10 FAQ’s about Wind

1) How much wind is currently installed in the US?
2) What are the benefits of wind energy to the power system?
3) How can wind’s variability be incorporated into power system operations?
4) Does wind plant output start/stop suddenly?
5) Can wind be predicted?
10 FAQ’s about Wind

6) Can the power system be reliably operated with wind energy?
7) Does wind need backup or storage?
8) Is there a limit to how much wind can be accommodated on the grid?
9) Can wind power plants be controlled?
10) Can wind energy make effective use of transmission lines?
11) Bonus Question: How can more wind be accommodated on the grid?

1) How much wind is currently installed in the US?

[Map of the United States showing wind power capacity by state.]

Total: 16,740 MW
(A of 12/31/07)

Wind Power Capacity

- Multi-MW (150 - 1500)
- 50 - 200
- 1 - 50
- Less than 1

Data from the American Wind Energy Association (AWEA) and State Energy Contacts (SEC) databases.

U.S. Department of Energy
National Renewable Energy Laboratory

Multitask 1.07
1) How much wind is currently installed in the US?

Colorado/Xcel: Approx 20% wind penetration (wind capacity/system peak)

Iowa: Approx 16% wind penetration (wind capacity/system peak)

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1b) How much wind is currently installed in Europe?

<table>
<thead>
<tr>
<th></th>
<th>MW Installed</th>
<th>End 2006</th>
<th>Installed 2007</th>
<th>End 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total EU-12</td>
<td>419</td>
<td>263</td>
<td>675</td>
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</tr>
<tr>
<td>Total EU-15</td>
<td>47,651</td>
<td>8,291</td>
<td>55,860</td>
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<tr>
<td>Total EU-27</td>
<td>48,069</td>
<td>8,554</td>
<td>56,535</td>
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</table>
2) What are the benefits of wind energy to the power system?

- Wind energy displaces
  - Fuel
  - Emissions; carbon
- Wind provides a hedge against rising fuel prices (natural gas, coal)
- Wind is an energy source with limited capacity contribution → other generation is also required
- Wind can be cost-competitive with other forms of generation and may reduce electricity cost

3) How can wind’s variability be incorporated into power system operations

- Electric load (without wind) varies considerably
- Power system operating practices are built around meeting the variable load with dispatchable generators that can change their output level
- Wind adds more variability to the system
- Existing operating practice can be used/expanded upon with wind
4) Can wind power start and stop suddenly?

- Large wind farms have many individual wind turbines
- The turbines are spread over many miles and do not experience the same wind at the same time
- TX event Feb 24, 2007: drop of 1,500 MW over 2 hours is similar to behavior of load

5) Can wind be predicted?

- Wind forecasts are derived from weather prediction models
- Wind forecast accuracy is improving
- Several wind forecasting firms in U.S.

Courtesy: WindLogics, Inc. St. Paul, MN
6) Can the power system be reliably operated with wind energy?

- Yes – additional flexible generation (operating reserves) may be necessary at higher wind penetrations
- This additional operating reserve has a modest cost, typically about 10% of the cost of the wind energy itself
- Graph shows this level of operating reserve (blue) is a relatively small, varying fraction of wind generation

7) Does wind need backup or storage?

- Increased operating reserves may be necessary, but not dedicated backup
- Although new storage has value, it may not be cost effective
- There is typically already storage on the system
  - Natural gas in the pipeline or storage facility
  - Controllable hydro
- A recent study by Xcel Energy in Colorado found
  - existing pumped storage provided $1.30/MWh offset to wind integration cost
  - Enlarging existing gas storage facility was economic at large wind penetration

<table>
<thead>
<tr>
<th>Wind Penetration</th>
<th>10%</th>
<th>15%</th>
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<tbody>
<tr>
<td>$/ MWH Gas Impact No Storage Benefits</td>
<td>$2.17</td>
<td>$2.52</td>
</tr>
<tr>
<td>$ / MWH Gas Impact With Storage Benefits</td>
<td>$1.26</td>
<td>$1.45</td>
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</table>
8) Is there a limit to how much wind can be accommodated on the grid?

- Current studies in the U.S. have analyzed up to 25% of all electric energy from wind
- Based on work done so far, the question is not whether wind can be accommodated at high penetrations, the question is how and at what cost of integration

8) Is there a limit to how much wind can be accommodated on the grid?

- Recent International Energy Agency Report: Design and operation of power systems with large amounts of wind power

8) Is there a limit to how much wind can be accommodated on the grid?

Denmark has access to large export markets


9) Can wind power plants be controlled?

- New low-voltage ride-through (LVRT) grid codes in the U.S. will help wind turbines contribute to grid reliability
- Wind turbines can be controlled but not to the extent that conventional generation can be controlled
  - Ramp rate limits
  - Up-regulation (operate below potential so that wind output can be increased if needed)
  - Curtailment, if necessary and economic, at low-load/high-wind conditions
10) Can wind energy make effective use of transmission lines?

- Conditional-firm transmission tariff (recent FERC ruling)
- Wind does not need transmission all of the time
- Most transmission paths have some open capacity most of the time
- Adding wind can result in more efficient usage of existing transmission

11 Bonus) How can more wind be accommodated on the grid?

- Utility balancing areas can combine or cooperate – large electricity markets (example: Denmark/Europe)
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- Utility balancing areas can combine or cooperate – large electricity markets

- Example: **Ramping, or changing output of generators that can be eliminated with larger balancing areas**

- Power system operations practices and wind farm control/curtailment
- Integration of wind forecasting and real time measurements into control room operations (WindLogics/EnerNex/UWIG / Xcel study underway in Minnesota)
- Hydro dispatch, pumped hydro
- Longer term: other storage and markets (plug-hybrid electric vehicles, hydrogen)
11 Bonus) How can more wind be accommodated on the grid? What about Storage?

- Storage can have significant benefits to the power system
- Storage may help integrate wind, but storage is not necessary or economic based on results in the U.S. at low-moderate penetrations

Large-Scale Studies in Process

- Western Wind & Solar Integration Study
  – 30% Wind in footprint, 20% in WECC
- Eastern Wind Integration Study
Increasing Attention in North America

- Updated in 2007
- Wind Power Coordinating Committee Wind Super-Session, Summer 2008
- Utility Wind Integration Group (UWIG): Operating Impacts and Integration Studies User Group
  www.uwig.org
Texas Event Feb 26, 2008

• 15:00 – Wind generation output at 2000 MW and begins a 3.5 hour ramp down to 360 MW at 18:30. The down ramp was 2 hours sooner and somewhat faster (8 MW/minute vs 5 MW/minute) than forecast the day ahead

• 17:10 – Evening load ramp begins, increasing 3800 MW in 90 minutes, (42 MW/minute). The evening load ramp-up began 25 minutes earlier than the short-term hour-ahead load forecast predicted

Texas Event Feb 26, 2008

• 17:44 – 150 MW conventional unit trips offline
• 18:28 – ERCOT calls on non-spin service to come on-line
• 18:33 – 328 MW of Responsive (spinning) Reserve deployed
• 18:41 – ERCOT calls for EECP step 2
• 18:49 – ERCOT instructs all available LaaRs to reduce consumption
Texas Event Feb 26, 2008

- 18:59 – 1108 MW of LaaR was reduced within 10 minutes (1200 MW within 12 minutes)
- 18:56 – Spinning reserve deployment ends
- 20:08 – ERCOT ends step 2 and enters step 1
- 21:40 – EECP terminated

Lessons Learned

- Load forecast failed to predict the large ramp up in demand
- The accurate wind energy forecast was not used in scheduling (this has been rectified)
- LaaR was very effective in economically reducing demand
- Wind event was a ramp event, not a contingency event (similar to 2007 event)