Intraday Forecasts of the Wind Energy Production for Transmission System Grid Nodes

Stephan Vogt, 9 June 2016
Agenda

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- Methods
  - Approximation with Reference Wind Farms
  - Generic Power Curve
  - Combination with Spatial Weights
- Results
  - Experiment Setup
  - Farm Errors
  - Significance
- Conclusion
Introduction

German transmission system operators (TSO)

Example of a Transmission Grid Node

Previously common:
future grid node wind power production as constant proportion of the control zone forecast

Amprion
TransnetBW
TenneT
50Hertz

measured reference wind farms

Grid Node
Motivation

TSOs ensure secure network operation. Therefore necessary:

- Load flow calculations
- Consider volatile power production (wind & PV)

Highly suspected redispatch causes:

- Errors in control zone intraday forecasts (15min to 8h)
- Spatially variable wind power production → missing grid node forecast
Method #1 – Approximation with Reference Wind Farms (RWF)

Estimate farm wind-to-power transform with Extreme Learning Machines.

Interpolation of normalized feeds at unmeasured Farms.

Multiplication by installed capacity.

Aggregate to region.

Output: forecast time series.

Real time wind power measurements
Numerical Weather Prediction (NWP)

RWF #1
RWF #2
RWF #3
RWF #4
RWF #\(N_{Ref}\)

Installed wind power capacity

Wind Farm A
Wind Farm B
Wind Farm C

85% Farm B
15% Farm A

Farm C: No measurements
Method #2 – Generic Power Curve (PC)

- Speed to power transformation with a “physical” power curve
- Wind speeds from numerical weather prediction (NWP)
- Considers local NWP data
  - But: Does not use any real time measurements

Output: forecast time series

Wind Speed

Norm. Power

% Wind Speed

Multiplication by installed capacity

Aggregate to region

installed wind power capacity

normalized power

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Method #3: Combination with Spatial Weights

\[
    p_{\text{combined},j} = w_{PC}(\bar{x}_j) \cdot p_{PC,j} + \sum_{i=1}^{N_{RWF}} w_{RWF,i}(r_{i,j}) \cdot p_{RWF,i}
\]

\[
    w_{PC}(\bar{x}_j) = \frac{\alpha}{\alpha + \sum_{i=1}^{N_{RWF}} \varphi_s(r_{i,j})}
\]

\[
    w_{RWF,i}(r_{i,j}) = \frac{\varphi_s(r_{i,j})}{\alpha + \sum_{k=1}^{N_{RWF}} \varphi_s(r_{k,j})}
\]

- \(p_{PC,j}\): Power curve (PC) forecast of unmeasured wind farm \(j\)
- \(p_{RWF,i}\): \(i\)-th ref. wind farm (RWF) forecast
- \(p_{\text{combined},j}\): Combined power
- \(w\): Weight of the Methods
- \(\alpha\): Influence factor of the PC
- \(\varphi_s(r_{i,j})\): Radial basis function where \(r_{i,j} = \|\bar{x}_i - \bar{x}_j\|\)
Experiment Setup

12 previous 15min real time measurements of 58 wind farms, 96 x per day

Approximation with reference farms (Method #1)

Legend:
- Combination with spatial weights
- 12 previous 15min real time measurements of 58 wind farms, 96 x per day
- Generic Power Curve (Method #2)
- Comparison based on 82 reference farm measurements (Forecast Horizons: 15min, 30min, … 8h)

<table>
<thead>
<tr>
<th>Partition</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>01/01/2013</td>
<td>30/05/2014</td>
</tr>
<tr>
<td>Validation</td>
<td>30/05/2014</td>
<td>15/12/2014</td>
</tr>
<tr>
<td>Test</td>
<td>15/12/2014</td>
<td>30/06/2015</td>
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Results – Farm Errors

- **Real time measurements** → improve unmeasured farms in the first 3 to 4 hours
- Generic power curve does a surprisingly good job
- Best to combine real time supported reference farm forecasts with power curve, but is it significantly better?

<table>
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<tr>
<th>Method</th>
<th>Reference Farm Approximation</th>
<th>Generic Power Curve</th>
<th>Combination</th>
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</table>

- **Figure:**
  - **X-axis:** Forecast horizon [h]
  - **Y-axis:** Average nRMSE of 82 wind farms [%]
  - **Legend:**
    - Method #1
    - Method #2
    - Method #3
  - **Interquartile range of the bootstrapped single farm nRMSE value average**

- **Table:**
  - **X-axis:** Single Farm nRMSE (2h horizon) [%]
  - **Y-axis:** Interquartile range of the bootstrapped single farm nRMSE value average
Significance of the Improvement

Improvement over all single Wind Farms with the average error of 1000 bootstrap sets with 82 single wind farm errors:

- **Power Curve vs. Combination**
- **Reference Farm Approximation vs. Combination**

Method #3 is better than Method #2 for all forecast horizons [h].

Method #3 is better than Method #1 for all forecast horizons [h].
Conclusion

- 3 Methods forecast the production of unmeasured wind:
  - Reference farm method: Extrapolation of single farm forecasts to region
  - Generic Power Curve
  - Combination
- Methods compared: 2.5 years of NWP and 15min power measurements
- Generic power curve ≈ reference farms
- Combination (method #3) results in significant improvement
Acknowledgements

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