Improved intraday power forecasts of unmeasured wind plants with weather predictions and nearby online power measurements

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Introduction

Measured reference wind farm RWF #1

Unmeasured wind farm

RWF #2

RWF #3
Method #1 – Approximation with Reference Wind Farms (RWF)

Real time wind power measurements

Numerical Weather Prediction (NWP)

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

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

Interpolation of normalized feeds at unmeasured Farms

Wind Farm A

Wind Farm C

Wind Farm B

85% Farm B

15% Farm A

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

Wind speeds from numerical weather prediction (NWP)

Speed to power transformation with a generic power curve

Considers local NWP data
- **But:** Does not use any real time measurements
### Method #3: Combination with Spatial Weights

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

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

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{PC,j} )</td>
<td>Power curve (PC) forecast of unmeasured wind farm ( j )</td>
</tr>
<tr>
<td>( p_{RWF,i} )</td>
<td>( i )-th ref. wind farm (RWF) forecast</td>
</tr>
<tr>
<td>( p_{\text{combined},j} )</td>
<td>Combined power</td>
</tr>
<tr>
<td>( w )</td>
<td>Weight of the Methods</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>Influence factor of the PC</td>
</tr>
<tr>
<td>( \varphi_s(r_{i,j}) )</td>
<td>Radial basis function where ( r_{i,j} = | \tilde{x}_i - \tilde{x}_j | )</td>
</tr>
</tbody>
</table>

- **Wind Farm A**: 50% Farm B
- **Wind Farm B**: 40% Power Curve
- **Wind Farm C**: No measurements
Experiment Setup

<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>
</tr>
</tbody>
</table>

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

Approximation with reference farms (Method #1)

Generic Power Curve (Method #2)

Combination with spatial weights

Comparison based on 82 reference farm measurements (Forecast Horizons: 15min, 30min, ..., 8h)

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

Last IFS (ECMWF) weather forecast 3h resolution, 6.25h delay, 2 x per day
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?

**Reference Farm Approximation**
- Generic Power Curve
- Combination

![Diagram showing the comparison of different methods for farm errors.](image)

- **Method #1**
- **Method #2**
- **Method #3**

**Average nRMSE of 82 wind farms [%]**

- **Interquartile range of the bootstrapped single farm nRMSE value average**

**Forecast horizon [h]**

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8

**Single Farm nRMSE (2h horizon) [%]**

- 10
- 15
- 20
- 25
- 30

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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**
  - Method #3 is better
  - Method #2 is better

- **Reference Farm Approximation vs. Combination**
  - Method #3 is better
  - Method #1 is better
Conclusion

- 3 Methods forecast the production of unmeasured wind farms:
  - 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 $\approx$ reference farms
- Combination (method #3) results in significant improvement
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