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EVOLUTION OF A SHORT TERM WIND ENERGY FORECASTING SYSTEM

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1. INTRODUCTION

The short term forecast period is critical for dispatch planning for utilities. During this 0-3 hour forecast time range, tactical decisions must be made as to the allocation of the energy portfolio. The variable nature of most renewable resources, such as wind and solar energy, complicates this process. More accurate wind energy forecasts improve the decision making process and reduce the utilities' exposure to the real-time energy market costs.

A short term forecast system is distinct from a ramp forecast system. While ramps do have a major impact on a utility's operations, they are relatively rare events, occurring once or twice per week on average at a farm. A ramp forecast system would warn a utility of the timing and magnitude of these phenomena, enabling an event-driven response. On the other hand, utilities' actions that depend on an accurate short term forecast occur every hour of every day.

The National Center for Atmospheric Research (NCAR) has developed a wind energy forecast system for Xcel Energy. The system forecasts out to 7 days into the future. These forecasts are updated every 15 minutes. During the first 3 hours of the forecast, the forecast interval has a 15 minute resolution due to the operational need for high temporal resolution in the short term. Two subsystems contribute to the power forecast during this short term forecast period. The first is an automated consensus forecast system. Hub height wind speed forecasts from this system are passed to an advanced wind-to-power conversion module.

The system that NCAR developed for Xcel Energy has evolved during the course of this collaborative project. Several of the modifications have improved the performance of the short term wind power forecast and these modifications will be discussed in the following sections.

2. OPERATIONAL CONSIDERATIONS AND OBSERVATIONS

Xcel operates in three distinct regions, which are roughly described as Minnesota, Colorado and Northern Texas. In each of these regions, decisions must be made concerning the power allocations for the next hour. This paper focuses on results from the most challenging forecast region of these, Public Service of Colorado (PSCO) that has about 1.7 GW of wind energy capacity. Market decisions for the next hour must be submitted to the system before 40 minutes after the hour. Given that it takes up to 20 minutes for processing, Xcel has been using the NCAR forecast generated at 15 minutes after the hour to make its operational short term decisions for the following hour.

For very short term wind forecasting, a persistence forecast is difficult to beat. That is, usually the current winds are a very good guess at what the winds will be the next 15 minutes. However, for longer forecast lead times, the errors for a persistence forecast rise quickly and are soon worse than the errors of a forecast based upon atmospheric models. The goal of any short term forecast system is to beat persistence as early as possible.

In order to evaluate system performance, Xcel has made long term comparisons of observed wind and power to the predicted wind and power in the NCAR wind energy forecasts. Xcel has presented these results in many forums. In calculating the error, Xcel typically uses Normalized Mean Absolute Error (NMAE), the most commonly used measure used in the wind energy industry. It calculates the average absolute error between the forecast and the observed power and divides this quantity by the total capacity of the wind farm (or region). As these errors can vary substantially over short time periods, it is best to average these results over a longer time window such as a 30 or 90 day running average of NMAE.

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3. RESULTS

Through the development of the NCAR system for Xcel, significant changes in forecast error have been observed. The following figures show the errors of the NCAR wind power and persistence forecasts over the course of 12 months early in the project, from November 2009 through November 2010.

Figure 1 shows the errors for the current hour, that is, the hour in which the forecasts are made. Clearly, persistence is a very difficult forecast to beat during this time period and persistence errors are typically around 2% NMAE. The NCAR forecasts begin at about 6-10% NMAE in November 2009 but decrease to an average less than 4% NMAE after March 2010. Since forecasts for this initial time period are not actionable, this is interesting but not much value operationally to the utility.

In Figures 2 and 3, the hour ahead and two hour ahead forecast errors are displayed. From the :15 forecast generation time, the forecast lead times for these two periods are 0:45-1:45 and 1:45-2:45 respectively. Both the NCAR forecast and persistence forecast show increasing errors with lead time. However, as expected, persistence errors increase more rapidly with lead time. The crossover point for better forecast performance lies somewhere within the 45 minute to 1:45 time range.

Three distinct phases in the error evolution can be seen in the figures. The first phase was characterized by a rapid reduction in the errors in the NCAR system due to system tuning. The second was a phase in which little changed in the system. In the one hour ahead forecast, the NCAR system's errors continued to be only slightly greater than those of the persistence forecast. In the third phase, the NCAR system began to outperform the persistence forecast at the hour ahead forecast due to changes made in the summer of 2010.

The first phase runs roughly from November 2009 through March 2010. This period is marked by a decrease in the difference in the forecast errors. At this point the one hour ahead forecasts are comparable, although the NCAR forecast still displays slightly higher NMAE than persistence and the two hour ahead forecast reaches a point where it outperforms persistence. During this period, Xcel and NCAR worked diligently to incorporate all the farms into the Xcel forecasting system.

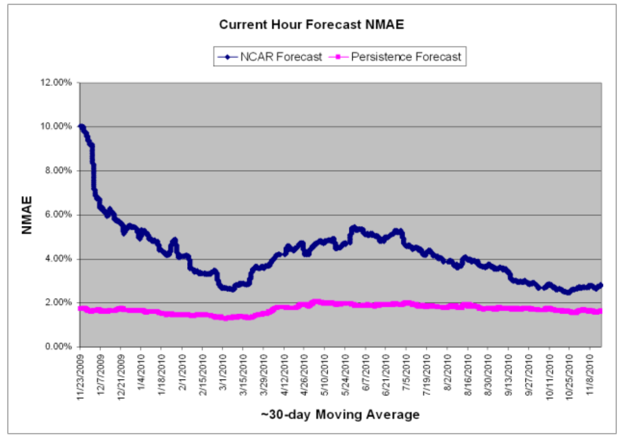

Figure 1: Current Hour NCAR and Persistence Forecast Errors

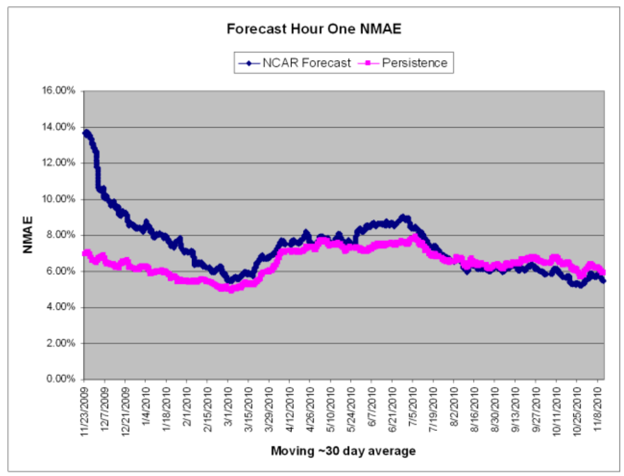

Figure 2: NCAR and Persistence Forecast Errors for the Next Hour. The forecast lead time for these is from 45 minutes to 1:45.

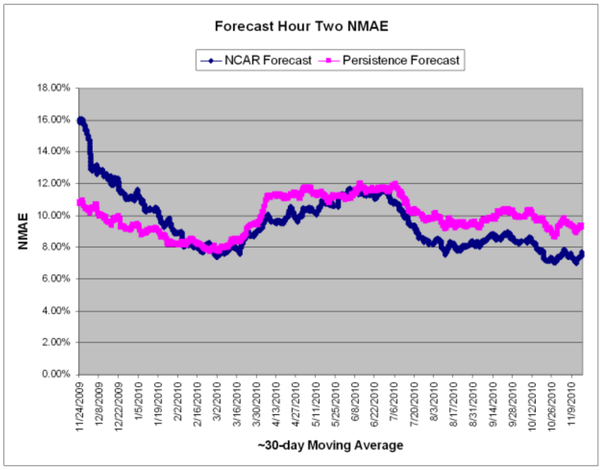

Figure 3: NCAR and Persistence Forecast Errors for the two hour ahead period. The forecast lead time for these is from 1:45 to 2:45.

The consensus forecast system, DICast, requires observations from each individual turbine's Nacelle anemometer in order to learn how to make a better wind speed forecast. The logistics of obtaining this data set was a bureaucratic challenge to Xcel, who owns only a fraction of the wind farms contributing to their grid. After agreements were put in place with the wind energy providers, Xcel still had to face the technological challenge of processing and delivering all these data to NCAR. Eventually Xcel obtained observational data from over 90% of its wind resources and had it flowing into the NCAR system. Meanwhile, DICast required training data to learn how to make an optimized forecast for each location. The result was a gradual reduction in the errors of the NCAR wind forecasts.

Throughout the period that DICast was learning how to make better wind forecasts, the system still produced power forecasts based on the incompletely optimized DICast wind forecasts. For farms newly added to the system, the Wind-to-Power conversion system simply used an industrial power curve. Results for farms incorporated into the system earlier had shown that an empirically derived power derivation function significantly reduced the wind to power conversion error rate. However, again, time was required to capture an adequate amount of data for the data mining system to develop robust empirical relationships for each farm.

Gradually, as these empirical "power curve" relationships were put into place and the input wind speed forecasts improved, the forecast errors decreased to a level almost as low as those for persistence. The value of turbine and farm level data is very clear. Without these data, the tuning wind speed forecasts and developing empirical power curves would not be possible. A completely untuned system, compared to a tuned system, have a difference of more than 7%NMAE. Thus it is clear that observational data are valuable to the forecast process!

In the second phase, from roughly March 2010 through August 2010, little changed in the system and persistence forecasts still outperformed the fully tuned DICast and Wind-to-Power forecasts throughout the period by up to 1% NMAE in the one hour ahead period. During this time, the system was being evaluated and new ideas were being developed and tested within the wind-to-power conversion system.

During the second phase it had been noticed that, while most wind farms produced high quality data, a handful were quite undependable. These observations were used heavily in the near term empirical wind-to-power relationships. The system used these observations in a rather simplistic way up to that point, making the simple yet naive assumption that if a farm was not reporting power, its current power output was zero. Clearly a better initial guess could be made. Better estimates of the current power at these irregularly reporting farms handled these data failure situations and dramatically improved the short term power forecasts at these farms. As a result, the overall errors were slightly reduced.

Simultaneously, just before this third phase, several modifications were made to the NCAR Real-Time Four-Dimensional Data Assimilation (RT-FDDA) WRF modeling system. These model runs were more heavily weighted by DICast in the early parts of the forecast than further out in lead time. While it not clear which of these upgrades were responsible for the improvement seen after August 2010, the result was that the NCAR forecasts had slightly lower errors than the persistence forecasts throughout the remainder of that year for the hour ahead forecast period.

4. CONCLUSIONS

The NCAR forecast system developed for Xcel Energy has demonstrated good results for the short term forecast when compared to a persistence forecast at the one hour ahead time range. This is an important decision making time for utilities in an hour ahead market. While persistence is still better than the NCAR forecast during the current hour, this is not usable in the decision making process for a utility as all relevant market decisions have already been made during the previous hour. At the two hour lead time, a persistence forecast has larger errors than the NCAR forecast.

It turns out that persistence achieves its error scores by being right most of the time and incredibly wrong at others. The NCAR forecast errs a little bit nearly all the time and captures the big changes some of the time. To a utility, persistence adds little information about the future. On the other hand, the NCAR forecast blends additional information about the state of the atmosphere. However the main result is not really about a choice as whether to use persistence or the NCAR forecast. Instead it is a mark of progress of a complicated model against an uncomplicated model. The uncomplicated model will never improve. New forecast systems will continue to improve and beat persistence earlier in the forecast.

5. REFERENCES

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