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A Comparison of Turbine-Based and Farm-Based Methods for Converting Wind to Power

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NCAR is currently performing work that involves forecasting the power production at a variety of wind farms based on the forecasted winds at each of the farms. The work described below was done to compare a turbine-based method with a farm-based method for doing the wind to power conversion for the power forecast. The turbine-based method involves forecasting winds at each turbine at a given farm. The wind to power conversion is performed on a per-turbine basis and the resulting turbine powers are summed to produce an overall power forecast at the given farm. The farm-based method involves using a mean wind forecast for the entire farm. The wind to power conversion is performed by modeling farm power against the mean observed winds at a given farm. Finally, the forecasted mean winds are converted to farm power using the mean wind to farm power model. The results of the comparison are shown below.

Alternative Approach Methodology

Turbine-based (Sum of Turbines) Approach:

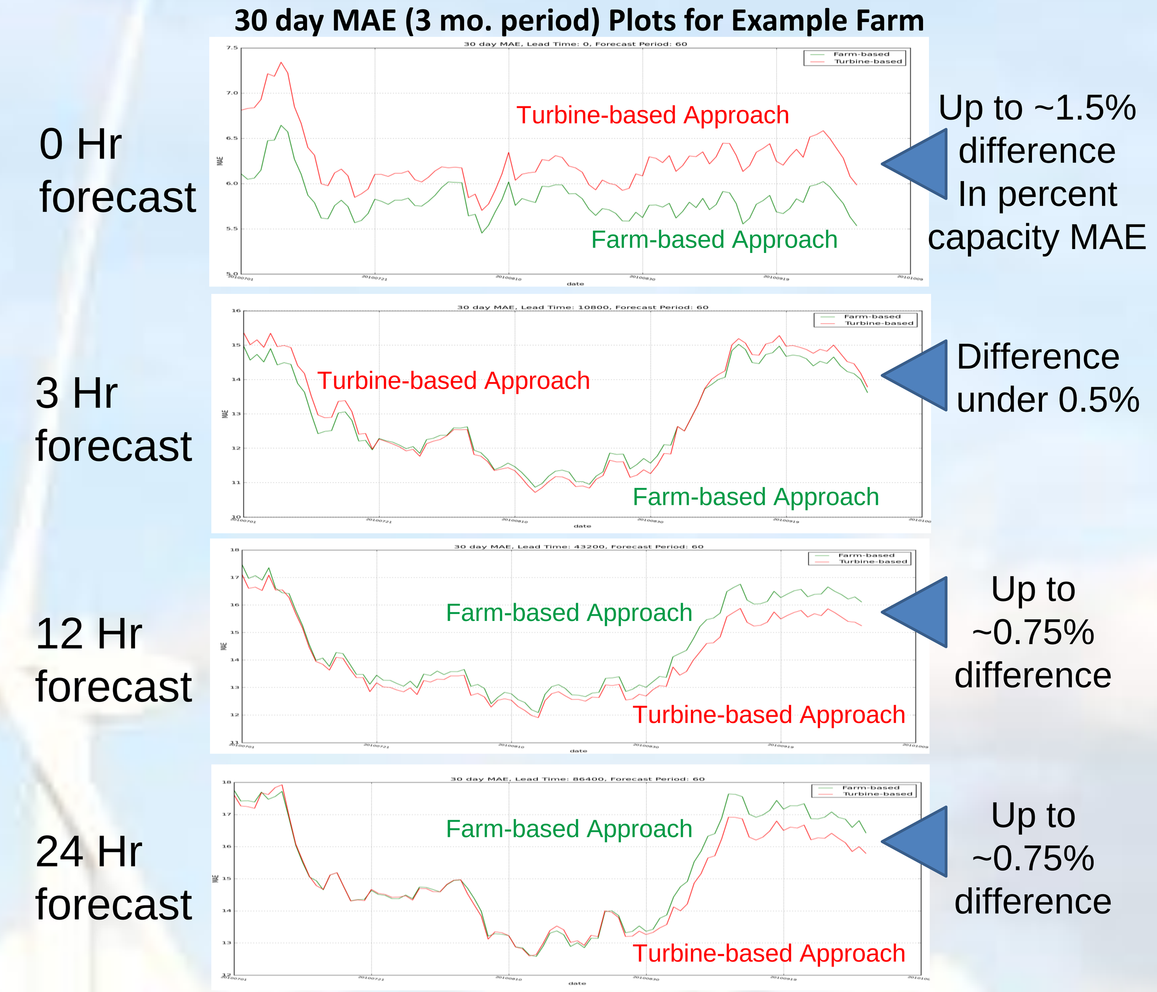
- Create models based on:
  - Observed turbine power
  - Observed nacelle wind speed at turbine
  - Group data from turbines of the same type
- Power Forecast for Farm based on:
  - Wind forecast at every turbine
  - Current observed turbine power
  - Current observed wind speed
  - Forecast power at every turbine and sum power to get power forecast for Farm
- Turbines without Wind Observations:
  - Use turbine type model or power curve with wind forecast at turbine

Farm-based Approach:

- Create models based on:
  - Capacity-weighted average observed wind speed for farm node
  - Observed farm node power
- Power Forecast for farm based on:
  - Capacity-weighted average wind forecast for farm
  - Current observed farm node power
  - Current capacity-weighted average observed wind speed for farm
- Farms without Wind Observations:
  - If no wind observations at any turbines, no farm model created, default to turbine-based (sum of turbines) approach

Initial Error Results: MAE of Power Forecast for Example Farm

30 day MAE (3 mo. period) Plots for Example Farm



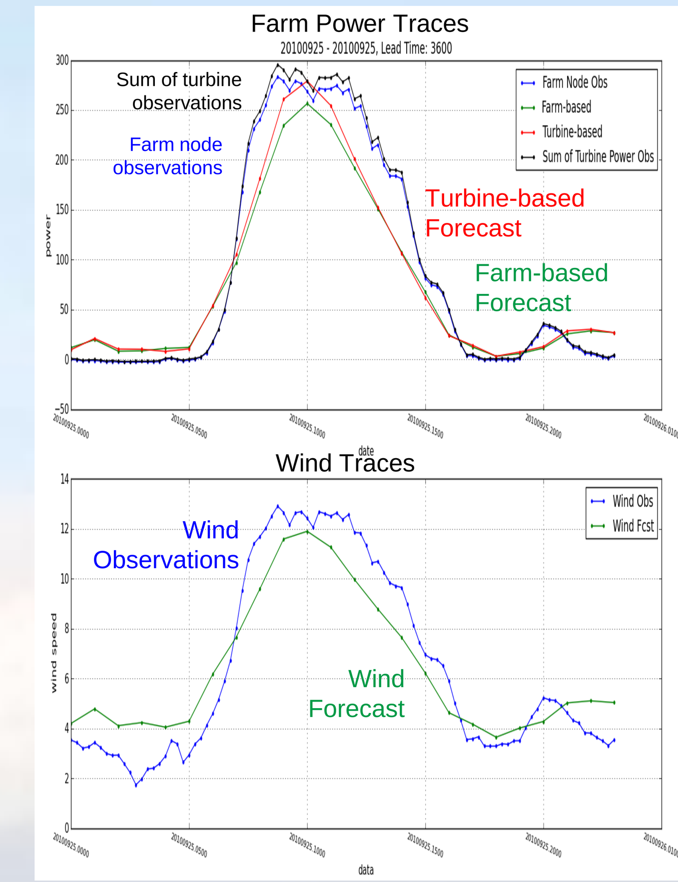
After creating models based on the two different approaches, a power forecast was made using the same wind input data over a four month period. These runs were used to create 30 day mean absolute error (MAE) statistics for each forecast lead time. Initial results show lower MAE in the power forecast for short forecast lead times using the farm-based approach when compared to the turbine-based approach. As lead time increases, however, the two methods performance converges with some indication that the turbine-based approach may have slightly better performance.

Initial Error Results Explained

One difference in the error results of the two power forecast methods can be explained by the difference in power observations that each method is trained and scored on.

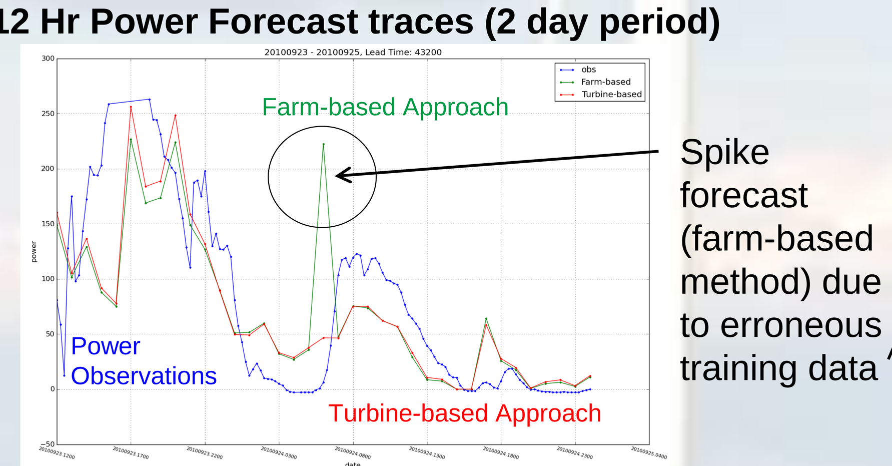
In general, the sum of all the turbine power observations for a farm is greater than a farm's node power observations, therefore the two methods have a slightly different power target during training. Since a farm's node power observations are what each method is scored against, the farm-based method has a slight advantage, especially in short term forecasts.

One hypothesis why the turbine-based approach seems to have slightly improved error statistics over the farm-based approach for longer lead times is that the turbine-based approach will perform better when wind events are under forecasted. (see figure)

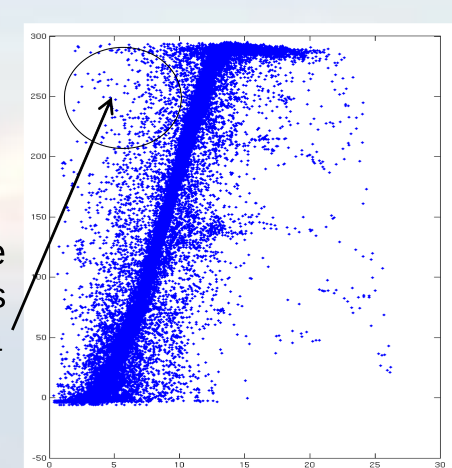


Farm-based Data Quality Issues

12 Hr Power Forecast traces (2 day period)



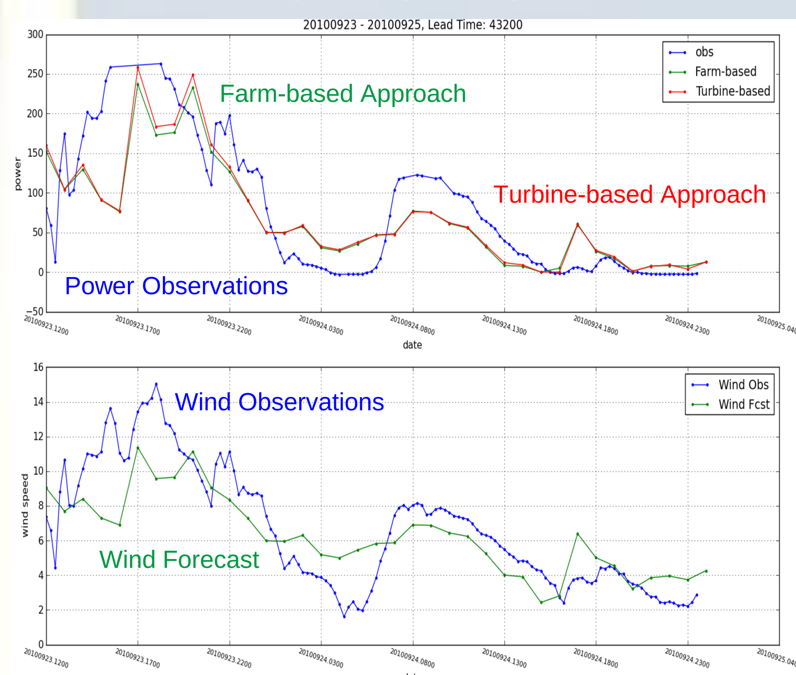
Training Data for Farm-based data mining



One issue that arose in the power forecast from the farm-based method was 'spike' forecasts. These forecasts would deviate from nearby forecasts and did not relate well or track the wind forecasts over the period. These spikes were due to quality control issues in the farm-based training data. The image on the right, above, shows the training data that was used to create the farm-based model that resulted in the spike forecast as seen in the upper left. This phenomenon was not seen in the power forecast created from the turbine-based models.

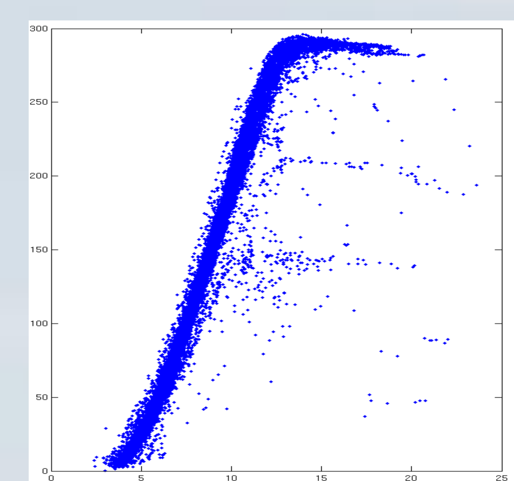
Quality Control Improvements

12 Hr Power and Wind Forecast traces (2 day period)



Now the power forecasts for the two methods are in line with each other and the wind forecast

Training Data for Farm-based data mining post QC



After quality controlling the data by eliminating farm node power observations that were not in line with the sum of all the turbine level power observations for the farm, the power curve used for training the farm-based models, seen to the right above, is considerably more distinct and clean. This process, along with quality control checks added to the power forecast procedure, eliminated the spike forecast phenomenon. A second run of the power forecast with the new farm-based model produced the following forecast traces, above to the left, where now the farm-based and turbine-based models forecasts are in line with each other.

Summary of Findings

Advantages of turbine-based models:

- Turbine-based models are available for all farms regardless of available data
- Turbine-type models or manufacture power curves can be used at farms where limited or no turbine level data is available.
  - This ensures that new or expanding farms' power forecasts can begin immediately
- Models not as sensitive to quality control issues in the data

Advantages of farm-based models:

- Farm-based models show improved performance in short term forecasts across all data-rich farms, i.e. farms where we get turbine level wind and power information.
- Longer lead time performance similar to the turbine-based approach for most data-rich farms
- Some farm-based models perform better at longer lead times with respect to MAE when compared to the turbine-based models

Disadvantages of turbine-based models:

- Need turbine level wind forecasts
  - Creates a more complex system
- Training target is slightly higher than desired target
  - Need to add in conversion between the total of the power for all turbines at a farm and the farms' node power

Disadvantages of farm-based models:

- Only used for data-rich farms
- Forecasts more sensitive to quality control issues
  - Saw spike forecasts across most farms
  - Need to quality control wind-power data to improve farm-based forecast, not done for turbine-based models
- May need to still run turbine-based approach as part of the quality control effort
  - Using this method only adds complexity to a forecasting system
- New and expanding farms require new models to be created immediately yet it takes time to build up enough farm-based data to create models