A Systematic Approach for Streamlining Condition Monitoring Data

Integrating Condition Monitoring Systems into a Condition-based Maintenance Program

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Introduction

- “CbM” and “CMS”
- Step 1: Determine need for CMS
  - CMS data “wants”
  - CMS data “needs”
- Step 2: CMS system choices
- Step 3: Systematic approach to CMS data reduction
- Step 4: Validate the approach
- Other Recommendations
CbM v. CMS

- **CbM Definition**: Maintenance based upon assessment of the condition of the equipment
- Assessments are made based upon data from various sources
- CMS is just one of those data sources
- Data can be of varying quality and presented in different formats
- Data can be contradictory or overwhelming
- Integrating and streamlining each data source will improve the CbM program
- We need a strategy to integrate and streamline CMS data into the CbM program
Who Needs a CMS?

Step 1: Determine need for CMS

- Do you have a problem?

- Has each one of the existing data sources been incorporated, streamlined and integrated?
  - SCADA (e.g. mining)
  - Service Records (e.g. CMMS, MTBF, MTTR)
  - Independent Inspections (e.g. EOW)
  - Field Observations (e.g. daily route)
  - Industry Experience (e.g. user’s groups)
  - Other? (e.g. ?)

- Will the system provide a positive ROI?
  - Consider all factors

- Increased revenue from production
- Lower O&M costs
- Improved morale
- Higher level of safety
- Reduction of environmental impact
- Improved public image
CMS Choices

**Step 2: Choose a CMS system that achieves the desired result, AND automates or minimizes the amount of data presented**

**Observation:** Wear particle and vibration-based systems are complimentary
CMS Data Drivers ("wants")

- 24/7, constant monitoring
- Multiple sensor locations: 1 main bearing, 4+ gearbox, 2 generator, 3+ blades, more for offshore
- Multiple measurement types: Waveform, velocity and acceleration spectra, enveloped spectra, acoustic
- Process parameter import for correlation, triggering and filtering—all process data, or at least wind speed, power, yaw deviation, yaw activity, temperatures, alarm status, wear particle counts….
- Data storage: All baseline data, historical milestones, failure mode progression, maintenance activity effects, and all measurements initially for analysis recall with data thinning over time
- Automated fault detection with expert system or programmable alarming
- Powerful, user friendly GUI: enterprise view with traffic lights, project view with site layout, wind turbine with traffic lights, waveforms and FFTs with alarms and fault frequencies, waterfalls, stacked plots, overlaid plots, trends, Bode plots
- Output relays
- Alerting and Reporting
- Data export: OPC, .csv, etc.
- An analyst who won’t quit after sitting in front of the pipe for 6 months
CM System Data Drivers ("needs")

- Fault notification
- Early warning
- Location of fault
- Repeatable result
- Alternative confirmation
- Manageable data
- Site-level exception notification
- Enterprise monitoring and analysis
- ?

Planetary Bandwidth Enveloped Spectrum Warning - RMS Value = 3x Baseline
Oil Particle Count Warning (26,437)
Oil Filter Differential Pressure Warning (2.7 bar)
Needs-driven CM System Specification

Step 3: Apply “needs” rules at each level
Measurement Streamlining

- Monitor RMS or peak values from overall measurements or band alarms
  - For overall, filter LS dynamics with HFE or Fmin
  - For band alarms, consider “section” bands v. fault frequency bands. WHY?
  - Numerical values are easy to trend
  - Numerical values are easy to export to other platforms

- Use process parameters to trigger consistent measurements
  - Trends will be more consistent
  - Look for parameters that indicate inconsistent operating conditions (e.g. off yaw, high shear)

- Interrogate constantly, sample only when triggered

- Use alarm thresholds sparingly to keep spectra and waveform samples
Example of Waveform Overall Trend

- Time waveform overalls include all dynamics, including low-speed dynamics.
- This does not pinpoint the fault, however.

(Courtesy: Turning Point)
Example of Spectral Band Alarms

- Use band alarms specific to a fault frequency or band of frequencies (i.e. HS bearings)
- Band alarm Peak or RMS values are small numbers that can be trended

(Courtesy: Turning Point)
Example of Band Alarm Trend

- The band alarm RMS or Peak value is a small number that can be exported to SCADA or via OPC.
- Relays can be triggered by band alarms and sent to SCADA.

(Courtesy: Turning Point)
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- Use process parameters to trigger more consistent measurements
  - Trends will be more consistent
  - Look for parameters that indicate inconsistent operating conditions (e.g. off yaw, high shear)
  - Use off-condition data to identify potential sources of accelerated wear

- Interrogate constantly, sample only when triggered (Use alarm thresholds sparingly to keep spectra and waveform samples)
Process Parameter Correlations

- RPM is constant while Power tracks wind speed
- How does DT Acceleration (from SCADA) respond to power?
- How does DT acceleration respond to yaw?
- What is maximum yaw error?
- What is the affect of yaw error on DT acceleration?
- Is there a correlation between operational parameters and damage accumulation?

### Variable Speed WTG Wind Speed, Power, and RPM Correlation

![Variable Speed WTG Wind Speed, Power, and RPM Correlation](image)

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![Variable Speed WTG Wind Speed, Power, and RPM Correlation](image)
Vibration Amplitude and Wind Speed

**Measurement Point**

![Graph showing vibration amplitude and wind speed measurement points.](image)

- Vibration Amplitude (mm/s)
- Bandwidth Measured

**Vibration Amplitude and Wind Speed**

- **Average of 3P**
- **Average of 6P**
- **Average of 9P**
- **Average of Ring Gear Mesh**
- **Average of O-all**

**W/S Bin (10 min)**

- 4
- 6
- 8
- 10
- 12
- 14

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Overall Trends and Detailed Data Capture

- Constant monitoring
- Real time data volume is small
- Keep detailed digital records for subsequent analysis as necessary.
- Digital records are triggered using preset parameters

(Courtesy: Swantech)
Stored Digital Records That Add Value

(Courtesy: Swantech) (Courtesy: Turning Point)

“Good” Turbine

(Courtesy: Swantech)
Component Level Streamlining

- Determine which components *NEED* monitoring

- Reduce sensor count
  - Main Bearing?
  - Gearbox 2?
  - Generator 2?

- Add all the pucks at initial installation (incl. additional pucks for HS shaft alignment)
Turbine-Level Streamlining

- Feed RMS and Peak values directly to the controller and integrate into SCADA
- Import process data from controller directly to CMS data collector to trigger consistent measurements
- Nacelle data collectors should have on-board memory
  - Store condition-triggered time waveform and spectral data.
  - The analyst can call for data as necessary
  - Back-haul to the CMS server for archiving as low-priority stream
Project Level Streamlining

- Determine how many turbines should be monitored in a project
  - Consider phasing in your system
  - Consider supplementing wear particle monitoring with portable vibration-based monitoring
  - Determine cost saving by not installing 100%

- Monitor alarms on SCADA system, not CMS server

- Relocate the site server to central operations
  - Do data collectors have IP addresses and can they input data to SCADA?
  - Check bandwidth capacity, avoid “remote desktop” applications
  - Can data be stored in memory on the data collector for extended periods or is the connection “live”?
Enterprise Level Streamlining

- Import SCADA data with CMS RMS and Peak values to data enterprise system via OPC or Modbus (e.g. PI) and monitor alarm status at that level

- Pick one CMS system for the enterprise

- Locate the CMS server for all projects at the enterprise operations center
  - The analyst wants to work at the enterprise office
  - One analyst can cover many wind projects
  - The CMS server has important data analysis and database management software
  - Important data is managed by on the CMS server with dedicated software
The Litmus Test

**Step 4: Understand where the industry is heading and where you are heading**

- OEMs (Siemens, Vestas, GE, Gamesa, Clipper, Winergy, Moventas, . . .)
- Related industry (Maritime, Energy, Pharmaceuticals, Paper & Pulp, Mining, Oil & Gas)
- *Are your plans consistent with industry standards and trends?*
Other Recommendations

- Work with your CMS system supplier to provide a system that works for you
- Work with the OEM
  - Identify whether your OEM has qualified and integrated CMS system into the turbine controller
  - Will they let you have the data during the warranty period?
  - Negotiate how CMS data indicates a warrantable condition
- Consider a pilot project to qualify a system
Safeguarding life, property and the environment

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Thank You!