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Study of the Efficiency of the Solar Tracker System compared to the Fixed Solar Generation System

Estudo da Eficiência do Sistema de Rastreador Solar em comparação com o Sistema de Geração Solar Fixa

Estudio de la Eficiencia del Sistema de Seguidor Solar frente al Sistema de Generación Solar Fijo

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Abstract
This experiment aimed to analyse the behaviour of the generation difference between a photovoltaic plant using the solar tracking system (Tracker) compared to a Fixed system facing north. Both plants are installed in the region of Cascavel - Paraná. The system consists of two 300kW on-grid power plants with 810 500Wp modules. In the first period of data collection in November and December 2021, it was found that the plant that uses the solar tracker, during data collection, achieved greater generation efficiency compared to the fixed plant. Reaching an average efficiency of 30%, more than the fixed plant. For the second period with data collected in January and February 2022, the generation efficiency of the plant using the solar tracker was higher than 30% compared to the fixed plant. The test was used nonparametric Wilcoxon with continuity correction. The test was significant (p=2.578 x 10-6) indicating a significant difference between the compared methods (Tracker x Fixed).
Keywords: Photovoltaic Solar System; Tracker; Efficiency.

Resumo
Este experimento teve como objetivo analisar o comportamento da diferença de geração entre uma usina fotovoltaica utilizando o sistema de rastreamento solar (Tracker) em comparação com um sistema Fixo voltado ao norte. Ambas as usinas instaladas na região de Cascavel - Paraná. O sistema consiste em duas usinas on-grid de 300kW com 810 módulos de 500wP. No primeiro período de coleta de dados no mês novembro e dezembro 2021, verificou-se que a usina que utiliza o rastreador solar, durante a coleta de dados, alcançou maior eficiência de geração em comparação com a usina fixa. Atingindo uma média de eficiência de 30%, a mais que a usina fixa. Para o segundo período com os dados coletados em janeiro e fevereiro de 2022, a eficiência de geração da usina utilizando o rastreador solar ficou superior aos 30% em comparação com a usina fixa. O teste utilizou-se não paramétrico de Wilcoxon com correção de continuidade. O teste foi significativo (p=2,578 x 10-6) indicando diferença significativa entre os métodos comparados (Tracker x Fixo).
Palavras-chave: Sistema Solar Fotovoltaico; Rastreador solar; Eficiência.

Resumen
Este experimento teve como objetivo analizar o comportamento da diferença de geração entre uma usina fotovoltaica utilizando o sistema de rastreamento solar (Tracker) en comparación con um sistema Fixo voltado ao norte. Ambas usinas instaladas en la región de Cascavel - Paraná. El sistema consta de dos usinas conectadas a la red de 300kW con 810 módulos de 500wP. No primeiro período de coleta de dados no mês novembro e dezembro 2021, verificou-se que a usina que utiliza o rastreador solar, durante a coleta de dados, alcançou maior eficiência de geração em comparação com a usina fixa. Atingindo uma média de eficiência de 30%, a mais que a usina fixa. Para o segundo período con dados coletados en enero y febrero de 2022, una eficiencia de geração da usina utilizando o rastreador solar ficou superior aos 30% em comparação com a usina fixa. O teste utilizou-se não paramétrico de Wilcoxon com correção de continuidade. O teste foi significativo (p=2,578 x 10-6) que indica una diferencia significativa entre los métodos comparados (Tracker x Fixo).
Palabras clave: Sistema Solar Fotovoltaico; Seguidor solar; Eficiencia.

1. Introduction

Energy is one of the main factors for the development of a nation. A huge amount of energy is extracted, distributed, converted, and consumed in global society on a daily basis. In recent years, energy demand is increasing exponentially, while conventional energy reserves are rapidly depleting. Like, for example, China, had great growth but was not compatible with its conventional energy reserves (Said, 2018).

A solution may be the use of solar energy, which allows the implementation of a local production system, which brings benefits in terms of economics and efficiency since energy losses in transport are minimized. However, a disadvantage attributed to photovoltaic generation is the low efficiency of energy conversion. More and more researchers are studying different ways to improve the efficiency of photovoltaic systems (Venkateswari, et al., 2019).

The use of photovoltaic plants can be a solution for medium and large generations and may have some constructive alternatives.

One of the alternatives is fixed solar plants, which use high-efficiency solar modules fixed to the ground structures in a fixed way positioned to the north, obtaining the best performance by increasing in this position the intensity of the light that falls on it in the average of the year (Jaszczur, et al., 2021).

Another alternative is research on photovoltaic cell technologies to increase cell conversion efficiency and the use of bifacial modules (Khan, et al., 2019).

Another alternative used is the implementation of solar tracking devices (TRACKER), which aim to increase the efficiency of energy generation by keeping the panels perpendicular to the direct irradiance most of the time, thus capturing a greater amount of irradiance, achieving an increase of more 28% in power generation can be achieved with the use of single-axis solar trackers and up to 36% with two-axis solar trackers, depending on the geographical conditions of the installation site and the configuration of the automation system (Melo, et al., 2017).

Solar trackers are a set of automated solar modules that follow the sun to increase generating power, this technology keeps the panels always aligned with the sun. There are three types of solar tracking systems are single axis, dual axis, and triple axis tracking system. In a solar tracking system, automation control is one of the most important items for the security of continuous correction of the positioning of the plant in relation to the sun. As for tracking technology, they can have microprocessors and optical sensors, date and time-based algorithms (Lewandoski, et al., 2022), or a combination of both. The date and time tracking strategy have a computer or processor that calculates the position of the Sun employing algorithms that use date, time, and geographic data.

The resources of fossil fuels are increasingly limited and, in addition, their use results in global warming due to the emission of gases. To provide sustainable energy production and a clean world in the future, there is a growing demand for energy from renewable sources such as Solar, Wind, Biodigesters, and Hydrogen (Ochoa, et al., 2019).

Our country is rich in renewable sources. Brazil's renewable electricity matrix is 141,932 MW. In the total renewable energy potential, solar energy has a maximum percentage of 3% in the total generation of the country's renewable electricity matrix.

2. Materials and Methods

The experiment was carried out in the city of Cascavel, Paraná. The geographic location of the Fixed Solar plant is defined by the coordinates of latitude 24°54'57.58" South and longitude 53°21'10.07" West, with an approximate altitude of 750 meters, and the geographic location of the Tracker solar plant by the coordinates of latitude 25 °21' 27.61" South and longitude 53°30'53.54" West, with an approximate altitude of 745 meters.

The photovoltaic system consists of 810 monocrystalline photovoltaic modules from the Risen Solar Technology brand. The module has an efficiency of 20.6% and a maximum power of 500Wp with a current of 11.68A, and a voltage Vmpp 42.88V, totaling 405kWp of installed power, below (Figure 1) shows the solar tracker system and a (Figure 2) shows the fixed solar generation system.

Figure 1. Tracker photovoltaic system installed in Cascavel, Paraná.

Source: Authors.

For the experiment in question, 15 Tracker lines with 54 modules in line were assembled, tracking the sun from east to west according to the automation developed using a time-based algorithm, according to the time, day, and month of the year.

Figure 2. Fixed photovoltaic system installed in Cascavel, Paraná.

Source: Authors.

In the fixed solar plant, the sets are of 6 modules per ground structure, the experiment developed used two lines with a total of 810 modules, all facing north.

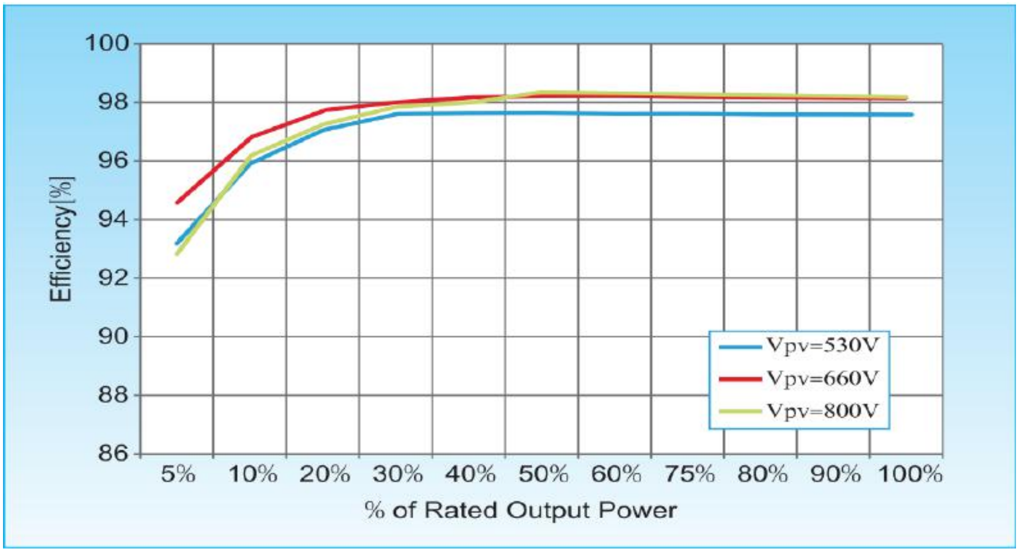
The solar inverters used for the experiment were five 60kW, three-phase, 90A SOFAR brands, below is the image (Figure3).

Figure 3. Inverter SOFAR 60kW.

Source: https://www.sofarsolar.com

The efficiency of the 60kW Sofar inverter is 98.6% as shown in the graph below (Graphic 1).

Graphic 1: Inverter efficiency curve (Sofar 60kW).



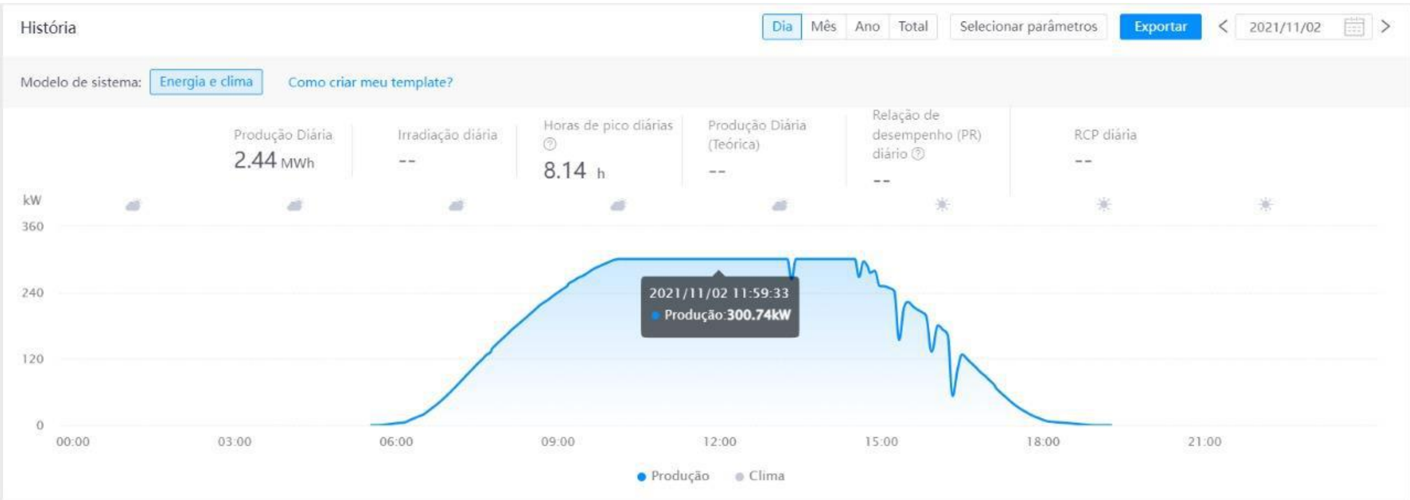
Source: https://www.sofarsolar.com

Data collection was divided into two periods, the first covering the months of November and December 2021, and the other covering the months of January and February 2022, each with 30 days of collection. The experiment considered the factors that affect the generation of photovoltaic energy between a fixed plant and a plant with a Tracker such as the orientation of the photovoltaic modules between the fixed plant and the plant with a tracker and the tracking of the sun performed by a plant that uses the tracker.

In the first part of the experiment, data were collected from a fixed plant with a north orientation is recommended for a better generation, with an inclination of 24°.

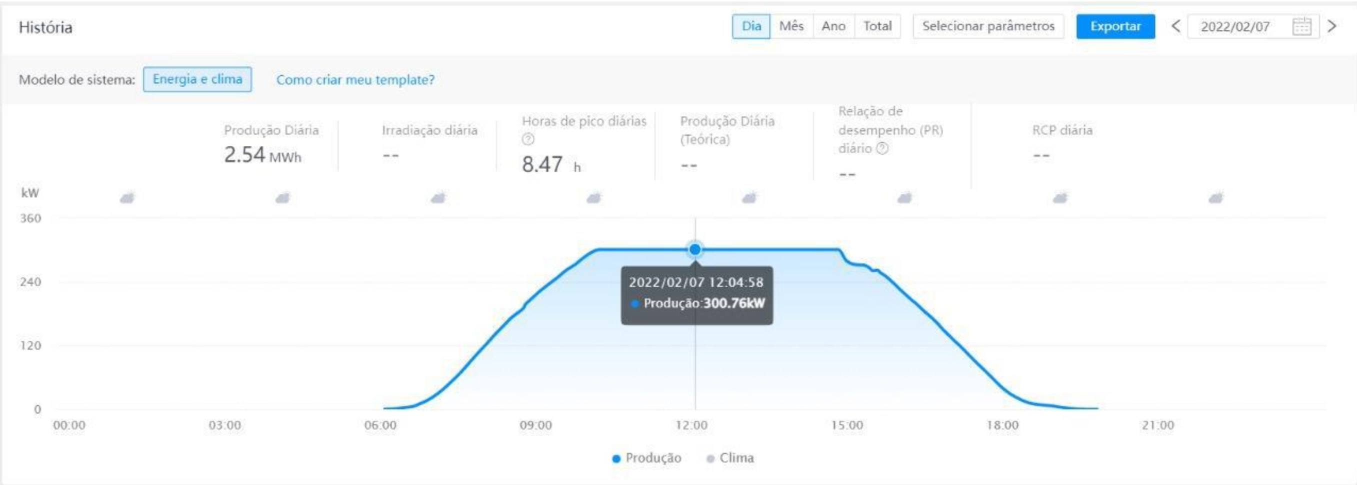
Below in figures 4 and 5, the production data collection of a fixed 300kW plant refers to the first and last month of collection.

Figure 4. Solarman Monitoring November 2021 Fixed 300kW Power Plant.



Source: Authors.

Figure 5. Solarman Monitoring February 2022 300kW Fixed Power Plant.



Source: Authors.

The other method is a single-axis tracking system. The single-axis solar tracking system has one degree of freedom that acts as an axis of rotation. The tracker's axis of rotation is typically aligned for the movement of the modules from East to West following sunrise and sunset. Motion direction is developed with advanced tracking algorithms. This model is capable of tracking and following the Sun's intensity to obtain maximum output power, regardless of engine speed. The system can be applied in small to large plants (Lewandoski, et al., 2021).

The motor chosen for the proposed system is a DC slew drive with geared motor. It is used to achieve the desired speed to move the panel according to the position of the sun. 24V DC voltage is used for this application. The most important effect of using geared DC motor in a single-axis tracking system is to achieve mechanical stability of the PV array without spending too much power on DC motors.

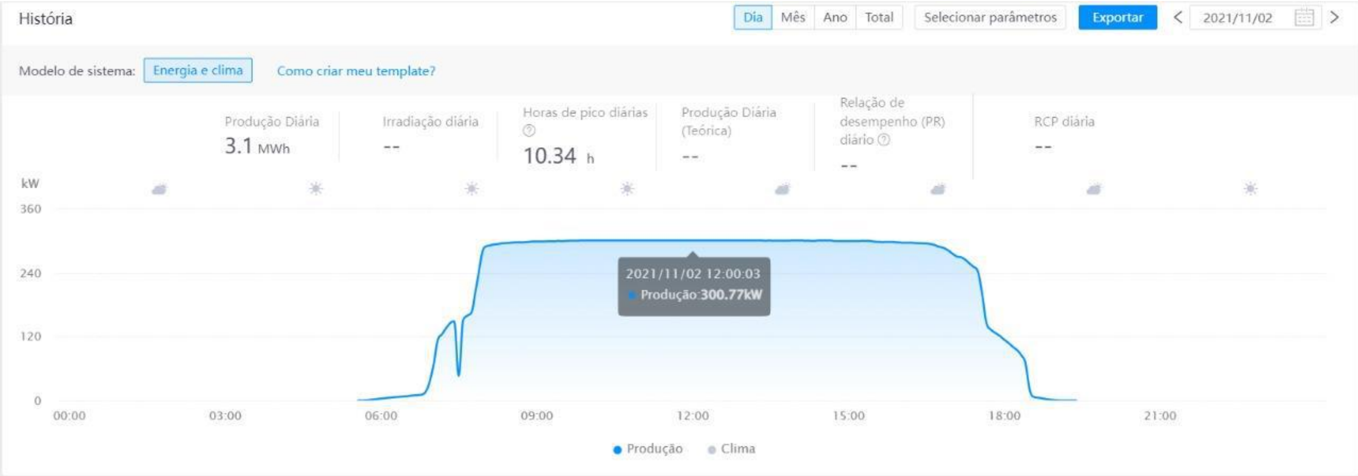
The DC motor works off-grid isolated from the generation powered by PV modules independent of the system, charge controller, and two 12V – 7Ah batteries as shown in figure 6 below.

Figure 6. Tracker Motor Drive Frame.

Source: Authors.

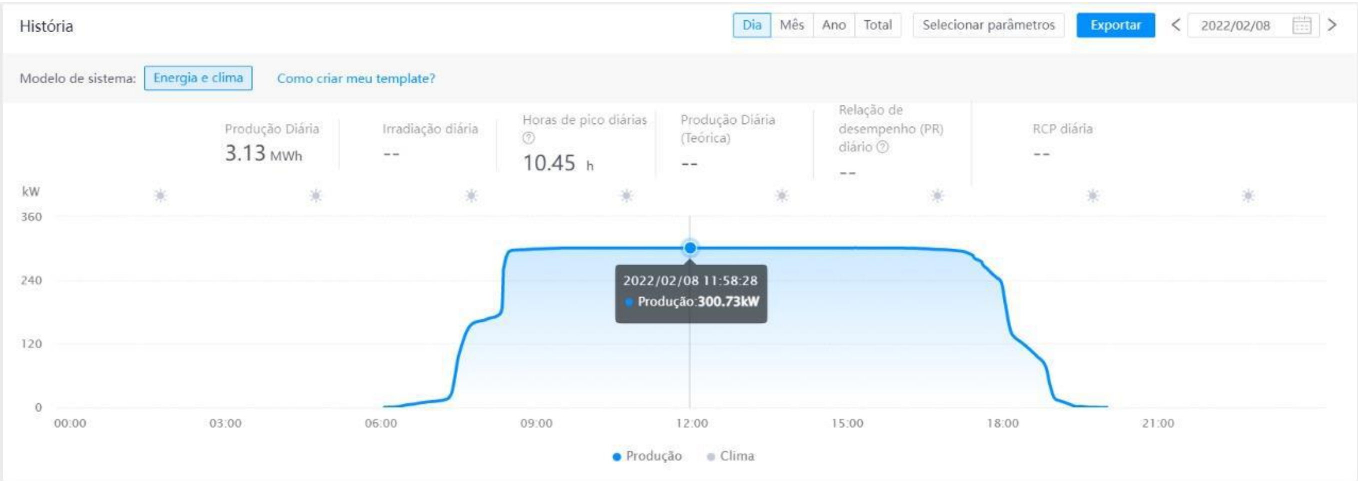
The energy generation data were obtained through the Solarman website, as well as the values of power, current and electrical voltage supplied by the system inverter. In short, the data provided by the site were processed, and then the hourly average of energy generation was performed through each string, figures 7 and 8 refer to the first and last month of Tracker collection.

Figure 7. Monitoring Solarman November 2021 300kW power plant tracker.



Source: Authors.

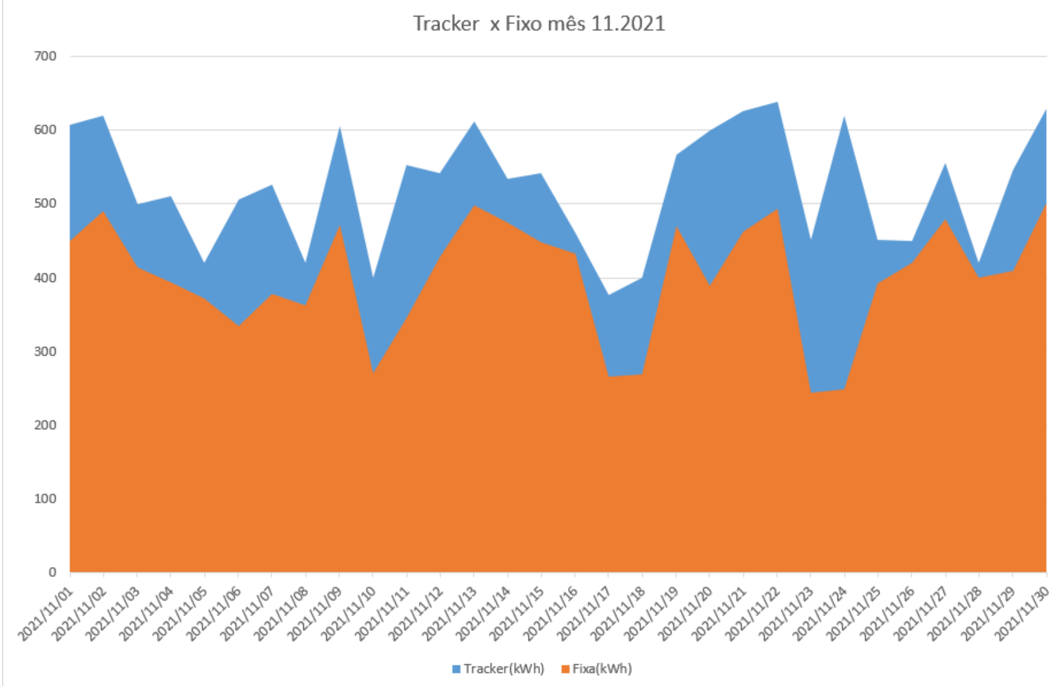
Figure 8. Monitoring Solarman February 2022 300kW power plant tracker.



Source: Authors.

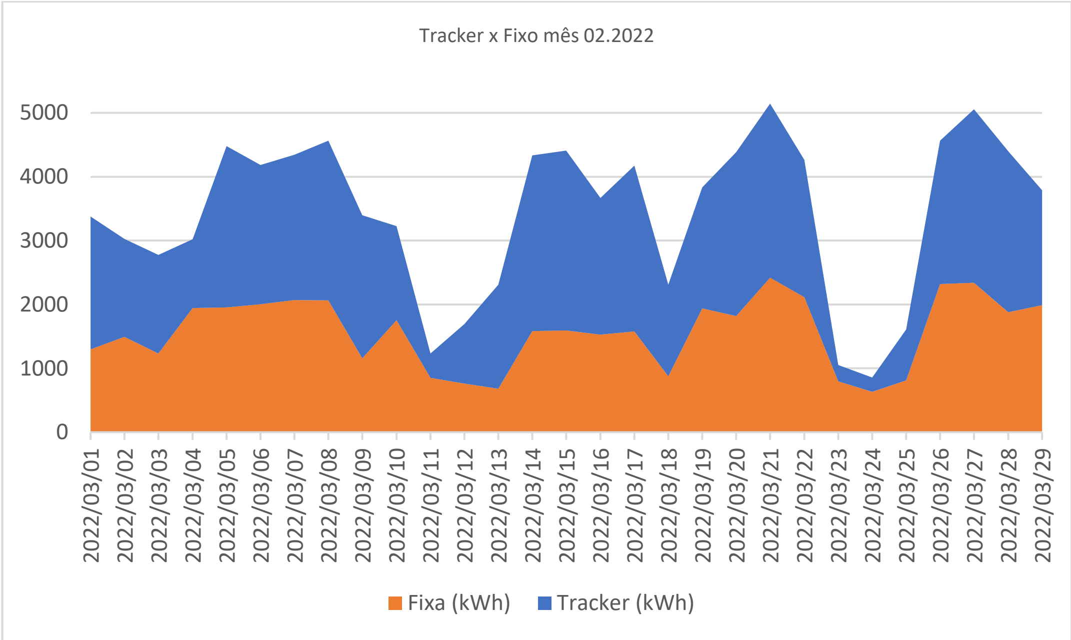
The study points out significant differences in energy generation using the methods presented, as shown in the graphs in Figures 9 and 10. Figure 9 shows the differences in the generation between a fixed 300kW plant and a 300kW plant with a Tracker system in the month of November 2021 Figure 10 shows the generation differences between the same plants, but for the month of February 2022. It is noteworthy that both plants have five SOFAR 60kW inverters using 810 500Wp modules, the average temperature between the months of November 2021 and February 2022 in the city of Cascavel - PR was 26.5°C, the modules of both plants were clean, and in generation conditions throughout the study.

Figure 9. Generation (Tracker) x (Fixed) month of November 2021.



Source: Authors.

Figure 10. Generation (Tracker) x (Fixed) month of February 2022.



Source: Authors.

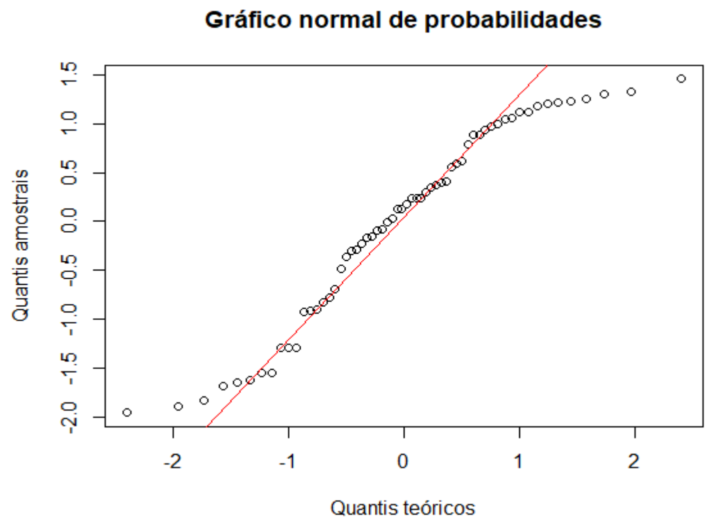
3. Results and discussions

t-Student test for comparison of treatment means

(Tracker vs fixed month 11-2021 comparison)

Initially, through the analysis of residues, the assumptions required for the referred test were verified. For this, the standardized Residues for the observations were obtained. Graph 2 presents a normal probability plot (Q-Q plot) of the standardized residuals. In the normal probability graph, a dispersion in the extremes is observed. The hypothesis of normality of the residuals, verified through the Shapiro-Wilk test, was rejected (p = 0.003707). Thus, it can be said that the distribution of residuals is not normal.

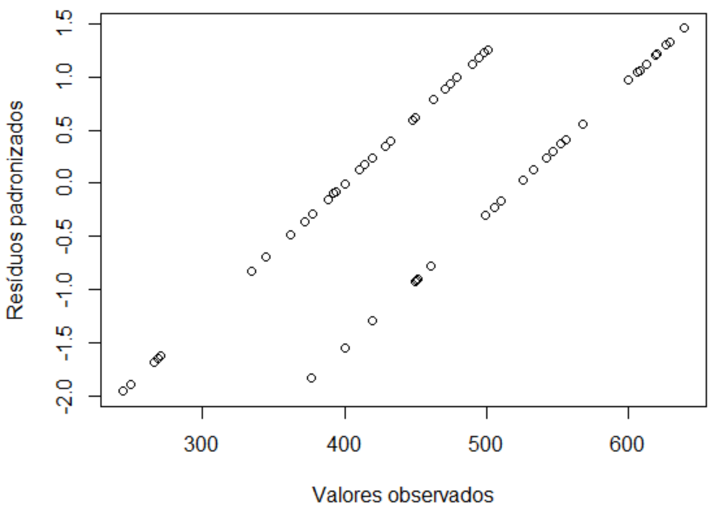
Graphic 2: Fixed x Tracker normal probability plot with generation samples.



Source: Authors.

Graphic 3 presents the graph of observed values and standardized residuals. The graph shows a positive correlation between the residuals (Correlation coefficient r = 0.788), indicating that the residuals are not independent.

Graphic 3: Graph of observed values and standardized residues Fixed x Tracker collected generation values.



Source: Authors.

Thus, as the requirements for performing the t-Student test were not met, the non-parametric Wilcoxon test with continuity correction was used. The test was significant (p=2.578 x 10-6) indicating a significant difference between the compared methods. This difference can be observed through the Box Plot chart shown in Figure 11.

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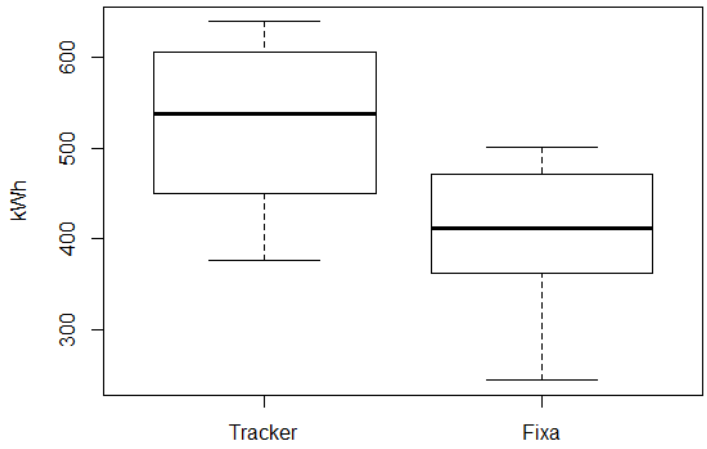
Figure 11: Box plot of observed values (Tracker and Fixed).



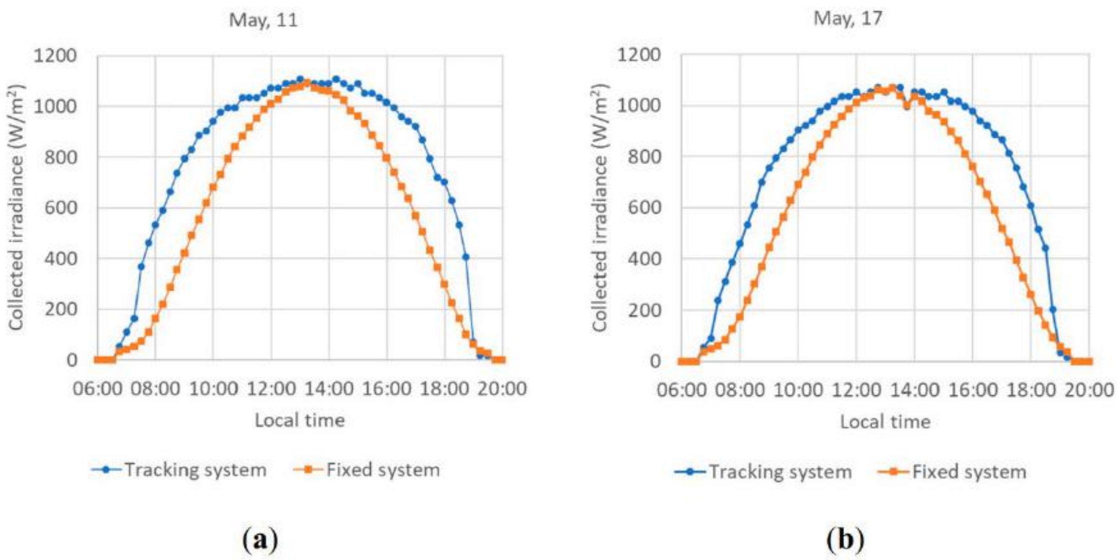
Source: Authors.

Under the conditions in which the present study was conducted, there was a significant effect in the application of the method of using the Tracker in relation to the fixed plant with a 60KW inverter.

The production gain exceeded 30% in the state of Paraná in November and December 2021.

We can also see something similar in the article by (Gutierrez, et al., 2020). Your experiment in the city of Aguascalientes, central Mexico, has an average gain of 29.9% in May compared to a fixed PV system with the optimal slope as shown in Figure 12.

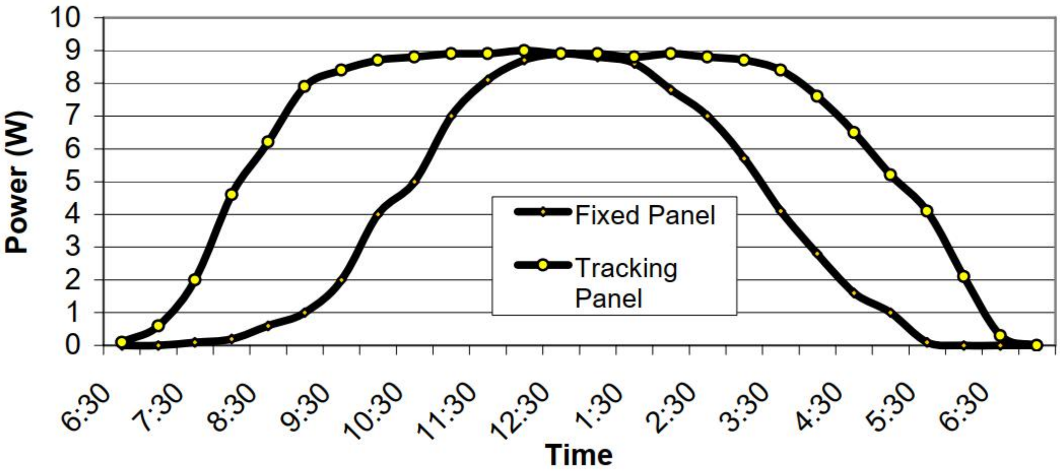
Figure 12: Irradiance graph between (Tracker and Fixed).



Source: Gutierrez, et al. (2020).

The experiment in northern USA Tracker achieved an energy efficiency of 39% compared to the fixed system, in terms of real value, this means that the total cost of a system can be reduced significantly, considering that much more energy can be provided by the solar panel coupled to a solar tracking device. (Rizk, et al., 2008), Figure 13 shows the results.

Figure 13: Tracker irradiation measurements and the fixed system.



Source: Rizk, et al. (2008).

4. Conclusion

During the period of the four months of data collection between November 2021 and February 2022, the production levels of kw/h were evaluated between the fixed solar generation system with the solar tracker system between 300kW plants in the Cascavel region - PR

According to the statistical analysis, the Wilcoxon parametric with continuity correction test was significant (p=2.578 x 10-6) indicating a significant difference between the compared methods (Tracker x Fixed). A generation efficiency that exceeded 30% of the system with solar tracking compared to the fixed system.

The Tracker showed a higher generation on all collection days during the four months of collections compared to the other fixed system.

Thus, although this work has fulfilled its objective, there is still much to research, investigate and analyze in the current scenario of solar plants.

In a future perspective, it is expected that this work will make possible new contributions to the field of comparison of photovoltaic plants using the tracker with bifacial modules and normal modules according to each region of our country.

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