1.2 STATISTICAL ALGORITHMS FOR SHORT-TERM WIND ENERGY FORECASTING

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1. INTRODUCTION

Wind energy is the fastest growing energy generation source today. Globally, wind energy saw an average annual growth rate of 31% over the past five years. Domestically, wind energy is a plentiful energy source, especially in the upper Midwest and the mountainous Western United States. The rapid recent growth can be attributed to advances in wind turbine design, which have significantly reduced the cost of wind energy, as well as federally mandated tax credits. Estimates are that within the next 15 years wind energy can fill between 2% to 20% of the domestic energy demand.

The wide range of expected wind energy penetration rates (the fraction that wind energy contributes to the total energy production) is due to various factors, one of the most important being the differences in opinion of the predictability of wind energy. Arguments against higher penetration rates are often centered on the perceived inability to forecast wind with any degree of accuracy; thus, so the argument goes, it must be backed up at a one-to-one rate by other generating reserves. While this is an erroneous assumption, it is true that increases in the accuracy of wind energy forecasts reduce the requirement for backup energy, resulting in increased power grid reliability, as well as significant monetary savings.

The development of forecasting technologies directly addresses these concerns. The most immediate requirement is for the development of improved short-range forecasting methods, which are necessary for transmission scheduling and resource allocation. Of central concern are wind energy forecasts on the 0-3 hour time horizon. This lead time is typical of the time necessary for transmission scheduling and the dispatching of resources.

Historically, forecasts at this time horizon have utilized observations of present plant output (and/or wind speed) with various persistence based statistical forecast models, including time series models (Brown, Katz and Murphy 1984) and neural network methodologies (Beyer et al. 1994). Giebel (2003) provides an up-to-date review of currently employed techniques for wind energy forecasting.

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2. USING OFF-SITE OBSERVATIONS AND STATISTICAL SPACE-TIME MODELS

In an on-going collaboration between 3TIER Environmental Forecast Group, Inc. and the University of Washington, we are developing a forecast algorithm to improve the short-term accuracy of wind energy forecasts. Our approach consists of identifying wind and/or wind energy production regimes at a given wind project, and using off-site observations in the vicinity of the wind farm. Since changes with wind often propagate with the wind, it is possible to use upwind observations to detect precursors to wind energy output at the wind farm. We contend that the use of geographically dispersed meteorological observations at upwind sites results in significant improvements to short-range forecasts.

While the idea of using off-site observations to predict energy output at wind farms has been pursued previously (Alexiadis, Dokopoulos and Sahsamanoglou 1999), the novelty of our approach lies in the application of statistical space-time modeling. Due to the early stage of the project and confidentiality issues, only very preliminary and partial results are available for this report. The subsequent sections describe the data and methods, and then the results, and we conclude with a discussion.

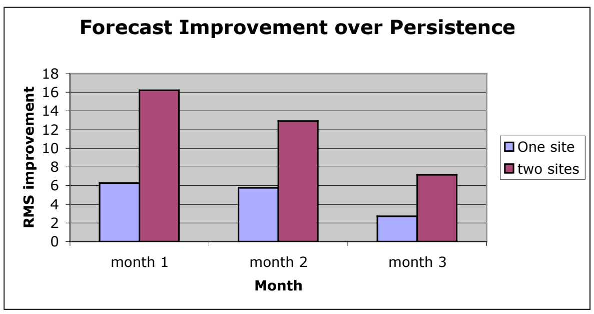
3. DATA AND METHODS

To investigate whether the use of upwind observations can improve short-range wind energy forecasts, four months of hourly power data at two wind energy sites were obtained. The two sites are approximately 150 km apart, and one site is upwind of the other. The diurnal pattern of wind energy production at the upwind site peaks in the afternoon, while the downwind site produces the most power at night. The cross-correlation function between the hourly power values at the two sites peaks at a 4 to 6 hour lag.

For this preliminary report, multivariate regression techniques were applied to a 30 day period of training data. The regression models fitted on the basis of the training data were used to provide forecasts of hourly energy production at the downwind site within a one week evaluation period, with the training and evaluation periods being consecutive. This procedure was repeated until forecasts for an entire month were issued. For reference we used persistence forecasts, given by the energy value at the downwind site two hours prior to the forecast period. The last values used by the multiple regression model were also from two hours before the forecast period.

4. RESULTS AND CONCLUSIONS

Initial results from the above case study suggest that the use of upwind observations can lead to significant improvements in wind energy forecasts. Specifically, we compared persistence forecasts, forecasts using on-site data only, and forecasts using both on-site and off-site data in terms of their respective root mean squared (RMS) error. The RMS improvement percent is the difference between the RMS persistence error and the RMS forecast error, divided by the RMS persistence error and multiplied by 100. Figure 1 shows that using both on-site data and data from the upwind site yields much bigger improvements over persistence foecasts, than does using on-site data only. The improvement in the forecasts was observed consistently over all three evaluation months.



5. DISCUSSION

Given the aforementioned encouraging preliminary results, we will be developing the approach, by using data from more than one upwind station, by identifying regional and local wind and/or wind energy production regimes, and by applying statistical space-time models. We anticipate that our approach can be successfully applied to wind farms all over the world, thereby suggesting that quality meteorological data from sites upwind of wind farms can generally be used to improve short-term wind energy forecasts. The resulting improvements in forecasting skill can contribute to the profitability and sustainability of wind power.

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REFERENCES

Alexiadis, M. C., Dokopoulos, P. S. and Sahsamanoglou, H. S. (1999), "Wind speed and power forecasting based on spatial correlation models," *IEEE Transactions on Energy Conversion*, 14, pp. 836--842.

Beyer, H. G., Degner, T., Hausmann, J., Hoffmann, M. and Rujan, P. (1994), "Short term prediction of wind speed and power output of a wind turbine with neural networks," in *Proceedings of the 5th European Wind Energy Association Conference and Exhibition*, Thessaloniki, Greece, pp.~349--352.

Brown, B. G., Katz, R. W. and Murphy, A. H. (1984), "Time series models to simulate and forecast wind speed and wind power," *Journal of Climate and Applied Meteorology*, 23, pp. 1184--1195.

Giebel, G. (2003), "A literature survey on short term prediction of wind energy," www.drgiebel.de/ShortTermPredLiterature.htm.