A Simple Method of Forecasting Wind Energy Production at a Complex Terrain Site:
An Experiment in Forecasting Using Historical Data

Lubitz, W. David and White, Bruce R.
Department of Mechanical & Aeronautical Engineering
University of California, Davis

Project Motivation

"Can a next-day wind energy forecasts be accurately and economically made with limited knowledge or data on local meteorological conditions?" A simplified forecasting method using a database searching (or "*matching*") approach was devised and tested as part of a California Energy Commission PIER funded research project to improve wind energy forecasting capabilities. In light of its relative simplicity and low computational overhead, results show promise over persistence as an economic means for obtaining wind energy forecasts.

Forecasts by Matching

This wind energy forecasting capability relies on an automated, desktop PC-based system which uses the Eta forecast model as the primary input.

Eta is a continental scale, non-hydrostatic operational weather forecast model operated by the National Center for Environmental Prediction (NCEP). It is initialized daily at 0Z and 12Z. Model output is generated on a 40 km grid that covers much of North America. Forecasted parameters are provided at 39 altitudes ranging from 1000 mb up to 50 mb. While this resolution is too coarse to predict near-surface conditions in complex terrain areas, they do provide upper atmosphere conditions.

Once Eta model data is downloaded, wind energy forecasts can be provided to users within minutes. The forecast is generated in several steps:

1. Eta 0 to 48 hour forecasts are downloaded as soon as they become available from NCEP.
2. The forecasted Eta parameters are interpolated from the Eta grid points to the location of the wind farm. Nineteen parameters are extracted: wind speed components, temperature and pressure at four altitudes from 1000 to 700 mb, plus barometric pressure and horizontal pressure gradients.
3. A historical database of past Eta forecasts is searched for the one most similar to the current Eta forecast. Forecast similarity is scored based on the sum of the normalized squared differences of the 19 parameters from the current and historical Eta forecasts. A similarity score is calculated for each past forecast in the database: the lowest scoring past forecast (indicating that the 19 parameters are closest to those in the current forecast) is taken as the matching forecast.
4. The wind farm energy production (or other parameters) matching the time of a past forecast is used as the new wind energy forecast.

Case Study

Match forecasting was implemented for a 90 MW wind farm in the Altamont Pass, California. The farm consists of approximately 900 100 kW turbines installed along ridgelines in a complex terrain region shown in figure 1.

The Eta forecast database used contained 16882 individual forecasts collected between December 2002 and March 2005. Each forecast was for a single time between 0 to 48 hours after initialization time.

The year 2004 was forecast diagnostically to evaluate the matching method. Each 2004 forecast in the database was used as the "current" forecast, and matched to the most similar forecast in the database. Forecasts within 4 days of the "current" forecast were excluded from the matching process to prevent matching two forecasts of the same meteorological events.

Results

Figure 2 shows the mean absolute error (MAE) as a percentage of the wind farm capacity for the matching method and persistence forecasts, versus the wind speed recorded at a nearby meteorological tower. Interestingly, MAE for both methods is highly dependent on wind speed, and increases significantly with wind speed. (The variability of MAE at high winds is due to the small number of times those high winds occurred.)

The energy forecast MAE is also dependent on the forecast interval (fig. 3). For forecast intervals of less than six hours, the persistence method outperforms the matching method. However, as shown below, the matching forecast has lower MAEs in the important 24 to 48 hour "next-day" interval.

Previously, two other organizations produced energy generation forecasts for the same Altamont Pass facility over a one year period ending Sept. 2002 (EPRI, 2003). Table 1 gives the overall MAE results of the two previous forecasting studies, the match forecast, and persistence forecasts. Skill score (S) is defined as $S = 1 - MAE_f/MAE_p$ where MAE_f is the MAE of the trial forecast method and MAE_p is the MAE for persistence forecasts during the same time period. The match forecasting was less accurate than the more sophisticated methods, but more accurate than persistence.

Conclusion

The matching method showed improved next day forecasting performance compared to persistence at a difficult site, while requiring only a modest increase in forecasting system complexity.

The case study wind farm was in a region of complex terrain. It is possible that the matching method may provide better forecasts in less complex terrain regions.

Benefits

Match forecasting provides reasonably good wind energy forecasting accuracy with limited site data. The only data required from the site is historical power production. Match forecasting also operates automatically and requires only an inexpensive internet-enabled desktop PC.

Acknowledgements

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Reference

EPRI Technical Report 1007339, *California Wind Energy Forecasting System Development and Testing Phase 2: 12-Month Testing.* 2003

Tables and Figures

Forecast *Oct. 2001 – Sept. 2002 **Jan. – Dec. 2004	MAE [% Cap.]	Skill Score vs. Persistence
Risø*	14.4	21.6%
TrueWind*	13.8	30.8%
Matching**	16.2	7.1%
Persistence**	17.4	0.0%

Table 1. Mean absolute error (MAE) as a percentage of observed wind farm capacity for four different forecast methods at the Altamont Pass wind farm. Skill score is percent improvement in MAE relative to persistence.

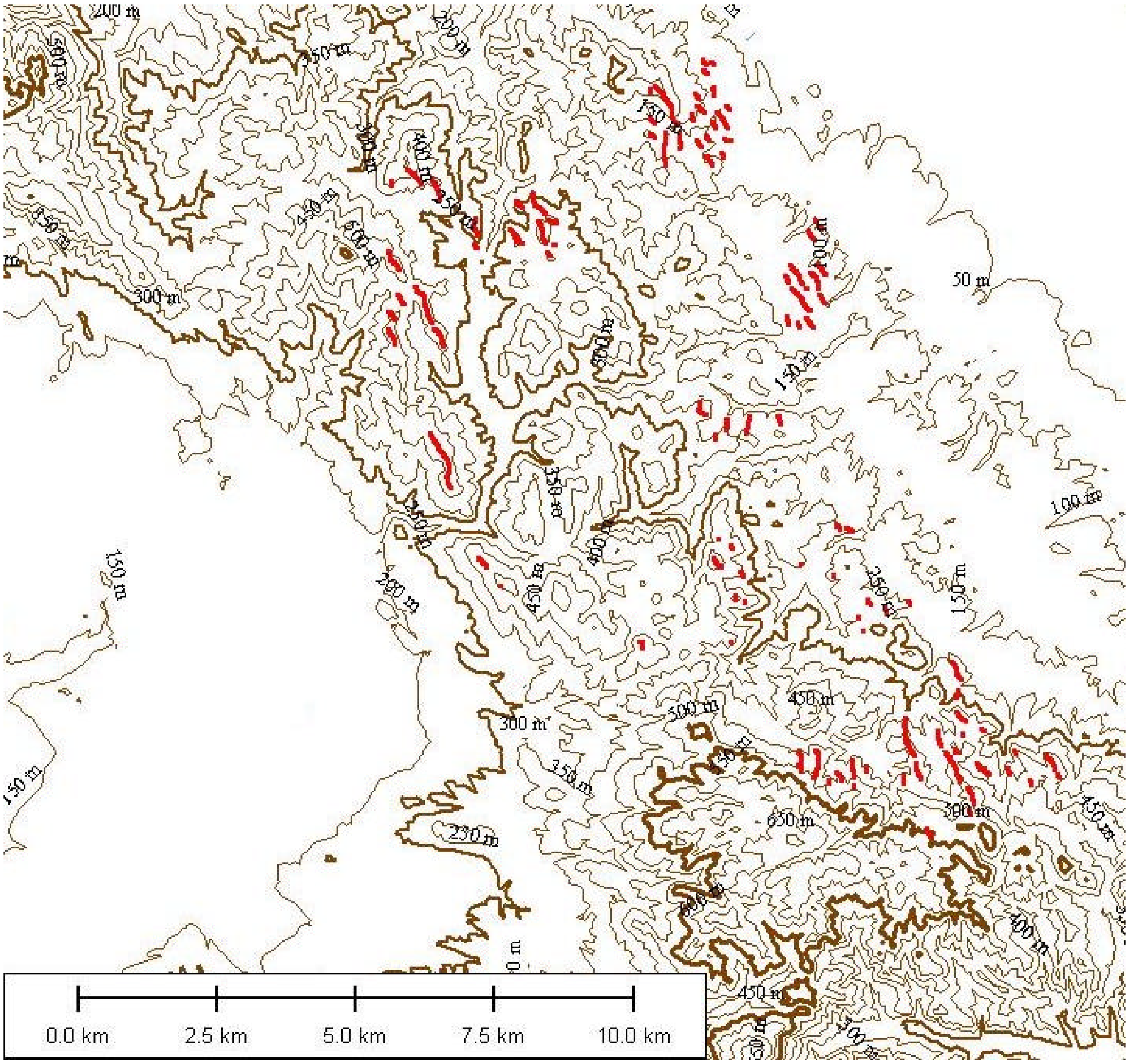

Fig. 1. Map of Altamont Pass wind farm. Turbine locations marked in red. Contour interval 50 meters.

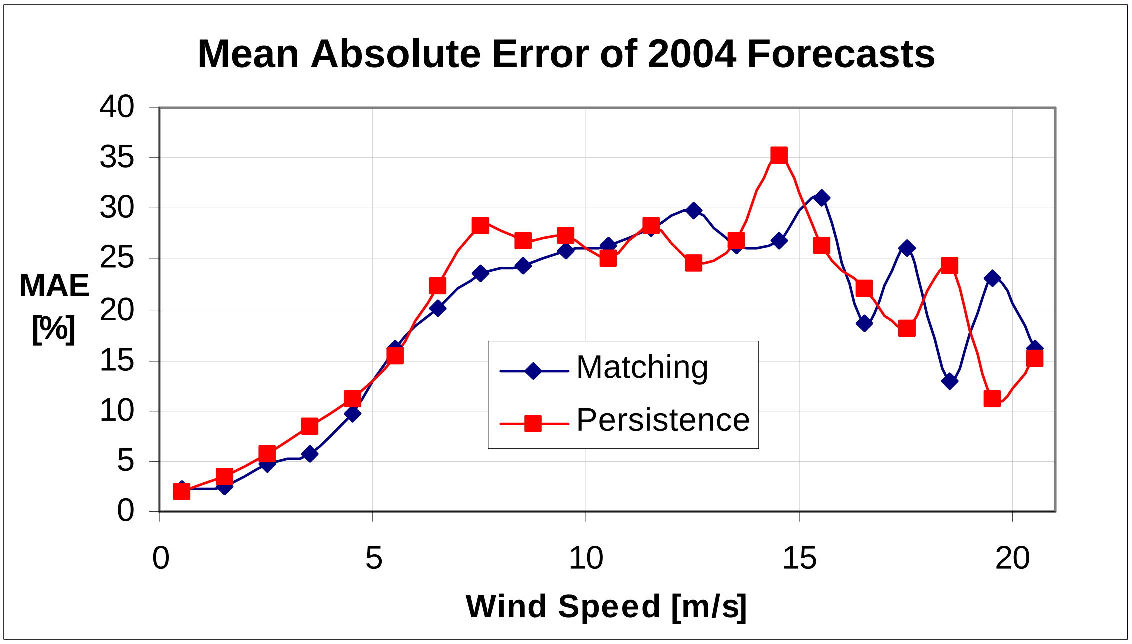

Fig. 2. Mean absolute error (MAE) of the match and persistence forecasts as a function of wind speed. January 1 to December 31, 2004.

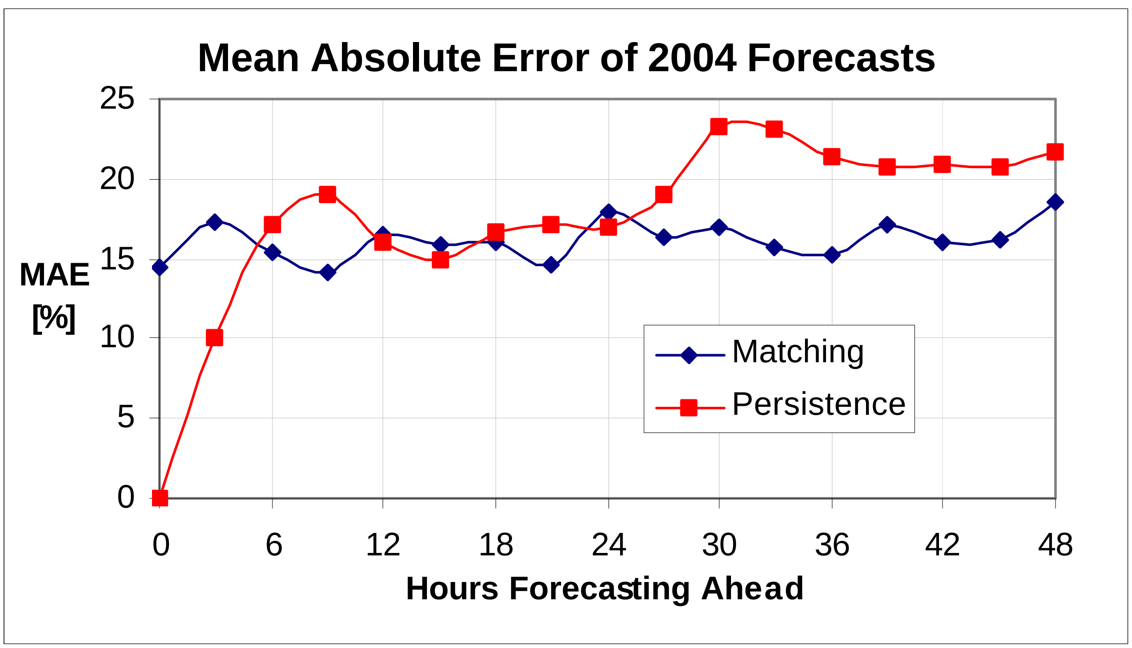

Fig. 3. Mean absolute error (MAE) of the match and persistence forecasts as a function of wind speed. January 1 to December 31, 2004.