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

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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.
Statistical Background

- Skewness – 3\textsuperscript{rd} Statistical Moment
  \[ \gamma = E \left[ \left( \frac{X - \mu}{\sigma} \right)^3 \right] \]

- Kurtosis – 4\textsuperscript{th} 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

γ = -0.62; κ = 1.03
ERCOT Day-Ahead Normal Q-Q Plot
Xcel Plant 1-Hour Normal Q-Q Plot
Xcel Hour-Ahead Persistence Comparison

Persistence Model

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

Operational Model

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

Persistence Model: \( \gamma = -0.03; \kappa = 0.15 \)

Operational Model: \( \gamma = -0.65; \kappa = 1.05 \)
## Persistence Comparison – Multiple Timescales

<table>
<thead>
<tr>
<th>Timescale</th>
<th>Persistence</th>
<th></th>
<th>Operational</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skewness</td>
<td>Kurtosis</td>
<td>Skewness</td>
<td>Kurtosis</td>
</tr>
<tr>
<td>15 Minutes</td>
<td>-0.68</td>
<td>30.64</td>
<td>-1.36</td>
<td>30.88</td>
</tr>
<tr>
<td>30 Minutes</td>
<td>-1.36</td>
<td>30.88</td>
<td>-0.88</td>
<td>1.97</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>-0.65</td>
<td>1.05</td>
</tr>
<tr>
<td>24 Hour</td>
<td>-0.03</td>
<td>0.15</td>
<td>-0.56</td>
<td>0.84</td>
</tr>
<tr>
<td>72 Hour</td>
<td>-0.03</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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: \( \pi = 0.087, \quad \zeta = 3.88 \times 10^{-5}, \quad \delta = 1.76 \times 10^{-6}, \quad \mu = 0.005. \)

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

![Graph showing power output and forecast intervals over time periods. The graph includes lines for forecast, power output, hyperbolic 95%, and normal 95% intervals. The x-axis represents time period in hour intervals, and the y-axis represents power in MW. The graph illustrates the variability and overlap between the different forecast distributions.]
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Questions?

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