Generalized Model for Solar Irradiance Forecasting

Jesus Lago

February 23, 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Marie Sklodowska-Curie grant agreement No 675318

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Problems with renewable energy sources (RES)

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$\Longrightarrow$ More complex grid management.

Importance of RES forecasting

Forecasting generation of RES needed to improve grid management tasks:

1. Ancillary services and reserves activation.
2. Operational planning and scheduling.
3. Congestion management.
4. Peak load matching.

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Importance of Solar Energy Forecasting

Observation

- Solar energy is one of the most unpredictable RES.
- More and more solar energy generation is being deployed worldwide.

$\Longrightarrow$ Forecasting of solar energy generation is key in grid management.

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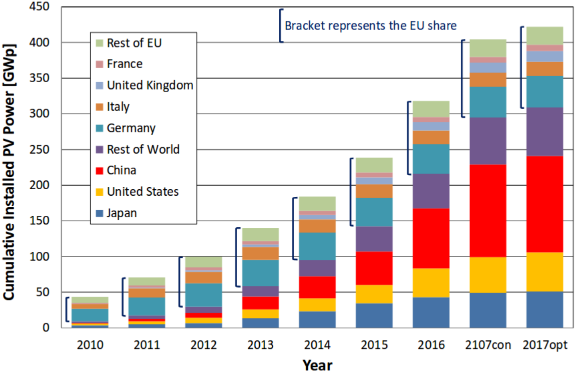

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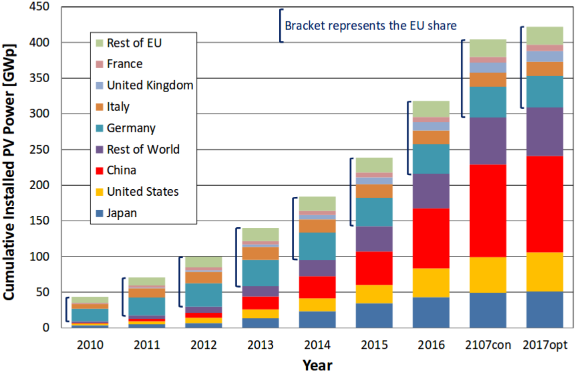

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Fundamentals of solar irradiance forecasting

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Forecasting of solar energy generation $\approx$ forecasting of solar irradiance.

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Standard Models for Irradiance Forecasting

Techniques categorized according to prediction horizon:

1. **Time series models**: short-term forecasts up to 6 hours ahead.
   1.1 Statistical and artificial intelligence models: **ground data**.
   1.2 Cloud moving vector models: **satellite images**.
2. **Numerical weather prediction models**: suitable for 6 hours onward. Simulate weather conditions, i.e. long computation time $\approx$ several hours.

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Motivation

Observations

- Classical statistical and artificial intelligence methods require ground measurements of solar irradiance.
- Considering the geographical dispersion of solar generators, ground measurements of all these sites are required.
- Obtaining all this local data becomes very expensive and hard.

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1. To obtain scalable solutions for irradiance forecasting, a global model that can forecast without the need of local data is needed.
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- General forecasting model for solar irradiance with ground measurements not required:
    1. Uses satellite images but easier to deploy than cloud moving vectors.
    2. As accurate as local models with local data.

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Note

- The aim of the model is not to be the most accurate.
- The aim is to be as good as local models to save operating cost.

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Model Structure

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1. Model structure flexible enough to generalize across multiple geographical locations.
2. Model inputs that, while correlating with irradiance, are general enough to be easily obtained for any given location.

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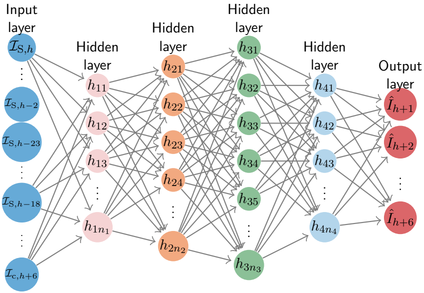
Deep Neural Network



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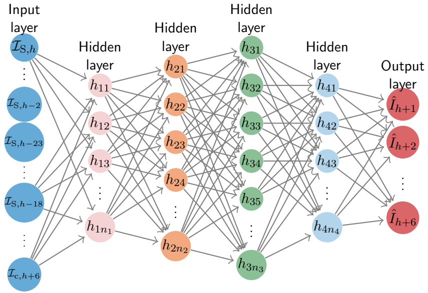
Deep Neural Network

- 6 hours ahead $\Longrightarrow$ 6 output neurons.
- 4 hidden layers.
- Optimized number of neurons.



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1. Clear-sky irradiance, i.e. irradiance without clouds, at prediction times.

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   - Pixel resolution $3 \times 3\,\text{km}$.
   - Source: METEOSAT.
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    - Pixel resolution 3×3 km.
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3. Weather-based forecast (NWP) at prediction times.

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Model generalization

Generalization across sites

To forecast without ground data, model needs to generalize across geographical sites:

1. Model trained in small subset of sites.
2. Model generalizes to other locations.

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Generalization across prediction horizons

To further strengthen the generalization capabilities, the model is trained to forecast at different hours of the day.

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1. Evaluate model performance in 25 out-of-sample sites during 1 year.
2. Compare performance with literature local models:
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Local Models

Local Model Types

Four different local models per location:

1. Persistent.
2. Autoregressive with exogenous inputs (ARX).
3. Gradient boosting tree (GBT).
4. Local DNN.

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Result

- Global model equal or better than local models.

Model	rRMSE [%]
Global DNN	31.32
ARX	32.20
Local DNN	32.32
Weather-based (NWP)	35.18
GBT	36.09
Persistent	42.27

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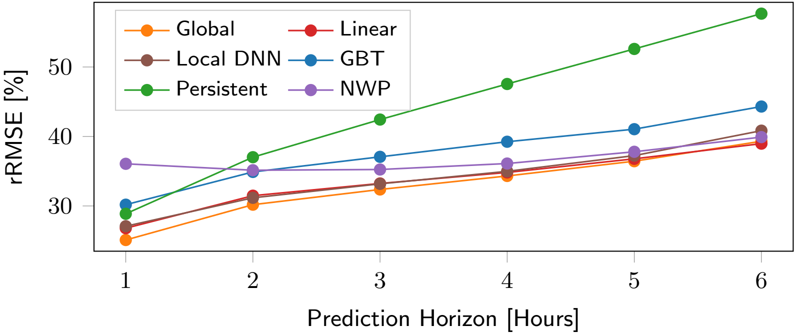
Comparison across horizon

Goal

- Global model should build accurate predictions across all horizons.



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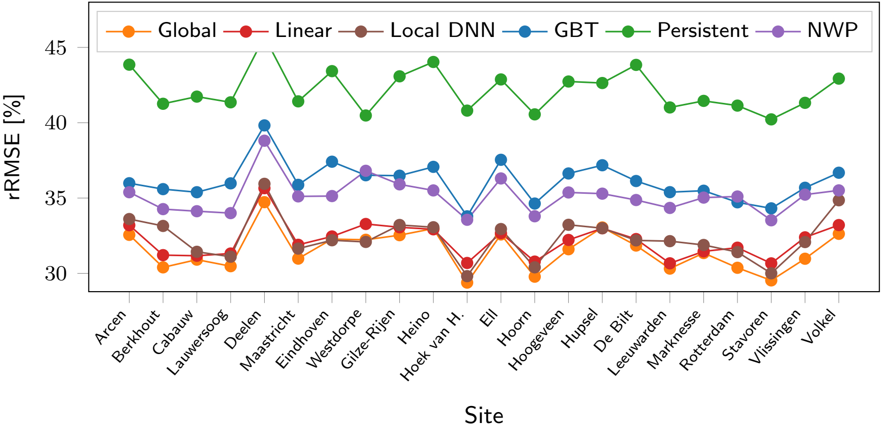

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Electricity Demand Forecasting Competition

Competition Information

- Organized by French grid operator RTE.
- Real-time contest: before 21:00 of day d each participant submitted the demand forecasts fo day $d+1$:
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- 15 days competition between 20/01/2018 and 10/02/2018.
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Result

- 3^{rd} in probability forecasting.
- 4^{th} in point forecasting.
- Developed models better than many commercial solutions.

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Thank you. Any Questions?

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