How to Improve Wind Turbine Operations: Predictive Maintenance

Increase availability and control costs via condition monitoring

### WIND POWER BY THE NUMBERS

<table>
<thead>
<tr>
<th>Region</th>
<th>Capacity (GW)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>35%</td>
<td>35%</td>
</tr>
<tr>
<td>Europe</td>
<td>31.8%</td>
<td>31.8%</td>
</tr>
<tr>
<td>Other</td>
<td>14.4%</td>
<td>14.4%</td>
</tr>
<tr>
<td>North America</td>
<td>18.8%</td>
<td>18.8%</td>
</tr>
<tr>
<td>Total</td>
<td>101.5 B (USD)</td>
<td>35%</td>
</tr>
</tbody>
</table>

- 340,000+ Wind turbines operating globally
- $101.5 B (USD) invested to-date in Wind Capacity globally

In U.S. wind comprises 20% of total power (and the largest source of renewable generating capacity in country)

### WIND UNPREDICTABILITY IS CHALLENGING

Shifting conditions cause varied fatigue and damage:
- Speed and direction of wind changes frequently
- Atmospheric conditions such as:
  - Temperature
  - Humidity
  - Wind Turbulence
  - Seasons
  - Others (towers, foundation, and other electrical or cooling systems fatigue or failure)

### LEADING FAILURE CAUSES GENERATE COST PRESSURE

When unmanaged and unmonitored, maintenance costs can quickly and significantly add up

### "In wind turbine operations, reducing repair costs delivers higher savings than reducing downtime; however, both are important."

~Bently Nevada Wind Team

### KEY BENEFITS OF PREVENTATIVE O&M STRATEGY VIA CONDITION MONITORING

- Proactive monitoring of turbine components identifies atypical part operation before failure occurs

- **IDENTIFIES** when turbine part requires repair
- **AVOIDS** down-tower component replacements
- **REDUCES** costs associated with replacement parts and use of cranes

### REPAIR COST DE-ESCALATION IN ACTION

Here’s what a real-life wind farm condition monitoring solution looks like:

1. Detect vibration increase on a component
2. Condition monitoring system triggers alarm to alert analyst
3. Technicians resolve issue before it escalates into major problem

### RUN-TO-FAILURE VS. CONDITION MONITORING

Proactively de-escalating maintenance costs is key to successful and sustainable wind operations

<table>
<thead>
<tr>
<th>Component</th>
<th>Replacement Cost (in USD)</th>
<th>Preventative Cost (in USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearings</td>
<td>$12-$15,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>Gearboxes</td>
<td>$300,000</td>
<td>$15,000</td>
</tr>
</tbody>
</table>

- **REPLACEMENT COST (in USD)** up to 93% savings
- **PREVENTATIVE COST (in USD)** up to 95% savings

### ACHIEVE TOTAL ASSET PROTECTION

A comprehensive condition monitoring solution — trusted hardware, software and service expertise — effectively de-escalates maintenance costs

Contact Bently Nevada to learn more | www.bently.com/wind