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OPERATIONAL ANALYSIS OF THE 'WOMEN IN SOLAR ENERGY' PHOTOVOLTAIC POWER PLANT AT THE NORTH COAST CAMPUS OF FEDERAL UNIVERSITY OF RIO GRANDE DO SUL

Summary

The "Women in Solar Energy" Photovoltaic Plant at Federal University of Rio Grande do Sul (UFRGS) is a pioneering initiative that integrates teaching, research, and sustainability. With 300 kWp of installed capacity, the plant supports energy transition efforts and the spread of renewable energy best practices. This study presents an operational analysis based on performance indicators like Performance Ratio (PR) and Capacity Factor (CF). Results show annual values of 10.31% (CF) and 53.66% (PR), below expectations. The performance was affected by inverter failures, flooding, and solarimetric data inconsistencies, along with administrative challenges. The study highlights the need for resilience against extreme weather events. It recommends structured operation and maintenance (O&M) practices, resilience strategies, and improved monitoring to optimize performance. The plant remains a valuable reference for sustainable energy management and gender equity in the energy sector.

Keywords: Photovoltaic Solar Plants, Operation and Maintenance, Performance Indicators.

1. Introduction

In recent years, solar photovoltaic (PV) energy has shown rapid growth in Brazil, driven by lower system costs, faster return on investment, and the country's commitments to reducing greenhouse gas emissions. Public institutions play a key role in promoting sustainability, serving as models for society. However, to ensure long-term efficiency and safety, solar PV systems—especially in public facilities—require proper maintenance and performance monitoring. The "Women in Solar Energy" Photovoltaic Power Plant at Federal University of Rio Grande do Sul's (UFRGS) North Coast Campus is a pioneering example of integrating sustainability with education and research. Despite its relevance, the plant has faced operational challenges since its inauguration in 2022, including inverter failures, flooding, and data inconsistencies.

The main goal of this study is to conduct a detailed operational analysis of the plant, focusing on its performance using indicators such as Performance Ratio (PR) and Capacity Factor (CF), in order to identify challenges and propose improvements for system efficiency and resilience.

2. Women In Solar Energy Photovoltaic Power Plant at the North Coast Campus of UFRGS

The North Coast Campus (CLN) of UFRGS (Fig.1) is located along the RS-030 highway in Tramandaí, RS, Brazil (coordinates: 29.97° S, 50.22° W). Since its inauguration in 2014, the campus has offered undergraduate programs in Energy Management Engineering, Service Engineering, Geography, and Rural Development, as well as graduate programs in Physics Education and Regional Development. The campus plays a key role in training professionals for the energy transition and sustainability challenges.

The "Women in Solar Energy" Photovoltaic Power Plant, installed on campus, exemplifies the integration of teaching, research, and sustainability. Funded by the Ministry of Education's EnergIF program with an investment of R$ 1.72 million, the plant has an installed capacity of 300 kWp. It consists of 996 photovoltaic modules (Phono Solar and Suntech, 380Wp and 350Wp) and 20 Fronius inverters of 15kW each. The plant supports SDG 7 (clean and affordable energy) and serves as a real-life lab for the Energy Management Engineering program.

(a) **(b)**

Fig. 1: Aerial images of the UFRGS North Coast Campus (CLN). Sources: (a) Google Earth and (b) Fabiano Passos.

The photovoltaic modules are installed in various orientations and fixed directly to a rooftop structure to make the best use of available space. The inverters are connected to arrays of 48 and 54 modules, allowing for maximum power extraction. This configuration also supports academic use by enabling easy interpretation and analysis. Additionally, 216 modules, totaling 75.6 kW, are installed on the ground with a north-facing orientation and a 30º tilt. The plant also includes a solarimetric station that measures solar radiation, wind speed, and direction.

Monthly productivity data from the plant's monitoring system (SolarWeb by Fronius) indicate significant intermittent generation across inverters. After filtering out the malfunctioning data, a typical seasonal photovoltaic generation curve emerges—higher output during summer and lower in winter. Generation varied by panel orientation, with productivity increasing in the following order: north, northeast, southwest, southeast, and northwest. Interestingly, the lowest productivity occurred in May, rather than in June as typically expected. A comparison of the best-performing inverter from each orientation confirmed these trends.

3. Results and Discussion

The energy data obtained was used to calculate the average daily energy production for each module of each inverter, and the results were compared with theoretical values. The theoretical generation was based on data adapted from Mendes (2020), who used PV*Sol software to design the plant. A notable finding was that the north position, which was expected to generate the most energy, ranked only 6th with its best-performing inverter. A possible explanation could be equipment malfunction, either in the inverters or modules, or shading. Since the north inverters are located on the ground, a fence was installed for safety. However, the fence is positioned too close to the plant, causing unwanted shading and reducing energy generation.

To calculate photovoltaic productivity based on module orientations, the study by Krenzinger, Prieb, and Gasparin (2022) was used. It involved monitoring the incidence of 456 different orientations across 33 meteorological stations in Rio Grande do Sul for over 15 years. The study identified the optimal orientation for solar radiation. Given the proximity of Tramandaí and Porto Alegre, the results are reliable. Theoretical photovoltaic productivity was calculated considering module inclination and azimuth for different orientations. When comparing real values with adapted values from the Photovoltaic Productivity Map for Rio Grande do Sul (Fig. 2), it was found that, for the best-performing inverters, the photovoltaic productivity matched or slightly exceeded the annual average productivity. However, for most other inverters, the productivity was lower.

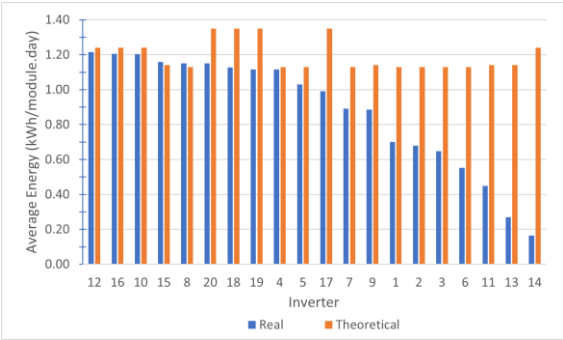

Fig. 2: Comparison of the average annual productivity of all inverters and the theory, in kWh/kWp/day, applying the correction by Krenzinger, Prieb, and Gasparin (2022).

According to SolarWeb (Fronius), from its commissioning until December 2024, the "Mulheres na Energia Solar" PV plant generated approximately 822.05 MWh, averaging 28.98 MWh/month. This energy output is equivalent to the residential monthly consumption of 428 Brazilians, based on EPE (2024) data. Considering the average CO_2 emission factor of the National Interconnected System (SIN) at 0.3719 tCO_2/MWh (MCTI, 2024), the avoided emissions would be 305.72 tCO_2. However, PV systems also emit approximately 0.0776 tCO_2/MWh (Suppen et al., 2018), resulting in a net avoided emission of 241.93 tCO_2—a 79% reduction.

Despite the installation of a solarimetric station, its data showed inconsistencies of 3% to 30% when compared to reliable sources (CRESESB, LABREN, Virtux), indicating possible operational faults. Thus, LABREN data was used for performance calculations. The highest irradiation was recorded in December (5.55 kWh/m².day), and the lowest in June (2.37 kWh/m².day). The Performance Ratio (PR) averaged 53.66%, below the expected 70–80%, due to inverter failures. The Capacity Factor (CF) was 45%, also below central PV plants in Brazil (~60%), affected by location and inverter underperformance.

A lack of regular maintenance has hindered the system's efficiency. Although a maintenance contract was planned, it had not been executed by the end of the study period (September 2024). Proper O&M practices, aligned with international guidelines (IEA, 2022), are crucial for optimal performance, longevity, and public accountability. Extreme events such as fires and floods highlight the urgent need for preventive protocols, reinforced by incidents in Rio Grande do Sul in 2024. Though this plant was not affected, procedures for resilience, safety, and end-of-life management (recycling/reuse of modules and inverters) must be prioritized.

4. Conclusions

This study analyzed the operation and maintenance (O&M) of the "Mulheres na Energia Solar" photovoltaic plant at UFRGS' Litoral Norte Campus. The annual Capacity Factor (10.31%) and Performance Ratio (53.66%) revealed the importance of performance monitoring and highlighted significant losses due to inverter outages, emphasizing the need for preventive and corrective maintenance.

Discrepancies between on-site solar data and reference databases point to the need for regular calibration of meteorological equipment. The plant also faces challenges common to public institutions, such as bureaucracy and administrative delays. Despite these barriers, implementing proper O&M strategies is key to ensuring system reliability and public resource efficiency.

No corrective measures had been taken during the study period, except the identification of failures to draft an emergency maintenance contract. A structured O&M plan with advanced monitoring tools can help reposition the plant as a model for sustainable and resilient solar energy systems.

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