Refining Wind-Solar Hybrid Plant Production Estimates with Sub-Hourly Time Series Data

Luiz Reis, Lúcio Paiva, Luis Castro, Letícia Vasconcelos and Rodrigo Santos

CdV Desenvolvimento

The nMBE and nRMSE values between hourly and sub-hourly curtailment are significantly affected by the correlation between wind and solar production as well as the hybrid index.

Abstract

The integration of wind and solar plants is gaining traction in Brazil due to the the synergies achieved by sharing electrical infrastructure and transmission systems. These hybrid plants enhance the reliability of energy supply and optimize the utilization of existing infrastructure.

Typically, electrical infrastructure and transmission system contracts for wind farms are designed for power levels close to the nominal capacity of the wind turbines. In regions with predominantly nighttime winds, this setup allows for the integration of solar generation, making use of the otherwise idle infrastructure capacity during the day.

To avoid exceeding these limits, it becomes necessary to curtail one of the energy sources. Due to the complexity of stopping or limiting wind turbines, it is common to reduce the solar plant's power setpoint to comply with established limits. Therefore, accurately calculating the expected solar generation in a hybrid plant requires accounting for curtailed energy. Sub-hourly data usage captures energy generation variability and curtailment impacts more accurately.

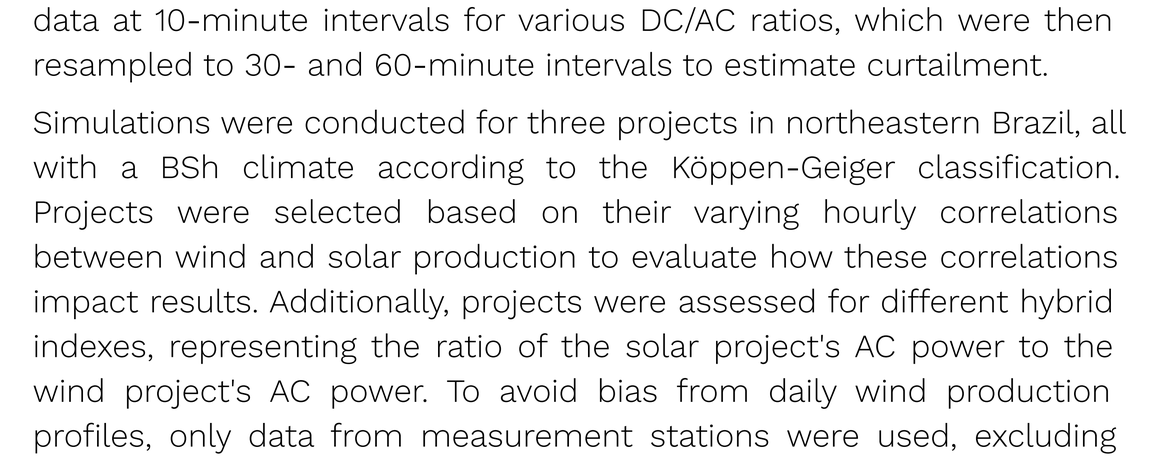
Methodology

This study investigates how the temporal resolution of wind production data affects curtailment estimates. Simulations used wind and solar data at 10-minute intervals for various DC/AC ratios, which were then resampled to 30- and 60-minute intervals to estimate curtailment.

Simulations were conducted for three projects in northeastern Brazil, all with a BSh climate according to the Köppen-Geiger classification. Projects were selected based on their varying hourly correlations between wind and solar production to evaluate how these correlations impact results. Additionally, projects were assessed for different hybrid indexes, representing the ratio of the solar project's AC power to the wind project's AC power. To avoid bias from daily wind production profiles, only data from measurement stations were used, excluding reanalysis series. Wind data were adjusted using a long-term capacity factor derived from frequency base analysis.

Accuracy of curtailment estimates was evaluated using hourly metrics with all results resampled to 60 minutes: normalized mean bias error (nMBE) and normalized root mean square error (NRMSE), with 10-minute data as the reference. These metrics assessed the accuracy and reliability of curtailment estimates across different time intervals.

Results



(a) (b)

Figure 1: Projects used in validation. (a) Geographic distribution of the projects. (b) Correlation between wind and solar (before curtailment) energy production.

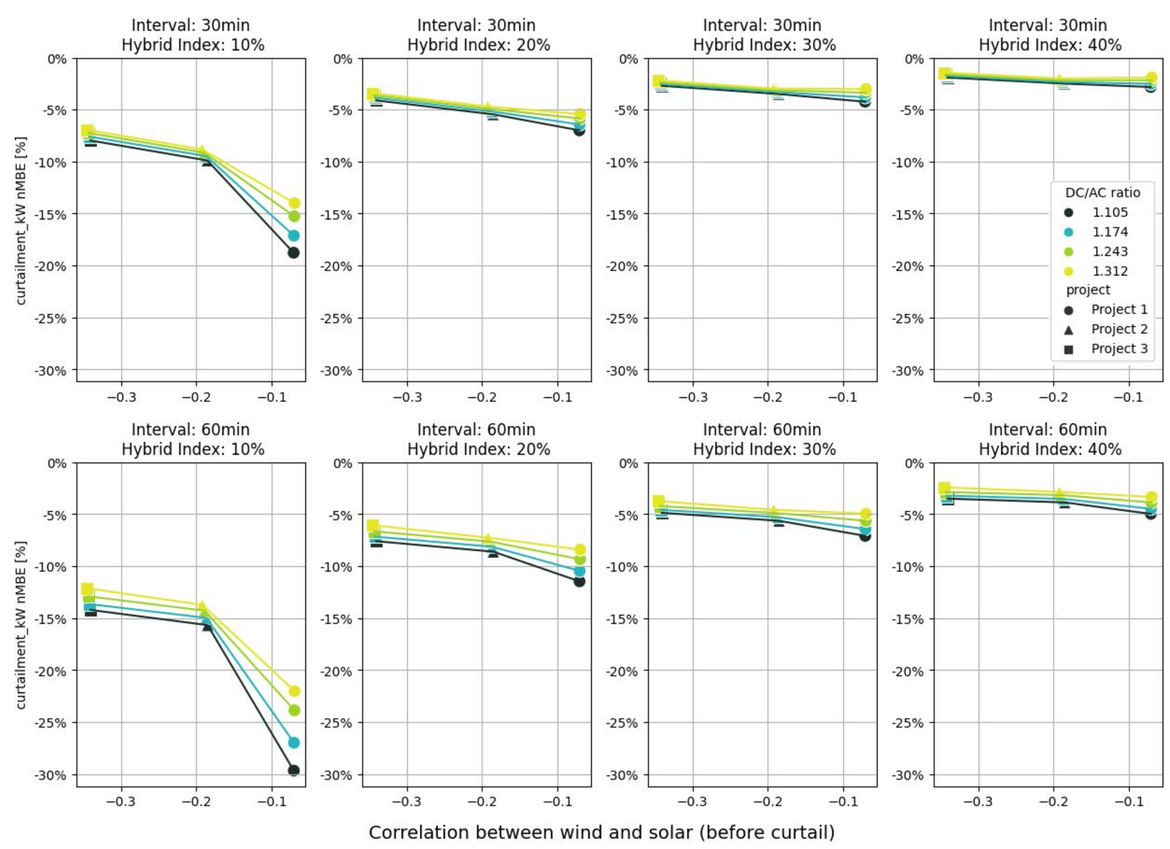


Figure 2: Analysis of curtailment nMBE between 10 min results and other temporal resolutions.

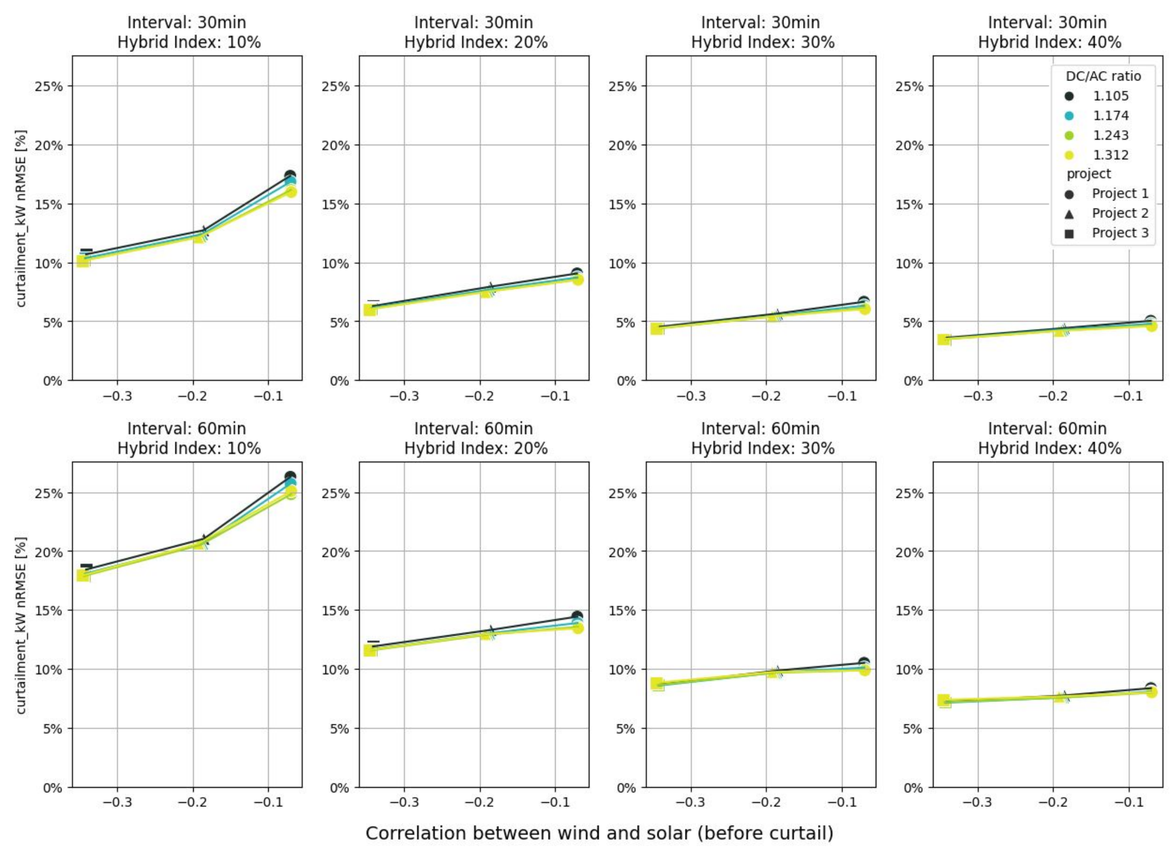


Figure 3: Analysis of curtailment nRMSE between 10 min results and other temporal resolutions.

Conclusion

The analyses show that nMBE and nRMSE values are strongly influenced by the correlation between wind and solar production and the hybrid index. Projects with a more negative correlation between wind and solar have lower nMBE and nRMSE values, with less dispersion across DCAC scenarios. Lower hybrid index values lead to greater differences between the reference curtailment and curtailment at other time resolutions. When the hybrid index is higher, the effect of correlation on these metrics decreases. Differences are most pronounced when the combined production of wind and solar is close to the limit, with more frequent sub-hourly fluctuations in projects where the correlation between wind and solar is less negative. For higher hybrid index values, the sum of average productions usually exceeds the limit, reducing observed differences.

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