Data integrity(*):
Prerequisite to Real World Power Curves

(*)integrity:
1. data’s consistency and freedom for corruption
2. the state of being whole or entire

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Challenges associated with power curve measurements:
  – Anemometer calibration
  – Data integrity of siting measurements
  – Data integrity of power curve measurements
Anemometer calibration challenges

- SWP acknowledges the need for improvements of the anemometer calibrations in order to lower the inter-calibration differences and uncertainties between wind tunnels.
- SWP encourages that the allowable inter-tunnel acceptance range is (at least) halved relative to the present limit (from present 1% to 0.5%).

### RR of 20 anemometers in three wind tunnels

<table>
<thead>
<tr>
<th>MAWS=8m/s</th>
<th>T1/T3 (%)</th>
<th>T2/T3 (%)</th>
<th>T2/T1 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>101.90</td>
<td>102.00</td>
<td>100.10</td>
</tr>
<tr>
<td>Max.</td>
<td>102.30</td>
<td>102.30</td>
<td>100.30</td>
</tr>
<tr>
<td>Min.</td>
<td>101.50</td>
<td>101.40</td>
<td>99.60</td>
</tr>
</tbody>
</table>

### Comparison at 150Hz

### Vector/Risø ratio vs. wind speed
Siting measurements

• **Problem:**
  – Incomplete pre-construction measurement campaigns with focus diverted from data integrity
  – Too little attention to other parameters than wind speed distribution

• **Solution: The siting departments wish list**
  – Documentation of the measurement campaign:
    • Mast layout
    • Boom orientation
    • Sensor calibration (cup, wind-vanes
    • Mast shadow influence and eventual corrections of the data
    • Atmospheric temperature, pressure, humidity
  – Measurements at hub height (avoid extrapolation from lower heights)
  – Wind speed and wind direction measurements at more heights (to determine the local shear and veer)
  – High frequency measurement campaigns of wind speeds, not just 10min statistics (to identify frequencies which may influence the turbine structure)
  – Even better: Combine use of met masts with remote sensing to measure the wind profile above hub height
Power curve measurements

- Data integrity jeopardized by:
  - Increasingly complex terrain locations
  - High hub height (new uncertainty source)
  - Large rotors (new uncertainty source)
  - Available measurement codes and practices not sufficiently precise to cope with the new challenges (hub height wind speed does not reflect the reality over the whole rotor)
  - The energy equivalent wind speed over the rotor needs from now on to be considered as the alternative to the hub height wind speed

AEP = 100%  <100%  >100%
Meeting the needs of the customer: **Site specific PC**

- Knowledge of the local conditions makes it possible to meet the customer’s economic considerations and offer site-specific power curves.
- Data integrity is a must.

- A realistic approach combines:
  - The turbine’s generic power curve
  - Site specific information (wind shear-veer profile, wind-rose and TI distribution, local topography)
  - Flow simulations
  - Experience from previous measurement campaigns in similar terrain

- The output:
  - A state-of-the-art site-specific power curve!
Conclusions

• Due to the large rotor evolution:
• The hub-height wind characteristics are not any longer always representative of the wind speed over the whole rotor and a new IEC revision 61400-12-1 is needed in order to incorporate the new measurement procedures
• New uncertainty sources (due to wind shear and veer over the rotor) need to be considered, additionally to the already existing ones
• Data integrity during the siting period is fundamental for being able to offer realistic power curves to the customer.
Additional info: Wind profile vs. hub height wind speed

\[ V = \frac{3}{A} \int_{H-R}^{H+R} \left( v(z) \cos(\varphi(z)) \right)^3 dA \]
Question:

Does the turbine produce better during low shear, low veer and higher TI conditions?

OR:

Has our filtering, modified the energy contents of the wind profile? (without our measurement method being able to register it!)