Applicability of wind power forecasting models in Japan

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The outline of the project

- A national R&D project, "Development of Wind Power Prediction Models Based on Numerical Weather Prediction" has been carried out since October 2005 until March 2008.

- The object of the project is "to develop a practical wind power prediction system for power system operation".

- The Project is funded by New Energy and Industrial Technology Development Organization (NEDO) and cooperated by five organizations.
  - The University of Tokyo (UT)
  - Itochu Techno-Solutions (CTC)
  - Central Research Institute for Electric Power Industry (CRIEPI)
  - Japan Weather Association (JWA)
  - E & E Solutions (EES)
The concept of the project

To meet any type of requirement in the future, two types of model will be developed.

WF model
- Based on detailed SCADA information.
- For wind farm owners.

Area model
- Based on limited SCADA information
- For grid operators.
The contents of the project

- Measurement (both on-line and off-line)
  - EES

- Development of wind power prediction model
  - CRIEPI + JWA (WF model), UT + CTC (Area model)

- Verification and error analysis of the model
  - CRIEPI (WF model), UT (Area model)

- On line implementation of the model
  - JWA (WF model), CTC (Area model)

- Development of the platform for wind power prediction model
  - CTC, UT

- Guideline for wind power prediction
  - CRIEPI, UT
The topic of this presentation

- As a part of “Development of wind power prediction model”, benchmark testing for existing area models were carried out by the University of Tokyo and CTC.

- The result of the benchmark testing carried out by University of Tokyo will be presented.
The benchmark test was carried out for the sum of the output from six large wind farms (total capacity 167MW) in Tohoku area, northern part of Japan.
Day ahead forecast and hourly forecast

Day ahead forecast
- Carried out once a day at 06:00 a.m. for the next day
- Main application: unit commitment

Hourly forecast
- Carried out every 30 minutes for next 24 hours
- Main application: load following
### The conditions of the benchmark test

<table>
<thead>
<tr>
<th>Test models</th>
<th>University of Tokyo Model, WPPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF</td>
<td>6 wind farms in Tohoku area (Total capacity 167 MW)</td>
</tr>
<tr>
<td>Geographic information</td>
<td>location of the WF, hub height, elevation, surface roughness</td>
</tr>
<tr>
<td>Input data</td>
<td>NWP(GPV-RSM, 20km resolution.JMA), SCADA data from each WF</td>
</tr>
<tr>
<td>Evaluation data</td>
<td>Sum of the SCADA data from six WFs</td>
</tr>
<tr>
<td>Training data</td>
<td>All the data in 2004 except for Feb., Apr., Jul and Oct.</td>
</tr>
<tr>
<td>Forecast value</td>
<td>30 minutes averaged power from each wind farm and the area</td>
</tr>
<tr>
<td>Forecast time</td>
<td>6:00 a.m. (day ahead forecast)</td>
</tr>
<tr>
<td></td>
<td>Every 30 minutes (hourly forecast)</td>
</tr>
<tr>
<td>Forecast horizon</td>
<td>0:00 to 24:00 next day</td>
</tr>
<tr>
<td></td>
<td>24 hours from the</td>
</tr>
</tbody>
</table>
Mesoscale model RAMS is used to downscale the 20km resolution NWP to 1km.

\[ P_{t+k}^{pc} = f(u_{t+k}^{pred}) \]

\[ P_{t+k}^{pred} = a(k)P_{t}^{meas} + b(k)P_{t+k}^{pc} \]
WF power curve and the parameters for power prediction model is estimated using adoptive method.

\[
P_{i+k}^{pc} = f\left(u_{i+k|t}^{pred}, \theta_{i+k|t}^{pred}, k\right)
\]

\[
P_{i+k}^{pp} = a\left(\theta_{i+k|t}^{pred}, k\right)P_{i}^{meas} + b\left(\theta_{i+k|t}^{pred}, k\right)P_{i+k}^{pc} +
\]

\[
c^{c}\left(\theta_{i+k|t}^{pred}, k\right)\cos \frac{2\pi h_{i+k}^{24}}{24} + c^{s}\left(\theta_{i+k|t}^{pred}, k\right)\sin \frac{2\pi h_{i+k}^{24}}{24}
\]

WF power curve and the parameters are the function of the wind direction.

SCADA data

NWP data

WF power curve model

Power prediction model

Predicted power
## Summery of the models

<table>
<thead>
<tr>
<th></th>
<th>UT model</th>
<th>WPPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution of NWP data</td>
<td>1km</td>
<td>20km</td>
</tr>
<tr>
<td>Adoptive approach for the parameter identification</td>
<td>Not used</td>
<td>Used</td>
</tr>
<tr>
<td>Training period</td>
<td>All the data in 2005 except for Feb., Apr., Jul. and Oct.</td>
<td>All the data in 2005 before the forecast time.</td>
</tr>
</tbody>
</table>
Day ahead forecast

- UT model seems to simulate extreme phenomena better
- This is because of the resolution
Error Analysis

In order to show the performance of the models, following measures were used.

\[
ME = \frac{\sum_{i=1}^{n} (P_i^{\text{pred}} - P_i^{\text{meas}})}{n}
\]

Mean Error (bias)

\[
RMSE = \sqrt{\frac{\sum_{i=1}^{n} (P_i^{\text{pred}} - P_i^{\text{meas}})^2}{n}}
\]

Root Mean Square Error

ME and RMSE is calculated as a non dimensional value (\%) relative to the total nominal power.
UT model gave better results for all the forecast horizon of the day ahead forecast.
Summery of the results

- For most of the months, UT model shows better performance.
- For UT model, forecast bias (ME) is not small.

* Forecast for February by WPPT may not be appropriate for benchmark testing because of the short time for training.
No significant difference can be found. WPPT seems to show slightly better result especially near the sharp peak.
For the time horizon shorter than 6 hours, WPPT model shows better performance because of the dynamical statistical model.
For 6 hour ahead forecast, WPPT shows better results especially the mean error (bias).

* Forecast for February by WPPT may not be appropriate for benchmark testing because of the short time for training.
When high resolution NWP data (1km resolution) was used as an input to the WPPT, it gave similar results upto 15 hours.
Conclusions

- For day ahead forecast, prediction error of UT model is smaller than that of WPPT. This is due to the difference in the spatial resolution of the NWP data used.

- For hourly forecast, prediction error of WPPT is smaller than that of UT model. This is because WPPT uses adoptive approach for the estimation of parameter in the statistical model.