Motivation

Wind farm developers and investors are under increasing pressure to utilise financing structures that maximise revenue and reduce risk. The risk is in part represented by the 1- and 10-year 90% probability of exceedance value (P90) produced from the pre-construction energy assessment evaluation.

One element that drives the P90 estimate is the uncertainty in how the wind farm will operate into the future. This poster introduces a data-based evaluation of the uncertainty in the availability loss factor based on operational wind projects across Europe and the world. The authors posit that the uncertainty in future operation can be informed by the distribution of historical operation, and therefore present system (whole wind farm) availability data to better define the realistic risk in project operations.

Background & Methods

The authors have utilised a global benchmark database that includes monthly system availability statistics calculated independently by DNV GL as well as values reported by wind farm operators and owners. The database represents over 60 GW of installed capacity including all major turbine technologies, the majority of which are modern, pitch regulated machines, and the wind farms in the database have one to ten or more years of operation.

For the purpose of this study, DNV GL used independently calculated values of energy-based system availability defined as:

**Energy produced by the wind farm**

Energy produced + energy lost due to all wind farm downtime events

<table>
<thead>
<tr>
<th>Region</th>
<th>Wind Farms</th>
<th>Wind Farm Years</th>
<th>Total Capacity (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>800 (374)</td>
<td>2513 (1333)</td>
<td>19 (8)</td>
</tr>
<tr>
<td>Rest of world</td>
<td>557 (161)</td>
<td>617 (589)</td>
<td>47 (12)</td>
</tr>
</tbody>
</table>

Analysis steps:
1. Monthly data were filtered to a) select energy-based system availability statistics and b) consider only data passing quality control procedures with high confidence (as summarised in Table 1).
2. System availability values were annualised by averaging across each year. Operating years with less than 12 months of data were excluded.
3. Data were divided by project characteristics, and metrics calculated:
   - Mean – average
   - Median – P50, i.e. 50% of the data have availability above and below this
   - P90 – 90% of data have availability higher than this
   - P90/P50 ratio – relative measure of the spread in a distribution
4. Conclusions

Results – All Europe

- Median (P50) = 96.7%
- Mean = 95.3%
- P90 = 90.7%
- P90/P50 = 94% for the entire European dataset

Results by Project Characteristics

The results of the analysis are presented in graphs below and are for Europe only except where noted. The results shown are relatively insensitive to small changes in groupings by project characteristics.

Conclusions

- Results from this database show that P50 energy-based system availability in European wind farms is:
  - Highest for small wind turbines (0.6-1 MW) and somewhat higher for >2 MW turbines compared to turbines in the 1-2 MW range
  - Higher for larger projects (>15 turbines) compared to small projects
  - Highest in middle years of operation and somewhat lower in years 1-2 and 10+. Conclusions for 10+ years are based on few data points.

- The ratio between the P50 and P90, or the ‘spread’ of the availability distribution, is greater for projects in the database that are small (<15 turbines). The spread is also slightly increased for turbines rated between 1 and 2 MW as well as for wind projects outside of Europe.

- Both the average system availability and the spread in the availability distribution remain fairly consistent through the middle years of a wind project’s life (approximately years 3-9).

- Understanding the expected distribution of availability at wind farms across Europe can help to understand and predict project performance.

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