Wind Power Forecasts for Operating Reserves Procurement

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Motivation

Wind power experienced substantial growth over the past decade in the U.S. and Europe. Installed capacity in the U.S. increased tenfold from 4,200 MW in 2001 to 47,000 MW in 2011. The growth of wind power has created reliability challenges for grid operators. In order to cope with the uncertainty and variability of wind power, operating reserves must increase. The Electric Reliability Council of Texas (ERCOT) recently increased its requirements for operational reserves due to wind. Texas currently has more wind than any state in the U.S. Operational reserves ensure grid reliability by providing needed generation during unforeseen events. This includes unexpected load increases, unexpected wind power drops and generator outages

Load and wind power are forecasted each day in the development of generator schedules. Uncertainty of these forecasts determine the amount of operational reserves required for a reliable grid.

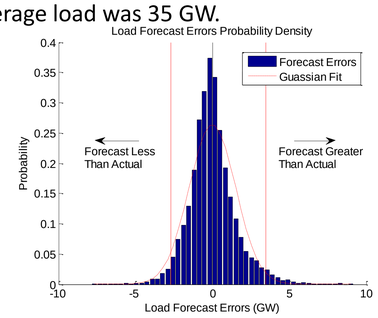
Data

Our analysis is based on forecasted hourly values of wind power and load as well as actual values from the Electric Reliability Council of Texas (ERCOT). Due to wind curtailments in ERCOT, we used estimated values of uncurtailed wind power as the actual values. Uncurtailed wind power estimates were determined by a wind forecast provider from meteorological measurements and curtailment instructions issued by ERCOT.

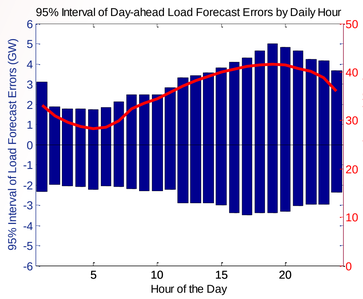
Load Uncertainty

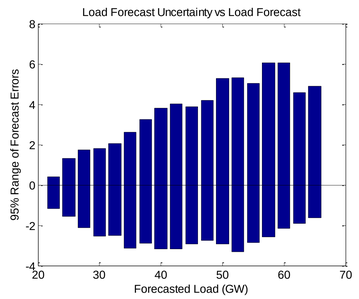
Load forecasts for ERCOT are taken roughly 20 hours before the start of the operating day. The probability density function of forecast errors shown contains data for forecasts taken in 2009 and 2010. Peak load during this time was 65 GW and average load was 35 GW.

Forecast errors are defined as the actual load minus the forecasted load. Positive errors occur when load is over forecasted. The vertical lines show the range containing 95% of the errors , -2.7 GW to 3.5 GW.



Load uncertainty depends strongly on the amount of load in the system. High loads are more difficult to predict. The left plot below shows the 95% forecast error range for each hour of the day. The red line is the average load daily load profile. The right plot shows the uncertainty of load for different levels of load forecasts.

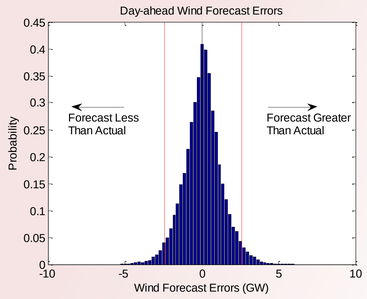


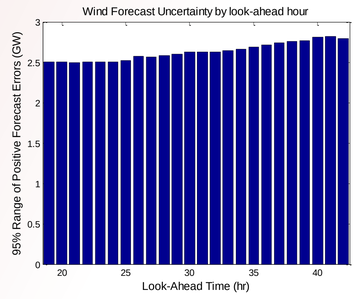


Wind Uncertainty

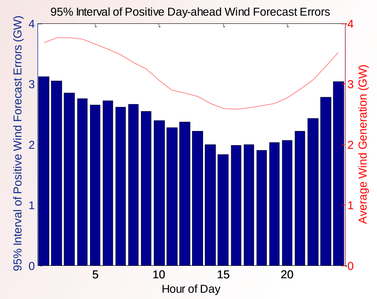
Wind power is more difficult to predict than load. Wind forecast accuracy depends on the look-ahead time and also the level of wind power predicted. Wind power forecast errors are shown in the left plot below. Ninety-five percent of the wind errors are between -2.4 and 2.6 GW. ERCOT had 8300 MW of wind power capacity at the end of 2008 which increased to 9300 MW at the end of 2010. Once again, positive forecast errors indicate that wind was over forecasted.

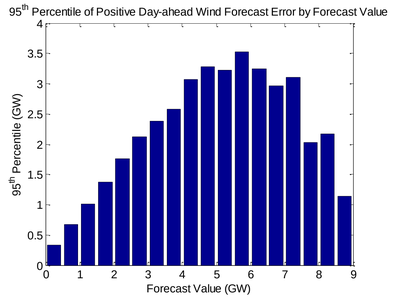
ERCOT must determine the amount of reserves required for an operating day by 6:00a.m. the previous day. Wind forecasts taken at 6:00a.m. use look-ahead times from 19 to 42 hours to cover each hour of the operating day. Over this range, the increase in uncertainty for positive forecast values is shown below to in the plot on the right. Only positive errors are displayed. The increase in uncertainty is modest in the range of look-ahead times used for day-ahead forecasts.





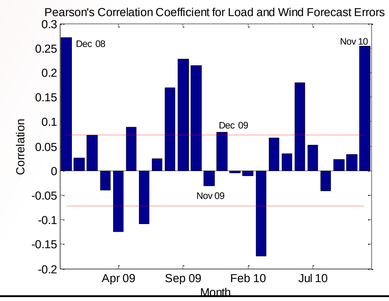
The lower left figure shows the 95th percentile of positive errors for each hour of the day with the average daily wind power profile. It clear that wind uncertainty is more strongly dependent on the level of forecasted wind. The figure on the right displays the 95th percentile of positive forecast errors for a range of forecast values.

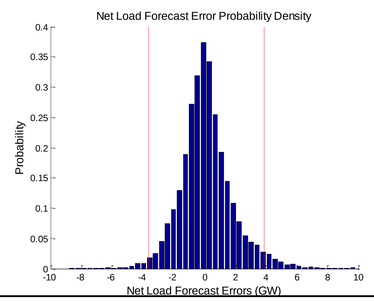




Net Load

Net load is defined as the wind power subtracted from the load. Uncertainty of net load forecasts depends on the uncertainty of wind and load as well as the correlation of wind and load forecast errors. The plot on the left below shows the Pearson's correlation coefficient for wind and load forecast errors for each month over two years. The dotted lines indicate the levels of correlation that are statistically insignificant from zero. Also shown is the probability density of the net load forecast errors. The 95% range spans from -3.6 to 3.9 GW.





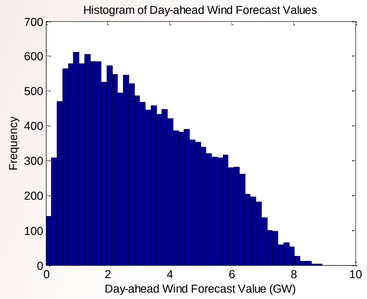
Operating Reserve Procurements

ERCOT uses historical data on net load forecast errors to make operating reserves procurement decisions. They ensure that the level of operating reserves is sufficient to cover 95% of past forecast errors. However, there is no direct use of forecasts to determine operating reserve amounts. Reserve calculations are made at the beginning of the month . Each day the same level of reserves are procured throughout the month.

Analysis

We use historical wind and load forecast uncertainty to determine the 95th percentile of positive net load errors for each hour of the day. The uncertainty is conditioned on the forecasted amounts of wind and load. This allows direct use of the forecasts to determine reserve requirements for each day. An algorithm based on this approach would calculate different reserve amounts each day .

By taking advantage of the fact that wind and load forecast uncertainty is much lower for low forecast values, it may be more cost effective to adjust reserve procurement each day based on forecasted levels of wind and load. This is especially true since the majority of wind forecasts in ERCOT from 2009 to 2010 were below 4 GW as shown in the histogram below.



Next Steps

Once hourly reserves are calculated for an entire year, we plan to compare the cost of procuring reserves with forecast to the current method in ERCOT using prices from the ancillary markets. We also plan to compare reserve procurements with each method to deployments in 2010 to compare exhaustion rates of reserves. Finally, we will extend this analysis to estimate the reserve generation costs with high levels of wind power by scaling up our analysis.

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