent to about 10,000 times the global energy demand. Recognizing this immense potential, significant endeavors are underway to harness solar energy for various applications. [1-3]. In the remote agricultural landscapes of southern Algeria, the unavailability of convenient energy sources, compounded by the absence of nearby electrical grids and the high cost of available options, has led many land reclaimers to turn to solar energy. Utilizing photovoltaic panels to satisfy their electrical energy needs, these systems operate on the principle of converting incident solar radiation into electrical energy, as proposed by Miral and Dincer in 2011 [4]. Originally developed for space applications, solar panels have become more accessible and efficient due to rapid technological advances in recent decades, making them a feasible investment for on-grid and off-grid electricity generation. Efforts to enhance the efficiency and performance of photovoltaic panels while reducing costs are ongoing [5–8]. One notable approach involves the use of motorized mounts that enable solar panels to dynamically track the sun's movement. This tracking system optimizes the angle of incidence, a crucial factor influencing panel performance. Fixed mounts, by contrast, often result in suboptimal incidence angles, particularly during the early morning or late afternoon hours. Robotic mounts with tracking mechanisms, employing either light sensors or programmable logic controllers, have been developed to address this issue [9–12].

Keskin et al. 2021, showed that the energy loss caused by the shading effect will reach up to power in MW scale when considered since photovoltaic energy systems have lifetime up to 30 years. [13].

Maftah et al. 2019, presented a comparison of two mathematical models of photovoltaic modules, namely: a Real Photovoltaic model and an Improved Photovoltaic Model. [14].

Benghanem et al. 2023, demonstrated that for high solar irradiation, the polycrystalline PV module experiences a smaller decrease in output power than the monocrystalline PV module as the module temperature increases. [15].

Hosseini et al. 2011, considered the combination of a PV system equipped with cooling system consisting of a thin film of water running on the top surface of the panel with an additional system to use the hot (or warm) water produced by the system. [16].

Mani et al. 2010, provided an appraisal on the current status of research in studying the impact of dust on PV system performance and identifies challenges to further pertinent research. [17]

Kasim et al. 2021, proposed an experimental study to analyze and evaluate the power efficiency of a PV system installed in Baghdad city, Iraq. [18]

Al-Odat et al.2022, found that the electrical efficiency and the productivity of the PV modules were approximately enhanced by 14%. Therefore, water cooling of the PV modules is essential to enhance their performance. [19]

Mussardet al. 2018, detailed the perspective the recent uses of solar PV installations under arid climates with the evolution of PV technologies [20].

Kazem et al. 2021, found that most of the dust of Sohar city consists mostly of sand (65%) coming from the Empty Quarter desert adjacent to the Al-Batinah region [21].

Research work on the photovoltaic axis is numerous, as well as the exploitation in PV systems in arid environments has become of major importance, therefore experimental study will be necessary on this type of renewable energy.

The novelty of this work is to focus on comparing the production and cost analysis of a photovoltaic energy source using fixed solar panels versus a sun-tracking solar panel system in the SidiKhoulid Ouargla region (Algeria). Through this comparison, the goal is to provide valuable insights into the efficiency, performance, and economic aspects of solar energy generation in this particular geographical context.

2. Study Methodology

The experimental study took place in the SidiKhouilid Ouargla region, located approximately 800 km away from the Algerian capital. This region is characterized by a dry climate, with a desert climate profile marked by predominantly clear skies throughout most of the year and intense solar radiation. (See figure 1).

Figure 1. Location of the studied system.

Experimental setup

In this study, three solar panels were employed: the first one fixed, the second equipped with a one-axis tracker, and the third featuring two-axis trackers. On each structure, we installed a multi-crystalline solar panel with a capacity of 55 watts. The fixed structure is oriented towards the south at an angle of 32 degrees, which roughly corresponds to the width of the Ouargla region.

The panel type is TE 500 P and contains 36 cells in series, broken down into 4 columns (9 cells in each column). The cell is square, 95 mm x 95 mm, and the panel is 1003 mm x 463 mm (see figure 2).

Figure 2. Overview of the experimental system studied

The table 1 below illustrates the electrical attributes of the photovoltaic solar panels employed in the study:

Table 1: Electrical Characteristics of Utilized Photovoltaic Solar Panels.

Peak power P_{max}	55 Wc
Short-circuit currentI_{sc}	3.5 A
Open-circuit voltage V_{oc}	22.2 V
Currentat $P_{max}I_{mpp}$	3.14 A
Voltage at $P_{max}V_{mpp}$	17.5 V

On May 21, 2023, the solar panels were evaluated and monitored for performance under uniform climatic conditions. The results, showcased in the following figures, depict the changes in solar radiation intensity experienced by each solar panel throughout different periods of the day.

3. Results and Discussion

Figure 3 displays the variations in solar radiation intensity impacting individual solar panels at different times of the day.

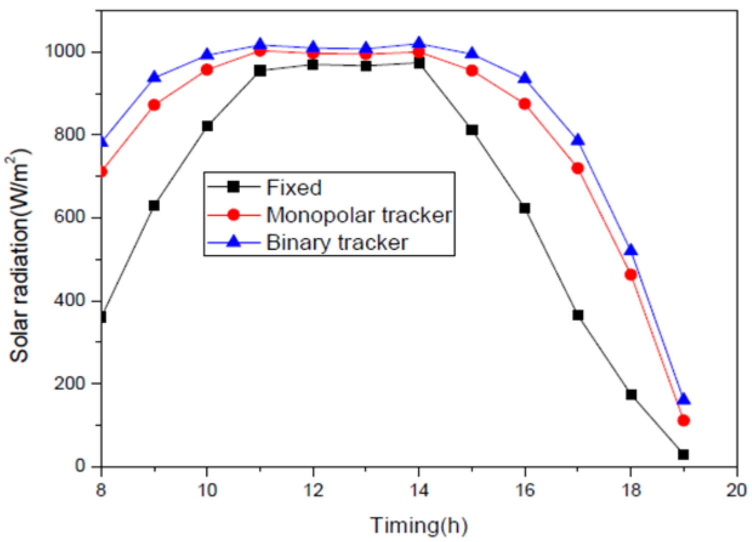

Figure 3. Daily variation of solar irradiation.

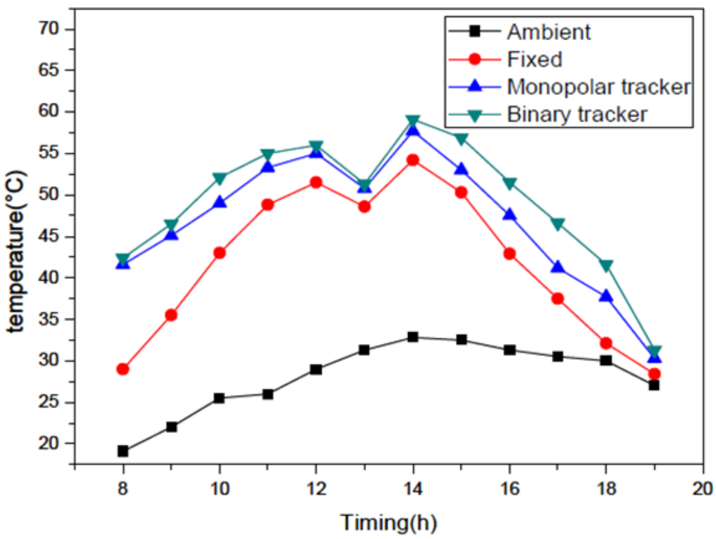

Figure 4. Daily variation of temperatures.

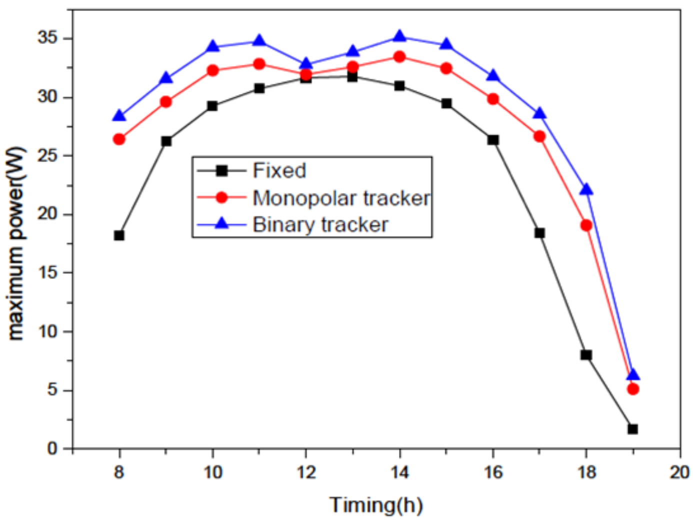

Figure 5. Daily Variations of Power .

Figure 3 depicts variations in solar radiation intensity on each panel throughout the day. It is evident that solar radiation intensity fluctuates during the day, reaching its zenith between 11:00 and 14:30. The results indicate that the solar tracker with two poles experiences the highest radiation intensity, followed by the one-axis tracker, while the fixed solar panel receives the least radiation. Additionally, the figure reveals a distinct divergence in incident radiation intensity between 8:00 and 11:00, as well as between 14:30 and 19:00. Notably, the curves for the one- and two-axis trackers closely align, suggesting the potential exclusion of the more expensive bipolar tracker in favor of the cost-effective monopolar tracker.

Figure 4 illustrates temperature fluctuations of the three panels and ambient temperature throughout the day. Notably, panel temperatures surpass ambient temperature from 8:00 to 11:00

before gradually converging. The one- and two-axis trackers-equipped panel exhibits the highest temperature, followed by the monopolar solar tracker and the fixed panel. The marginal temperature difference between the one- and two-axis trackers suggests a potential preference for the cost-effective monopolar option. During the period from 12:00 to 13:00, the presence of light, high-type clouds is observed.

Figure 5presents variations in the panels' maximum power throughout the day. The capacity of all panels increases from 8:00 to 11:00, with the two-axis tracker consistently leading in capacity, followed by the one-axis tracker and the fixed panel. Peak power for all panels occurs between 11:00 and 14:30, corresponding to maximum solar radiation. The temporary decline in maximum power from 12:00 to 13:00 is attributed to passing clouds. Between 14:30 and 19:00, a reduction in panel capacity is noted due to decreased solar radiation intensity, with the two-axis trackers maintaining the highest capacity compared to the other two panels.

Economic evaluation

The economic evaluation by SAM software is presented in table 2, The LCOE shows that the experimental system has an optimal economic feasibility during its operation between 15 and 20 years.

Table 2: The simulation outputs by SAM.

Annual energy (year 1)	1,297 kWh
Capacity factor (year 1)	22.4%
Energy yield (year 1)	1,965 kWh/kW
Performance ratio (year 1)	0.83
Levelized COE (nominal)	6.81 ¢/kWh
Levelized COE (real)	5.43 ¢/kWh
Electricity bill without system (year 1)	$2,158
Electricity bill with system (year 1)	$1,037
Net savings with system (year 1)	$1,121
Net present value	$7,410

Conclusion

The key results of this work are:

•The solar panels were experimentally studied for assessment under arid climatic conditions.

•An optimization in panel capacity is noted due to decreased solar radiation intensity, with the two-axis trackers maintaining the greatest capacity compared to the other two panels.

•The economic assessment is done by SAM software, and the LCOE is a key parameter for the feasibility studies of the PV systems.

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