MAXIMIZE PLANT PERFORMANCE:
Data mining to implement a better O&M strategy

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Agenda

• What is the objective of performance optimization and how is it executed?
• What role does data mining play?
• What are some typical performance indicators?
• Case study with Infigen Energy
How do I get back to my expected production levels?

• Benchmark performance based on realized wind & other conditions
• Identify causes of lost energy
• Implement corrective actions that yield positive returns on investment
Who Uses The Data?

• Plant Owners / Operators
  – Asset Managers
  – Corporate Finance
  – Site Managers
  – Operation and Control Center
• Investor / Partner
• Independent Service Provider
• Turbine Manufacturers
• Insurance Companies
Performance Optimization – General Process

- SCADA Data Mining
- Climatologic Data Analysis
- Turbine Technology

- Calculate Turbine Specific Power Curves and Lost Energy
- Identify Root Cause
- Implement Corrective Actions
- Quantify Results

Repeat Annually
What Role Does Data Mining Play?

**Data Mining**: Finding patterns and knowledge from numerous fields in large relational databases.

**Involves**: Adaptive analytics & machine learning techniques, such as cluster analysis and anomaly detection.

**Objective**: Distilling actionable intelligence (i.e., gold nuggets) from an overwhelming amount of information.
How Lost Energy is Calculated

• Diagnostic analysis using 10-minute SCADA data, site meteorological data, and monthly operating reports.

• Identify ‘normal performance’ for individual turbines to understand where underperformance occurs.

• Quantify lost energy and the potential for it to be recovered.
  − Adjustment to maintenance strategy and/or control settings
Examples of Diagnostic Performance Indicators

- **Lost Energy**
  - Determine “baseline” power curve for turbines
  - Understand how/why energy is lost

- **Availability**
  - Standard contracts are time-based guarantees
  - OEMs are moving to production-based guarantees
  - Many exceptions

Photo credit: Dan Bernadett, AWS Truepower
• **Energy to Downtime (EDT) Ratio**
  – EDT = Lost Energy/Lost Time
  – Turbines fail when systems are working hardest
  – Under time-based guarantees, this results in more lost energy than time
  – AWST uses EDT to track lost energy so that it can be minimized
  – Focus on EDT has reduced lost energy throughout the industry
  – 5-years ago typical EDT = 1.15, now ~1.05

Here’s an example...
Create power curves for each turbine.

Filter data to define baseline power curve.

Deviations from baseline indicate lost energy:

- Failed Nacelle
- Anemometers
- Curtailments
- Turbine Downtime
- Icing
- Underperformance

Pitch errors have high EDT since they occur near rated power at the “knee” of the power curve.
AWS Truepower partnered with Infigen Energy to optimize performance of a wind farm over a period of 4 years.

- 100 MW+ plant rated capacity
- MW scale turbines
A Case Study – Discussion of Events

Year 1: 2.9% loss due to large number of manual stops for maintenance.

Y1 EDT = 1.16

Data analysis used to refine scheduled maintenance plan.

Years 2 - 4: reduced maintenance losses to 0.6%. EDT = 0.85
Year 2: Pitch Lubrication Faults were excessive, resulting in 0.3 - 0.4% loss. **EDT=1.27**

Problem: turbine pitch bearing auto-greasers – daily restart required.
EDT lowest 6-8 am for the re-start.
Reduction to 0.1% - 0.2% loss in Year 3 and Year 4. **EDT = 0.7**
Year 2: Current Asymmetry Level event code. **EDT = 2.1**

Issue associated generator issues at high wind speeds.

OEM completed a generator retrofit, which eliminated the problem.

Reduction to **0.0% loss** after Year 2.
Year 4: Individual Turbine had a control setting issue with cable Autowind.

Turbine unwind occurred every 2 revolutions, not 3.

~2.0% additional loss in that turbine.
A Case Study – Discussion of Control Settings

Year 1: Test was completed for the Wind Sector Management (WSM) Strategy, odd vs. even turbines.

Test turbines were to be returned to standard strategy at 6-months.

One turbine did not return, but was curtailed through entirety of the year.
A Case Study – Discussion of Control Settings

Year 1: Turbines 26 and 32 shifted orientation with respect to the neighboring cluster.

Offset control settings were updated and monitored to alleviate issues.
Year 4: There was a control setting issue for turbine orientation for several units. This caused a shift in the WSM strategy for part of the year. Offset between the vane and yaw orientation was reset to alleviate issue.
A Case Study – Performance Indicator Summary

<table>
<thead>
<tr>
<th>Fault</th>
<th>Yr 1 loss</th>
<th>Yr 2 loss</th>
<th>Yr 3 loss</th>
<th>Yr 4 loss</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual softstop</td>
<td>2.9%</td>
<td>0.5%</td>
<td>0.6%</td>
<td>0.5%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Pitch system</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Current asymmetry</td>
<td>0.1%</td>
<td>0.02%</td>
<td>0.02%</td>
<td>0%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

Manual softstop minimized to 0.5-0.6% per year, consistent with a 60 hrs/turbine/year maintenance contract at an EDT of 0.85.

Pitch system loss and EDT minimized due to changes in auto-greaser protocol EDT from 1.27 to 0.7.

Current asymmetry issues resolved by OEM retrofit.
Summary

- Performance optimization improves energy production and increases return on investment from assets.

- Performance optimization benefits from data mining to derive actionable intelligence.

- The case study with Infigen Energy illustrates the magnitude of performance improvement achieved at one project.
Parting Questions

• Is your performance review program as robust as it should be? Is it an important part of your O&M program?
  – Third party audits/reviews can help.

• Are you making the greatest use of your project data?
  – Effective data mining and value-based decision making can improve your bottom line by reducing your lost energy.

• Are you gathering enough data and the right data to drive the most informed decisions?
Questions and Follow-up

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