Validation of the Optimal Performance Assessment Methodology for Photovoltaic Plants in the Context of EPC Contracts in Colombia

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Introduction

Solar photovoltaic (PV) energy has experienced remarkable growth in Colombia, however, many solar plants fail to meet the expected Performance Ratio (PR) set out in Engineering, Construction and Procurement (EPC) contracts, which has created financial problems for both contractors and investors.

The use of Typical Meteorological Year (TMY) data to establish performance expectations has been subject to criticism, as these data may not reflect actual operating conditions. Previous studies [1] have indicated that PR may not adequately capture nonlinear phenomena such as curtailment and clipping, which can result in discrepancies of up to 10% in performance assessment. In addition, the evaluation of the PR must meet a 95% acceptance range according to the criteria established by the National Renewable Energy Laboratory (NREL) [2].

This study aims to identify the causes of low performance in solar plants in Colombia and proposes a more robust methodology for the evaluation of performance indices in the context of EPC contracts.

Methodology

The study focuses on a comparative analysis of the behavior of expected and actual performance indices of solar plants in pre-operational Solar Plant A (19,3 MWp, 1,209 DC/AC Ratio) and operational Solar Plant B (27,4 MWp, 1,377 DC/AC Ratio) stages using Pvsyst as the simulation tool.

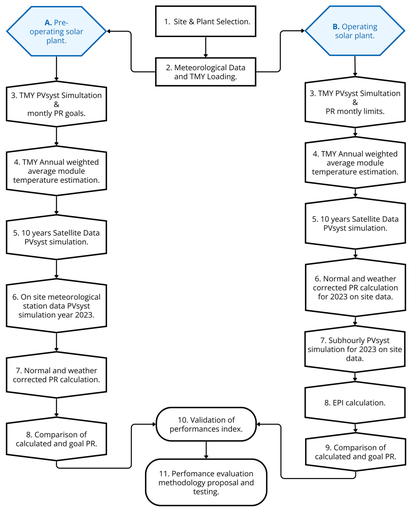


Figure 1. Metodology of the study

The calculation of the PR was performed based on the formula developed by IEC 61724-1 [3], as well as the weather-corrected PR using the TMY module temperature as a reference. The plane of array irradiation over curtailment was calculated as shown in equation 2.

$$PR = \frac{\sum_k P_{out,k} \cdot \tau_k}{\sum_k \frac{(P_0 \cdot C_k) \cdot G_{i,k} \cdot \tau_k}{G_{i,ref}}}$$

$$C_k = 1 + \gamma \cdot (T_{mod,k} - T_{mod,avg,TMY})$$

Equation 1. Weather-Corrected Performance Ration [3].

$$\sum_k^{POA_k = POA \geq STC \cdot \frac{1}{DC/AC_{ratio} \cdot PR_k}} POA_k \cdot \tau_k$$

Equation 2. POA over curtailment level.

Results

Satellite simulations of Plant A show less than 2% PR discrepancy, but using on-site data reveals larger deviations due to higher temperatures and POA over curtailment.

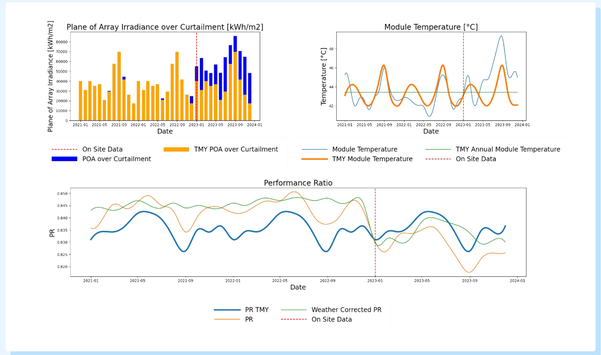


Figure 2. Solar Plant A simulation.

For Solar Plant B, the PR calculated from measured data was up to 10% lower than the guaranteed in the EPC contract. Simulations revealed that non-linear conditions, such as curtailment or clipping, caused lower performance leading to Non-Compliance in months with higher than expected curtailment.

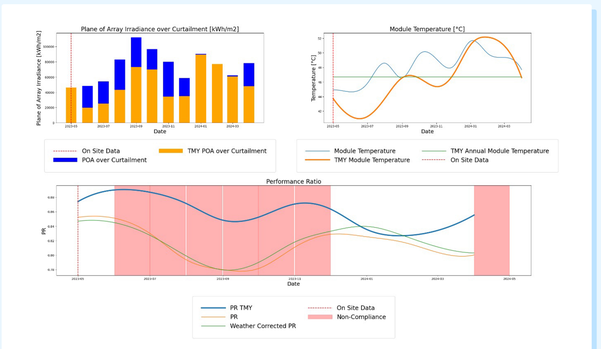


Figure 3. Solar Plant B calculation.

Proposed Assessment Procedure

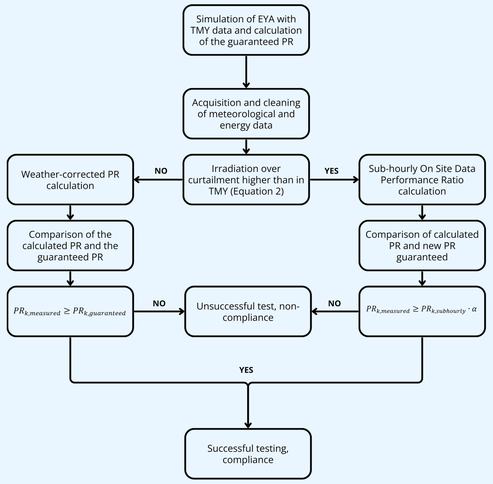


Figure 4. Performance Assessment Procedure Proposal.

Validation

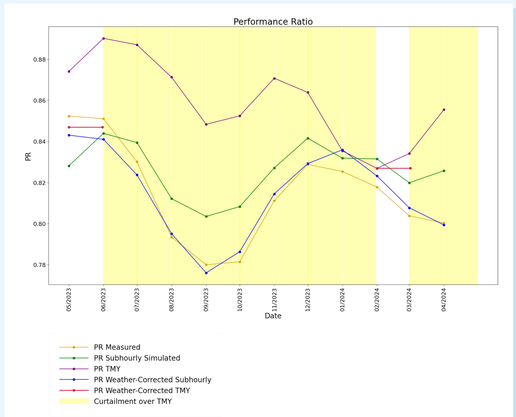


Figure 5. Performance evaluation methodology validation.

Analysis

For Solar Plant B, a Capacity Curve comparison between TMY and measured data revealed higher actual curtailment, indicating that the conditions for guaranteed PRs do not match the plant's reality during Non-Compliance months.

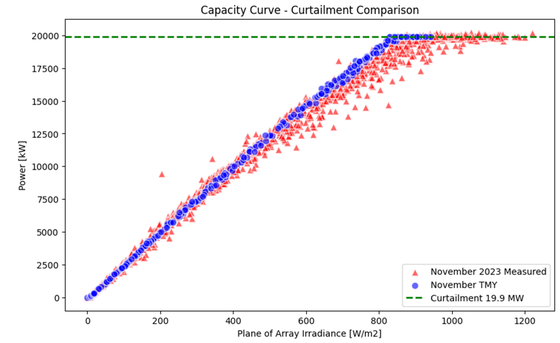


Figure 6. Solar Plant B capacity curve.

As TMY conditions and reality differ, a sub-hourly simulation was performed to avoid the omission of the curtailment effect when the irradiance is not constant for a full hour.

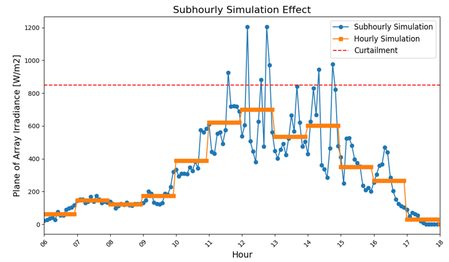


Figure 7. Subhourly simulation effect.

The sub-hourly simulation for Solar Plant B correlates well with measured data, suggesting that the issue is not poor performance but rather that the TMY PR fails to accurately reflect behavior under saturation, unlike the sub-hourly PR.

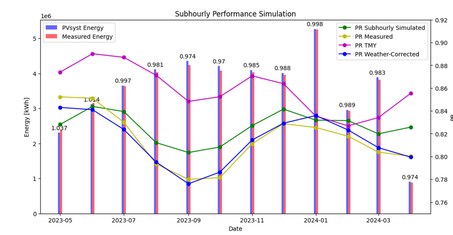


Figure 8. Subhourly perfomance simulation.

Conclusions

This study identified that performance expectations vary significantly depending on the databases used, showing discrepancies of up to 2% with ideal data and between 3% and 10% with data measured on site. These discrepancies are mainly due to the higher frequency of non-linear events, such as Curtailment and Clipping, which are not adequately represented in TMY-based simulations. For when this saturation exceeds what is predicted, a methodology based on sub-hourly simulations was proposed that considers intra-hourly saturation to calculate a new guaranteed PR that is a more accurate representation of the actual plant performance. This methodology allows for a fairer and more transparent evaluation of solar plants, ensuring that EPC contracts adequately reflect actual operating conditions.

References & Full Article

[1] D. Brivio, "We all trust the PV performance ratio test – but should we?", Pv Magazine, April 20, 2021.
[2] T. Dierauf, A. Growitz, S. Kurtz, J.L.B. Cruz, E. Riley, C. Hansen, "Weather-Corrected Performance Ratio (No. NREL/TP-5200-57991),"National Renewable Energy Lab (NREL), Golden, CO, United States, 2013.
[3] International Electrotechnical Commission. (2017). IEC 61724-1: Photovoltaic system performance - Part 1: Monitoring.
[4] International Electrotechnical Commission. (2016). IEC TS 61724- 3:2016 - Photovoltaic system performance - Part 3: Energy evaluation method. IEC.