A Probabilistic Forecasting System for Solar Power Generation

Carlo Siebenschuh, Hendrik Hamann, Rui Zhang

06-08-2021



This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number EE0008215.



June 8th, 2021 / © 2021 IBM Research

Solar Power Generation: Global

Electricity generation:



[yearbook.enerdata.net]

Record capacity added in 2020:

260 GW

[irena.org]

Fastest growing electricity source:



[c2es.org]

June 8th, 2021 / © 2021 IBM Research

Renewables add Uncertainty

- ISOs balance power in real-time
- renewables intensify this balancing challenge
- uncertainty necessitates more ramp
- higher ramp requirement (regulation) could offset the economic benefits of renewables
- maximize renewable penetration s.t. a balanced power network



Fig. 1: Relative energy generation mix by country

Deterministic Solar Forecasting



Uncertainty in Solar Forecasting



Watt-Sun: From v1 to v2







Fig. 3: 24h ahead forecasts of global horizontal irradiance (GHI), Las Topaz (CA), April 1st 2020

Watt-Sun v1 : The Model

Regression: global horizontal irradiance

Input Data:

Meteorological, Climatological, Topographical Data

$Y_{t+h,s} = \sum_{c=1}^{C} \left(f_{t,s,h,c}(X_t; \theta_{t,s,h,c}) \right)$

Legend

- t current time
- *h* forecast horizon
- s space (lat/lon)
- c weather category

Model instance:

- weather <u>category-aware</u>
- physical interpretability
- machine-learnt model blending

Watt-Sun v2 : The Model

Quantile Prediction: global horizontal irradiance

Input Data:

Meteorological, Climatological, Topographical Data

$$F^{-1}(p; Y_{t+h}) = \sum_{m=1}^{M} (f_{t,h,m}(X_t; \theta_{t,h}))$$

Legend

- *t* current time
- *h* forecast horizon
- *m* model instance
- F CDF

Model Instance:

- automatic filtering (diurnal/seasonal)
- space-time embedding learning
- rasterized output

Watt-Sun: Training and Test Data



Fig. 4: 24 GHI reference stations, and NOAA High-Resolution Rapid

Performance: PP-Plot



Performance: PP-Plot Metric



Computational Challenges

Storage

- temporal resolution: sub-hourly data
- spatial resolution: 3 km
- extent: North America

Computation

- infer thousands of parameters
- multiple optimization problem
- continuous deployment





IBM PAIRS : Graphical User Interface

Output: GHI, 50% quantile

Input Data: GOES 16



June 8th, 2021 / © 2021 IBM Research

IBM COS: Cloud Object Storage



Model Estimation

- integrated ML frameworks
- distributed deep learning

Model Deployment

- customizable environments (e.g. Python, R)
- reliable inference
- logging

Thank you!

carlo.siebenschuh@ibm.com

