The Distribution of Wind Power Forecasting Errors from Operational Systems

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Topics

- Introduction
- Statistical Background
- Datasets
- Normal Distribution Comparison
- Persistence Model Comparison
- Distribution Modeling
- Conclusions
Renewable Energy Portfolio Standards

New Wind Power and Energy Required by State RPSs by 2025

Total Wind Energy Required = 182,188 GWh
Total Wind Capacity = 59,359 MW

Note: For the purpose of this map, we assumed that wind power would supply 80% of the capacity and energy required from state RPSs. Also, Missouri, North Dakota, Virginia and Vermont have state voluntary goals but not RPSs, and these are not included in this map.

This map was created by the National Renewable Energy Laboratory for the U.S. Department of Energy. Author: Bill J. Roberts, GIS Analyst. April 23, 2008.
Renewable Generation Integration Background

Flexibility Supply Curve

- High Cost
  - Gas Generation and Coal Cycling
  - Flexible Generation
  - Existing Hydro, Pumped Hydro, and Gas Storage
- Low Cost
  - Markets
  - Improving Pricing and Demand Response
  - Heating and Transportation
  - Ice and Heat
  - New Loads
  - Thermal Storage
  - Existing Storage
  - RE Curtailment
  - Concentrating Solar Power
  - Electricity Storage
  - Supply Side Flexibility
  - Demand Side Flexibility

The relative order of these is conceptual only.
Statistical Background

- **Skewness** – 3rd Statistical Moment

\[ \gamma = E \left[ \left( \frac{X - \mu}{\sigma} \right)^3 \right] \]

- **Kurtosis** – 4th Statistical Moment

\[ K = \frac{E(\varepsilon^4)}{\sigma^4} \]
Datasets

• ERCOT data
  • Day-ahead forecasts
  • Hourly power output
  • 13 months of data
  • Forecasts made at 16:00 the day prior
  • ~9,000 MW wind capacity

• Xcel Energy data
  • Forecasts produced every 15 minutes for the next 72 hours
  • Hourly power output
  • 3 months of data
  • Single wind plant ~300 MW capacity
ERCOT Day-Ahead Histogram

$\gamma = -0.62; \kappa = 1.03$
Xcel Plant 1-Hour Normal Q-Q Plot
Xcel Hour-Ahead Persistence Comparison

Persistence Model

Operational Model

\[ \gamma = -0.51; \kappa = 5.97 \]

\[ \gamma = -0.01; \kappa = 17.62 \]
Xcel 24-Hour-Ahead Persistence Comparison

Persistence Model

γ = -0.03; κ = 0.15

Operational Model

γ = -0.65; κ = 1.05
# Persistence Comparison – Multiple Timescales

<table>
<thead>
<tr>
<th>Timescale</th>
<th>Persistence Skewness</th>
<th>Persistence Kurtosis</th>
<th>Operational Skewness</th>
<th>Operational Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Minutes</td>
<td>-0.68</td>
<td>30.64</td>
<td>-0.68</td>
<td>30.64</td>
</tr>
<tr>
<td>30 Minutes</td>
<td>-1.36</td>
<td>30.88</td>
<td>-1.36</td>
<td>30.88</td>
</tr>
<tr>
<td>1 Hour</td>
<td>-0.51</td>
<td>5.97</td>
<td>-0.01</td>
<td>17.62</td>
</tr>
<tr>
<td>3 Hour</td>
<td>-0.21</td>
<td>1.81</td>
<td>-0.88</td>
<td>1.97</td>
</tr>
<tr>
<td>24 Hour</td>
<td>-0.03</td>
<td>0.15</td>
<td>-0.65</td>
<td>1.05</td>
</tr>
<tr>
<td>72 Hour</td>
<td>-0.03</td>
<td>0.06</td>
<td>-0.56</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Innovation for Our Energy Future
The black line represents a hyperbolic distribution fit to the data with: \( \pi = 0.083, \ \zeta = 1.601, \ \delta = 0.105, \ \mu = 0.006. \)

The blue line represents a normal distribution with the same mean and standard deviation.
The black line represents a hyperbolic distribution fit to the data with: \( \pi = 0.087 \), \( \zeta = 3.88 \times 10^{-5} \), \( \delta = 1.76 \times 10^{-6} \), \( \mu = 0.005 \).

The blue line represents a normal distribution with the same mean and standard deviation.
Forecasting Error Distributions Implications

- Forecast
- Power Output
- Hyperbolic - 95%
- Normal - 95%

Power (MW)

Time Period (Hour Intervals)
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Questions?

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