IEAWIND Task 25: Design and operation of power systems with large amounts of wind power

EWEC’2010 Side Event Session
Hannele Holttinen, Operating Agent
VTT Technical Research Centre of Finland
### IEA WIND Task 25:
Design and operation of power systems with large amounts of wind power

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Hydro Quebec (A.Robitaille); Manitoba Hydro (T. Molinski); Natural Resources Canada (S.Lalande);</td>
</tr>
<tr>
<td>Denmark</td>
<td>Risø-DTU (Peter Meibom); Energinet.dk (Antje Orths)</td>
</tr>
<tr>
<td>EWEA</td>
<td>European Wind Energy Association (Frans van Hulle)</td>
</tr>
<tr>
<td>Finland (OA)</td>
<td>VTT Technical Research Centre of Finland (Hannele Holttinen)</td>
</tr>
<tr>
<td>Germany</td>
<td>ISET (Bernhard Lange); TSO RWE (Bernhard Ernst)</td>
</tr>
<tr>
<td>Ireland</td>
<td>ECAR/UCD (Mark O’Malley), TSO Eirgrid (Jody Dillon), SEI (John McCann)</td>
</tr>
<tr>
<td>Japan</td>
<td>AIST (Junji Kondoh)</td>
</tr>
<tr>
<td>Norway</td>
<td>SINTEF (John Olav Tande); TSO Statnett (T. Gjengedal)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>we@sea, ECN (Jan Pierik); TUDelft (M.Gibescu)</td>
</tr>
<tr>
<td>Portugal</td>
<td>INETI (Ana Estanquiero); TSO REN (João Ricardo); INESC-Porto (J. Pecas Lopes); UTL-IST (Ferreira Jesus)</td>
</tr>
<tr>
<td>Spain</td>
<td>University of Castilla La Mancha (Emilio Gomez Lazaro)</td>
</tr>
<tr>
<td>Sweden</td>
<td>KTH (Lennart Söder)</td>
</tr>
<tr>
<td>UK</td>
<td>DG&amp;SEE (Goran Strbac), TSO National Grid (A.Hiorns)</td>
</tr>
<tr>
<td>USA</td>
<td>NREL (Brian Parsons); UWIG (Charles Smith)</td>
</tr>
</tbody>
</table>
IEA WIND Task 25

OBJECTIVE:

to analyse and further develop the methodology to assess the impact of wind on power systems

First phase 2006-08, 11 countries + EWEA participate
Second phase 2009-11, 14 countries + EWEA participate.

- Provide an international forum for exchange of knowledge
- State-of-the-art: review and analyse the studies and results so far
  - methodologies and input data, system operation practices
  - Final report 2006-08 published in July 2009
- Formulate guidelines:
  - recommended methodologies and input data when estimating impacts and costs of wind power integration
  - Quantify the impacts of wind power on power systems
    - range of impacts/costs; rules of thumb

www.ieawind.org/AnnexXXV
Challenges to power systems with large share of wind power

- Variability of wind power production
- Prediction errors of wind power production
- Grid to connect and transfer the power
- Currently there is
  - the variable load – has more predictable patterns
  - the grid that can take and transfer power from existing units
- Impacts will depend on:
  - The share of wind power in the power system
  - The variability of load
  - The flexibility of power generation fleet
  - Possibilities to increase flexible production and consumption
  - The adequacy of grid (wind resource versus load centers)
Wind power in the power system: impacts on reliability and efficiency

Area relevant for impact studies

- System wide (1000-5000 km)
  - Primary reserve
  - Secondary reserve
  - Reduced emissions
  - Adequacy of power
  - Adequacy of grid
  - Grid stability
- Regional (100-1000 km)
  - Transmission efficiency
  - Congestion management
- Local (10-50 km)
  - Voltage management
  - Distribution efficiency
  - Power quality

Time scale relevant for impact studies
- ms…s
- s…min
- min…h
- 1…24 h
- years

Adequacy
Balancing
Grid
Where are we now?

- There is already experience from several countries integrating 5-20% of their electricity consumption from wind energy
  - TSOs use updated information of on-line production and forecasts as well as possibility to curtail in critical situations
  - They see increase in short term regulation/load following use
- Existing constraints to reinforce the transmission network can delay reaching 20% wind penetration on the European/North American scale
- Operation strategies to cope with wind generation from a high to a very high level (>20%) are still being developed. New tools are needed.
- Technical capabilities of wind power plants used more, and evolving
Experience from regions with large wind power penetration

- West Denmark: 2380 MW wind power, 3700 MW peak load (24 % of energy)
  - Balancing solved both inside and outside region. Wind power regulation has been used in rare occasions.
- North Germany: 2275 MW wind power, 2000 MW peak load (33 % of energy)
  - Balancing solved both inside and outside region. Wind power regulation has been used since 2003 in occasions with high wind and congested transmission. **Fault-ride-through needed to avoid wind power becoming a dimensioning fault** (> 3000 MW tripping off)
- Spain: 16754 MW wind power (11 % of energy)
  - Balancing solved inside the region. Wind power regulation has been used increasingly. Distributed energy connected to centers that convey data to TSOs and can react to control needs. Fault-ride-through needed to get higher penetration levels.
- Gotland, Sweden: 90 MW wind power, 160 MW peak load (19 % of energy)
  - Balancing solved outside region: **control enhanced to enable around 0 MW operation of HVDC link to mainland**
Estimating wind power impacts -
Smoothing effect in variability of large-scale wind power

- Variability reduced as more sites/turbines and shorter time scales

Source: ISET
Extreme ramps in wind power production – storm events recorded so far

- **Denmark**: 2000 MW (**83 % of capacity**) decrease in 6 hours or 12 MW (**0.5 % of capacity**) in a minute on 8th January, 2005
- **North Germany**: over 4000 MW (**58 % of capacity**) decrease **within 10 hours**, extreme negative ramp rate of 16 MW/min (**0.2 % of capacity**) on 24th December, 2004
- **Ireland**: 63 MW in 15 mins (~**12% of capacity**), 144 MW in **1 hour** (~**29% of capacity**) and 338 MW in **12 hours** (~**68% of capacity**)
- **Portugal**: 700 MW (**60% of capacity**) decrease in **8 hours** on 1st June, 2006
- **Spain**: 800 MW (**7 % of capacity**) increase in 45 minutes (ramp rate of **1067 MW/h, 9 % of capacity**), and 1000 MW (**9 %**) decrease in 1 hour and 45 minutes (ramp rate **-570 MW/h, 5 % of capacity**)

Predictability of wind power

- Predictions will be improved
  - for larger region (more sites)
  - for shorter times ahead
- Predictions have been improved, development work started in 1990’s

<table>
<thead>
<tr>
<th>NRMSE [%]</th>
<th>Germany (all 4 control zones) ~1000 km</th>
<th>1 control zone ~ 350 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>day-ahead</td>
<td>5.7</td>
<td>6.8</td>
</tr>
<tr>
<td>4h ahead</td>
<td>3.6</td>
<td>4.7</td>
</tr>
<tr>
<td>2h ahead</td>
<td>2.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Source: ISET
Summary capacity value of wind power

- Wind capacity value decreases at larger penetrations, faster for smaller areas.
- Differences: wind resource at peak loads, reliability level, methodology
Capacity value and capacity cost

- Cost estimates for the lower capacity value of wind power compared to thermal power plants should use correct comparison
  - based on same amount of energy per year from wind (2000-3000 full load hours per year) and thermal power (6000-7000 h/a)
- The deviation between capacity value of wind power and capacity value of a thermal power plant with the same yearly energy production can be denoted as “capacity cost”
  - if the power system with wind power or thermal power systems should have the same risk of capacity deficit, some capacity has to be added
- Added capacity is only used few hours per year, so important to use low investment cost plants for this purpose (Open Cycle Gas Turbines) or Demand Side Management.
- The range of 2-4 Euro/MWh for the wind power produced has been estimated by (Söder & Amelin, 2008).
Main messages from comparisons

- The case studies are not easy to compare
  - Different methodology, data, assumptions on interconnection

- Integration costs to be compared to f.ex. production costs or market value of wind power, or integration cost of other production forms
  - **Cost-benefit analysis**: integration costs vs. benefit from reducing total operating costs and emissions

- Issues impacting the amount of wind that can be integrated:
  - Large balancing areas: aggregation benefits help reducing variability and forecast errors of wind power as well as help pooling more cost effective balancing resources.
  - System operation/electricity markets at less than day-ahead time scales help reduce forecast errors of wind power.
  - **Transmission is the key** to aggregation benefits, electricity markets and larger balancing areas.
**Recommendations for wind integration studies**

- Capture the smoothed out variability of wind power production time series for the geographic diversity assumed:
  - Actual geospread data and/or synchronized weather simulation
  - Wind forecasting best practice for the uncertainty
- Examine wind variation in combination with load variations
- Capture system response through operational simulations
- Examine actual costs independent of tariff design structure
- Compare costs and benefits of wind power

- Future: development of simulation models - incorporating wind forecast errors, capturing variability costs; new wind power dynamic models for power system stability studies including aggregation and clustering of wind turbines;