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Forecasting day-ahead 1-minute irradiance variability from NWP output

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Accurate forecasts of solar irradiance are required for the large scale integration of solar photovoltaic (PV) systems. Fluctuations of energy generation in the order of minutes can lead to issues on the electricity grid, therefore accurate forecasts of minute-to-minute irradiance variability are required. However, state of the art numerical weather predictions (NWP) deliver forecasts at a much coarser temporal resolution, e.g. hourly averages.

In this work we present a methodology to forecast a quantification of minute-to-minute irradiance variability as well as the probability distribution function (pdf), by applying statistical postprocessing and machine learning on hourly NWP ourput. In total, 10 target parameters related to the irradiance variability are forecasted. The algorithm is tested using the NWP HARMONIE-AROME (HA) mesoscale model as input, with 1-minute irradiance observations for 18 locations throughout the Netherlands used as ground truth.

Results show that the proposed algorithm is capable of forecasting the 1-minute irradiance PDF with reasonable resemblence to the observed PDF. Moreover, we show that inaccuracies of the postprocessed result are to a large extent due toerrors in the radiation forecast of the NWP used as input, reducing the average R^2 score from 0.75 to .57 for the most relevant targets. The generalizability of the proposed algorithm is demonstrated by training the model on data of a single site and testing the performance on all 18 sites. Surprisingly, we find for 14 sites the model achieves higher accuracy than at the site it was trained on. Including data of all sites in the train set improves the accuracy on 3 of the 6 relevant target parameters while decreasing the accuracy on 1. Finally, we compare this work on post-processing to the next generation weather models based on high resolution Large Eddy Simulation (LES). A case study spanning four days is performed on four days well-captured by the NWP model and results are compared to results from the post-processing algorithm. While LES underestimates values of high irradiance due to lack of 3D radiative effects, it enables detailed analysis of the dynamics at high spatial and temporal resolution unreachable by statistical postprocessing.

The algorithm presented in this work is able to predict intra-hour irradiance variability based on day-ahead NWP output. Thereby moving forward significantly towards improving grid operation, planning, and resilience in relation to large-scale solar PV generation.