Assessing the Impact of Wind Power Variability on Electricity Prices

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INTRODUCTION

All forms of electric power generation have uncertainty associated with their output level, though significantly more concern surrounds the output from wind turbines than from conventional steam generators. Uncertainty in wind power generation forecast raises concerns of integrating wind power into power system operations and electricity markets at reasonable costs. This project quantifies the system cost of the uncertainty associated with wind power generation in terms of the change in production cost between the dispatch using an hour-ahead wind forecast and the real-time dispatch using actual wind generation.

WIND FARM MODEL

For the modeling presented here, ten-minute wind speed data from Nantucket Sound, MA[1] is used in conjunction with the GE 2.5MW wind turbine power curve[2] to represent the output from a hypothetical 550 MW wind farm. A three-steps method presented by Nørgaard and Holttinen[3] was implemented to capture the effect of geographic diversity on decreasing the variability in wind power generation.

1. Adjusting the Wind Speed Data for Geographic Diversity

The wind speed data from a single point was adjusted with a moving block average to represent the average wind speed across the wind farm.

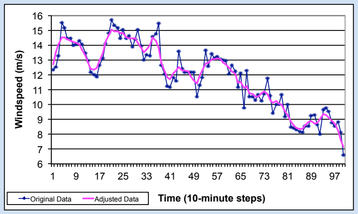

Figure 1: Windspeed data – Original and Adjusted for Geographic Diversity

2. Generating the Aggregated Wind Turbine Power Curve

The single wind turbine power curve was adjusted to represent the effective aggregated power curve from the multiple turbines in the wind farm.

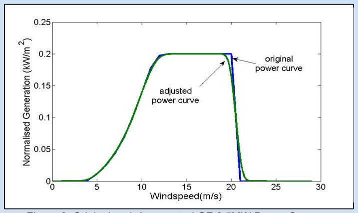

Figure 2: Original and Aggregated GE 2.5MW Power Curve

3. Translating Adjusted Wind Speed Data into Actual Generation

Figure 3 below shows the wind power output from a theoretical wind farm using the original wind speed data with the theoretical turbine power curve as well as the adjusted wind speed data with the aggregated power curve.

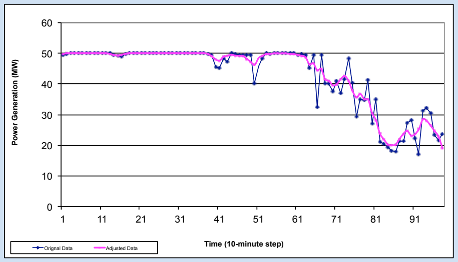

Figure 3: Original and Adjusted Wind Farm Power Output

THE TRANSMISSION NETWORK MODEL

The transmission system is represented with the 39 bus test system, loosely based upon the ISO-New England power grid. The bottom right star in Figure 4 represents the location of the hypothetical wind farm modeled in this project. One generator in this location is replaced with the wind generation

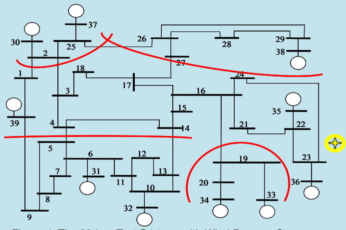

Figure 4: The 39-bus Test System, with Wind Farm as Star

ASSESSING THE IMPACT OF UNCERTAINTY WITH THE OPTIMAL POWER FLOW

The 39 bus test system is modeled with the optimal power flow(OPF) in Matpower[4]. Twelve scenarios with different regional load levels and constraints on the ramp rates of the non-wind generators are simulated. A distribution of the hour ahead power output forecast error is found based on a linear regression model of the complete dataset. (Figure 5) The forecast errors are implemented in a Monte Carlo Simulation framework..

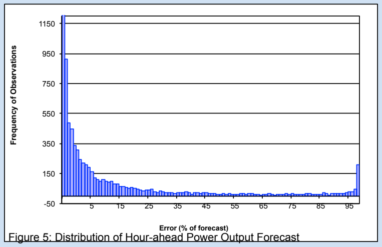

Figure 5: Distribution of Hour-ahead Power Output Forecast

Simulation Framework

1.The hour ahead dispatch is determined from the wind forecast using the OPF

2.A forecast error realization is obtained by sampling the distribution shown in Figure 5.

3.With the corrected forecast, the OPF is used to recalculate the dispatch which is constrained by the ramp limits of the other generators of the system.

RESULTS

- Production cost increases between 2.5% and 11% for the different scenarios
- The additional cost of the uncertainty is within 2.5% of the base cost for one third of the case
- When the ramp rate is constrained to 1% of the overall installed capacity, infeasible OPF solutions come up 38% of the time, indicating that the system would not be able to meet the load under the specified condition

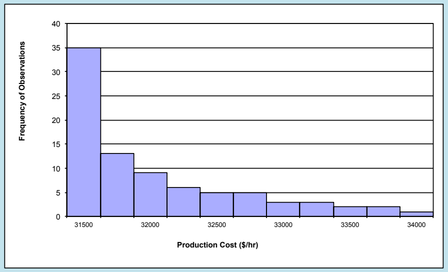

Figure 6: Increase in Production Cost Resulting from Wind Speed Forecast Error

CONCLUSIONS

The power system simulations presented above capture some of the system costs of uncertainty in wind power forecasts.

- These costs are shown to increase between 2.5% and 11% with the initial set of scenarios analyzed for the project.
- The next phases for the modeling include
  - Creating different forecasting models to provide error distributions that are conditioned upon wind power output level,
  - Multiple wind farms will be modeled to increase the geographic diversity and highlight the possibility of the transmission network exacerbating the uncertainty of the wind power output.
  - Ramp rates for individual generators will be defined according to different technology capabilities.

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