Forecasting Wind

Barbara O’Neill, Grid Integration Manager

Presented to the Southeastern Wind Coalition
UAG Forecasting and Integration Meeting
Raleigh, North Carolina
March 30, 2016
U.S. Wind Installation and Generation by ISO

Wind Energy Installation and Records by Regional Independent System Operators

Bonneville Power Administration
Record Wind Output: 4,512 MW on 2/22/2013
Percent of Generation: 40.9% on 9/30/2014

Xcel Energy Colorado
Record Wind Output: 1,966 MW on 5/23/2013
Percent of Demand: 60.5% on 5/24/2013

MISO
Record Wind Output: 11,835 MW on 1/8/2015
Percent of Demand: 25% on 11/23/2012

New York ISO (NYISO)
814 MW

ISO New England (ISO-NE)
1,731 MW

California ISO (CAISO)
7,741 MW

Midwest ISO (MISO)
13,211 MW

PJM Interconnection (PJM)
5,848 MW

Electric Reliability Council of Texas (ERCOT)
12,470 MW

CAISO
Record Wind Output: 4,768 MW on 4/12/2014
Percent of Generation: 17.5% on 4/7/2013

ERCOT
Record Wind Output: 10,957 MW on 12/25/2014
Percent of Demand: 39.7% on 3/31/2014

PJM
Record Wind Output: 5,461 MW on 11/3/2014
Percent of Demand: 7.1% on 4/7/2013

SPP
Record Wind Output: 7,625 MW on 1/7/2015
Percent of Demand: 33.4% on 4/6/2013

Source: AWEA 2014 Year-End Market Report

NATIONAL RENEWABLE ENERGY LABORATORY
“Flexibility” Can Help Address the Grid Integration Challenges

**Flexibility**: The ability of a power system to respond to change in demand and supply

- Increases in variable generation on a system increase the variability of the ‘net load’
  - ‘Net load’ is the demand that must be supplied by conventional generation unless RE is deployed to provide flexibility
- High flexibility implies the system can respond quickly to changes in net load.
Frequently Used Options to Increase Flexibility

RELATIVE ECONOMICS OF INTEGRATION OPTIONS

- Involuntary Load Shedding
- Residential Demand Response
- Expanded Balancing Footprint/Joint System Operation
  - Upward Reserve and Dispatch
  - Downward Reserves
  - Frequency Support
  - Voltage Support
- Sub-hourly Scheduling and Dispatch
- Flexibility Reserves
- RE Forecasting
- SYSTEM OPERATION
  - SERVICES FROM VARIABLE RE
- LOAD
- FLEXIBLE GENERATION
- TRANSMISSION
- STORAGE
- Chemical Storage
- Fuel Storage/Flexible Scheduling
- Pumped Hydro Storage
- Thermal Storage
- Transmission Expansion
- Transmission Reinforcement
- Advanced Network Management
- Hydro Ramping
- Coal Ramping

Option costs are system-dependent and evolving over time.
Frequently Used Options to Increase Flexibility

- Numerous options for increasing flexibility are available in any power system.
- Flexibility reflects not just physical systems, but also institutional frameworks.
- The cost of flexibility options varies, but institutional changes may be among the least expensive.

Low capital cost options, but may require significant changes to the institutional context.
More Frequent Decisions Reduce Uncertainty

Why Is Forecasting Crucial to Integrating Variable RE to the Grid?

Operating with increased uncertainty...

Average day ahead error: 8%-10% for wind farm, 4% for system
Ramp error: Over 50% for large ramps

Source: Pierre Pinson, DTU, Denmark
Forecasting Can Provide Situational Awareness

What Services Can a Forecast Provide?

- Economic benefits through:
  - Improved unit commitment
    - Day-ahead forecasts for most thermal units
    - 4-hour-ahead forecasts for combined cycle natural gas plants
  - Reduced re-dispatch costs
    - Less “mileage” on operating units
    - Less starting of gas turbines and other fast acting units
  - Reduced reserve levels
    - Regulation reserve
    - Flexible/load following reserve
  - Decreased curtailment of RE generation

- Potentially impacting all timescales:
  - System Load (MW)
  - Time of Day (hr)
  - Load Following
  - Scheduling
  - Days
  - Unit Commitment
### How Are Wind and Forecasts Used in System Operations?
Examples from the United States

<table>
<thead>
<tr>
<th>Balancing Authority</th>
<th>Type of variable RE forecasted</th>
<th>Forward Unit Commitment (Day-ahead, week-ahead, etc.)</th>
<th>Intra-day Unit Commitment</th>
<th>Transmission Congestion Management</th>
<th>Reserves</th>
<th>Management of Hydro or Gas Storage</th>
<th>Generation/Transmission Outage Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta Electric System Operator</td>
<td>Wind</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arizona Public Service</td>
<td>Wind</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonneville Power Administration (BPA)</td>
<td>Wind</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>California Independent System Operator (CAISO)</td>
<td>Wind and solar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glacier Wind</td>
<td>Wind</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idaho Power</td>
<td>Wind</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northwestern Energy</td>
<td>Wind</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sacramento Municipal Utility District*</td>
<td>Solar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern California Edison*</td>
<td>Wind* and solar</td>
<td></td>
<td>X</td>
<td></td>
<td>X**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turlock***</td>
<td>Wind</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xcel Energy</td>
<td>Wind and solar</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Also participants in the CAISO’s Participating Intermittent Resource Program
** For hydro only, not natural gas
*** Uses forecast for trading, optimization, marketing, and compliance with BPA scheduling directives

• Variable RE and load forecasts provide enormous return on investment
• But value chain is not being fully utilized, especially for variable RE
• More value can be extracted if there is more focus on the elements to the right
  – *These convert data into actions and outcomes*
Why Are Forecast Errors Important?

- **Forecast error** is the difference between predicted and real-time generation from VRE resources (MBE, MAE, RMSE)
- More accurate forecasts (i.e., lower forecast errors) lead to higher efficiency in the unit commitment and dispatch process
  - Reduced curtailment
  - Lower reserve requirements

Historic forecast errors are used to benchmark different forecasting methods
- Persistence forecasts
- Numerical Weather Prediction (NWP) models
- Statistical corrections (autoregressive, machine learning)
- Ensemble methods
Wind Forecast Data Requirements and Methods

**Weather data**
- Wind speed
- Wind direction
- Barometric pressure
- Air temperature
- Etc.

**Numerical weather prediction (NWP)**

**Wind power plant data (SCADA data)**
- Power production
- Availability information
- Etc.

**Physical methods**

**Wind production forecast**

**Statistical methods**

Feedback loop
## Wind Forecasting Role in Market Operations

<table>
<thead>
<tr>
<th>Type of Forecast</th>
<th>Time Horizon</th>
<th>Key Applications</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-hour</td>
<td>5-60 min</td>
<td>Regulation, real-time dispatch market clearing</td>
<td>Statistical, persistence.</td>
</tr>
<tr>
<td>Short term</td>
<td>1-6 hours ahead</td>
<td>Scheduling, load-following, congestion management</td>
<td>Blend of statistical and NWP models</td>
</tr>
<tr>
<td>Medium term</td>
<td>Day(s) ahead</td>
<td>Scheduling, reserve requirement, market trading, congestion management</td>
<td>Mainly NWP with corrections for systematic biases</td>
</tr>
<tr>
<td>Long term</td>
<td>Week(s), Seasonal, 1 year or more ahead</td>
<td>Resource planning, contingency analysis, maintenance planning, operation management</td>
<td>Climatological forecasts, NWP</td>
</tr>
<tr>
<td><strong>Decision support</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ramp forecasting</td>
<td>Continuous</td>
<td>Situational awareness, Curtailment</td>
<td>NWP and statistical</td>
</tr>
<tr>
<td>Load forecasting</td>
<td>Day ahead, hour-ahead, intra-hour</td>
<td>Congestion management, demand side management</td>
<td>Statistical</td>
</tr>
</tbody>
</table>
What Impacts the Magnitude of Forecast Errors?

Forecast errors are affected by the forecast time-horizon, local geographic conditions, geographic diversity and data quality

- Forecasts become less accurate for longer look-ahead time horizons
- Local conditions affect RE forecasts differently
  - **Wind**: Hills and trees reshape wind speeds and directions
    - Complex topography increases wind forecast errors
  - **Solar**: Clouds cause variability and uncertainty in real-time solar irradiance
    - Cloudless areas typically have lower forecast errors
- **Geographic diversity** of RE resources reduces errors
- **Data quality** can greatly improve forecast accuracy
Data Access Via https://maps.nrel.gov/wind-prospector/
The WIND Toolkit is a grid integration dataset

**RE integration datasets**

- High resolution (temporal and spatial)
- Long duration (multiple years)
- Realistic energy generation characteristics
- Generation data covering one or more Electric Reliability Council

**What’s new in the WIND Toolkit?**

- Seamless in time and space
- Covers CONUS
- Uses WRF
- Validated against multiple data sources
- Site-specific WTG power curves
- Data are available online

The WIND Toolkit is a collaboration between NREL and 3Tier, run on supercomputers at Sandia and NREL, with input from a board of SMEs
Ways to use the WIND Toolkit data

Great for grid integration studies...
- 7 years of data at 2-km resolution
- Time-synchronous with load profiles
- Site-specific turbine choices
- Easy to access
- Can be duplicated and refined

But not a prospecting tool
- No environmental or curtailment losses
- Site performance estimates assume a flat site
- No adjustment for turbulence
- Wake model doesn’t take into account turbine layout
Key Takeaways

• Wind and solar generation increase variability and uncertainty; however, actual operating experiences from around the world have shown up to 43% annual penetrations are possible.

• Forecasts, along with other complementary sources of flexibility, become increasingly important as wind and solar penetration increases in a system.

• Forecasting provides economic and other benefits to stakeholders across the power system.
  o At the system level, forecasts increase operational efficiency, reduce overall costs, and allow more renewable energy to be economically integrated.
  o At the plant level, forecasts increase the value of an owner’s generation capacity and ensure that it is utilized to the greatest extent possible.

• The economic value of forecasting varies based on a variety of factors (including the extent to which forecast timeframes are aligned with system operation and market timeframes); however, improved forecasting is likely to benefit nearly all systems integrating wind and solar.

• There are a variety of approaches to and sources of forecasting. Regardless of approach, procuring a forecast is the most important first step!