Enhancing Solar Farm Performance Monitoring Using Attention-Based LSTM Models and Satellite Weather Data

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Introduction

- Accurate monitoring of utility-scale photovoltaic (PV) plants is critical.
- Most utility-scale PV plants have weather stations.
- However, even a well-maintained weather station often provides data that contain gaps due to equipment failures.
- Missing meteorological data can be substituted with satellite data, but this may introduce additional errors.

Objectives

- Investigating the deviation between satellite-extracted weather parameters—including plane-of-array (POA) irradiance and module temperature—and on-site measured parameters.
- Assessing the impact of these deviations on the estimation of the weather-corrected performance ratio (WCPR), a key reliability indicator.
- Addressing these deviations between satellite weather data and on-site measurements using advanced deep learning approaches.

Methodology

A. Data

- Weather data from a utility-scale PV site in Australia, collected since 2023.
- Satellite-derived weather metrics were obtained from NASA's database using the plant's geographical coordinates.

B. Model training and validation

- Long Short-Term Memory (LSTM) and attention-based LSTM models were trained on historical satellite data.
- Model performance was evaluated using Mean Squared Error (MSE) against the on-site measurements.

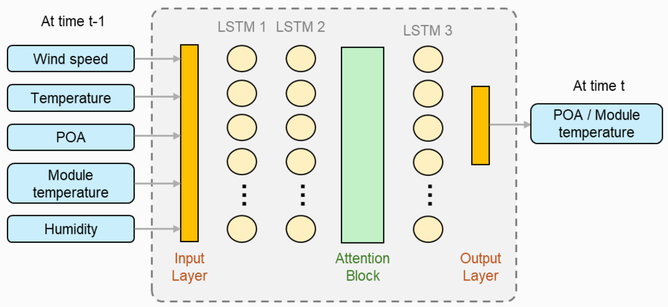

Figure 1: Attention-based LSTM model.

Main results

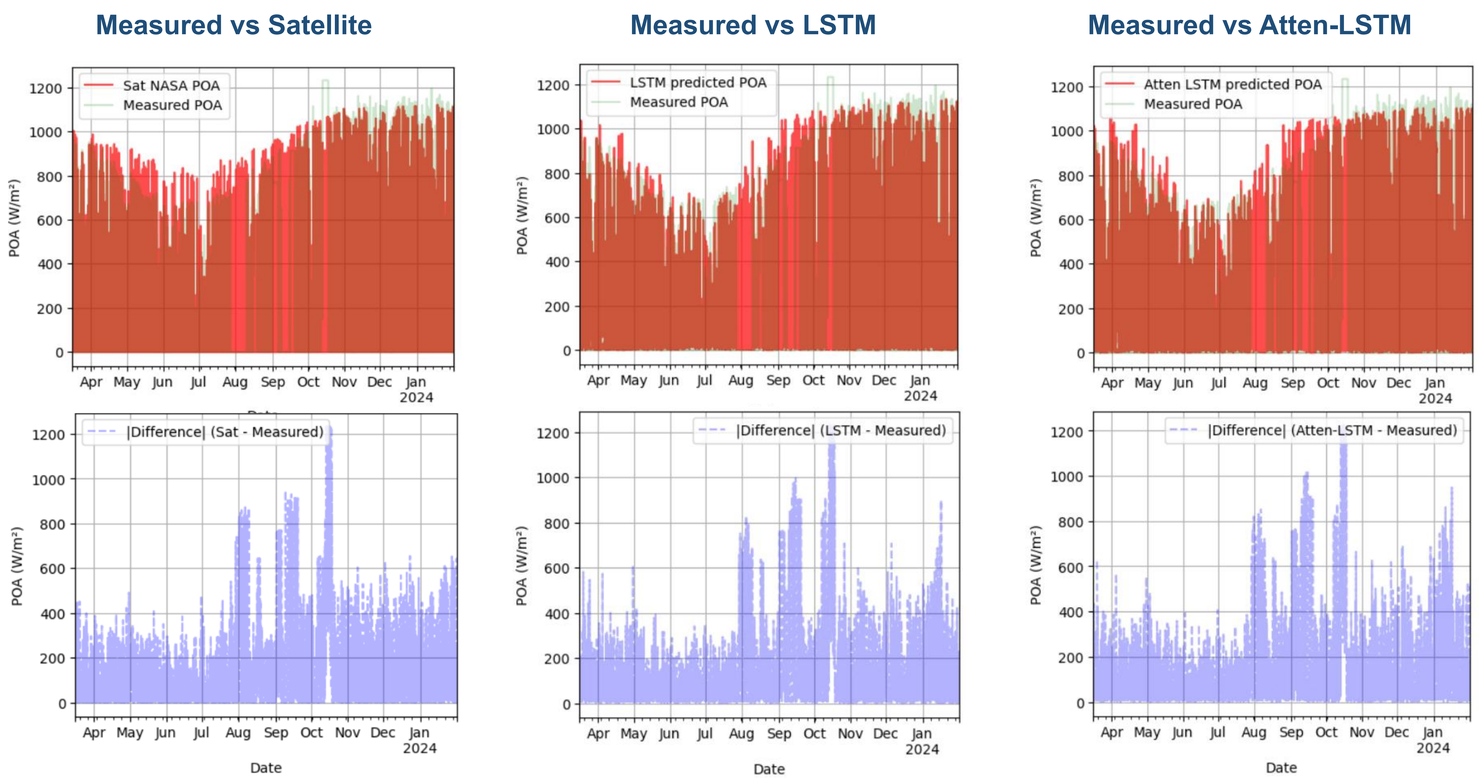

Figure 2: Comparison between the measured data and predictions of the 2023 weather parameters from (a) satellite data, (b) LSTM, and (c) attention-based LSTM.

Table 1: MSE comparison.

POA	MSE
Measured vs Satellited data	20,292
Measured vs LSTM	9,828
Measured vs Attention-based LSTM	7,888

Table 2: WCPR comparison.

Used data	WCPR
Measured data	0.778
Satellite data	0.816
LSTM	0.796
Attention-based LSTM	0.795

- LSTM predictions demonstrate better alignment with the measured POA and module temperature than satellite data, with lower and more stable errors throughout the year.
- The attention-based LSTM model further improves the prediction accuracy of POA and module temperature compared to both satellite-derived data and standard LSTM predictions.

WCPR Comparison

- The error percentage between the satellite-estimated and the measured WCPR is 4.9%.
- Using the attention-based LSTM approach to predict the weather, the error percentage is reduced to 2.2%.

Conclusions

- This study addresses the critical challenge of incomplete weather data in utility-scale PV plant performance analysis.
- By integrating satellite data with advanced attention-based LSTM models, accurate predictions of weather parameters were achieved.
- The relative error between the WCPR calculated using on-site measured data and that calculated using attention-based LSTM-predicted data is only 2.2%.

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References
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