# 5B.3 UTILITY SECTOR WIND POWER FORECASTING: STATUS AND MEASUREMENT NEEDS

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## 1. INTRODUCTION

The installed capacity, or the theoretical annual production capacity, of wind power plants in the United States was 25.2 gigawatts (GW) at the end of 2008 with 8.4 GW having been installed during that year (American Wind Energy Association, 2009). The total U.S. installed capacity is expected to reach 30 GW by the end of 2009. The increasing level of wind power penetration into the U.S. electricity grid has recently emphasized the importance of accurate wind power forecasting to utilities and independent system operators (ISOs).

System operators are required to balance generation and load within a very tight band. This means that if load is rising, or wind power is declining, other generation must rise to keep the system balanced. Figure 1 shows typical time frames that affect the operation of the power system. Typically the most important time frames are for unit commitment (days) and scheduling (daily). Large thermal units (e.g., those driven by steam turbines) need large notification times to synchronize to the grid and start generating. Because of this, utilities and ISOs need to know a day-ahead how much load is anticipated throughout the next day. With large penetrations of wind power, it also becomes essential to know within good certainty what the total wind power production on the system will be during each hour. When wind power forecasts are lower than what occurs, the system operator may have already turned on additional units that were not needed, thereby increasing costs. When wind power forecasts are higher than what occurs, the system operator may not have committed enough generation in advance and will either have to run expensive fast-start combustion turbines or in some cases shed load.

As discussed in this paper, the shorter term wind forecasts in the “load following” time frame are also very important in balancing load, especially when wind power may be changing rapidly in magnitude either ramping up or down.

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## 2. UTILITY WIND FORECASTING EXPERIENCE

Wind power generation forecasting has become a commercial venture in the United States, in Europe, and in other parts of the world, serving clients that operate major grids and trade in electricity markets. Figure 2 shows the system operators in selected major electricity markets in the United States and Canada. In the United States, organizations that operate electricity markets in California, Texas, New York, and the upper Midwest, have already selected wind forecasting vendors to produce wind power forecasts for wind plants in their regions. Market structures vary across the country; therefore, grid operators must take various approaches on how their particular wind generation forecasting program is structured. For example, the New York ISO administers a centralized forecasting system utilizing a commercial forecasting company. Every wind plant contributes to the cost of the forecasting service through a fee structure. Each wind generation forecast is provided to the individual plant in addition to the ISO. The input to the forecasting system includes power and meteorological output data from the individual wind plants provided to the forecasting vendor every 15 minutes. The ISO has the authority to penalize facilities that do not maintain their equipment in good working order, which leads to bad or missing data. In contrast, the original California ISO forecasting program, called the Participating Intermittent Resources Program, was voluntary for individual wind plants that belonged to the ISO. Costs for either under prediction or over prediction of the wind resource on the system were assessed on a monthly basis. This penalty structure channeled much of the effort by the forecast provider into providing forecasts with little overall bias, but this was likely at the expense of the accuracy of individual forecasts. California is looking to redesign its market and adjust the design of its forecasting program.

## 3. WIND POWER FORECASTING TECHNIQUES

Wind generation forecasts cover a wide range of time frames. Typical power forecasts time frames include day-ahead hourly averages and hourly or more frequent same day average forecasts. Power forecasts valid for periods beyond several hours from the forecast origination time are developed by a two-step process. First, wind speed forecasts at wind plant sites are derived from numerical weather prediction model output. A wide range of models are used by the various commercial firms as the basis for the speed predictions. A recent trend in commercial forecasting is to use an ensemble of model output that often includes the Weather Research and Forecasting model and large-scale national models such as the Global Forecast

System (United States), the Global Environmental Multiscale (Canada), and the European Center for Medium-Range Forecasts model to forecast the wind speeds at wind plant sites. Ensemble wind speed results provide an indication of the uncertainty of the speed and therefore power production forecasts that are quite important to utility system operators. The forecasted wind speeds must then be converted to forecasted power output in megawatts. This information will then be used in utility operations such as for unit commitment and dispatch of non-wind resources. Converting wind speed to wind power production has to account for factors such as the power production curve of the turbines, wind plant layouts, and wind direction. This is not a straightforward process. The most important problem is developing an accurate power production curve (the production of energy by wind speed) for the wind plant as a whole. Forecasting experience from existing wind plants has demonstrated that estimating wind power plant output at a given wind speed by adding the theoretical power output from all individual wind turbine power curves does not adequately match the observed wind plant power. Rather, processes that occur within a wind plant that are not always well measured or understood, such as flow effects caused by the rows of wind turbines and interactions of the flow with local terrain, have a noticeable effect on the total wind plant output.

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) is conducting research with Xcel Energy in Colorado on the conversion of wind speed to power production. The project will investigate forecasting techniques with substantially more data than has been used before. Output from individual turbines, as opposed to output from the entire plant or a set of turbines, will be collected at high resolution and used with data collected from meteorological towers to create a strong relationship between wind speed and wind power. Artificial neural networks will be used to evaluate further relationships and detail other factors that can adjust the conversion from the typical manufacturer's power conversion curve.

Statistical forecasting techniques are frequently used to predict near-term (0 to 3 hours ahead) power production. Statistical methods that have been used include Kalman filters, regression equations, and neural networks. Critical input for the short-term forecasts includes historical power output from the wind plant and basic meteorological data from at least one location on site in addition to the data from the numerical models. The availability of the local data from the wind plants to the forecast providers has been irregular in most forecasting projects, which has affected the accuracy of the forecasts. The maintenance and reliability of measurement equipment (as opposed to the wind turbines) has not been a high priority of the wind plant operators. However, this is changing as power forecasts become more critical to the reliable operation of electricity systems.

### 3.1 Wind Generation Ramp Forecasting

Individual utilities and electricity providers, such as Xcel Energy in Colorado and the Bonneville Power Administration (BPA) in the Pacific Northwest, are faced with rapidly increasing penetration of wind onto their systems. These organizations are now aggressive in implementing advanced wind forecasting programs. A particular type of forecasting problem is the accurate prediction of wind power ramps. These are rapid increases or decreases (20% or greater change in megawatts) in wind power output over a short period of time (30 to 120 minutes). System operators need to have a reliable tool to predict these extreme events so they can take compensating measures to maintain the quality of the electricity system.

Figure 3 shows a downward wind power ramp event that occurred in the Electric Reliability Council of Texas (ERCOT). The orange plot represents the actual ramp and the green line represents the hourly wind generation forecast issued the day before (February 25, 2008). The forecasted wind generation is slightly lower than but matches quite well the trend in actual generation over the 6-hour period. Unfortunately, ERCOT had not yet integrated wind forecasts into its system operation at that time. Instead they scheduled according to wind resource plans (red line) produced by the wind generation facilities and their scheduling coordinators.

Forecasting programs designed to predict ramp events face some significant challenges. First, the causes of wind power ramps are varied. They include synoptic conditions and mesoscale convective events. Second, because operators are concerned with the change of generation during a ramp event, a ramp forecasting model's focus must be different from the forecasting model that predicts overall power production and tends to produce smoother generation forecasts. Finally, methods that measure the accuracy of a ramp forecasting model in terms of its timing, duration, and magnitude are just now being developed and are likely to be modified in the future.

## 4. FUTURE RESEARCH

A significant forecasting question facing utilities that are integrating large amounts of wind generation onto their systems is whether establishing a network of offsite real-time boundary layer measurements near wind plant locations will improve the accuracy of forecasting models and the value of short-term forecasts. There is currently no industry standard for instrumentation design. The network can include anemometers, pressure sensors, thermometers, and remote sensing equipments such as Sodar and Lidar. Anecdotal evidence from the Pacific Northwest (BPA, 2009) indicated that additional offsite observations have increased the accuracy of the short-term wind speed, wind power forecasts and characterization of local weather events. However, the national public record is extremely limited on the effect that offsite measurements have on the effect of forecast accuracy. In addition to working with NREL, Xcel Energy in Colorado is working with the National Center for Atmospheric Research on a large field campaign to evaluate how high resolution atmospheric data can be used to develop a robust and cost-effective wind characterization program, including more accurate forecasts. This 2-year project started in late 2008, and the initial results are expected to be made publicly available in about one year.

## 5. CONCLUSION

Improvements in wind generation forecasting alone will not ensure the continued growth of wind energy on the nation's transmission grid. Forecasting data must be smoothly integrated into control room operations for the information to have both monetary and operational value. The challenges of accurate wind generation forecasting, both for overall energy production and extreme events like power ramps, will occupy an increasing segment of the utilities, wind industry, and the meteorological research community in the next few years. The broad spectrum of participants actively engaged in solving wind energy integration challenges will help ensure that wind energy, a plentiful resource, can meet the future U.S. energy needs.

## 6. ACKNOWLEDGEMENTS

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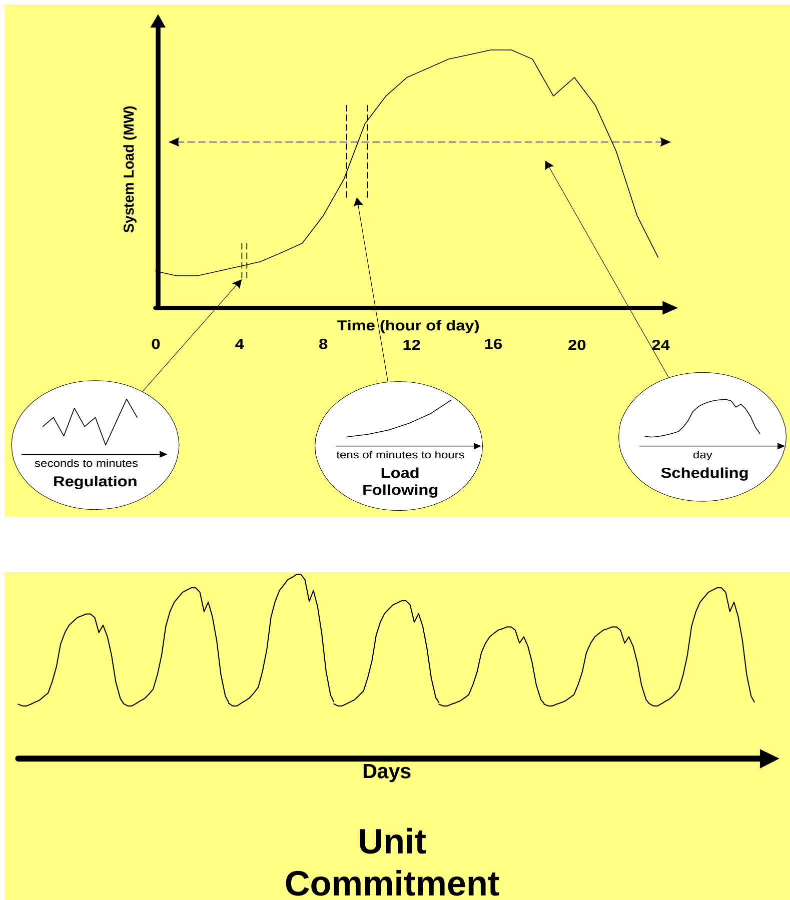


Figure 1.
Different time frames in the perspective of
power system operations

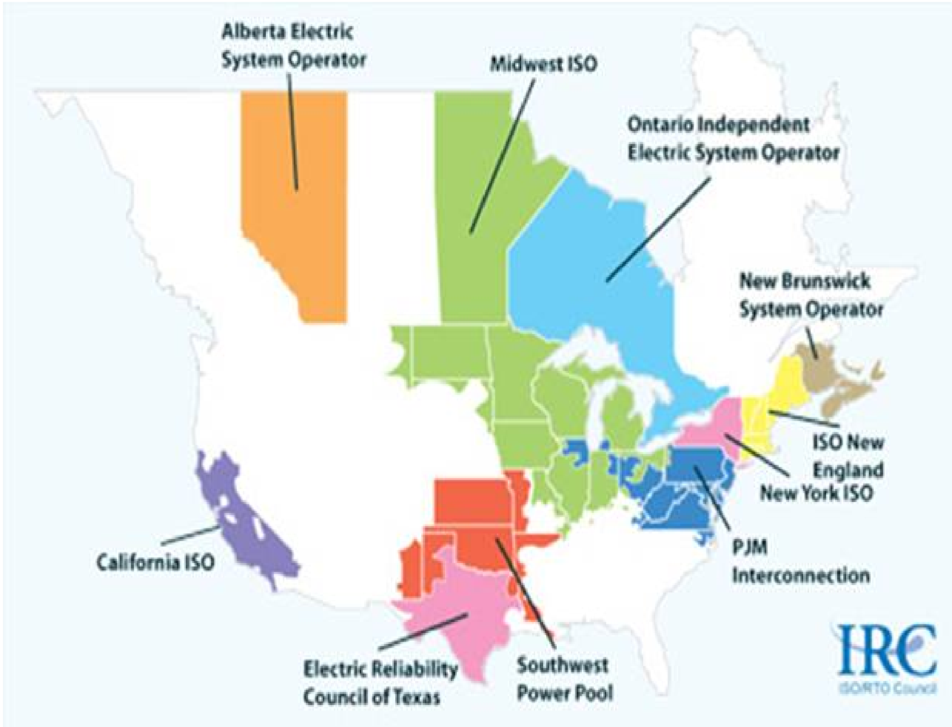


Figure 2.
Selected System Operators for Electricity Markets

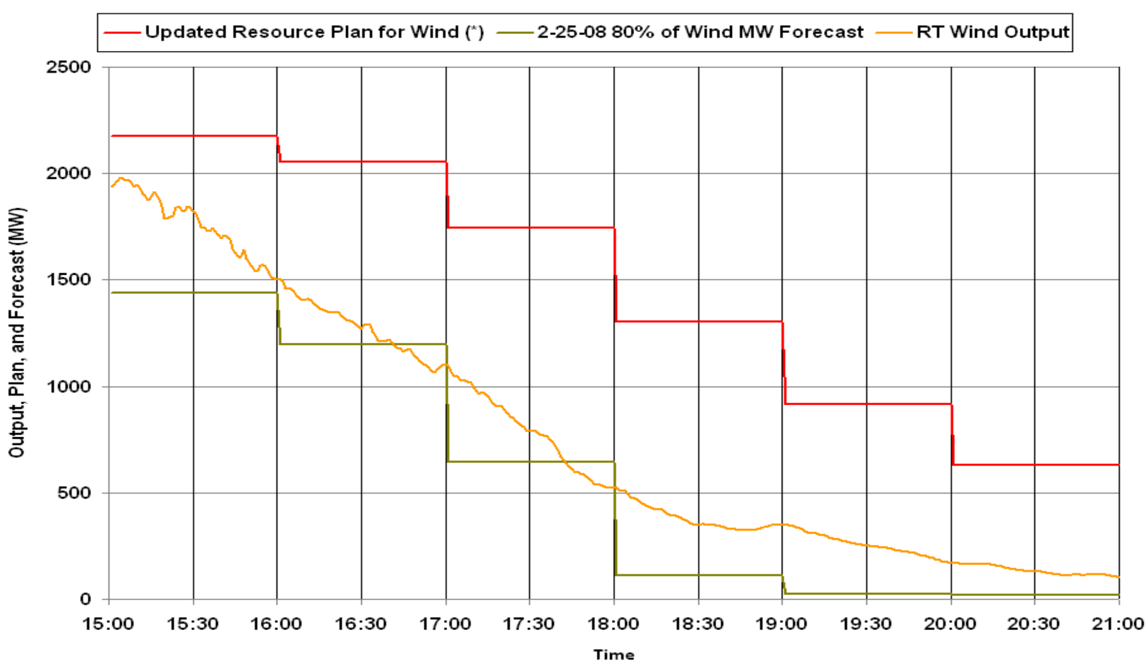


Figure 3.
Downward wind ramp occurring on February 26, 2008 in ERCOT