An Introduction to Wind and Solar Power Forecasting

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Overview

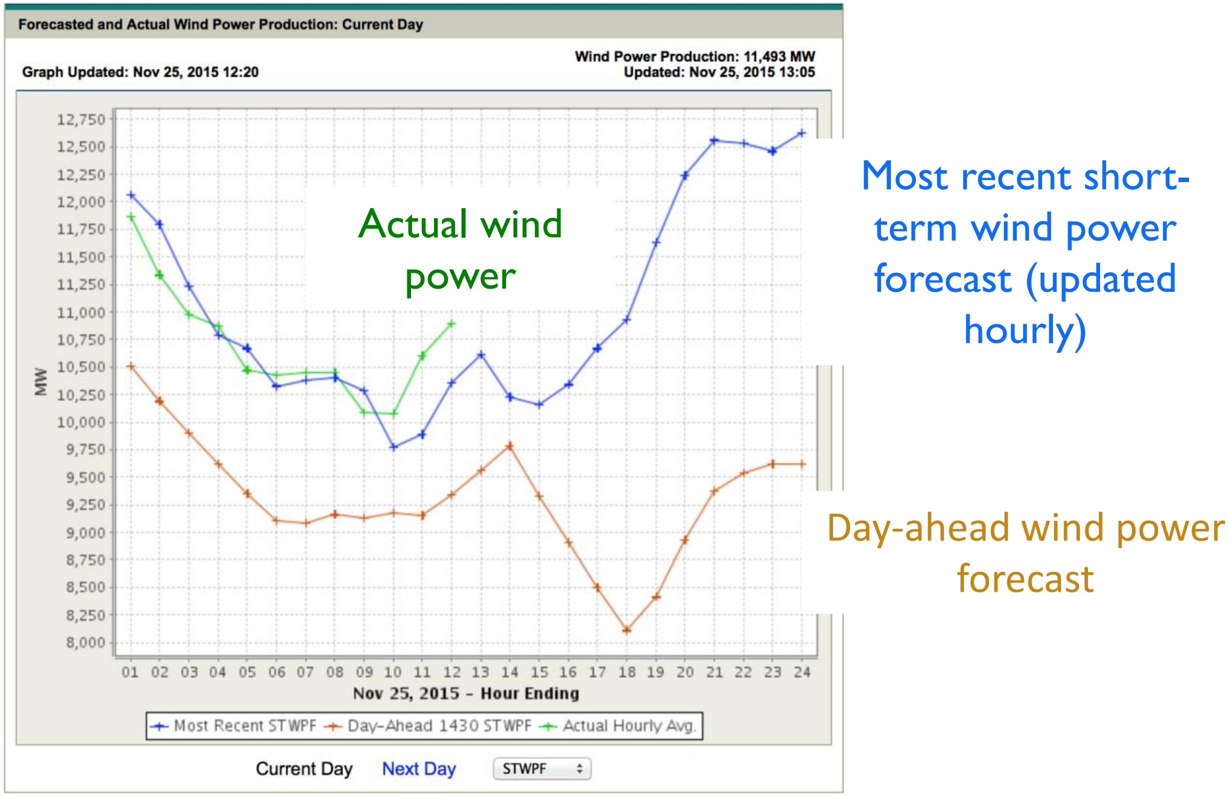
- How can wind and solar forecasting enhance power system operations?
- How are forecasts produced?
- What approaches and actions can your system take to implement a forecasting system?

IMPACT OF WIND AND SOLAR FORECASTING ON POWER SYSTEM OPERATIONS

Forecasting Reduces the Uncertainty Associated with VRE

We use the term *forecasting* primarily to refer to the near-term (usually up to day-ahead) prediction of electricity generation from wind and solar power plants.

Example: Texas' wind power production forecasts

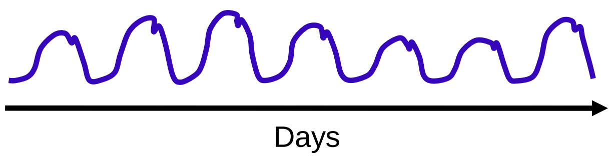


Source: Electricity Reliability Council of Texas short-term wind power forecast

Load forecasting refers to the prediction of electricity demand.

Forecasting Supports Efficient Power System Operation at All Timescales

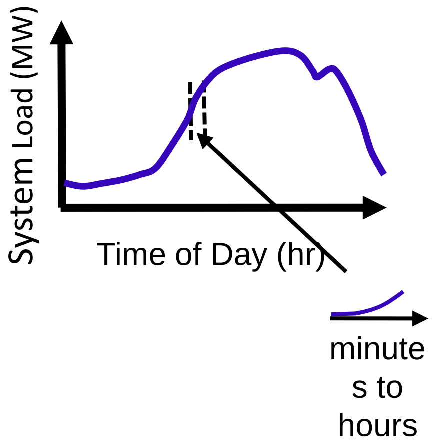
- ***Long-term forecast*** (1 week+) informs resource and operations and maintenance planning



- ***Medium-term forecast*** [day(s) ahead], along with uncertainty band, informs scheduling (unit commitment), market decisions, and reserve requirement

- ***Short-term forecast*** (1-6 hours ahead) enables scheduling adjustments and congestion management

- ***Intra-hour forecast*** (5-60 minutes ahead) allows operators to respond to real-time fluctuations and to assess reserves



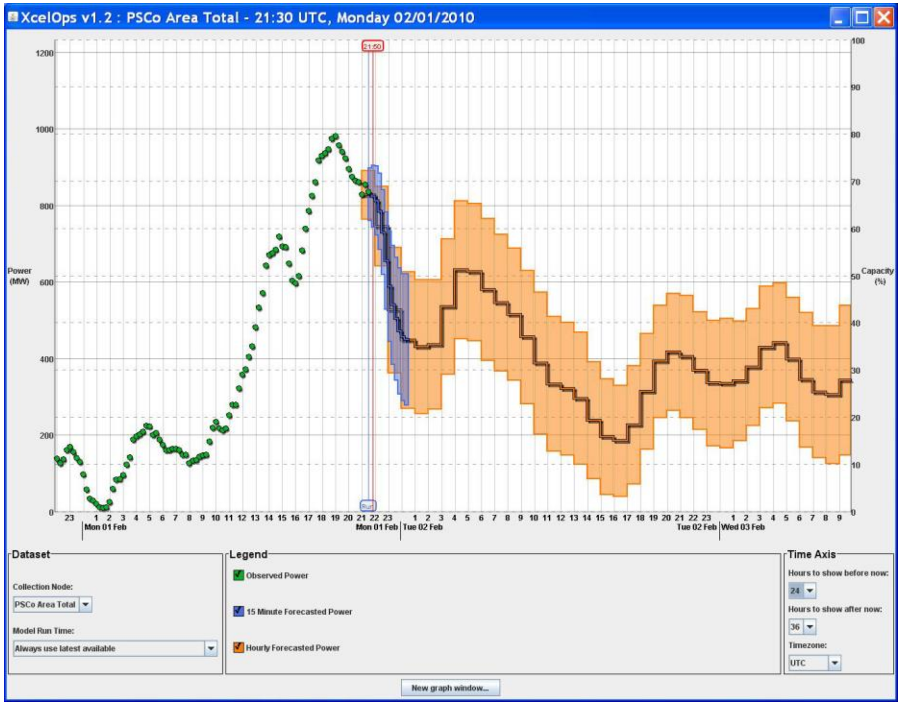
Forecasting Leads to Economic and Operational Benefits

- **Improved unit commitment and dispatch efficiency**
- **Reduced reliability issues**
- **Decreased curtailment of RE generation**

The Value of Forecasting: Xcel Energy Case Study

- **Leading utility wind provider in the United States, and top 10 for solar.**
  - 15% of total energy supply from wind in 2014
  - Up to roughly 70% instantaneous wind penetration
  - 5,794 MW wind capacity installed

- **Partnered with two national laboratories to develop a state-of-the art forecasting model, which is maintained by a third party**



Outcomes:

- Reduced average forecast error from 16.8% in 2009 to 10.10% in 2014
- Saved ratepayers US $49.0 million over the 2010-2014 period

Sources: Staton 2015; NCAR 2015; Xcel Energy 2015

HOW ARE FORECASTS PRODUCED?

How are Wind and Solar Forecasts Produced?

National Environmental Prediction

Numerical Weather Prediction (NWP) Models
(National Meteorological Agencies)

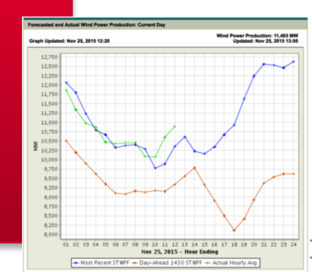
Measured Data

Weather data
(Meteorological stations)

Wind and solar plant data
(Generating units)

Power Prediction Systems
(In-house, vendors)

Power Prediction

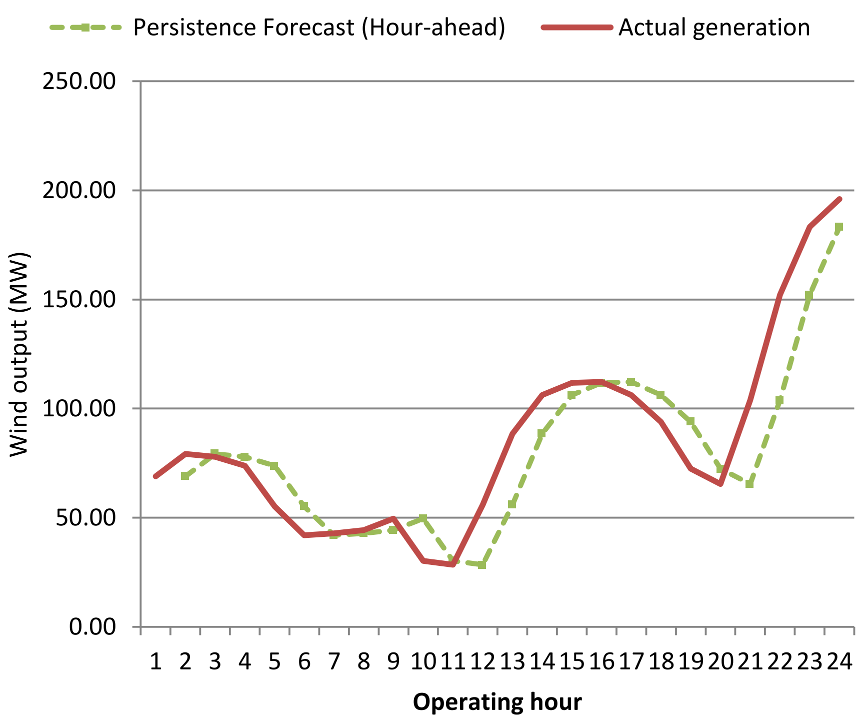


Adapted from Justin Sharp

Forecasting Methods

- Physical (dynamical) methods
  - Inputs weather data (temperature, pressure, surface roughness, obstacles) into numerical weather prediction (NWP) models to create terrain-specific weather conditions

- Statistical methods
  - Uses historic and real-time generation data to statistically correct results derived from NWP models.
  - ***Persistence forecasting***: uses the last observation as the next forecast.



- Ensemble forecasting
  - Aggregates results from multiple different forecasts

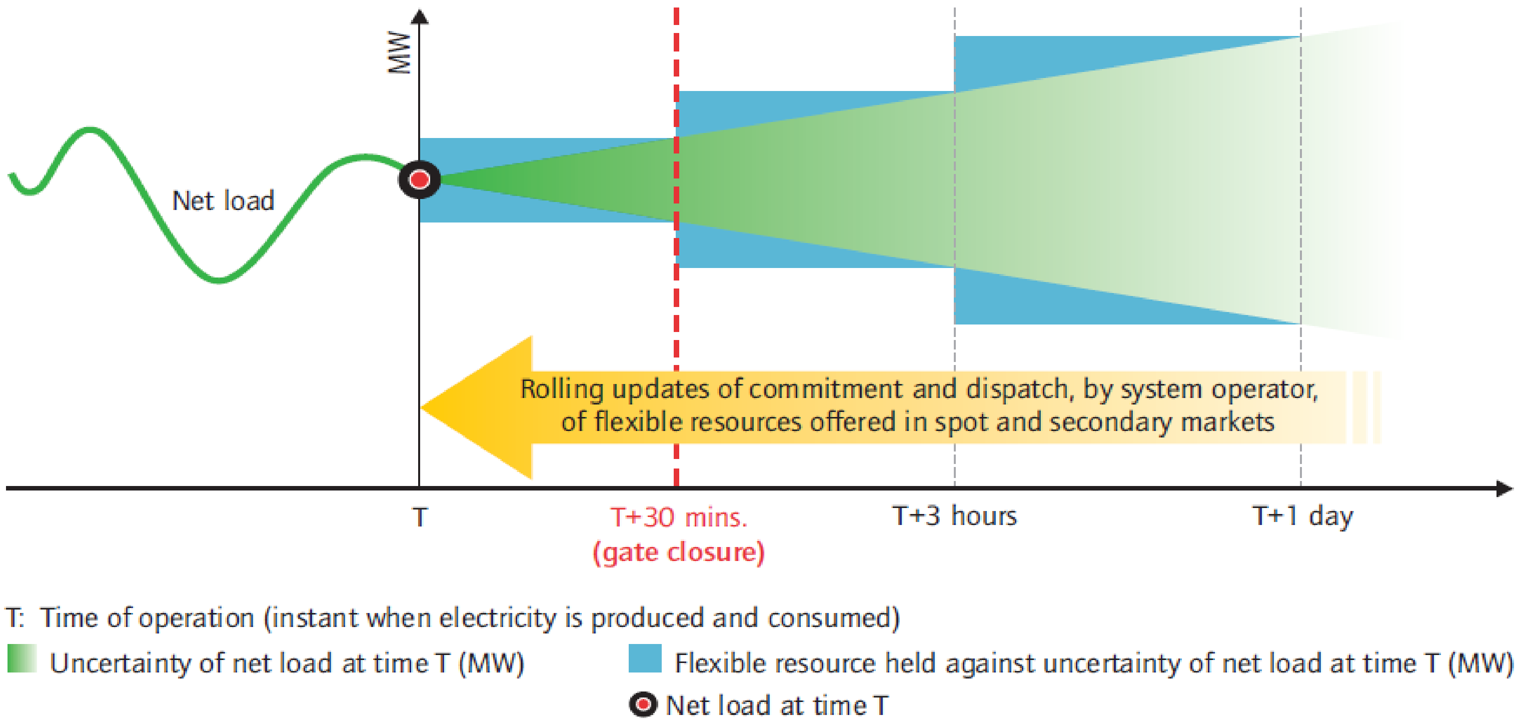
What Impacts Forecast Quality?

Examples:

- **Meteorological data – e.g., density and frequency of observations**
- **NWP models – e.g., data assimilation, parameterization**
- **Operational information for wind and solar generators – e.g., turbine or panel availability, curtailment**
- **Power conversion algorithms**

CONSIDERATIONS FOR IMPLEMENTING FORECASTING SYSTEMS

More Frequent Decisions Reduce Uncertainty



While more frequent forecasts provide greater accuracy, they are only useful to the system operator up to the timeframe in which ***actions can be taken*** in response to the forecast.

Source: Harnessing Variable Renewables – A Guide to the Balancing Challenge, International Energy Agency, 2011

Different Roles for Centralized and Decentralized Forecasts

Centralized Forecasting (by the system operator)

- Enables the use of forecasting in unit commitment and dispatch
- Requires mechanisms to obtain data from generators and encourage data quality
- Allows greater consistency and reduces uncertainty at the system level

Decentralized Forecasting (by the generator)

- Used by off-takers when making offers
- Helps project operators optimize operation and maintenance
- Informs operators of potential transmission congestion
- Limited scope can decrease utility

Centralized forecasting by the system operator, supported by generator-level forecasts from the plant operator, is widely considered a best practice approach.

Monitoring and Verification is an Essential Component of Forecasting

Purposes of forecast verification:

1. **Monitor forecast quality -** how accurate are the forecasts and are they improving over time?
2. **Improve forecast quality -** the first step toward getting better is discovering what you're doing wrong.
3. **Compare the quality of different forecast systems and a baseline -** to what extent does one forecast system give better forecasts than another, and in what ways is that system better?
4. **Financial verification –** ensuring that generator reporting matches actual conditions.

Error rates are not static; they vary based on time of year, extent of spatial or geographic aggregation, among many other factors

Adapted from Justin Sharp

Data Collection Strategies for System Operators

- **Policy mandates**
- **Interconnection or market requirements set by federal and state government, utilities, and RTO/ISO**
- **Power purchase agreements**
- **Penalties/rewards**
- **Partnerships with meteorological agencies**
- **Third-party vendors**

Xcel Energy's Model PPA includes provisions for forecasting data collection

Model Wind PPA
February 2013

WIND ENERGY PURCHASE AGREEMENT

BETWEEN

NORTHERN STATES POWER COMPANY, A MINNESOTA CORPORATION

("COMPANY")

AND

[________________]
("SELLER")

Xcel Energy

- [date] -

http://www.xcelenergy.com/staticfiles/xe/Corporate/Corporate%20PDFs/Model_Power_Purchase_Agreement.pdf

What Data is Needed to Set up a Forecasting System?

Static

- Plant location (Latitude, Longitude)
- Installed Capacity
- Historic Data (training data)

Dynamic

- Real-Time Generation
- Availability Data
- Park Potential (potential total output based on available resources at the wind/solar farm level)
- Meteorological Data

Options for Procuring Forecasts

Third-Party Vendors

- Vendor uses proprietary power prediction models to estimate generation.
- Requires wind and solar plant data from generators or the system operator.
- In-house meteorologists still play a role in reviewing forecasts and identifying critical periods.
- Typical forecasts are selling for USD \$200/project/month to \$2000/project/month (source: Justin Sharp)

- **In-house Forecasting**
  - Staff meteorologists/analysts develop power prediction models and are responsible for assembling and validating meteorological and plant data.
  - Can allow flexibility for custom and state-of-the-art approaches that reflect system-specific concerns.
  - Will be significantly more expensive to develop and require significantly more computing power and expertise to maintain than vendor forecasts.

Working with vendors can be an inexpensive, introductory way to get experience with forecasting. This can be a valuable first step.

Example Areas for Early Actions

- Update interconnection standards, power purchase agreements to enable data gathering
- Work with national meteorological institutes to improve underlying weather data or access to it
- Facilitate training of operators on meteorology, how to interpret forecasts, and work with vendors
- Support vendor trials and development of a smooth IT interface between forecast vendors and users

Key Takeaways

- **Forecasting facilitates the integration of variable renewable energy to the grid by reducing uncertainty and improving the efficiency of operations at multiple timescales.**

- **Better information is only valuable when it leads to better decisions**
  - Understanding areas where forecasting improves decision-making is a first step in considering how to implement forecasting systems
  - Interpreting forecasts is a critical element of effective implementation

- **Centralized and decentralized have unique value; in general, moving toward centralized forecasting is most effective in reducing uncertainty at the system level.**

- **There is no one-size-fits-all approach to collecting data and procuring and monitoring forecasts. Power systems should tailor their forecasting programs to their unique context and needs.**

Contacts and Additional Information

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Greening the Grid

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