Designing Electricity Markets with Large Shares of Wind Power

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Background and Current Status

Wind power generation has increased rapidly in the United States over the last few years, and at the end of 2009 there was more than 35,000 MW of installed capacity at a national level. Wind power is already having a significant impact on the operation of electricity markets and power systems in areas with high penetration of wind power, such as in the Electric Reliability Council of Texas (ERCOT) and the Midwest ISO (MISO, see Figure 1). A number of challenges arise when integrating wind power into the power system, from transmission planning, resource adequacy, and interconnection standards to dealing with the increased uncertainty and variability in short-term operations.

There is therefore a need to revisit current electricity market designs and traditional procedures for system operations in light of the increased uncertainty and variability from wind power generation. System operators in the United States and abroad are currently adjusting their operational procedures and market designs to accommodate the increasing shares of wind power. Different solutions are being tested and implemented, and it will take considerably time before consensus emerges on the main principles for new market designs that better address the implications of increasing reliance on wind power and other renewable energy sources.

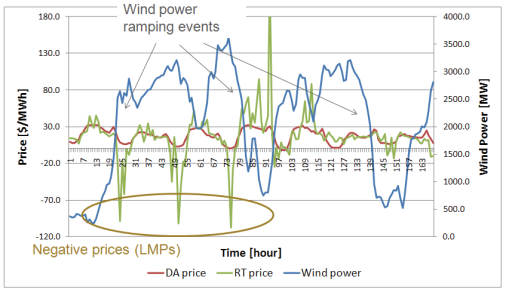

Figure 1: Wind power generation in Midwest ISO and day-ahead (DA) and real-time (RT) prices in Iowa (MEC interface), May 11–17, 2009.

The organized electricity markets in different regions of the United States have seen considerable convergence in market design in recent years (Table 1). ISO/RTO markets already have several features that are advantageous for the integration of wind power into the power system:

1. ***Large Balancing Authority Areas*** give the system operator the control of system resources over large areas, increasing the overall flexibility of the system to handle variations in wind power generation.
2. ***Centralized unit commitment and scheduling*** of energy and operating reserves for a large pool of generation and load resources can be used to effectively accommodate fluctuations in wind power.
3. ***Frequent real-time dispatch*** reduces the need to maintain expensive regulation reserves to respond to short-term fluctuations in load, wind power, and other renewable generation.
4. ***Locational marginal prices (LMPs)*** give locational market-based incentives for short-term operation and long-term expansion.

Table 1: Characteristics of five ISO/RTO markets in the United States.

	MISO	NYISO	PJM	ERCOT	CAISO
Wind Power Capacity [MW]	Ca. 7,600	Ca. 1,300	Ca. 2,500	Ca. 9,000	Ca. 3,000
Peak load [MW]	116,030 (7/31-06)	33,939 (8/2-06)	144,644 (8/2-06)	62,339 (8/17-06)	50,270 (7/24-06)
Centralized unit commitment	Yes	Yes	Yes	No	Yes
Congestion management	LMP	LMP	LMP	Zonal	LMP
Co-opt. of energy and reserves	Yes (DA and RT)	Yes (DA and RT)	Yes, but limited	No	Yes (DA and RT)
Dispatch frequency	5 min.	5 min.	5 min.	15 min.	5 min.
Wind power forecasting	Since 2008	Since 2008	Since 2009	Since 2008	Since 2004

Wind Power Forecasting in Market Operations

Forecasting will play an increasingly important role in the operation of power systems as the level of wind power generation increases. However, most system operators in the United States have only recently introduced wind power forecasting to support their operations (Table 1). Wind power forecasting models have been improving continuously over the last decade (Monteiro et al. 2009). The desired forecasting capabilities typically vary among user groups. System operators are particularly concerned with the ability to forecast rapid changes in wind power production (ramping events) and to predict forecast uncertainty. Wind power producers may be more concerned with average forecast accuracy over a longer time period to better schedule their resources in the marketplace. Potential use of wind power forecasting in market operations is illustrated in Figure 2.

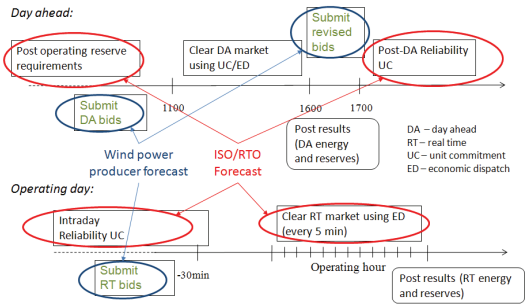

Figure 2: Market operations timeline (based on Midwest ISO) and potential use of forecasting for wind power producers and system operators.

The challenge for system operators is to efficiently integrate information from advanced wind power forecasting tools into their operational decisions, from determination of operating reserve requirements to unit commitment and dispatch. Wind power producers use wind power forecasts to support their scheduling and bidding into the electricity market. A more detailed discussion on the use of wind power forecasting in U.S. electricity markets is provided in Botterud et al. (2010).

Improvements in Market Design

We briefly discuss important areas of improvements in market design to accommodate the increasing levels of wind power. An overarching challenge is to efficiently handle the additional variability and uncertainty from wind power. It may be possible to handle the uncertainty from wind power by increasing the level of operating reserves (Figure 3). However, changes in unit commitment and dispatch procedures are also needed, and these will contribute to efficiently balance the overall supply and demand in the power system. Hence, there is clearly a need to revisit existing rules to achieve a cost-effective electricity supply without compromising reliability. This is further discussed below.

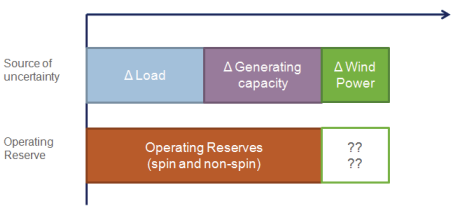

Figure 3: Uncertainties are typically handled with operating reserves in electricity markets.

Operating Reserve Requirements

Several improvements to existing operating reserve requirements and procedures should be considered, including:

1. ***New definitions of operating reserve requirements*** that better reflect the needs in power systems with a large share of wind power. An additional type of "wind power reserve" is proposed in Figure 4. Such a reserve category would better address the characteristics of wind power. It would probably have different trigger criteria and slower response and restoration times. Hence, these reserves should be less expensive than the traditional contingency reserves.
2. ***Improved determination of reserve requirements*** based on a probabilistic representation of wind power and other uncertainties in the system.
3. ***Dynamic and frequent updating of reserve requirements*** based on the most updated system information, including the most recent wind power forecast.

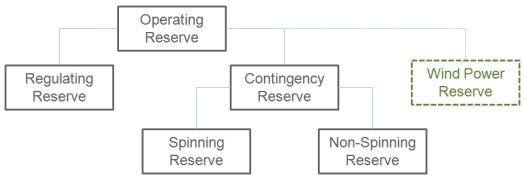

Figure 4: Current operating reserve categories and a proposed new category to address uncertainty and variability in wind power.

Day-Ahead Market

Wind power will have an increasing impact on the marginal cost of electricity, and this reality should be properly reflected in the day-ahead market, where most of the energy is settled. For the day-ahead market to reflect the expected real-time conditions as closely as possible, it is important that the market participants have the right incentives to provide the best possible wind power forecast information through their bids. One way to encourage participation of wind power generation in the day-ahead market is to reduce the time period between the deadline for bidding into the day-ahead market and the real-time operations. Additional balancing markets between day-ahead and real-time would also enable wind power producers to adjust their market positions based on better forecasts. Finally, deviation penalties should be designed so that producers have incentives to provide unbiased bids in the day-ahead market.

Reliability Assessment Commitment

The reliability assessment commitment takes place between the day-ahead market and real-time dispatch, and gives the system operator an opportunity to adjust unit commitment decisions as necessary to ensure reliability. At this step, it is crucial to account for the stochastic nature of wind power generation. This objective can be achieved through increased reserve requirements, as discussed above. Alternatively, the use of a conservative wind power forecast would also lead to additional operating reserves. However, in order to better assess the operational costs and risks, the ideal approach is to use a stochastic unit commitment model with an explicit representation of the uncertainty from wind power (and other sources) in the problem formulation.

Real-Time Market and Dispatch

An important challenge in real-time operations is to effectively control the output of wind power generation during constrained system conditions. To obtain efficient dispatch and prices, it is therefore important for wind power to be represented in the real-time market with price/quantity bids. Then, if there is a need to curtail wind power, it can be done in an economically efficient manner. New York ISO (NYISO) and PJM have already introduced rules for mandatory real-time bidding and control of wind power.

Conclusions

A large-scale introduction of wind power into the electric power system gives rise to a number of operational challenges. There is therefore a need to revisit and improve the design of current electricity markets to better accommodate the uncertainty and variability from wind power and other renewable resources. A key challenge for system operators and market participants is to efficiently make use of the information provided by state-of-the-art wind power forecasts. At the same time, probabilistic approaches to scheduling and operations will play an increasingly important role as the amount of wind power generation continues to increase.

References

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Research on wind power forecasting and electricity markets at Argonne: http://www.dis.anl.gov/projects/windpowerforecasting.html

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